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Re-Examination of the Relationship between Agricultural Economic Growth and Non-Point Source Pollution in China: Evidence from the Threshold Model of Financial Development

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Abstract: The coordinated development of agricultural economic growth and non-point source (NPS) pollution is an important task in enhancing pollution prevention. Significantly, agricultural economic growth and NPS pollution are interrelated, and their mechanism will be affected by financial development. For this reason, the current study established a panel smooth transformation regression (PSTR) model to reveal the mechanical evolution under different financial development levels. It was found that the impact of agricultural economic growth on NPS pollution was significantly positive in the low level of financial development, which is manifested as an "intensification effect". Fortunately, when the level of financial development reaches the medium and high thresholds, agricultural economic growth will inhibit agricultural NPS pollution. At the same time it was also found that the impact of agricultural economic growth on NPS pollution is manifested as an "inhibition effect" at the overall level, but presenting significant structural differences. Specifically, the impact on the eastern and central regions of China is manifested as an "inhibition effect", whereas the impact in the western region of China is characterized as an "intensification effect". Finally, the elasticity analysis showed that the influence of financial development on agricultural NPS pollution was significantly positive, and that its intensification effect is ubiquitous.

Keywords: agricultural economic growth; NPS pollution; financial development; PSTR model

1. Introduction

China is a rapidly developing country that is transitioning from a socialist system to one where an increasing proportion of its goods and services, including food, are being allocated by prices and other market forces [1]. Since its reform and opening-up, China's economy has developed rapidly, and a large amount of manpower and material resources have been gathered to develop agriculture [2]. With the intensive introduction of various policies that benefit agricultural development, the agricultural economy has made remarkable achievements. From the perspective of major economic indicators, the added value of agriculture increased from 139.7 billion yuan in 1978 to 12.397 trillion yuan in 2019, with an average annual growth rate of 11.56% (the annual growth rate is calculated based on the given data from the China Statistics Bureau, as are other data referenced herein). The total grain output increased from 304.765 million tons in 1978 to 663.843 million tons in 2019, with an annual growth rate of 1.19%. In 1978, the per capita disposable income of rural residents was 134 yuan, and this indicator increased to 16,021 yuan in 2019, with an average annual increase rate of 12.38%. There is general recognition that under Deng Xiaoping's rule, the regulation of the Chinese government was "green". A raft of new laws and new agencies has taken into action a fulfillment of the promise to protect the environment [3,4].

The achievement of agricultural development has laid a solid foundation for China's agricultural modernization. At the same time, it also provides references for other developing countries to overcome poverty. From this perspective, the impact of China's agricultural development on the world is also obvious. However, increasing evidence has proven that returns from intensive production of high-yielding varieties have diminished, and that the Chinese government is now aware of measures that are needed to counter corresponding negative environmental impacts [4,5]. In the new era, as the agricultural development of China has shifted into a new strategic stage, more emphasis is placed on its green development. Meanwhile, considering its effects on soil and water sources, more attention will be paid in the future to agroecosystems' capacities for production [6]. Moreover, the new developing concept of "green" will guide the new direction for agricultural economic development.

Achievements and dilemmas are two opposite sides of agricultural development. However, environmental problems are the more challenging issue. The agricultural transformation associated with the industrialization process is still in progress, but its current state will cause irreparable damage to the earth's environment and reduce the quality of life for future generations [7,8]. Meanwhile, China's agriculture is undergoing rapid modernization, which brings opportunities for commercialization and puts stress on the environment [9,10]. Thus, it is necessary to reflect and find a way to realistically break constraints. Under the background of pollution prevention in China, environmental problems caused by the rapid growth of the agricultural economy are particularly concerned. Nowadays, the conflicts between China's agricultural development and the environment are quite acute. Agriculture has become the most serious industry of non-point source (NPS) pollution, surpassing developed countries in breadth and depth [11].

In terms of generation mechanisms, the causes of agricultural NPS pollution are intricate, but most of them are related to the input of chemicals in agricultural production, including pesticides, chemical fertilizers, mulch film, diesel fuel, and other chemicals. Through surface runoff, soil erosion, and farmland drainage, these chemicals enter the water, soil, or atmosphere, forming agricultural NPS pollution. Generally, NPS pollutants are usually sedimented without rain, which cannot drastically change the water quality of rivers. However, the direct flows to rivers increase during the rainfall, resulting in an augment of NPS pollution as the sedimented pollutants in soils are discharged to the water system. Therefore, soil sediment pollutants washed by rainfall will deteriorate water quality and threaten hydro-ecology health [12]. Compared with point-source pollution, agricultural NPS pollution has the characteristics of intermittence and uncertainty, and its treatments are also more difficult. Hence, agricultural NPS pollution has increasingly become the biggest obstacle to accurately prevent pollution. Under this background, with the guidance of the concept of green development, it is urgent that new ways to control agricultural NPS pollution be explored.

Generally speaking, economic growth will harm environmental quality from two aspects. On the one hand, economic growth requires factor inputs, which in turn required an increase in the use of resources. On the other hand, more output will bring about more pollution emissions [13]. Among all factor inputs, the financial factor bears the brunt. With the continuous deepening of financial innovation and the establishment of an inclusive financial system, financial services have played a leading role in agricultural economic growth, contributing a lot to the long-term development of the agricultural economy [14]. According to the statistical database of the China Statistics Bureau, the total agricultural loans in 1978 were 15.59 billion yuan, rising to 3.97 trillion yuan in 2019, with an average annual increase rate of 14.45%. The financial interrelations ratio rose from 11.16% in 1978 to 32.02% in 2019, and the role of financial development in driving economic growth increasingly enhanced. Meanwhile, under the background of improving the welfare level and promoting agricultural development, financial services will be more precise. Furthermore, the level of financial development, service quality, and investment will be further strengthened, and support for agricultural economic growth will be stronger in particular.

