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Exploration of the Application of Resource Circular Economy in the Agricultural Industry Chain

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Keywords: Resource circular economy; agricultural industry chain; supply and demand uncertainty; comprehensive evaluation system; risk sharing mechanism

Abstract: The application of resource circular economy in the agricultural industry chain focuses on the dual uncertain risks faced by short-life-cycle food supply chains, specifically manifested as long production lead times, short sales cycles, large demand fluctuations, and raw material supply fluctuations caused by natural factors (such as temperature and light) and demand uncertainties caused by market factors (such as brand competition and price changes). Existing research has mostly focused on a single uncertain dimension in the secondary supply chain, without fully incorporating the perishable and low residual value characteristics of short-life-cycle foods. Furthermore, data-driven dynamic matching methods need to be deepened. To fill the theoretical gap and meet practical needs, this study adopts a difference-in-differences model to identify policy effects, and combines benchmark regression, propensity score matching, parallel trends test, robustness tests, and heterogeneity analysis to construct a comprehensive evaluation system of economic, ecological, and social effects. It quantifies the risk transmission paths in the tertiary supply chain and designs a risk sharing mechanism. The study finds that at the economic level, it has reduced production costs, increased the added value of agricultural products, and promoted the growth of farmers' income as well as the extension of the industrial chain. At the ecological level, it has reduced the use of fertilizers and waste emissions, and improved soil quality and water environment. On the social front, it has promoted the development of agricultural mechanization, optimized the labor structure, and created employment opportunities. To achieve precise application and sustainable development of resource circular economy in the agricultural industry chain, it is necessary to strengthen industrial integration and market expansion to build a closed loop of the entire industry chain, increase financial support and subsidies, and improve the composite subsidy system. It is also necessary to strengthen technical training and talent cultivation to enhance farmers' skills, promote ecological agricultural technologies and models, and establish ecological compensation mechanisms. Based on heterogeneous strategy adjustments, economically underdeveloped regions need to strengthen regional cooperation, regions with unreasonable industrial structures need to optimize their layouts, and regions with weak fiscal capabilities need to expand financing channels.

1 Introduction

The exploration of the application of resource circular economy in the agricultural industry chain focuses on the dual uncertainty risks of supply and demand faced by the short life cycle food supply chain - long production lead time, short sales cycle, large demand fluctuations, combined with natural factors (such as temperature and light) causing fluctuations in raw material supply and market factors (such as brand competition and price changes) causing demand uncertainty. Although the improvement of cold chain logistics and transportation infrastructure has enhanced spatiotemporal efficiency, the dual uncertainty poses higher requirements for supply chain resilience. It is necessary to achieve risk sharing through cooperation contracts and alliance mechanisms, and promote the transformation of supply chains from individual competition to inter chain collaboration. Traditional research often focuses on a single uncertain dimension (demand or supply) in the secondary supply chain, with limited exploration of the transmission mechanism and coordination strategies for the dual uncertainty of supply and demand in the tertiary supply chain; The perishability and low residual value characteristics of short lifecycle foods have not been fully incorporated into the risk model, resulting in a lack of targeted contract design; The data-driven dynamic matching method still needs to be deepened, and the effectiveness verification of existing contracts in uncertain supply and demand scenarios is insufficient. The motivation for work lies in filling theoretical gaps and practical needs, quantifying the transmission path of risks in the three-level supply chain through data analysis, designing a risk sharing mechanism to achieve coordination, and the goals include revealing the impact of risks on decision-making, constructing a dynamic matching contract design framework, and verifying the effectiveness of the mechanism in profit distribution and efficiency improvement. The contribution is reflected in the innovative three-level supply chain risk sharing model at the theoretical level and the inclusion of short lifecycle characteristics. At the methodological level, a data-driven dynamic matching strategy is proposed to optimize supply chain resilience. At the practical level, it provides operational cooperation mechanisms and decision-making tools for enterprises. The specific framework identifies policy effects through a double difference model, selecting variables such as rural residents' disposable income, fertilizer use, and economic output. Combined with benchmark regression, propensity score matching, parallel trend testing, robustness testing, and heterogeneity analysis, a comprehensive evaluation system is constructed to promote the precise application of resource circular economy in the agricultural industry chain, covering background, challenges, motivations, goals, contributions, and a comprehensive exploration of the methodological framework.

