Promote or inhibit? The effects of Forest Carbon Sinks projects on agricultural development: Evidence from Sichuan, China

by Yuan Hu, Lena Kuhn, and Wenxue Zheng

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Abstract:

Forest carbon sinks (FCS) project play an important and irreplaceable role in tackling climate change and achieving sustainable development. On the basis of the critical overview relationship between the FCS project and agricultural development, this article regards the FCS pilot project launched in Sichuan at the end of 2004 as a quasi-natural experiment, adopting synthetic control Method (SCM) and difference in difference (DID) method empirically test the impact of FCS project implementation on regional agricultural development and its mechanism. The results demonstrated the following: (1) the direction of the FCS project's impact on agricultural development in the pilot areas varies according to the length of the implementation period. Specifically, it has an inhibitory effect on regional agricultural development in the short term (3 years on average), but it has a significant promotion effect in the long term. (2) After conducting a series of robustness checks, the above conclusions are still robust. (3) Further analysis of the influence mechanism found that the implementation of FCS project can promote rural labor employment and agricultural production efficiency, which constitutes two channels for the long-term impact of FCS project on agricultural development.

Keywords: Forest carbon sinks; agricultural development; SCM; DID

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1. Introduction

With the advent of the post-Kyoto era, the role of Forest Carbon Sinks (FCS) including carbon sequestration and greenhouse gas emission reduction in tackling climate change and achieving sustainable development have become increasingly prominent (Duong and De Groot, 2020; Pagiola et al., 2005). The international FCS trading market and its industrial development has been showing a whole shape, and domestic "Kyoto Protocol" and "non-Kyoto Protocol " FCS projects have been increasing day by day (Minang et al., 2007). In particular, as the seven “pilot” programs for carbon emissions trading have been integrated into the national unified market to implement, the FCS has not only become the main alternative way of reducing carbon dioxide (CO2) emissions, but also has emerged as a promising instrument for the industrial countries working together to combat climate warming and meet the quantified emission limitation targets, as well as an important part of China's commitment to increase the provision for carbon emission reduction and accelerate the reform of the ecological civilization system (Dang et al., 2020; Mufan et al., 2020). The reason why FCS can be regarded as an important countermeasure in many international legal documents in the process of climate negotiations, conclusion and policy is that it has multiple economic, social and ecological benefits besides removing carbon and releasing oxygen (Diafas et al., 2017; Nhem et al., 2018). Yet in practical applications, compared with conventional energy and industrial sector carbon trading, the FCS project tends to have some certain shortcomings such as time-consuming, small emission reductions, complex methodology, and low development gains, therefore it falls short of expectation in occupying market competitive advantages (Cao, 2011; Mufan et al., 2020). Whereas, in terms of meeting the objectives of improving the ecological environment, adapting to climate change, promoting the sustainable development and alleviating poverty of communities, FCS has special value that other conventional projects do not have, which makes the FCS projects have huge development space and broad applicable prospects (Ranjan, 2019). Whether the FCS project can successfully acquire Certified Emission Reductions from the National Forestry Finance Fund (FONAFIFO) (Pagiola, 2008), and win the understanding and support of the government, society and community residents to achieve its smooth implementation and long-term operation, mainly depends on its comprehensive benefits (Sommerville et al., 2010).Therefore, deepening the understanding of the comprehensive benefits of FCS is not only an important proposition related to the healthy development of carbon funds, carbon markets and carbon industries, but also a key channel to improve the FCS management and operation system, which will help China furtherly played an important role in driving forest carbon projects.

Compared with non-pilot areas, the FCS project area uses low-yield, ecologically degraded or sloping farmland for afforestation or reafforestation, which can accelerate large-scale and intensive land management, promote the efficiency of farmland production, improve the economic income of farmers and their living standards, thus promote the sustainable development of agriculture (Haile et al., 2019; Wang et al., 2020). However, due to insufficient incentives and supervision during project implementation, some high-quality, flat farmland may also be used for carbon sink afforestation, resulting in a decrease in food production (Yan, 2019a), which will cause a negative effect on the sustainable development of agriculture. In the background of the rural revitalization in China, the conflicts between ecologically environmental protection and agricultural development have gradually emerged. As an ecological compensation policy with multiple effects such as adapting and mitigating climate change and achieving poverty reduction (Du and Takeuchi, 2019; Gao et al., 2019), the implementation of FCS project will promote or inhabit the sustainable development of agriculture? Yet the response about this problem from the academic circle remains mixed. Additionally, little literature has quantitative analyzed the policy effects between FCS projects and agricultural development based on the perspective of policy evaluation, and thus cannot be given to a scientific and accurate evaluation of the policy effect. Some studies have drawn through correlation analysis between the two, but it is still not enough to truly reflect its causality. For example, (Muenzel and Martino, 2018) illustrated that carbon payment service can offer a premium carbon market as well as help reduce grazing pressure across a larger number of saltmarshes and promote agrienvironmental development.

The goal of this article is to regard the FCS project that was piloted nationwide at the end of 2004 as a quasi-natural experiment, taking the level of agricultural development as the research object to examine the impact of forest carbon sink policies on agricultural development and its mechanism, so as to make a comprehensive assessment of the beneficial agricultural effects of FCS projects.

2. Background and theoretical analysis

2.1 Background

The FCS projects are used around the world to improve the climate change and incentivize sustainable development objectives (Benites-Lazaro et al., 2018; Galik and Jackson, 2009; Liu et al., 2021). Responding to the two objectives is one of the crucial historical missions shared by the world today, which is not only related to the survival and development of mankind, but also related to the stability, harmony and prosperity of the world. As one of the three flexible emission reduction mechanisms within the framework of the Clean Development Mechanism (CDM) under Kyoto Protocol (1997), the FCS is defined by the international community as "voluntary transactions between developed country and developing country that are condition on the developed one fulfill its commitments to reduce emissions by investing in emission reduction or carbon sequestration projects in developing one, while at the same time being able to provide additional funds and advanced technologies for the host of the project, thereby helping developing country achieve sustainable development (Wunder, 2015; Yang et al., 2018; Zhao et al., 2017). Recently, with the successive drafting or signing of climate change related documents such as the "Bali Roadmap" (2007), the "Copenhagen Accord" (2009), and the "Paris Agreement" (2016), FCS, which are more economical and efficient than other ways of reducing carbon emission (Chan et al., 2017; Farley and Costanza, 2010), have been considered as an innovative and effective approach to protect natural resource and alleviate poverty by investing capital in impoverished mountainous area and therefore attracting worldwide attention among different governments, scholars and conservation practitioners (Mufan et al., 2020). In the short term, compared with carbon trading in conventional energy and industrial sectors, the FCS projects often lacks a competitive advantage. However, due to its multiple non-carbon effects, for instance, mitigation and adaptation to climate change, vegetation restoration and biodiversity protection, promotion to the sustainability of communities, the development of forest carbon projects, such as, Afforestation and Reforestation (AR), Reduction of Emissions from Deforestation and Forest Degradation (REDD+), and Improvement of Forest Management (IFM), can contribute to climate mitigation in two methods-first, through increased sequestration of the carbon dioxide and second, through preserving the carbon stock in the forests (Aggarwal and

Brockington, 2020; Duchelle et al., 2018; Sheng et al., 2019). It has been argued that FCS can transform the advantages of ecological resources in underdeveloped areas into capital and technology, and promote "green water and green mountains" to play the role of "golden mountains and silver mountains". These projects can provide alternative livelihoods and other socioeconomic benefits for local communities, its multiple non-carbon effects have gradually emerged (Brownson et al., 2020; Le and Leshan, 2020).