So, will financial development exacerbate the antagonism between agricultural economic growth and NPS pollution? What are the conditions for financial development to coordinate agricultural economic growth and NPS pollution control? This is the scientific question of this article. For one thing, this study can reveal the interaction mechanism between financial development and agricultural economic growth on NPS pollution, and clarify the financial conditions needed to coordinate the two so that they can expand existing research dimensions. Additionally, financial development and agricultural economic growth have a synergistic effect on NPS pollution. By examining this effect, it is possible to assess the constraints of the current financial environment in time, which can provide empirical evidence for agricultural economic growth and stimulate the innovation of green financial products in the new era. To this end, this paper establishes a panel smooth transformation regression (PSTR) model to empirically reveal the mechanism evolution between agricultural economic growth and NPS pollution under different financial development threshold levels. This model can offer theoretical support and empirical evidence to aid scientific decisions.

The main contributions and innovations of this paper are as follows: First, the interrelationship and mechanism between agricultural economic growth and NPS pollution are explored. The current researches mainly start from overall environmental quality, to explore the effects of agricultural economic growth [15,16], but few studies have linked agricultural economic growth with NPS pollution. Under the realistic background of NPS pollution prevention, it is of great practical value to study this issue. Second, the evolutionary law of a mechanism between agricultural economic growth and NPS pollution is discussed based on financial development level. The existing research has often studied the direct relationship between agricultural economic growth and environmental quality, but because of different preconditions few have noted the significant difference in the interrelationship and mechanics of the two. As the "bloodline" of agricultural economic growth, the financial element can provide a solid support for the rapid development of green finance, which also has theoretical value and practical significance for the construction of the inclusive financial system. Third, a distinctive research method is applied. It is well-known that the PSTR model is the frontier approach for nonlinear measurement, helping to find new contradictions and problems. At the same time, the PSTR model also has significant advantages in solving endogeneity, and can not only reveal the interaction effect of financial development and agricultural economic growth on NPS pollution, but also reveal the heterogeneity of financial development on NPS pollution. Therefore, the scientificity and credibility of the conclusion are greatly enhanced.

The following contents are arranged as follows. Section 2 is the literature review and research hypotheses. Section 3 conducts empirical analyses. Section 4 details the empirical results and analyses. Finally, Section 5 summarizes the research conclusions and puts forward policy recommendations.

2. Literature Review and Research Hypotheses

In recent decades, the phenomenon of environmental pollution has attracted lots of scientific interest, and abundant studies have focused on the relationship between environmental degradation and economic growth. However, terms of a whole economy, the existing literature is limited just to agriculture, a high pollutant sector [7,17]. Generally speaking, agricultural pollution is mainly NPS pollution. As a major problem affecting environmental quality, NPS pollution has received widespread attention worldwide. The Environment Protection Agency in the US reported that five of the top six identified sources of river and stream quality impairments were NPS [18]. From a global perspective, about 30–50% of NPS pollution is mainly from agriculture, and Corwin et al. [19] and Volk et al. [20] have provided corresponding data and evidence. For this reason, research on agricultural NPS pollution has been a hotspot to economists and politicians for a long time. Furthermore, in the technical dimension, a consensus has been reached on the causes of NPS pollution. It is generally believed that the excessive use of chemical fertilizers, pesticides, mulching films, and other chemicals will lead to the rapid accumulation of nutrients and sediments in agricultural runoff, which will further exacerbate water eutrophication and soil erosion. Therefore, NPS pollution is the main cause of surface water quality degradation [21–24]. Additionally, chemical inputs are the most important driving factor for agricultural economic growth, especially for output growth [25]. So, when revealing the causes of agricultural NPS pollution, some scholars regard economic growth as an important factor, and have attempted to characterize the relationship between economic growth and NPS pollution.

If you trace it back to the source, the relationship between the two stems from the famous "Environmental Kuznets Curve" (EKC)—the research on economic growth and environmental quality discussed by American economists Grossman and Krueger [26]. Grossman and Krueger advocated that pollution level increases with an increase in GDP per capita at low-income levels, and decreases with GDP growth at high-income levels. In other words, the relationship between environmental quality and income level is manifested as an inverted "U" shape. What's more, Panayotou [27], Shafik, and Bandyopadhyay [28] have also drawn unanimous conclusions. In recent years, with the transition of developing countries' growth modes and innovations in green development concepts, scholars have shifted focus to the economic growth and environmental quality of developing countries. Shahbaz et al. [29], Tiwari et al. [30], Lau et al. [31], and Lopez et al. [32] have previously demonstrated the relationship between economic growth and environmental quality in developing countries such as Romania, India, Malaysia, and Venezuela, respectively. Chinese scholars such as Peng and Bao [33] and Duan and Xu [34] selected per capita GDP and certain environmental pollution indicators for their research. In the end, they also concluded that believing in economic growth would aggravate the environment, which is consistent with the EKC.

However, some scholars believe that there is no evidence to prove that the continuous deterioration of environmental quality is necessarily associated with economic growth [35], and that the relationship between economic growth and environmental quality is subject to other conditions. Many studies have pointed out that the most pivotal condition is financial development. In the initial stage of rural financial development, the level of a country's financial development plays an important role in agricultural economic growth and farmers' income. The efficient utilization of capital can significantly increase material output and achieve rapid growth [36]. However, the rapid increase in material output inevitably leads to an increased employment of natural resources and emissions of pollution, which in turn puts greater pressure on the environment [37,38]. Furthermore, as the agricultural micro-management subjects, farmers are usually "short-sighted" when making production decisions [20]. Chemical inputs are wildly used, but farmers often choose to ignore the problems that NPS pollution brings about. This short-term behavior will cause long-term damage to soil and water, whereas farmers do not need to make any ecological compensation when obtaining higher economic benefits [39]. It can be seen from both macro and micro perspectives that financial development harms the environmental mechanism of agricultural economic growth, and that agricultural economic growth will lead to an increase in pollution that is largely related to the level of financial development.