2 Correlation theory

2.1 Analysis of multidimensional effects of green farming and circular agriculture

Green planting and breeding circular agriculture [1] achieves resource recycling and waste disposal through deep integration of planting and breeding industries, reduces external resource dependence and waste emissions, and promotes the transformation of agriculture towards green, low-carbon, and sustainable directions. Its core lies in following natural ecological laws, optimizing the architecture of agricultural production systems, improving operational efficiency, and achieving an organic integration of economic and ecological effects. The policy effect is reflected in the actual impact caused by policy implementation in multiple fields, covering the degree of goal achievement, the role of interest groups, and short-term and long-term effects, involving multidimensional effects such as economic regulation, social equity protection, and ecological environment protection. The economic effect is manifested as a chain reaction triggered by changes in economic variables, ranging from micro level enterprise decision-making impact, meso level industrial resource flow to macro level national economic adjustment, specifically reflected in cost savings, income enhancement, industrial driving, and international competitiveness enhancement. Ecological effects focus on the impact of human or natural processes on the structure, function, and biodiversity of ecosystems. Green farming and circular agriculture has shown positive effects in improving soil organic matter, reducing water pollution, protecting biodiversity, and reducing greenhouse gas emissions. The social effect is reflected in the extensive impact caused by social phenomena, involving social structural adjustment, diversified relationships, updated cultural concepts, and lifestyle changes, such as optimizing labor structure, expanding social relationship networks, and enhancing awareness of sustainable development, jointly promoting the evolution of society towards fairness, harmony, and sustainability.

2.2 Theoretical basis and research hypotheses of green farming and circular agriculture

The theory of circular economy[2] takes ecological laws [3] as its core, advocating a closed-loop flow model of "resources products renewable resources", achieving efficient resource utilization and minimizing waste through the principles of reduction, reuse, and recycling, and promoting the ecological transformation of economic activities. The theory of sustainable development emphasizes the three-dimensional synergy of economy[4], society, and environment, following the principles of fairness (intragenerational and intergenerational equity), sustainability, and commonality, to ensure that contemporary needs are met without compromising the development capacity of future generations. The theory of comprehensive evaluation advocates the integration of multiple dimensions and methods for evaluation, covering the entire stage of background, input, process, and results. It combines qualitative and quantitative methods such as regression analysis and case studies to provide comprehensive decision-making basis. Based on the above theoretical framework, this study proposes the following hypotheses: in the economic dimension, resource recycling can reduce production costs, improve the quality and added value of agricultural products, promote farmers' income increase, and extend the industrial chain; From an ecological perspective, waste resource utilization and fertilizer reduction can improve soil quality, reduce pollution emissions, and enhance ecosystem stability; From a social perspective, the development of mechanization and industrial synergy can create employment, optimize labor structure, and promote the transformation of rural social relations; At the level of regional differences, the level of economic development, industrial structure (such as the proportion of primary industry), and government fiscal capacity will affect the effectiveness of policy implementation. Regions with sufficient resources and mature industries are more likely to achieve policy goals.

3 Research method

3.1 Research Model and Variable Setting

This study is based on the comprehensive evaluation theory framework and adopts a quasi natural experimental design to evaluate the effectiveness of green planting and breeding circular agriculture pilot policies. 97 counties from several pilot provinces were selected as the experimental group, and 125 similar agricultural counties from non pilot provinces were matched as the control group to construct a counterfactual reference frame to control endogeneity issues. The study uses a difference in differences (DID) model [5]to analyze county-level panel data from 2014 to 2023, capturing the dynamic impact of policies through time and individual fixed effects to ensure evaluation reliability. The model settings are as follows:

$$Y_{it} = \alpha + \beta did_{it} + \gamma X_{it} + u_i + \lambda_t + \varepsilon_{it} \tag{1}$$

Among them, Y_{it} is the dependent variable (such as per capita disposable income of rural residents, amount of agricultural fertilizers used);

$$did_{it} = treated_i \times time_t \tag{2}$$

As the core explanatory variable, if county i implements pilot policies in year t or later, take 1; otherwise, take 0; X_{it} is the control variable (covering agricultural output value, forestry output value, animal husbandry output value, fishery output value, total crop sowing area, effective irrigation area, etc.);u_i and λ_t are individual and time fixed effects, respectively. ε it is a random shock. The coefficient β reflects the net effect of the policy: if $\beta > 0$, Indicating that policies promote an increase in the dependent variable, while the opposite suppresses growth. The selection of variables follows the principle of multidimensional evaluation: the economic effects are measured by the per capita disposable income of rural residents and the total output value of agriculture, forestry, animal husbandry, and fishery; Ecological effects are reflected through the application of agricultural fertilizers and pesticides; Social and structural effects are included in the total power of agricultural machinery, the level of industrial structure (such as the proportion of the primary industry), regional GDP, and general public budget revenue. The study verifies the specific performance and mechanism of policies in multidimensional effects through benchmark regression, propensity score matching, parallel trend testing, and robustness testing, providing scientific basis for the precise application of resource circular economy in the agricultural industry chain.