However, the status of agricultural development in the FCS project area is not optimistic. From the macro perspective of community, the implement of FCS projects is often companied with a series of environmental, economic and social risks caused by natural disasters, human activities and other factors in project areas (Bayrak and Marafa, 2017; Galik and Jackson, 2009). There is a high degree of uncertainty in the impact of FCS on the regional environment and society. In terms of environment, FCS may bring the spread of diseases and insects to the region, increase in soil surface nutrient consumption and soil sheet erosion, decrease in surface water, cause the loss of native tree species, even reduce biodiversity of local community (Brownson et al., 2020; Cao, 2011). In terms of negative social effects, FCS may lead to the loss of control by communities and farmers on land and forest products, and give rise to the property rights conflicts with external investors (Wang et al., 2012). In particular, due to the lagging economic and social development, local governments often offer preferential policies such as land transfer at a low price to introduce projects, at the same time it is prone to leading to the externalization of natural resources and interests in poor areas, thereby hindering the sustainable development of agriculture (Yang et al., 2020). On the basis of farmers' micro-perspective, in order to avoid carbon leakage, the implementation of the FCS project areas and its surroundings, farmers' livelihood activities such as planting, cutting firewood, and grazing are often restricted, which ultimately hinders agricultural development (Haile et al., 2019; Wang et al., 2017; Wang et al., 2020).

In conclusion, in the real situation where the contradictions between ecologically environmental protection and agricultural development are gradually emerging, does the implement of FCS project promote or inhibit regional agricultural development? Therefore, a further empirical evaluation is still needed.

2.2 Theoretical analysis

Academically, many studies have been carried out studies based on the Ecological compensation project (ECP) and related about agricultural development. The research in this article involves three types of literature. The first type of literature mainly evaluates the policy effects of ECP, which generally conducted on the mechanism of the implementation of PES from the perspective of ecology, society and economy (Jiangyi et al., 2020; Wang et al., 2012; Wu et al., 2019). The second type of literature discussed the main factors affecting agricultural development in terms of regional natural endowments, external socioeconomic environment, and institutional policies, focusing on the effects of agricultural production efficiency, value, and agricultural scale operation, farmers' income, so on (Liu et al., 2021; Shen et al., 2018; Zhang et al., 2018). The third type of literature focuses on the relationship between ECP and agricultural development, and is closer to the main content which we need further study in this article. For instance, (Cheng and Li, 2018) used a balanced analysis to calculate the agricultural economic losses caused by ecological water compensation projects, showing that there is a conflict between river ecological system and household' food safety guarantee. When it comes to the effects that ECP on agricultural ecological environmental pollution, (Gao et al., 2019) pointed that the agricultural eco-compensation strategy can be a good instrument to reduce nitrogen and phosphorus fertilizer application in the field. While for forest ECP, it has played an active role in alleviating the pollution of the agricultural environment, such as reducing greenhouse gas emissions and reversing natural risks (storms, fire, and insect outbreaks) (Brownson et al., 2020; Galik and Jackson, 2009). Moreover, on the basis of a field survey of 474 herdsmen in Inner Mongolia and Gansu China, (Xiaolong et al., 2019) found that the grassland ecological compensation policy has a significant positive impact on the overgrazing behavior of herdsmen. However, some scholars hold the opposite view. Using the micro-survey data of farmers and herdsmen in the agro-pastoral ecotone, (Shengqiang and Kai, 2019) found that due to the low compensation income, after the implementation of the grassland ecological compensation policy, the livestock production of herdsmen did not decrease.

The above literature mainly focuses on the policy effects of ecological compensation and the factors affecting agricultural development, only a little existing literature that focus on the impact of ecological compensation policies on agricultural development. However, these studies lack a comprehensive assessment based on market-oriented forest ecological compensation policies, that is forest carbon sinks. In recent years, some scholars have begun to pay attention to the economic effects of FCS projects and found that FCS projects can optimize the local industrial structure and increase the regional capital stock, thereby promoting its economic development (Yuan et al., 2021). Whereas, they have not discussed the impact of FCS project on agricultural development in depth. As a market-oriented ecological compensation project, its unique environmental and economic attributes make the pilot area of the FCS project has the dual characteristics (increasing forest coverage and decreasing agricultural production resources), which in turn has dual effects on agricultural development.

On one hand, the development of FCS projects may have a negative inhibitory effect on agricultural development. Theoretically, compared with non-pilot areas, the FCS project pilot area emphasizes the importance of ecological environment protection. Therefore, the contradictions between agricultural development and ecological environment protection are more obvious in the FCS project area. For instance, the implementation of the FCS project uses part of the cultivated land for afforestation activities, then directly reduces the land resources used for agricultural production, which in turn results in a decrease in the total agricultural output (Dang et al., 2020). In the practice of FCS project, owing to the rigid constraints of ecological policies, there may be some non-slope farmland used for afforestation, leading to the leakage of high-quality farmland (Yan, 2019b), which will further strengthen this inhibitory effect. Additionally, the implementation of FCS project will directly affect the livelihood activities of the farmers in the project area in the short term, such as understory planting and free grazing, thus restrict their livelihood strategies and reduce their household income (Ba et al., 2020; Dang et al., 2020; Jindal et al., 2012). Coupled with the relatively single source of income for farmers, the decline in family income and living standards may squeeze out their input for agricultural operation, and ultimately have a negative impact on agricultural development.

On the other hand, under the trend of large-scale operation and modern management in agriculture, the development of FCS projects may also promote agricultural development. In particular, first, the FCS project advocates afforestation on low-yield sloping farmland, which can optimize the allocation of labors and capital in agricultural production, and concentrate production factors such as high-quality labors and capital on high-quality flat land, thus improving the operation efficiency of farmland (Duong and De Groot, 2020; Wang et al., 2017; Yu et al., 2020). (Du and Takeuchi, 2019) highlighted the forest roads and water conservancy facilities built by some certain FCS projects objectively improved the construction of local infrastructure construction and benefited local agricultural production. Moreover, the development of FCS projects will directly absorb part of the rural surplus labor force for nearby employment, increasing the wage and property income of rural households (Mori-Clement, 2019a; Wood, 2011). Theoretically, the increase in household income can increase the input of farmers in agricultural production, for example, land leveling, agricultural machinery, and labor force, thereby indirectly increasing agricultural output. Particularly, after the implementation of the FCS project, the ecological benefits it brings can directly improve the local ecological environment, reduce the risk of natural disasters such as landslides and mudslides, therefore, it indirectly provides external environmental protection for the sustainable and healthy development of agriculture (Eissler, 2018; Sommerville et al., 2010).