In the meantime, some scholars have put forward different views on the "growth-environment" paradox in financial development. They believe that as financial development enters the stage of industrialization, environmental quality will usher in an "inflection point". Based on the studies of financial functions, these scholars believe that the financing function can provide lower financing costs for environmental protection projects and encourage companies to adopt low-carbon technologies and cleaner production processes [40]. At the same time, through technological innovation, financial development can reduce pollutants per unit of product, improve energy efficiency, and promote the production of alternatives to highly polluting products [41]. It can be seen that financial development is conducive to ameliorating environmental problems and reducing the negative externalities of NPS pollution [42,43]. Thus, as a critical method for stimulating financial development, the financial system should be continuously consummated, in combination with environmental policies and economic policies, to promote green economic development and improve environmental quality [44,45]. In a comprehensive perspective, the influence mechanism of agricultural economic growth and NPS pollution are closely related to financial development. Based on the above, this paper proposes the following hypotheses:

Hypothesis 1. *Financial development is crucial for agricultural economic growth, and the impact of agricultural economic growth on NPS pollution is limited by financial development.*

It is well recognized that financial development is crucial to economic growth. How does financial development promote economic growth? Patrick [46] marked the relationship between financial development and economic growth as the hypothesis of supply leading and demand following. The supply leading hypothesis proposes the causality of financial development, which means that the establishment of financial institutions and markets will increase the supply of financial services and further stimulate agricultural economic growth. The demand following hypothesis holds that with the growth of the agricultural economy, the demand for financial services increases. At the same time, Patrick further pointed out that financial development can promote agricultural economic growth mainly by affecting capital stock. In this view, a sound financial system is the most fundamental feature of financial development to affect capital stock, thus promoting agricultural economic growth [47]. From China's development practice, the process of agricultural economic growth is also the process of establishing the rural financial system. Since its reform and opening-up, China's rural financial system has evolved by following the marketization of rural financial institutions and the opening of rural financial markets. In particular, China has reformed financial institutions since 2006, so that plenty of new financial institutions are set in rural areas. To a certain extent, these financial institutions compensate for the shortage of rural financial service supply and meet the capital demand of agriculture. It can be seen that financial development is a precondition to promote China's agricultural economic growth. The impact of agricultural economic growth on NPS pollution is limited by the financial development level. It is obvious that there are some theoretical defects in exploring the mechanism between agricultural economic growth and NPS pollution without preconditions.

Hypothesis 2. *Financial development and agricultural economic growth have an interactive impact on NPS pollution. If the level of financial development is low, the intensification effect of agricultural economic growth on NPS pollution will be further strengthened.*

Financial development has an indirect impact on pollution by promoting agricultural economic growth. Grossman and Krueger [48] have contended that the inverted "U" relationship between pollution and per capita income may reflect the changing strength of the scale and technique effects on the environment. Initially, increases in economic activity generate more pollution, but as incomes and living standards continue to rise, citizens' increased desires for a cleaner environment adopt a more stringent standard. Meanwhile, older technologies will be subsequently replaced by newer and cleaner ones [49]. Therefore, the interaction between financial development and agricultural economic growth is also reflected in the scale effect and the technical effect. In terms of the scale effect, agricultural economic growth will increase the input of factors and the consumption of resources, which will further increase the discharge of pollutants. When the level of financial development is relatively high, the financial system will guide resources to flow into environmental protection industries, such as ecological agriculture, to reduce resource consumption and inhibit agricultural NPS pollution. However, if the level of financial development is low, the function of finance will not be able to work, or could even become counterproductive. In addition, from the perspective of the technology effect, the availability of financial services is an important factor influencing farmers to adopt environmentally technologies. To this point, Wei et al. [50] have provided empirical evidence. At the same time, when finance develops to a certain stage, the level of FinTech will also be enhanced, and its role in improving efficiency in green development will be further highlighted. The low-carbon lifestyle and green development model brought by FinTech have been fully confirmed in China. For example, platforms such as "Ant Forest" on Alipay have shown unprecedented potential in green development. So far, over 56 million "ant trees" have been planted across the country with promising results. For example, the Saihanba Plateau in China, once a dusty wasteland, has become the world's largest manmade forest [51]. Generally speaking, the mechanism between agricultural economic growth and NPS pollution will be significantly different due to varying levels of financial development.

3. Empirical Analysis

3.1. Model Description

According to the hypothesis, the influence mechanism of agricultural economic growth on NPS pollution is limited by financial development level. Generally speaking, the most common approach to revealing this precondition and interaction mechanism is to introduce interaction terms or establish a panel threshold regression (PTR) model. However, the introduction of interactive terms can only reveal the static relationship of variables, and cannot describe the dynamic mechanism. In comparison, building a PTR model seems to be a good choice. The PTR model proposed by Hansen [52] often assumed the transfer function was discrete and discontinuous, as well as abrupt and non-stationary, requiring all economies to act in concert quickly, at the same time, to achieve the expected effect of the model. However, this outcome is often difficult to achieve [53]. Fouquau and Hurlin et al. [54] relaxed the assumptions on both sides of this threshold and proposed a panel smooth transition regression (PSTR) model wherein the heterogeneity of the panel data interception is obtained by using the continuous transformation function instead of the original discrete function. Moreover, based on the smooth and continuous nonlinear transformation of random variation, the authors conducted parameter processing and obtained a more realistic fitting model. In general, the PSTR model can be regarded as a generalization of the PTR model and the panel linear model with individual effects [55]. Using this as a basis, the current paper establishes a PSTR model to empirically reveal the relationship between agricultural economic growth and NPS pollution under different financial development levels.

$$NPS_{it} = \alpha_i + \beta_0 AEG_{it} + \beta_1 AEG_{it} g(FD_{it}; c) + \mu_{it} \tag{1}$$

where i indicates the region, t represents time, NPS_{it} is the agricultural NPS pollution, and AEG_{it} is the agricultural economic growth. Additionally, FD_{it} is the financial development as well as the threshold variable in the model, c denotes the threshold parameter, and $g(FD_{it}; c)$ is the transfer function, which can be further expressed as Equation (2):

$$g(FD_{it}; c) = \begin{cases} 1, \ FD_{it} \geq c \\ 0, \ FD_{it} < c \end{cases} \tag{2}$$