3.2 Overview of Data Sources and Descriptive Statistics

The data is sourced from multiple sources of statistical yearbooks and economic databases, covering the period from 2014 to 2023. By using average growth rate, average value, and linear interpolation to fill in some missing data, a 10-year panel dataset of 222 counties was formed. To improve distribution characteristics, reduce heteroscedasticity, and highlight the rate of change, all variables were logarithmically processed as shown in Table 1

Table 1 Descriptive Statistics of Main Variables

Variable Type	Indicator Name	Sample Size	Mean	Std. Dev.	Min.	Max.
Economic Effect	Rural Residents' Per Capita Disposable Income	2220	9.662	0.377	8.491	11.031
Ecological Effect	Agricultural Chemical Fertilizer Application	2220	1.464	0.874	-3.912	4.281
Social Effect	Total Power of Agricultural Machinery	2190	4.23	0.75	1.883	6.579
Agricultural Output	Agricultural Output Value	2220	12.952	0.741	10.368	15.732
Forestry Output	Forestry Output Value	2220	9.849	1.141	5.673	13.135
Animal Husbandry Output	Animal Husbandry Output Value	2220	12.482	0.668	10.084	14.809
Fishery Output	Fishery Output Value	2220	9.829	1.872	2.197	13.998
Crop Sowing Area	Total Crop Sowing Area	2102	4.671	0.73	1.843	6.485
Effective Irrigation Area	Effective Irrigation Area	1890	3.711	0.838	0.341	5.745
Oil Crop Yield	Oil Crop Yield	2204	9.464	1.927	1.099	14.509
Grain Yield	Grain Yield	2218	12.937	0.871	4.736	15.096
Meat Yield	Meat Yield	2197	11.119	0.717	7.132	13.162
Total Agriculture Output	Total Agriculture, Forestry, Animal Husbandry and Fishery Output Value	2220	13.59	0.626	10.886	16.088
Pesticide Application	Pesticide Application	2220	6.626	0.99	-1.398	8.834
Regional Economic Capacity	GDP (100 million Yuan)	2220	5.678	0.826	3.369	10.478
Industrial Structure	Primary Industry Value Added Ratio (%)	2220	3.36	0.138	2.795	3.994
Government Fiscal Capacity	General Public Budget Revenue (100 million Yuan)	2220	11.874	0.941	8.864	15.039

This dataset has been rigorously processed to ensure that the distribution characteristics of variables are adapted to the model requirements, providing a robust foundation for subsequent empirical analysis.

3.3 Tendency score matching and parallel trend test results

To eliminate endogeneity effects of policies, propensity score matching (PSM)[6]was used to integrate feature variables, calculate propensity scores through Logit regression, and perform sample matching based on Mahalanobis distance. Mahalanobis distance[7]considers the covariance structure of data, which can eliminate the influence of inter variable correlation and scale differences. The balance test after matching showed that the absolute values of the standard deviations of each variable were less than 20, and the p-value of the t-test was greater than 0.1, indicating that the characteristics of the experimental group were similar to those of the control group, and the matching was effective. The parallel trend test adopts the event study method to analyze the dynamic effects of rural residents' disposable income and agricultural fertilizer use. Before the implementation of the policy, the interaction coefficient between the year dummy variable and the treatment group dummy variable was not significant and the 95% confidence interval contained 0; After implementation, the coefficient of the interaction term[8] is significant, satisfying the parallel trend hypothesis and ensuring the scientific and reliable evaluation results of the double difference method.

4 Results and discussion

4.1 Robustness test results

To verify the robustness of policy effects, multiple tests were used. The counterfactual test advanced the policy time by three years, and the results showed that the policy effect was no longer significant, indicating the consistency between the original policy time and variable changes, supporting the effectiveness of the policy. After caliper k-nearest neighbor matching (caliper value=propensity score standard error × 0.25, k=5), the differential influence coefficient was significant at the 10% level, consistent with the original results, verifying the robustness of economic and ecological effects. In terms of replacing the dependent variable, replacing the per capita disposable income of rural residents with the total output value of agriculture, forestry, animal husbandry, and fishery, the coefficient is significantly positive at the 1% level; Replacing the amount of agricultural fertilizer application with the amount of pesticide use, the coefficient is significantly negative at the 1% level, verifying the policy effect from multiple dimensions. After bilateral truncation at the 1% and 5% levels on the core variables, the regression results remained significant and highly consistent with the original results, further enhancing the robustness of the conclusions.