It can be seen that the FCS project may be a double-edged sword. It is expected to improve agricultural production by improving the human capital and economic capital of farmers, at the same time it could further stimulate the contradiction between agricultural development and ecological environmental protection. Moreover, China owns a huge population, so agriculture plays a primary role. In conclusion, it is particular important to evaluate the impact of FCS on agriculture, because the effects induced by these policies may result in unexpected outcomes if the project are not properly designed. Accordingly, this paper proposes the following research hypotheses:

H1: The implementation of FCS projects has led to a decrease in arable land resources used for agricultural production, thereby inhibiting agricultural development in the short term.

H2: The implementation of FCS projects is conducive to promoting the employment of rural labor, improving agricultural production efficiency, thereby promoting agricultural development in the long run.

3. Materials and Methods

3.1 Method

According to incomplete domestic statistics, as of the end of 2017, a total of 110 FCS projects covering 148 counties/cities/district in 23 provinces in China have been filed and implemented by the National Development and Reform Commission. Wherein, 75 carbon sink afforestation and reforestation projects have been implemented and account for the highest proportion (68.18%), involving 118 counties/cities/district in 21 provinces; followed by the 28 forest management projects. Sichuan Province is rich in land resources and its ecological locations (such as climate, soil and terrain) are extremely suitable for the growth of forestry. Additionally, it is also regarded as an important natural carbon pool in the world, as well as the first batch of national FCS pilot projects, which give Sichuan Province the unique advantage of carrying out FCS projects. The FCS pilot projects in Sichuan has already been at the forefront of China. For example, of the five CDM projects registered by the United Nations Clean Development Mechanism Executive Board (EB), Sichuan occupies two, and has gradually become the focus of China's FCS projects. The most representative ones are the " Afforestation and Reforestation on Degraded Lands in Northwest Sichuan, China " and the " Forestry Carbon Sequestration, Community and Biodiversity Project in Southwest, Novartis”. The former was implemented in five counties of Sichuan: Lixian, Maoxian, Beichuan, Qingchuan and Pingwu, which was officially launched in 2004; the latter was implemented in five counties of Liangshan Prefecture: Ganluo, Yuexi, Zhaojue, Meigu, and Leibo, which was officially launched in 2010.

Considering the other counties in Sichuan are not affected by the pilot project, we regard FCS project as a quasi-natural experiment conducted in the pilot counties. According to the project experience, we treated FCS pilot counties as processing groups, and other counties in Sichuan Province are treated as the control group. Comparing the differences between the treatment group and the control group can estimate the impact of the FCS project on the total agricultural production. An intuitive idea is to use the Difference-in-Difference (DID) method to compare the changes in the agricultural production of the pilot counties and the non-pilot counties before and after the implementation of FCS project respectively. Then the difference between the two changes can reflect the impact of the implementation of FCS project on the total agricultural production in the pilot counties. Nevertheless, the DID method called for the totally random selection between processing group and control group, and the result was prone to have certain selectivity errors (Li et al., 2020). In this paper, the FCS pilot counties could have been selected for specific reasons, such as natural resource endowment and national policy propensity. Thus, there tended to be deviations if we used the DID method in all sample ranges. Later, some scholars (Du and Takeuchi, 2019; Mori-Clement, b) tried to introduce the propensity score matching method (PSM) to overcome such shortcomings of the DID method. To a certain extent, it could improve the comparability between the treatment group (pilot counties) and the control group (non-pilot counties) before the implementation of the project. However, the PSM method still has limitations: first, this method was more suitable for the processing group and the control group with large samples of micro-data, but it was difficult to obtain ideal matching results for regional samples in this study. Second, this method selected county-year data as individuals to form mixed data, which could not effectively analyze the agricultural development of individual counties. For example, Beichuan County (2004) and Beichuan County (2005) were regarded as different observation objects, but when the two counties were compared with Li County (2005), this model did not find differences between the two comparative groups. Third, in the process of selecting matching variables to calculate matching scores, whether it was the covariance of the current series or the covariance of a lagging period, the results were biased because of county-year interleaving.

Therefore, some scholars have proposed the use of synthetic control method (SCM) to overcome the shortcomings of the above two types of policy evaluation methods (Cerulli, 2019; Wan et al., 2018). This method has certain similarities with PSM, because both are based on the characteristics of non-pilot counties to construct an artificial control group. First, the SCM selected a pilot county that has implemented the project as a processing group. Second, it used a data-driven method to determine the weight of each non-pilot county based on the characteristics and similarities of their own data. Finally, according the weight of each non-pilot county SCM could construct a control group (synthetic group) that are completely similar to the processing group before it implemented the FCS project, then compared the two groups. Its advantages are mainly reflected in: ① The weight of each non-pilot county is determined by data driving, which reduces the subjective selection error; ② The use of multiple control samples to simulate the processing group before it implemented the FCS project can obtain the contribution of each control sample to the synthetic sample, and it also avoids excessive extrapolation; ③ It is possible to compare every single treatment group with the synthetic group one by one, avoid the result error caused by the average evaluation, and analyze the policy effects of different implementation time nodes. For example, using a SCM, (Sheridan et al., 2020) evaluated the impact of the California 1995 smoke-free workplace law on population smoking prevalence. (Lin and Chen, 2018) treated the "Increasing Block Electricity Prices" policy implemented in Sichuan Province of China in 2006 as a natural experiment and used SCM to answer the question of whether IBEPs effectively regulate residents' electricity demand.

In this section we will clarify the detailed application steps of SCM. First, we suppose we have observed the agricultural development of $K+1$ counties, among which the first county (pilot county) was affected by the FCS project in T_0 year and the other K counties (non-pilot counties) are regarded as the control samples. Then, we can observe the agricultural development in all sample counties in T year. $fgdp_{it}^{N}$ represents the agricultural development of the sample（non-pilot?）county i that did not t implement he FCS project in the end of t year, and $fgdp_{it}^{Y}$ represents the agricultural development of pilot county after it had implemented the FCS project. Thus, $\theta_{it} = fgdp_{it}^{Y} - fgdp_{it}^{N}$ means the net effect after implementing the FCS project. Second, the synthetic control method assumes that when $t < T_0$, the agricultural development in all sample groups meet $fgdp_{it}^{Y} = fgdp_{it}^{N}$; when $T_0 < t \leq T$, the agricultural development in the processing groups meet $fgdp_{it}^{Y} = \theta_{it} + fgdp_{it}^{N}$. Third, this article assumes fcs_{it} is a dummy variable for whether the sample counties had implemented FCS projects, that is, $fcs_{it} = 1$ indicates that the sample is a pilot county, and $fcs_{it} = 0$ indicates that the sample is a non-pilot county. Thus, the level of agricultural development observed in the i county in the t year can be expressed as $fgdp_{it} = \theta_{it} + fgdp_{it}^{N}$. Specifically, when $t < T_0$, non-pilot county $fcs_{it} = 0$, $fgdp_{it} = fgdp_{it}^{N}$; when $T_0 < t \le T$, $\theta_{1t} = fgdp_{it}^{Y} - fgdp_{it}^{N} = fgdp_{it} - fgdp_{it}^{N}$. Since only the first county in the full sample started to be affected by the FCS project after T_0 , thus if we estimated θ_{1t} , the impact of the FCS project on the agricultural development in the pilot county can be obtained. However, to obtain θ_{1t} , we need estimate the unobservable potential factors of agricultural development $fgdp_{it}^{N}$. Therefore, this article sets a model of potential agricultural development:

$$fgdp_{it}^{N} = \alpha_t C_t + \beta_t \delta_t + \gamma_t + \varepsilon_{it} \qquad (1)$$