The economic implication of Equation (2) is: if $FD_{it} \geq c$, then the influence coefficient of agricultural economic growth on NPS pollution is $\beta_0 + \beta_1$, but if $FD_{it} < c$, the influence coefficient is β_0. From the above model, it can be seen that the relationship between agricultural economic growth and NPS pollution conforms to a two-regime, discrete linear model. However, due to strict theoretical assumptions, the model needs to be further optimized. To this end, the numbers of regime transformation are extended to r, and a smooth transition function is introduced to optimize the model [56]. Therefore, the model can be further rewritten as:

$$\begin{cases} NPS_{it} = \alpha_i + \beta_0 AEG_{it} + \beta_1 AEG_{it} g(FD_{it}; \gamma, c) + \mu_{it} \\ g(FD_{it}; \gamma, c) = \frac{1}{1 + exp[-\gamma(FD_{it} - c)]}, \ \gamma > 0 \end{cases} \tag{3}$$

where γ indicates the slope parameter, which determines the mechanism conversion rate; c presents the threshold parameter of mechanism conversion in the PSTR model, denoting the threshold value of the regime transformation; and $g(FD_{it}; \gamma, c)$ is a continuous smooth bounded function concerning FD_{it}, which it usually presents as a logic function with a value characteristic of $0 \leq g(FD_{it}; \gamma, c) \leq 1$. Compared with the PTR model, the superiority of the PSTR model is axiomatic. While revealing the time-varying characteristics of parameters, the PSTR model can better solve the problems of endogeneity, heterogeneity, and robustness. With the change of FD_{it}, the influence coefficient of AEG_{it} on NPS_{it} pollution can be defined as the weighted average value of β_0 and β_1 when c is given. That is to say, if FD_{it} is different from AEG_{it} at the time of t, the influence coefficient of AEG_{it} on NPS_{it} pollution in region i can be defined as:

$$e_{it} = \frac{\delta NPS}{\delta AEG} = \beta_0 + \beta_1 g(FD_{it};\gamma,c) \tag{4}$$

Due to $0 \leq g(FD_{it};\gamma,c) \leq 1$, it is known that when $\beta_1 > 0, \beta_0 \leq e_{it} \leq \beta_0 + \beta_1$. If $\beta_1 < 0$, then $\beta_0 + \beta_1 \leq e_{it} \leq \beta_0$. According to the research results of Ho [57] and Corbin [58], the PSTR model can be further extended to $r+1$ regimes, as shown in Equation (5):

$$NPS_{it} = \alpha_i + \beta_0 AEG_{it} + \sum_{j=1}^{r} \beta_j AEG_{it} g\left(FD_{it};\gamma_j,c_j\right) + \mu_{it} \tag{5}$$

In general expressions, at the time of t, the influence coefficient of AEG_{it} on NPS_{it} pollution in region i can be defined as:

$$e_{it} = \frac{\delta NPS}{\delta AEG} = \beta_0 + \sum_{j=1}^{r} \beta_j g\left(FD_{it};\gamma_j,c_j\right) \tag{6}$$

3.2. Estimation Method

The estimation of the parameters of the PSTR model consists of eliminating the individual effects by removing individual-specific means and then applying nonlinear least squares to the transformed model [54]. A testing procedure is proposed to test the linearity against the PSTR model and identify the number of r (i.e., transition functions). Suppose H_0: $\gamma = 0$ or H_0: $\beta_0 = \beta_1$, then the test of linearity in a PSTR model (i.e., Equation (3)) can be achieved by testing the two hypotheses. However, it is worth noting that the test will be non-standard, since under the hypotheses the PSTR model contains unidentified parameters. This issue is well reflected in Hansen's research [59]. To properly solve this issue, a first-order Taylor expansion of $g(FD_{it};\gamma,c)$ around $\gamma = 0$ is introduced to test an equivalent hypothesis in an auxiliary regression.

If we denote the panel sum of squared residuals under H_0 (linear panel model) as SSR_0, and the panel sum of squared residuals under H_1 (PSTR model with two regimes) as SSR_1, then the corresponding F-statistic is defined by:

$$LM_F = \frac{SSR_0 - SSR_1}{SSR_0/(TN - N - 1)} \tag{7}$$

In Equation (7), it is clear that LM_F has an approximate F (1, $TN - N - 1$) distribution. When testing the number of transition functions in the model, the logic is quite similar. A sequential approach is used to test the null hypothesis of no remaining nonlinearity in the transition function. Specifically, if the linearity hypothesis is rejected, then the test is shifted to examine whether there is one transition function (i.e., H_0:r = 1) or two transition functions (i.e., H_0:r = 2), and so on. For instance, if the H_0:r = 0 is rejected and the H_0:r = 1 is not rejected, then the paper should construct the PSTR model with one transition function. Otherwise, if the H_0:r = 0 and H_0:r = 1 are both rejected, then H_0:r = 2 should be tested to verify whether it is also rejected. If the H_0:r = 2 is not rejected, it means the paper can construct a PSTR model with two transition functions. However, if the H_0:r = 2 is rejected, then a sequential step is to test whether the H_0:r = 3 is rejected. That is to say, the test procedure continues until the first acceptance of H_0. Furthermore, according to the model selection criteria proposed by Gonzalez et al. [56] that "the model with the strongest rejection of the null hypothesis is optimal", the PSTR model is finally established based on the result at the 1% significance level.