4.2 Model experiment

Mechanism analysis shows that policies promote the level of agricultural mechanization through subsidies, technology promotion, and other means. Using the total power of agricultural machinery as a proxy variable, empirical evidence shows that pilot policies effectively promote the process of agricultural mechanization, thereby driving the development of agricultural machinery related industries, creating employment opportunities, optimizing rural employment structure, promoting technical exchanges and talent cultivation, and enhancing social effects.Heterogeneity testing is conducted from three dimensions: regional economic scale, industrial structure, and government fiscal capacity. Regions with larger economic scales have a more significant positive driving effect on green farming and circular agriculture, and have outstanding development potential; Regions with small economic scales can promote development through measures such as tapping into characteristic resources, strengthening regional cooperation, and optimizing policy support. In terms of industrial structure, regions with a high proportion of primary industry have a better development trend of green circular agriculture due to abundant resources and sufficient experience; Regions with low proportions face challenges such as limited land resources and insufficient technical experience. In terms of government fiscal capacity, areas with high public budget revenue can provide more sufficient funds and policy support for industries, have greater development potential, and are more likely to achieve a positive interaction between the economy and the environment. The above results verify the heterogeneity of policy effects in different dimensions, providing empirical evidence for formulating development strategies tailored to local conditions.

4.3 Effect analysis

The benchmark regression results show that the regression coefficient of the policy variable (did1) on the per capita disposable income (RU) of rural residents is significantly positive under different model settings (such as RU (1) column 0.348, RU (2) column 0.258, RU (3) column 0.417, RU (4) column 0.007), reflecting the logic of "resource efficient utilization industry synergy economic value-added" in the circular economy - optimizing the material cycle of the agricultural system through the utilization of livestock and poultry manure resources, returning straw to fields and other planting and breeding combination models, reducing production costs and increasing income, and the promoting effect of agricultural, forestry, animal husbandry and fishery output on income (such as agricultural output value RU (1) column 0.223, RU (2) column 0.034) further confirms the industrial synergy effect. The regression coefficient of the policy variable (did2) on the amount of agricultural fertilizer applied (HF) is significantly negative (such as HF (1) column -0.271, HF (2) column -0.284, HF (3) column -0.126, HF (4) column -0.164 * *), which conforms to the principle of "reduction reuse recycling" under sustainable development theory, reducing dependence on chemical fertilizers to alleviate non-point source pollution and maintain long-term productivity of soil ecosystems. After controlling for individual fixed effects, the policy effect is still significant, indicating that the policy has formed a new ecological agricultural paradigm by reconstructing the flow path of agricultural materials. Propensity score matching (PSM) test shows that after matching, the absolute standard deviation of each variable is less than 20 and the t-test p-value is greater than 0.1, indicating that the matching is valid; The parallel trend test was validated through the event study method, and the interaction coefficient between the dummy variables in the year before policy implementation and the dummy variables in the treatment group was not significant and the 95% confidence interval contained 0. After implementation, the interaction coefficient was significant, meeting the parallel trend hypothesis.

5 Conclusion

The exploration of the application of resource circular economy in the agricultural industry chain focuses on the multidimensional impact and optimization path of policies on the economy, ecology, and social effects. At the economic level, policies promote the integration of planting and breeding by building a "resource product renewable resource" loop, reducing production costs and increasing the added value of agricultural products, increasing farmers' income and extending the industrial chain, and achieving improved economic effects. At the ecological level, policies reduce the use of fertilizers and waste emissions, improve soil quality and water environment through the resource utilization of livestock and poultry manure and the substitution of organic fertilizers, enhance ecosystem stability, and reflect positive ecological effects. At the social level, policies promote the development of agricultural mechanization, optimize the labor force structure, create employment opportunities, and facilitate the transformation of rural social relations, thereby enhancing social effects. Heterogeneity analysis [9] shows that regional economic level, industrial structure, and government fiscal capacity significantly affect policy effectiveness: regions with developed economies, high proportion of primary industries, and strong fiscal capacity are more likely to achieve policy goals, forming a virtuous cycle through resource optimization allocation, industrial synergy, and policy support. To promote the application of resource circular economy, it is necessary to strengthen industrial integration and market expansion, and build a closed loop of the entire industry chain; Increase financial support and subsidy efforts, establish special funds, and improve the composite subsidy system; Strengthen technical training and talent cultivation, enhance farmers' skills and cultivate new professional farmers; Promote ecological agriculture technologies and models, strengthen the utilization of waste resources, and establish ecological compensation mechanisms; Increase subsidies for the purchase of agricultural machinery and R&D investment, and support innovation in green agricultural machinery equipment; Improve the agricultural machinery service system and rural labor transfer training to meet the needs of green industries. Based on heterogeneity strategy adjustment, economically underdeveloped areas need to strengthen regional cooperation and policy support, areas with unreasonable industrial structure need to optimize layout and integrate the tertiary industry, and areas with weak fiscal capacity need to expand financing channels and establish a diversified funding guarantee system [10], ultimately achieving precise application and sustainable development of resource circular economy in the agricultural industry chain.

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