In formula (1), C_t represents the control variable not affected by the FCS project, β_t represents the unobservable common factors in ($1 \times F$) dimension, δ_t represents the regional fixed effect that cannot be observed in ($F \times 1$) dimension, γ_t represents the time fixed effect, and ε_{it} represents the random error term with mean value 0. Furthermore, the K non-pilot counties are weighted and combined according to the weight vector $W = (w_2, \cdots, w_K, w_{K+1})$, and the weight is required to be positive and the sum is 1. Within it, all vectors can be weighted:

$$\sum_{K=2}^{K+1} w_K \, fgdp_{it}^{N} = \sum_{K=2}^{K+1} w_K \alpha_t C_t + \sum_{K=2}^{K+1} w_K \beta_t \delta_t + \gamma_t + \sum_{K=2}^{K+1} w_K \varepsilon_{it} \qquad (2)$$

Suppose there is a vector group $W^{*} = (w_2^{*}, \cdots, w_K^{*}, w_{K+1}^{*})$ that satisfies:

$$\begin{aligned} &\sum_{K=2}^{K+1} w_K^{*} \, fgdp_{K1} = fgdp_{11}, \sum_{K=2}^{K+1} w_K^{*} \, fgdp_{K2} = fgdp_{12}, \cdots, \\ &\sum_{K=2}^{K+1} w_K^{*} \, fgdp_{KT_0} = fgdp_{1T_0}, \sum_{K=2}^{K+1} w_K^{*} C_K = C_1 \end{aligned} \qquad (3)$$

If $\sum_{i=2}^{T_0} \beta_t' \beta_t$ is a non-singular matrix, we can get:

$$fgdp_{it}^{N} - \sum_{K=2}^{K+1} w_K^* fgdp_{it} = \sum_{K=2}^{K+1} w_K^* \sum_{S=1}^{T_0} \beta_t (\sum_{N=1}^{T_0} \beta_N' \beta_N)^{-1} \beta' (\varepsilon_{KS} - \varepsilon_{K1}) - \sum_{K=2}^{K+1} w_K^* (\varepsilon_{KS} - \varepsilon_{K1}) \quad (4)$$

Generally, the right side of equation (4) will be close to 0. Therefore, when $T_0 < t \le T$, $\sum_{K=2}^{K+1} w_K^* fgdp_{Kt}$ can be used as an unbiased estimate of $fgdp_{it}^{N}$ to present $fgdp_{it}^{N}$. Similarity, $\theta_{1t} = fgdp_{it}^{Y} - fgdp_{it}^{N} = fgdp_{it} - \sum_{K=2}^{K+1} w_K^* fgdp_{Kt}$ presents the estimate of θ_{1t}. Furthermore, if formula (4) is valid, two conditions are required: ①Ensure that the feature vector of the first region is within the convex combination of the feature vector groups of other regions; ②the weight W^* exists. With reference to the study of (Abadie et al., 2015), this paper determines the weight W^* by the minimizing distance between A_1 and $A_0 W$. Specifically, A_1 represents the feature vector of the non-pilot counties before the implementation of the FCS project in（$F \times 1$）dimension. The A_0 represents the（$F \times K$）matrix, and the Kth column of A_0 represents the feature vector of the Kth sample county before the implementation of the FCS project.

The feature vector is any linear combination of factors that determine the agricultural development in formula (3). The V in the distance function $\| A_1 - A_0 W \| V = \sqrt{(A_1 - A_0 W)' V (A_1 - A_0 W)}$ represents a （$F \times F$）symmetric positive semi-definite matrix, moreover the selection of V may affect the estimation error. According to previous research of SCM (Mohan, 2017), this paper chooses the symmetric positive semi-definite matrix to be minimized in order to achieve a synthesis county that possesses a nearly similar agricultural development as the pilot county before the implementation of the FCS project.

3.2 variables and resources

According to the research of (Abadie et al., 2015; Mohan, 2017), the use of SCM first needs to ensure that there are multiple periods of data before project implementation, to ensure that synthetic control can have a high degree of fit in predictive variables and outcome variables before project implementation. In this way, the reliability of the conclusions can be enhanced. Therefore, the time span of the sample selected in this paper is from 2000 to 2015. Similarly, in the sample selection process, in order to ensure the scientific of the SCM, the sample counties that non-continuously implemented FCS projects in Sichuan Province after 2005 were excluded from the control group, and finally 118 samples were obtained. The SCM needs to determine the dependent and predictive variables in the estimation process, so this article selects the total agricultural output (calculated based on the price in 2000) as the dependent variable to reflect the development of agriculture. Furthermore, in order to calculate the optimal weight combination and use it to construct the synthetic control result, this paper selects the number of agricultural, forestry, animal husbandry and fishery employees, the area of cultivated land at the end of the year, the amount of agricultural chemical fertilizer (converted scalar) and the total power of agricultural machinery as predictive variables to respectively reflect the input factors such as labor, land, fertilizer and agricultural machinery in the agricultural production process. The data we used above are all extracted from the “Sichuan Statistical Yearbook” and the “County Statistical Yearbook" from 2001 to 2016.

Currently, the FCS transactions are all project-level and certified emission reduction transactions in China, including three main types of projects. One is FCS projects under the Clean Development Mechanism (CDM); the second is China’s certified emission reduction mechanism (CCER); the last is voluntary projects. Table 1 summarizes the information of the pilot counties for FCS projects in Sichuan Province since 2000, and these pilot counties all started FCS projects from 2000 to 2015. Compared with the research on SCM mentioned above, there are multiple pilot cases in this research, which provides the possibility to eliminate the influence of interference policies. The reason is that even if there are other interference policies that accompany with a certain pilot county, the probability that all pilot counties have implemented the similar policies at the same time and all that have worked will be greatly reduced.

Table 1. Basic situation of pilot counties for the FCS project in Sichuan Province

County	Types of projects	project name	Starting year	Crediting period (year)	Area （hectare）
Miannig	CCER	Audi Panda Habitat, Multi-benefit of forest restoration and afforestation carbon sink project	2012	30	153.4
Jinyang	CCER		2012	30	181.7
Lixian	CDM	Afforestation and Reforestation on Degraded Lands in Northwest Sichuan, China	2004	20	747.8
Maoxian	CDM		2004	20	234.9
Beichuan	CDM		2004	20	200.2
Qingchuan	CDM		2004	20	878.3
Pingwu	CDM		2004	20	190.6
Ganluo	CDM	Forestry Carbon Sequestration, Community and Biodiversity Project in Southwest,	2010	30	924.3
Yuexi	CDM		2010	30	1245
Meigu	CDM		2010	30	731.6
Zhaojue	CDM		2010	30	441.8
Leibo	CDM		2010	30	854.1

County	Types of projects	project name	Starting year	Crediting period (year)	Area （hectare）
		Novartis			
Yingjing	VCS	Reforestation Project in Yingjing County, Sichuan Province	2011	30	159.2

4. Results and discussion

In this section, we will describe our empirical approach, then examine the impact of FCS project development on agricultural development and its key hypotheses. Taking Beichuan County as a case study, we first use SCM to seek the optimal weight combination. Additionally, the causal influence of FCS on agricultural development is verified in sequence, on the basis, the robustness of the conclusion is tested.