3.3. Variable Description

Dependent variable: agricultural non-point source pollution (NPS). Generally speaking, scholars mainly measure agricultural NPS pollution from the perspective of greenhouse gases [7,17]. However, due to the imperfection of the statistical system, China's statistical departments have not published this statistical index. Above all, the air pollution caused by agricultural greenhouse gases is only a part of agricultural NPS pollution. In reality, agricultural NPS pollution is principally composed of soil pollution and water pollution. Air pollution caused by greenhouse gases cannot explain the whole connotation of agricultural NPS pollution. Therefore, it is not feasible to measure agricultural NPS pollution from the perspective of greenhouse gases. From the perspective of the mechanism, agricultural NPS pollution is mainly composed of soil sediment particles, nitrogen and phosphorus, pesticides, and various atmospheric particles, which enter the water, soil, or atmospheric environment through surface runoff, soil erosion, and farmland drainage. Chemical fertilizer (*CF*), pesticide (*PE*), mulch film (*MF*), and diesel fuel (*DF*) used in agricultural production and agricultural mechanization are the main contents of agricultural NPS pollution. Therefore, this study uses a more convenient and scientific method to proportionately weight these pollution sources. If the weights of chemical fertilizer (*CF*), pesticide (*PE*), agricultural mulch film (*MF*), and diesel fuel (*DF*) consumption are set to 0.25, then the overall level of agricultural NPS pollution can be expressed as Equation (8).

$$NPS_{it} = 0.25 \times CF_{it} + 0.25 \times PE_{it} + 0.25 \times MF_{it} + 0.25 \times DF_{it} \quad (8)$$

Compared with the existing methods, the scientificity of the method is mainly reflected in the following aspects: First, in the aspect of index selection, this method closely follows the concept and generation mechanism of agricultural NPS pollution, and integrates chemical fertilizer, pesticide, mulch film, diesel fuel, and other major NPS pollution sources for weighting, which can avoid the interference of a generalization index and fit the connotation essence of agricultural NPS pollution to the greatest extent. Secondly, in the aspect of weight setting, all NPS pollution elements are equally weighted, which is conducive to depicting the general level rules and revealing the general characteristics. What's more important is that although there are different resource endowments and development differences in different regions, all kinds of pollution sources are involved at different degrees and scopes in different regions. All kinds of pollution sources are common phenomena in agricultural production in various regions. Therefore, the equal empowerment and equal treatment of all pollution sources can be closer to the reality of agricultural NPS pollution in China, and more in line with the attribute of the empirical test from the overall level of this study.

Independent variable: agricultural economic growth (AEG). Generally speaking, the governance of agricultural NPS pollution is closely related to the economic growth rate and the economic development level. At different levels of economic development, a government's emphasis on environmental issues and interventions can also differ [51]. From the perspective of evaluation, agricultural economic growth is not only reflected in the expansion of agricultural production scale, but also the increase in agricultural economic benefits. Moreover, it still embodies the economic growth rate and economic efficiency brought by the improvement of agricultural production efficiency. Following the traditional measurement method, this article uses the added value of agriculture to measure agricultural economic growth.

Threshold variable: financial development (FD). According to the research hypothesis, financial development is set as a threshold variable. Since McKinnon [60] proposed the financial development theory, financial development has been widely deemed important to developing countries, and has been placed in the macro-strategic framework to reveal differences in economic growth. Financial development means an expansion of the transaction scale, improvement of industrialization, and the elimination of financial repression, which can meet the diversified financing needs in agricultural production. Meanwhile, financial development denotes the optimal accumulation of agricultural capital and the allocation of resource elements, facilitating the green transformation and coordinated development of the agricultural economy. Considering the scientificity of the indicators as well as the availability of data, the level of financial development in this study is measured by agricultural loans in each province of China.

3.4. Data Sources and Modeling Software

The data in this paper are the panel data of 31 provinces in mainland China from 1998 to 2017. Among them, the data of chemical fertilizers, pesticides, mulch film, and diesel fuel used in the measurement of agricultural NPS pollution are taken from China Rural Statistical Yearbook. The agricultural added values are from China Statistical Yearbook and *China Rural Statistical Yearbook*. Moreover, the agricultural loan used in the index quantification is from China Financial Yearbook and Statistical Data Collection of 60 Years of New China: 1949–2008. At the same time, it should be noted that the missing data in the sample should be replaced and supplemented with the average value of the previous two years. The descriptive statistics of the data are shown in Table 1, which were obtained using Stata 16 software. MATLAB software was used to estimate the PSTR model, and the source code was written by Colletaz and Hurlin [55].

Table 1. Variable descriptive statistics.

Variable		Mean	Standard Deviation	Minimum	Maximum	Observations
NPS	overall	240.124	188.928	3.221	859.860	620
	between		185.584	7.404	713.436	31
	within		48.058	23.547	436.373	20
AEG	overall	6780.941	5048.142	1258.000	30,374.730	620
	between		2565.462	3998.237	14,172.750	31
	within		4370.831	−1910.805	22,982.930	20
FD	overall	3147.370	4898.639	0.871	31,000.000	620
	between		2547.012	211.743	11,457.030	31
	within		4208.149	−8084.668	22,690.340	20

4. Empirical Results and Analysis

4.1. Threshold Effect Test

The key step to constructing the PSTR model is to carry out a nonlinear test—also called a homogeneity test—to verify the existence of the threshold effect. Generally speaking, the methods used for nonlinear tests mainly include the Wald test (LM), Fisher test (LMF), and Likelihood ratio test (LRT) [54,55]. In order to reflect the research hierarchy, the threshold effect tests in this section were mainly carried out from the overall and structural dimensions. Thereinto, the threshold effect test at the overall level adopted the overall emissions of agricultural NPS pollution, and the tests at the structural level were mainly conducted from the perspectives of different pollution sources such as chemical fertilizers, mulch film, diesel fuel, and pesticides. The test results at the overall level are shown in Table 2, from which it can be seen that the results of the Wald test, Fisher test, and LRT test all rejected the null hypothesis of the linear model (H_0:r = 0) and the PSTR model that had at least one threshold (H_0:r = 1) at the 1% significance level. Meanwhile, the null hypothesis of the PSTR model that had at least two thresholds (H_0:r = 2) was not rejected at the 1% significance level. Therefore, we constructed a PSTR model with two thresholds, which is consistent with the optimal selection result of the MATLAB procedure.

Table 2. Threshold effect test of the overall model.

Hypothesis	Statistics		
	Wald	Fisher	LRT
H_0:r = 0 vs. H_1:r = 1	69.402 *** (0.000)	74.116 *** (0.000)	73.603 *** (0.000)
H_0:r = 1 vs. H_1:r = 2	19.382 *** (0.000)	18.910 *** (0.000)	19.691 *** (0.000)
H_0:r = 2 vs. H_1:r = 3	5.180 ** (0.023)	4.928 ** (0.027)	5.201 ** (0.023)

Note: ** and *** indicate significance at the 5% and 1% significance levels, respectively.