4.1 Comparative analysis of synthetic control results

We use the county units of the control group (non-pilot counties) that had not implemented FCS, and use synthetic control ideas to construct the counterfactual result of "unimplemented FCS projects". The effectiveness of this method can also be verified from the statistic indicators before the implementation of FCS projects shown in table 2. Using the SCM, table 2 reports the comparison of counterfactual Beichuan County and actual Beichuan County based on the data of each year before the implementation of the project. It is easy to see that, on the basis of optimal weight combination, the difference between the counterfactual group and the actual group before the implementation of FCS project is very small, and this difference is lower than the difference between the actual group and the average of 113 control group counties. This also proves the validity of this synthetic control method used in this paper.

Table 2. Comparison of synthetic control index results

Variables	**Specific meaning**	**Li county**		**the average of 113 control group counties**
		Actual value	**synthetic value**	
Dependent variables	total agricultural output (Ten thousand yuan)	24217.29	23 985.40	60 644.24
predictive variables	Number of employees in agriculture, forestry, animal husbandry and fishery (person)	81082.00	80 242.16	232 404.60

Cultivated land area at the end of the year (ha)	12746.40	25 411.14	25 954.10
Agricultural fertilizer application (tons)	5 466.00	5 406.08	12 789.59
Total power of agricultural machinery (100,000 million watt)	3.60	3.56	10.57

4.2 Analysis of optimal weight combination

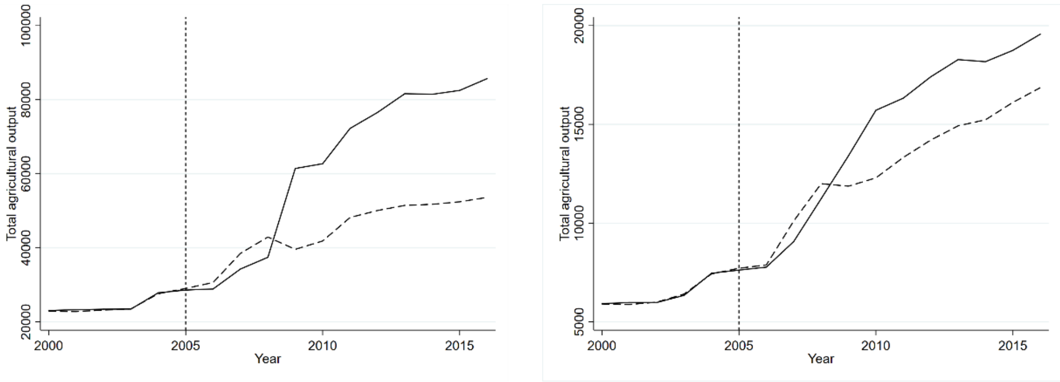
On the basis of the SCM, we can also obtain the optimal weight combination in the composition of the synthetic control group. This method is completely promoted by the data for each previous year prior to the implementation of FCS project, which has overcome the possible non-random problems of the treatment group; in addition, the weight of each control group county in the composite control result can be directly obtained. Figure 3 reports the weight combinations obtained under the optimal algorithm for the 113 control group counties in the analysis of Beichuan County. The results show that prior to the implementation of the FCS project, the trend line of total agricultural output of Beichuan County can be obtained by the weighted combination of 13 counties, including Derong, Jinyang, Wanyuan, etc., however, the weights of other counties are assigned 0 in this synthesis process. Among the 13 control counties, Derong County's contribution weight is as high as 0.523%, which means that after considering various agricultural economic indicators, it has the greatest degree of similarity with Beichuan County. Additionally, the weight contribution of each county also provides a research basis for our subsequent placebo testing. Due to space limitations, this article does not report the weight combinations in the analysis of other counties.

Table 3. The optimal weight combination constructed by the SCM

County	**Xinlong County**	**Batang County**	**Daocheng County**	**Derong County**	**Huili County**	**Ningnan County**	**Jinyang County**
Weight	0.002	0.001	0.001	0.523	0.009	0.031	0.140
County	**Jianyang City**	**Xuanhan County**	**Dazhu County**	**Wanyuan City**	**Songpan County**	**Ganzi County**	
Weight	0.003	0.030	0.029	0.139	0.001	0.085	

4.3 Basic estimation results

Based on the mentioned above analysis, we assessed the impact of the implementation of FCS on the agricultural development in Beichuan County and Li County. The results presented in Figure 1, indicating that after the implementation of the FCS project, the total agricultural output of the two counties has shown an overall trend of first decline and then rise. This reveals that the implementation of FCS pilot projects will have a certain degree of restraint on regional agricultural development in the short term, but in the long run, it will significantly promote regional agricultural development.



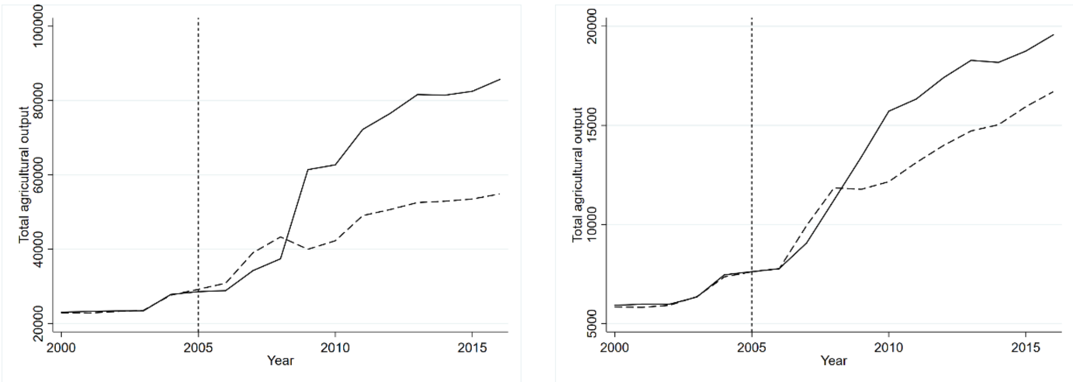
(a) Beichuan county (b) Li county

Fig. 1 FCS and total agricultural output

4.4 Robustness checks

4.4.1 Reselect control group

In fact, a small number of counties have successively implemented FCS projects such as carbon sink afforestation and forest management in the time interval that our article studies. For example, the "Reforestation Project in Yingjing County, Sichuan Province" began to be implemented in 2011; the "Audi Panda Habitat, Multi-benefit of forest restoration and afforestation carbon sink project" was implemented in Mianning and Jinyang County in 2012. In order to ensure that the implementation of these projects will not affect the reliability of our conclusions, we strictly excluded the sample counties that implemented other FCS projects during this period from the control group counties, and re-estimated this impact. As shown in Figure 2, after narrowing the sample counties in the control group, the impact of the implementation of FCS project on agricultural output is basically consistent with the above regression results shown in Figure 1. Therefore, even after excluding a few counties that successively implement other afforestation projects, the impact between the two is still significant. In addition, considering that the FCS project itself has strong externalities, we eliminated five counties that are the geographical borders of the FCS pilot county and used the SCM to estimate again, and the conclusion is still stable.

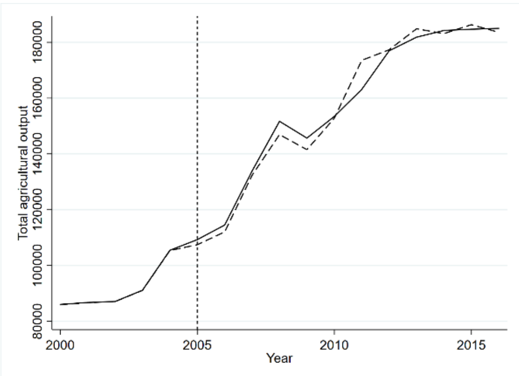


(a) Beichuan county (b) Li county

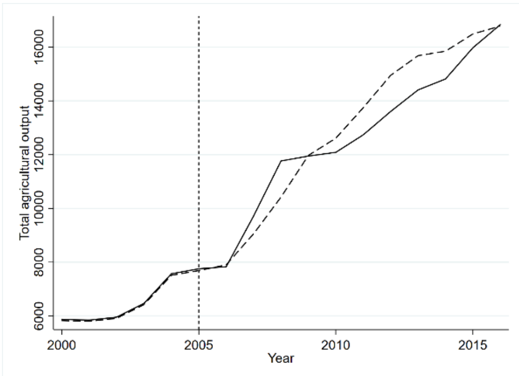
Fig. 2 Analysis results of narrowing the sample scope of the control group

4.4.2 Placebo test

As mentioned earlier, because of multiple FCS project pilot counties in this study, it provides us the possibility for mutually check and eliminate the influence of interference policies. Even so, we still tried two placebo test methods to verify the robustness of our empirical results. On one hand, we separately "find" a non-pilot county that is most similar to the pilot sample county to conduct a Falsification Test. If there is no implementation effect in non-pilot county under the “same model” and “same starting period of FCS project”, it can testify there indeed has the impact of FCS projects on agricultural development in pilot county. In fact, in the process of constructing the optimal weight combination in non-pilot counties (control group), which realized in part 4.2, just provided the similarity of each control group with the pilot county. Thus, we respectively regarded the non-pilot counties with the largest weight contributions as the false pilot counties. Figure 3 presents the results of the implementation effect of false pilot counties, showing that even in very similar counties, if there is no FCS project, there will be no beneficial agricultural effects found in the counties. Therefore, the placebo test also confirmed that the casual relationship between FCS and agricultural development exists, whereas the impact of other interference factors is limited.



（a） Derong county (Beichuan county)



（b） Jinchuan county (Li county)

Fig. 3 False experimental estimation results

On the other hand, although we have found in the empirical results that the total agricultural output of Beichuan County first decreased and then increased after the implementation of the FCS project, however, it is not certain whether the impact of the FCS project on the total agricultural output is significantly different from 0 in statistic. To this end, this article draws on the Ranking Test Method proposed by (Abadie et al., 2015) to re-verify the empirical results. Our basic idea is to assume that the counties in the control group implemented the FCS project in 2004, use the SCM to construct the synthetic total agricultural output of each county, and estimate the effect of the policy implementation under the assumption. Comparing the implementation effect of FCS project between Beichuan County and the control groups, if there is a big difference between the two policy effects, it means that the implementation of the FCS project has a significant impact on the total agricultural output of Beichuan County. More precisely, it is not an accidental phenomenon, vice versa. The steps are as follows.

First of all, in order to eliminate sample counties with poor fitting effects of synthetic control before the implementation of FCS, avoid large fluctuations after the pilot project, and enhance the credibility of the SCM, the average forecast error of Beichuan County is calculated, and the calculation formula is as follow.

$$MSPE = \frac{1}{T_0}\sum_{t=1}^{T_0}(y_{1t} - \sum_{j=2}^{j+1} w_j^* y_{jt})^2 \qquad (1)$$

Secondly, in order to further improve the accuracy of the empirical results, this paper refers to the screening criteria of (Abadie et al., 2010), and chooses to exclude samples in the control group whose MSPE value is twice higher than Beichuan County, thus a total of 75 samples are eliminated. The 75 sample counties had a poor fit of the total agricultural output before the implementation of FCS project, which reduced the explanatory power of the change in the total agricultural output after the FCS project implementation. Finally, 39 sample counties are retained for ranking test, and the results are shown in Figure 4.

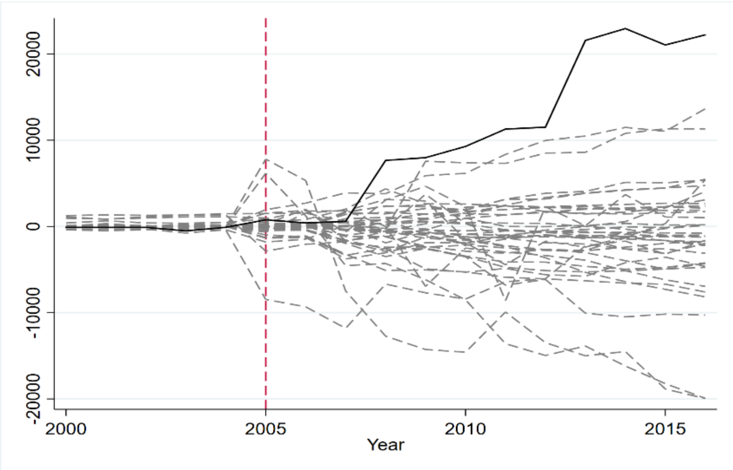


Fig. 4 Comparison of MSPE values between Beichuan County and the control group

4.4.3 Replace estimation method

In order to verify the advantages of the synthetic control method (SCM) when selecting the control group and the robustness of our estimation results, this section uses the DID model to re-estimate the impact of the FCS project on agricultural development. The model is set as follows:

$$\ln fgdp_{it} = \beta_0 + \beta_1 fcs_i \times time + \beta_2 control + \delta_i + \gamma_t + \varepsilon \qquad (1)$$

Where $\ln fgdp$ presents the logarithm of the total agricultural output. We assign a value fcs =1 for the processing group (pilot counties), and fcs =0 for the control group (non-pilot counties). The five pilot counties in the processing group started piloting the FCS project in 2005, thus we assigned the value of the time that before and after the implementation of FCS project. Specifically, the county started piloting the FCS project after 2005, the value of $time$ =1; before 2005, the value of $time$ =0. The coefficient of the interactive item ($fcs \times time$) is the net effect of FCS project on the total agricultural ptoduction. $control$ presents the control variables, including "the number of employees in agriculture, forestry, animal husbandry and fishery"," cultivated land area at the end of the year"," agricultural fertilizer application"," total power of agricultural machinery". δ_i presents individual fixed effect, and γ_t presents time fixed effect. The data is selected from 2000 to 2015, and the sample is the 118 counties in Sichuan Province selected as above.