Table 3 shows the test results of the threshold effect in terms of the structural level. From the perspective of different pollution sources, the chemical fertilizer and pesticide models both rejected the H_0:r = 0 and H_0:r = 1 in the Wald test, Fisher test, and LRT test. Therefore, the chemical fertilizer and pesticide models were both PSTR models with two thresholds. At the same time, the results of the mulch film and diesel fuel models both rejected the H_0:r = 0, but did not reject H_0:r = 1, in the Wald test, Fisher test and LRT test, from which it can be judged that the mulch film and diesel fuel models were both PSTR models with one threshold. In general, the PSTR models established for different pollution sources still had significant heterogeneity at the structural level.

Table 3. Threshold effect test of the pollution sources model.

Type		Model					
		H_0: Linear Model; H_1: PSTR Model That Has at One Threshold			H_0: PSTR Model that Has at One Threshold; H_1: PSTR Model That Has Two Thresholds		
		Wald	Fisher	LRT	Wald	Fisher	LRT
Pollution source	Chemical fertilizer	95.364 *** (0.000)	106.881 *** (0.000)	103.549 *** (0.000)	40.430 *** (0.000)	40.879 *** (0.000)	41.809 *** (0.000)
	Pesticide	68.766 *** (0.000)	73.352 *** (0.000)	72.887 *** (0.000)	20.92 *** (0.000)	20.465 *** (0.000)	21.283 *** (0.000)
	Mulch film	51.071 *** (0.000)	52.782 *** (0.000)	53.297 *** (0.000)	2.486 (0.115)	2.359 (0.125)	2.491 (0.115)
	Diesel fuel	2.419 * (0.100)	2.303 * (0.100)	2.424 * (0.100)	0.490 (0.484)	0.463 (0.496)	0.490 (0.484)

Note: *, *** mean significance at the 10% and 1% significance levels, respectively.

4.2. PSTR Model Estimation

Based on the results of the threshold effect test, the PSTR model should be further estimated. According to the research of Fouquau and Hurlin et al. [54], the PSTR model was generally estimated by the nonlinear least estimation square method (NLS), whose estimation results are shown in Table 4. From the results, it can be seen that in the overall model there are two thresholds for financial development, namely, 248.917 billion yuan and 760.345 billion yuan. To this end, the level of financial development can be divided into a low threshold interval (−∞, 2489.17), a medium threshold interval (2489.17, 7603.45), and a high threshold interval (7603.45, +∞). Under these three threshold intervals, the influence coefficients of agricultural economic growth on NPS pollution are 0.491, −0.195, and −0.039, respectively, and they are all significant at the significance level of 1%. It can be seen that the influence mechanism of agricultural economic growth on NPS pollution will be significantly different depending on the financial development level. Specifically, when financial development is at the low level, the impact of agricultural economic growth on NPS pollution is significantly positive, which is mainly manifested as an "intensification effect", and the contradiction between the two is extremely prominent. However, when the financial development level crosses the two thresholds and enters the medium and high threshold interval, the impact of agricultural economic growth on NPS pollution is significantly negative, which manifests as an "inhibitory effect".

Table 4. Estimation results of the PSTR model.

Variable	Overall	Pollution Source			
		Chemical Fertilizer	Pesticide	Mulch Film	Diesel Fuel
$AEG_{g(FD1)}$	0.491 *** (25.65)	0.352 *** (29.52)	0.013 *** (21.95)	0.012 *** (9.97)	0.115 *** (8.72)
$AEG_{g(FD2)}$	−0.195 *** (−9.15)	−0.135 *** (−9.37)	−0.005 *** (−9.50)	−0.005 *** (−4.41)	−0.052 *** (−4.03)
$AEG_{g(FD3)}$	−0.039 *** (−2.88)	−0.034 *** (−3.07)	−0.003 *** (−4.53)		
Position parameter c	248.917	248.917	311	248.917	248.917
Position parameter c_1	760.345	778.89	568		
Transfer function slope γ	0.208	0.208	0.209	0.205	0.208
Transfer function slope γ_1	0.200	0.200	0.200		
AIC	27.243	26.658	20.069	21.399	26.251
BIC	27.293	26.708	20.119	21.428	26.279

Note: *** means significant at the significance level of 1%. AIC: Akaike Information Criterion. BIC: Bayesian Information Criterion.

On the whole, agricultural economic growth will not inevitably lead to the intensification of NPS pollution, and whether the two can achieve coordinated development is largely dependent on the level of financial development. When the level of financial development is low, the opposition and contradiction between agricultural economic growth and NPS pollution are more prominent. But when the level of financial development exceeds the critical value, the coordinated pattern of agricultural economic growth and NPS pollution appears. Hence, to achieve the goals of promoting agricultural economic growth and controlling NPS pollution, it is necessary to continuously reform the rural financial system and promote its development. Meanwhile, it is also necessary to innovate green financial products that are pertinent to the agricultural environment, so that the coordinated development of agricultural economic growth and NPS pollution will be enhanced.

Furthermore, from the structural dimensions of pollution sources, this paper reveals the heterogeneity of the influence mechanism between agricultural economic growth and NPS pollution at different financial development levels. The results show that there are two thresholds for the financial development in the chemical fertilizer model, namely, 248.917 billion yuan and 778.89 billion yuan. Therefore, the level of financial development can be divided into a low threshold interval (−∞, 248.917), a medium threshold interval (248.917, 778.89), and a high threshold interval (778.89, +∞). Under these three threshold intervals, the influence coefficients of agricultural economic growth on chemical fertilizer NPS pollution are 0.352, −0.135, and −0.034, respectively, and they are all significant at the level of 1%. It can be seen that only when the level of financial development crosses the first critical value of 248.917 billion yuan can the impact of agricultural economic growth on NPS pollution be manifested as an "inhibition effect", which is consistent with the overall estimation results. In addition, the pesticide model is analogous to the chemical model. There are also two thresholds for the financial development level in the pesticide model, namely, 311 billion yuan and 568 billion yuan. So, the level of financial development can also be divided into a low threshold interval (−∞, 311), a medium threshold interval (311, 568), and a high threshold interval (568, +∞). Under these three threshold intervals, the influence coefficients of agricultural economic growth on pesticide NPS pollution are 0.013, −0.005, and −0.003, respectively, and they are all significant at the significance level of 1%. Therefore, in the pesticide model, only after the first threshold of 311 billion yuan is exceeded can the relationship between agricultural economic growth and NPS pollution be manifested as an "inhibition effect".