As is shown in Table 4, the columns (1) and (2) indicated that the estimated coefficient of the interactive item ($fcs \times time$) is significantly positive at the 5% level after including the control variables. Namely, compared with non-pilot counties, the FCS pilot counties have a dramatic increase in their agricultural production from 2005 to 2015, which indicates that the FCS project has promoted the agricultural development of the pilot counties and further verified the robustness of the above analysis results. In conclusion, based on the parameter estimation results, the implementation of the FCS project increased 27.12% of the total agricultural production of the processing group from 2005 to 2015, with other variables unchanged.

Table 4. Robustness test results of the replacement estimation method

Variable	DID estimation		PSM-DID estimation	
	（1）	（2）	（3）	（4）
fcs×time	0.102 4	0.271 2**	0.095 9	0.285 6**
	（0.617 9）	(2.274 6)	（0.565 6）	（2.224 0）
fcs	-0.779 3***	-0.016 8	0.096 3	0.114 0
	（-5.645 9）	(-0.165 8)	（0.746 9）	（1.233 8）
time	0.522 1***	0.279 6***	0.627 9***	0.356 2***
	（8.757 6）	(7.847 1)	（4.962 2）	（3.191 0）
control	NO	YES	NO	YES
Constant term	10.497 9***	9.369 6***	8.867 6***	8.374 3***
	（208.740 3）	(240.560 3)	（83.477 0）	（77.588 1）
N	1 888	1 888	112	112
R^2	0.0588	0.7522	0.3088	0.8062

Note: ①The t value is in parentheses; ②***, **, * indicate the significance levels of 1%, 5%, and 10% respectively; ③ All regressions use the clustering robustness standard error with the county as the clustering variable.

Furthermore, in order to overcome the possible systematic differences in the changing trends of agricultural development between the pilot counties and non-pilot counties, as well as reduce the bias in the DID estimation, this paper continues to use PSM-DID to conduct a robustness test based on kernel matching. The matching results showed that only 2 pilot counties were matched to 5 similar control samples, which can demonstrate the scientific of the SCM used in this article when selecting the control group. The test results of the covariates show that after propensity score matching, the difference in the mean of the covariates between the processing group and the control group has changed from significant to insignificant, and the distribution of each variable between the two sample groups has become balanced. It shows that it is necessary to introduce PSM into DID estimation. The estimation results in columns (3) and (4) of Table 4 show that the estimated coefficient of the interaction term $fcs \times time$ has increased slightly and the statistics are still significant, indicating that the use of DID method will underestimate the treatment effect, and the results are still robust. In addition, in order to ensure that the treatment effect estimated by PSM-DID truly reflects the causal effect between the FCS project and the total agricultural production, this paper further verifies the parallel trend hypothesis. As is shown in Figure 5, before the FCS project, the agricultural production between the processing group and the control group maintained roughly a same growth trend, but after the project was implemented, the growth trend of the agricultural production between the two sample groups changed significantly. Hence, if this paper uses the PSM-DID model to test the robustness of the research conclusions, it is in accordance with the prerequisite of the parallel trend hypothesis. As is shown in Figure 5, from the change trend of the agricultural production of the two sample groups, we can see that the growth rate of the agricultural production of the processing group was significantly lower than that of control group from 2005 to 2008. However, after 2008, the growth rate in the processing group overtook the growth rate in the control group and this trend maintained for a long time, which further verified the research conclusion of the SCM, that is, the FCS project has a depressive effect on agricultural development in the short term, but in the long term, it will promote the development of local agriculture.

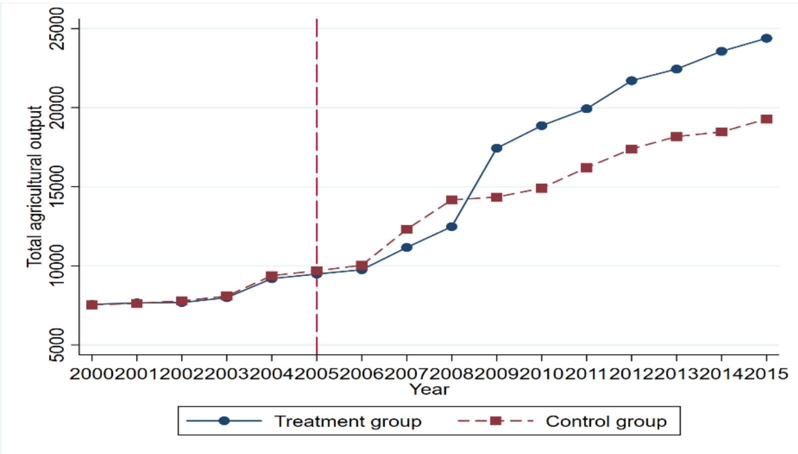


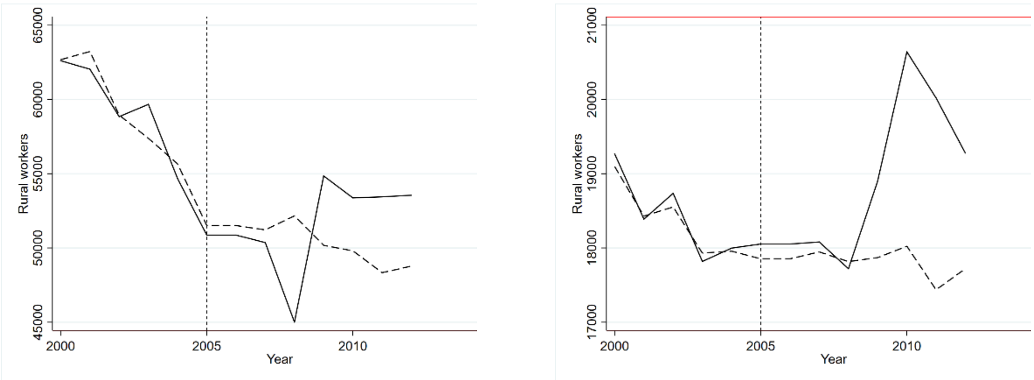
Fig. 5 Parallel trends in agricultural production

5. Analysis of influence mechanism

The previous empirical analysis shows that the development of FCS projects has a short-term inhibitory effect on agricultural development, but has a long-term promotion effect. Then, we can't help but come up with this idea that through which channels does this effect play a role? It is obvious that the implementation of the FCS project is to use part of the low-quality, slope, arable land for afforestation or reforestation, which will crowd out the agricultural land resources, thus reduce the total agricultural output by reducing resource input. Nevertheless, from an opposite view, the reduction of agricultural land resources will inevitably force farmers to improve agricultural production efficiency in order to maintain their daily agricultural income. Additionally, the implementation of FCS projects can also release rural surplus labor and absorb rural labor to enter the employment market, which will promote agricultural development through the improvement of human and economic capital. Therefore, this section mainly analyzes the mechanism from two aspects: labor employment and agricultural production efficiency.

5.1 The impact of FCS project development on rural labor employment

From the perspective of labor employment, the development of FCS projects can drive labor employment in the project area and directly increase the human capital and economic capital of rural residents, and this is a driving force that cannot be ignored to promote agricultural development. Therefore, we further discussed this kind of potential influence mechanism. We take rural employees as an example to empirically test the impact of FCS project development on rural labor employment. The results in Figure 6 show that after the implementation of the FCS project, rural workers in Beichuan County showed a trend of first decreasing and then increasing. We assume the possible reason is that at the initial stage of the project, some rural workers were unable to achieve rapid employment transition in a short period of time. However, after a transition period of about three years, the number of rural employees has gradually increased. It turns out the rural employees in Li County had no obvious impact in the short term, but it had also shown a significant growth trend after three years. Thus, absorbing rural labor to participate in employment is also a potential mechanism for the FCS project to promote agricultural development, but it shows a certain degree of heterogeneity in different pilot counties.



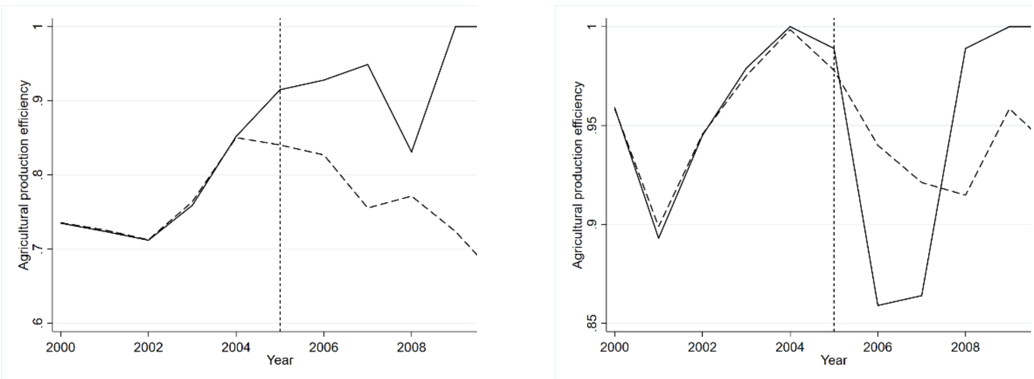
(a) Beichuan county (b) Li county

Fig. 6 FCS and rural workers

5.2 The impact of FCS project development on agricultural production efficiency

The development of FCS projects may also promote agricultural development through a channel of agricultural production efficiency. Therefore, we further examine the impact of FCS project on agricultural development from the perspective of agricultural production efficiency. One idea is that adopting the Data Envelopment Analysis method (DEA), regarding each county as a decision-making unit. Following the research about agricultural efficiency (Ma et al., 2021; Mwambo et al., 2021), we set agricultural labor, land, fertilizer and agricultural machinery as input variables, and set the total output of food and meat, as well as the total agricultural output as output variables. According to the above variables which selected from 2000 to 2010, the comprehensive efficiency of each county's agricultural input and output is calculated and used it as a proxy variable of agricultural production efficiency. Thereinto, the agricultural labor force is calculated by the number of employees in agriculture, forestry, animal husbandry and fishery, reflecting the number of laborers engaged in agricultural production and operation in rural areas; agricultural land is calculated by the effective irrigation area, reflecting the scale of land that can be used for agricultural production and operation; agricultural fertilizers and machinery are measured by the amount of agricultural fertilizer application (reduced scalar amount) and the total power of agricultural machinery respectively. The all variables reflecting agricultural output value are calculated at the price level in 2000. In addition, considering that some pastoral areas in Sichuan Province have little or even no grain output, we combine the output of grain together with the meat, use the added output to reflect the value of the real results of agricultural production. Since the DEA method is to evaluate the efficiency of cross-sectional data (Mao and Koo, 1997), when evaluating the agricultural production efficiency of the county, this paper divides the data into 11 years for calculation, and then organizes the results into panel data. Finally, the SCM was used to test the impact of FCS project development on agricultural production efficiency, and the estimated results are shown in Figure 7.

Figure 7 shown that although the short-term impact of the FCS project on agricultural production efficiency is not obvious. Specifically, Beichuan County has steadily improved agricultural production efficiency after the implementation of the FCS project; while Li County has shown a short-term decline and then an upward trend. However, in the long run, its positive promotion effect has begun becoming significant. The above conclusion shows that the development of FCS project has significantly promoted the improvement of agricultural production efficiency, particularly, this impact is more reflected in long-term results.



(a) Beichuan county (b) Li county

Fig. 7 FCS and agricultural production efficiency

6. Conclusion and policy implications

6.1 Conclusion

On the basis of a quasi-natural experiment of the FCS pilot project, this article explores the impact of the implementation of FCS project on the regional agricultural development. In order to deal with the non-randomness in the selection of pilot counties for the FCS project and guarantee the similarity in the selection of the control group, we adopted a purely data-driven synthetic control method (SCM) to conduct our research. The results indicated the following: first, the FCS project has an inhibitory effect on regional agricultural development in the short term (3 years on average), but it has a significant promotion effect in the long term. Second, after conducting a series of robustness checks, including reselection the control group, the placebo test of a falsification test and the ranking test method, as well as the replacement of the estimation method, the above conclusions are still robust. Third, further analysis of the influence mechanism found that the implementation of FCS project can not only effectively increase the human capital and economic capital of rural households by promoting rural labor employment, but also promote the improvement of agricultural production efficiency, which constitutes two channels for the long-term impact of FCS project on agricultural development.

Currently, insufficient attention is being paid to the study of the forest carbon sink project and agricultural development based on empirical analysis and its long-term effect. Thus, in future studies, our model can be a reference to test this effect and its long-term effect, which will provide a better understanding of FCS project and have further implications for policy making. Nevertheless, our study did have limitations. First, since this article is aimed at the evaluation of the policy effects of a case-based pilot in Sichuan Province, this may also lead to the defect of poor conclusion extrapolation. Second, due to the limitation of data sources, this article can only conduct empirical analysis based on county-level data, but the FCS project pilot area does not cover the entire county, so the empirical results may include certain random effects from other non-pilot areas. Third, we adopted data from 2000 to 2010, which was not timely for making persuasive comparisons. In future research, if micro data at the project area level can be collected and the most recent data can be acquired, the accuracy of the estimation results will be more assured.

6.1 Policy implications

Taking FCS project in Sichuan province as a case, this study adopts a data-driven synthesis control method (SCM), with the influence mechanism analysis. Our results have theoretical significance and practical value for quantitatively exploring the beneficial agricultural effects of forest carbon sinks and the transformation of modern agriculture. Consequently, several policy implications are proposed, which are detailed below:

First of all, for the audit and certification of increasingly "market-oriented" FCS projects, we must not only focus on their carbon sequestration effects, but also consider their non-carbon effects in promoting agricultural development, so as to increase the market attractiveness and competitiveness of forest carbon sinks. Second, the evaluation of the effects of forest carbon sinks policies should pay attention to the long-term nature of the implementation of

FCS project. The research in this article verified the long-term effect of FCS projects on agricultural development. Our conclusion is the same as the study of (Yuan et al., 2021), who pointed that owing to the long project cycle, the effect of the Afforestation Clean Development Mechanism project on socioeconomic development was not immediate and had an obvious hysteresis effect. Third, under the background that the marketization degree of FCS projects is still not deep (Brownson et al., 2020; Yang et al., 2013), we should further promote the pilot projects of "market-oriented" ecological compensation projects such as forest carbon sinks, and effectively guide the ecological resources such as "green water and green mountains" to play the role of "golden mountains and silver mountains", thereby promoting China's ecological environment protection and agricultural modernization.

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