In the mulch film model and diesel fuel model, the financial development has only one threshold, which is 248.917 billion yuan. Therefore, in these two models, the financial development level can be divided into two intervals of (−∞, 248.917) and (248.917, +∞). This means that the impact of agricultural economic growth on NPS pollution in these two models is significantly positive in the former interval and prominently negative in the latter, which is represented as a typical inverted "U" shape. That is to say, the impact of agricultural economic growth on NPS pollution is manifested as an "intensification effect" when the financial development level is low, and the impact will be manifested as an "inhibition effect" when the financial development is at the high level.

So, what is the impact of agricultural economic growth on NPS pollution? What staged characteristics will be presented? To accurately describe the influence effect of agricultural economic growth and pollution, the financial development level was further calculated to judge the actual effects of agricultural economic growth on NPS pollution in different regions from the overall and structural level. The results are summarized in Table 5. At the overall level, the average value of the financial development level is 300.424 billion yuan. According to the results of the PSTR model, the financial development level has crossed the first threshold, and the impact of agricultural economic growth on NPS pollution is shown as an "inhibition effect". Furthermore, in terms of the structural level, the financial development level has crossed the threshold in the chemical fertilizer, mulch film, and diesel fuel models, and the impacts of agricultural economic growth on NPS pollution are mainly manifested as the "inhibition effect". However, it is worth noting that the financial development level in the pesticide model does not exceed the critical value, and the impact of agricultural economic growth on NPS pollution is manifested as an "intensification effect". Therefore, in the new era, pesticide treatment should be attached great importance and be considered a crucial breakthrough in the process of agricultural NPS pollution control. Meanwhile, financial support ought to focus on the field of "pesticide reduction", guiding social capital to participate in the work of pesticide reduction through financial innovation.

Table 5. The judgment of overall and regional effects.

Area	Overall	Pollution Source			
		Chemical Fertilizer	Pesticide	Mulch Film	Diesel Fuel
China	-	-	-	-	-
Eastern region	-	-	-	-	-
Central region	-	-	-	-	-
Western region	+	+	+	+	+

Note: "-" represents inhibition effect; "+" represents intensification effect.

In order to make a better regional comparison, the average levels of financial development in different Chinese regions were further calculated. The indexes in the eastern, central, and western regions of China were 376.54 billion yuan, 325.01 billion yuan, and 214.21 billion yuan, respectively. Comparing with the results of the PSTR model, it is easy to see that the financial development levels in the eastern and central regions have crossed the first threshold at the overall and structural level, and the agricultural economic growth has had an inhibition effect on NPS pollution. However, whether in the overall level or structure level, the average levels of financial development in the Chinese western region are all less than the threshold, which means the impact of agricultural economic growth on NPS pollution is manifested as an intensification effect. Therefore, from the regional perspective, the research conclusions reflect the backward financial development level in the western region, where even financial repression is experienced [61]. In the meantime, a serious divergence and disconnection between agricultural economic growth and NPS pollution control in the western region is also revealed. Therefore, the western region of China can be seen as the principal area for transforming the agricultural economic growth mode and making coordinated development between agricultural economic growth and environment come to fruition.

4.3. Elasticity Analysis of the Impact of Financial Development on Agricultural NPS Pollution

The PSTR model can not only reveal the influence of agricultural economic growth on NPS pollution at different financial development levels but also depict the heterogeneity influence of financial development itself on NPS pollution. Table 6 and its attachment present a brief introduction and the time-varying characteristics of the impact of financial development on agricultural NPS pollution. From the overall level, the impact of financial development on agricultural NPS is positive in the time dimension, which indicates that the development of agricultural finance will increase the emission of pollutants and result in the continuous deepening of agricultural NPS pollution. This is consistent with the research conclusions of Zhu [62] and Hu and Li [63]. However, the intensification effect of financial development on agricultural NPS pollution presents a decreasing trend. By considering the entire sample interval, it can be seen that the minimum elasticity value of the impact of financial development on NPS pollution emerged in 2017. This was mainly related to the continuous deepening of rural financial reform and innovation during recent years, as well as the unceasing improvement of the green financial system. It also obtained effective feedback at the practical level, such as the launch of green financial services the Agricultural Bank of China (ABC) including the "Five Water Treatment" and "Loans for Beautiful Rural". The ABC has emphasized the green life consumption and production needs of agricultural operators. Moreover, through the integration and innovation of multiple financial tools, the ABC has also helped to decrease the use of chemical fertilizers and pesticides, moderating the spread of agricultural NPS pollution.

Table 6. The impact of financial development on agricultural NPS pollution in China.

NO.	Province	Mean	Standard Deviation	NO.	Province	Mean	Standard Deviation
1	Beijing	0.127	0.008	17	Hubei	0.112	0.025
2	Tianjin	0.132	0.034	18	Hunan	0.100	0.015
3	Hebei	0.068	0.001	19	Guangdong	0.065	0.000
4	Shanxi	0.168	0.118	20	Guangxi	0.076	0.015
5	Inner Mongolia	0.132	0.059	21	Hainan	0.108	0.007
6	Liaoning	0.088	0.029	22	Chongqing	0.079	0.013
7	Jilin	0.078	0.007	23	Sichuan	0.064	0.000
8	Heilongjiang	0.071	0.009	24	Guizhou	0.064	0.000
9	Shanghai	0.084	0.013	25	Yunnan	0.064	0.000
10	Jiangsu	0.316	0.067	26	Tibet	0.291	0.118
11	Zhejiang	0.127	0.040	27	Shaanxi	0.249	0.059
12	Anhui	0.074	0.001	28	Gansu	0.421	0.007
13	Fujian	0.088	0.017	29	Qinghai	0.283	0.118
14	Jiangxi	0.088	0.004	30	Ningxia	0.100	0.016
15	Shandong	0.09	0.007	31	Xinjiang	0.102	0.022
16	Henan	0.087	0.007				

Note: complete data will be attached in detail.

By comparing provinces at the transverse level, it can be seen that the provinces with small financial development elasticity coefficients on agricultural NPS pollution are mainly concentrated in the Chinese western region. In Table 6, the top 10 provinces in this regard are Yunnan, Guizhou, Sichuan, Guangdong, Hebei, Heilongjiang, Anhui, Guangxi, Jilin, and Chongqing. Thereinto, the eastern provinces account for 20%, the central provinces account for 30%, and the western provinces account for 50% (more details in supplementary material). Comparatively speaking, financial development in the western region has a less elastic influence on NPS pollution, indicating that financial development does not have a more predominant effect on the control of agricultural NPS pollution in that region. The conclusions in Table 5 reflect that the financial development level in the Chinese western region has been in a dilemma, and in need of further improvement. At the same time, according to Table 4, it is known that the financial development of the central and western regions has crossed the critical value, and the impacts of agricultural economic growth on NPS pollution have all manifested as an inhibition effect at the overall and structural levels. Why then are the impacts of financial development on agricultural NPS pollution still relatively large? This may have something to do with the large scale agricultural loans and slow growth rate in the central and western regions. In general, although the inhibition effect of the linkage mechanism between financial development and agricultural economic growth on NPS pollution has been highlighted, there still exist numerous structural contradictions in financial development. Hence, the green financial system needs to be further constructed, and its potential requires stimulation. Only in this way can the green financial system provide basic conditions for agricultural economic growth and NPS pollution control.

5. Conclusions and Policy Recommendations

The contradictory problems of agricultural economic growth and environment have always been the focus of political and academic circles. Under the background of pollution control and the practice of China's economic transformation, these issues have been endowed with a new research perspective and policy connotations. However, it is impossible to ignore various preconditions when exploring the mechanism of the agricultural economy and NPS pollution, especially the level of financial development which is regarded as the "blood" of the economy. The coordinated development of the agricultural economy and NPS pollution needs the support of financial development. To this end, based on the relevant theoretical hypothesis, this research establishes a PSTR model to empirically demonstrate the mechanism and dynamic characteristics of agricultural economic growth and NPS pollution under different financial development levels. The main conclusions and policy recommendations are as follows:

① At the overall level, financial development and agricultural economic growth have an interactive mechanism and a significant threshold effect on NPS pollution. When financial development is at a low level, the relationship between the two is shown as an "intensification effect". However, when the financial development is in the middle or high threshold interval, the impacts of agricultural economic growth on NPS pollution are manifested as an "inhibition effect". So, the deepening of financial development and the support of financial service for agricultural economic growth should be promoted. It is necessary for China to continuously reform the rural financial system and guide more market-oriented financial entities to practicably participate in the control of NPS pollution.

② From a structural perspective, the influence mechanism of agricultural economic growth and NPS pollution has significant heterogeneity under different financial development levels in the chemical fertilizer, pesticide, mulch film, and diesel fuel models. To this end, financial resources need to be structurally optimized, and the financial support for agricultural green development should shift to pest control. Moreover, more social capital should be guided to improving the efficiency of financial mechanism innovation, so as to help the green development of agriculture and NPS pollution control.

③ In terms of regional distribution, the financial development levels in the Chinese eastern and central regions have crossed the first critical value at the overall and structural levels, and the agricultural economic growth has had an inhibition effect on NPS pollution. However, whether at the overall level or the structure level, the average levels of financial development in the western region of China are all less than the critical value, which means the impact of agricultural economic growth in the western region on NPS pollution is manifested as an intensification effect. Under such conditions, the coordination between the agricultural economy and NPS pollution in the western region has become the key factor affecting the whole situation. Therefore, it is necessary to make full use of various strategies and opportunities for western regional development to accelerate high-quality leapfrogging and provide effective supports for coordinated development.

④ In addition, the final elasticity analysis shows that the impact of financial development on NPS pollution is positive, and the intensification effect is ubiquitous. To some extent, this reflects the dilemma of the imperfection of green financial systems and the lack of green financial products. Hence, to achieve the green development of the agricultural economy in the new era, financial innovation must conform to the general trend of the development of green financial products. Meanwhile, the supply of green financial services and the availability of green financial services must be enhanced to restrict agricultural NPS pollution. Furthermore, in the innovation of green financial products, financial technology full use can be made of resolving the problems of adverse selection and moral hazards to promote the high-quality development of green financial products and control agricultural NPS pollution comprehensively.

For a long time, research on the relationship between agricultural economic growth and NPS pollution have been following the EKC curve. Although the first test reflects the relationship between agricultural economic growth and NPS pollution, this model also ignores the factors that affect the interaction between agricultural economic growth and NPS pollution. Financial development is the core element of agricultural economic growth, and in this study is regarded as the main factor affecting the interactive regime transformation of agricultural economic growth and NPS pollution. To a certain extent, exploring the evolutionary law of the mechanism between agricultural economic growth and NPS pollution under different financial development levels is an effective expansion of the existing theory of the EKC curve. However, many factors affect the interaction mechanism between agricultural economic growth and NPS pollution, such as urbanization, industrial structure, human capital, social capital, infrastructure conditions, and so on, causing this interaction mechanism to change accordingly. Financial development is just one of these factors, but it alone cannot fully reveal the change of this interactive mechanism. This is also the deficiency of this study, although it is the key area that the new period of study plans to break through. From the perspective of multi-factor comparison, it is an important direction for follow-up studies to follow in order to reveal the differences in the interaction mechanism between agricultural economic growth and NPS pollution.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4441/12/9/2609/s1, Table S1: The impact of financial development on agricultural NPS pollution in China.

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