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Regional Environmental Governance and Sustainable Consumption: A System Transformation Perspective from China's National Ecological Civilization Pilot Zones Policy-Based Evidence from the Regression Control Method

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Article

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Abstract

Regional environmental governance is increasingly recognised as an important driver of sustainability transitions because it can simultaneously influence production systems, market incentives, and the conditions under which consumers make decisions. However, while its environmental and economic outcomes have been widely examined, considerably less is known about how environmental governance facilitates sustainable consumption through broader regional system transformation. Using panel data from 29 provinces (autonomous regions and municipalities) in China from 2004 to 2023, this study exploits the first batch of the first National Ecological Civilization Pilot Zones (NECPZs) established in Fujian, Jiangxi, and Guizhou to evaluate the policy effects of regional environmental governance on sustainable consumption. The results show that NECPZs' implementation significantly enhanced regional green consumption, and the results remain robust to a temporal placebo test and optimal subset selection. Mechanism analysis further suggests that regional environmental governance promotes sustainable consumption by facilitating production-side structural transformation and improving environmental conditions. These findings provide empirical evidence that regional environmental governance extends beyond environmental protection to reshape the broader regional systems that support sustainable consumption. They also offer policy insights for integrating production-side transformation with consumption-side strategies to advance sustainable production and consumption.

1. Introduction

Sustainable consumption has become an essential component of sustainability transitions because it supports low-carbon development while reducing resource use and environmental pressures. Achieving sustainable consumption, however, requires more than changes in individual consumer behaviour. It also depends on broader institutional arrangements that shape production systems, market conditions, and environmental quality. Consequently, regional environmental governance has attracted increasing attention as a policy approach for enabling sustainable production and consumption through system-wide transformation.

In China, the National Ecological Civilization Pilot Zones (NECPZs) represent one of the country's most comprehensive place-based environmental governance initiatives, aiming to promote ecological protection and green development through institutional reform. (Chen et al., 2023[1]). While the policy has been widely recognised for advancing ecological civilization, it remains unclear whether and how regional environmental governance can facilitate sustainable consumption. Addressing these questions will not only enrich the theoretical literature on ecological civilization construction but also provide empirical support for further deepening the reform of NECPZs, advancing ecological civilization construction, and promoting high-quality economic and social development. Accordingly, this study investigates the effects of NECPZs construction on regional green consumption and explores the underlying transmission mechanisms.

Existing studies primarily focus on the conceptualization of green consumption, its quantitative measurement, the identification of its influencing factors, and the analysis of its economic effects. Although no universally accepted definition exists, most studies describe green consumption as consumption patterns that minimise resource use and environmental impacts throughout the product life cycle while supporting sustainable development. Early discussions emphasised consumers' environmental responsibility (International Organization of Consumers Unions, 1963; Huang, et al.,2022[2]), followed by formal conceptualizations of green consumption and broader definitions highlighting low-carbon and environmentally friendly consumption (Islam, 2022 [3]) argued that green consumption refers to high-quality consumption oriented towards energy conservation, carbon reduction, and ecological protection. Chinese scholars have further emphasised life-cycle environmental impacts and whole value-chain sustainability (Zhang Shuchun and Zhang Fan, 1994 [4]; Kang Nannan, 2025 [5] and Wu Jingbo, 2026 [6]). Overall, green consumption is widely recognised as an environmentally responsible mode of consumption that reduces resource use and environmental impacts across the product life cycle.

Existing studies have also devoted considerable attention to the measurement of green consumption. A number of scholars have developed green consumption evaluation indicator systems from different perspectives (Cui and Yu, 2022 [7]; Xie et al., 2022 [8]; Jia, 2025 [9]) followed by the introduction of China’s official Green Development Indicator System in 2016, and the first municipal-level green consumption evaluation system, the Suining Green Consumption Evaluation Indicator System, in 2018. Existing research on the determinants of green consumption has mainly examined the issue from both micro-level perspectives, including individual consumer behavior and showing that demographic characteristics, cognitive factors, and psychological factors influence green consumption behavior; and macro-level perspectives, such as intelligent development (Long et al., 2023 [10]), monetary and time resources (Sun et al., 2024 [11]), and digital new quality productivity(Ren et al., 2026 [12]). In addition, some studies have found that green consumption contributes to high-quality economic and social development in China (Chen, 2024 [13]; Yuan and Liu, 2025 [14]). Despite these advances, comparatively less attention has been paid to whether regional environmental governance can reshape the production systems, environmental conditions, and institutional settings that jointly influence sustainable consumption.

To address this gap, this study makes three potential contributions. First, it constructs a comprehensive provincial-level green consumption evaluation indicator system and empirically examines the policy effects of NECPZs construction on regional green consumption. Second, this study exploits the quasi-natural experiment created by the implementation of the NECPZ policy and employs the Regression Control Method (RCM) to quantitatively identify the impact of pilot zone construction on regional green consumption. Third, this study investigates the mechanisms through which NECPZ construction influences regional green consumption and empirically tests the proposed transmission pathways, providing empirical evidence and policy implications for improving the implementation of the pilot zone policy, promoting green consumption, and advancing ecological civilization construction.

2. Theoretical Analysis and Research Hypotheses

As a pioneering platform for institutional innovation in ecological civilization and green development in China, the NECPZs provide a setting for examining how regional green consumption patterns influence green consumption through both direct regulatory incentives and indirect multidimensional transmission

pathways, promoting the transition of consumption behavior. Consequently, the effects of NECPZ implementation are expected to emerge through multiple transmission pathways, including production-side structural transformation and environmental improvement.

2.1 The Effect of National Ecological Civilization Pilot Zone Construction on Green Consumption

The establishment of National Ecological Civilization Pilot Zones directly influences green consumption through a range of institutional arrangements and policy incentives, which are reflected in the following aspects. Rather than relying on a single policy instrument, the pilot zones employ a coordinated package of regulatory, market, and institutional measures that reshape both the supply of and demand for green products. Consequently, green consumption is expected to evolve through changes in the broader regional production and consumption system rather than through isolated policy interventions.

(1) Implementation of a stringent environmental regulatory system. Pilot zones have taken the lead in implementing stringent environmental regulations, including tiered pricing systems for water, electricity, and gas resources, volume-based municipal waste charging, and comprehensive waste-sorting systems. These measures are intended to discourage energy-intensive, highly polluting, and irrational one-time consumption. In addition, restrictions on non-degradable plastic products and preferential transport policies for new energy vehicles impose direct constraints on carbon-intensive consumption patterns.

(2) Establishment of a green product supply and distribution system. Pilot zones have reduced barriers to obtaining green products by establishing physical marketing platforms for green products and encouraging e-commerce platforms to create dedicated green product sections.

(3) Implementation of green consumption incentive policies. Pilot zones have introduced policy guidance and financial incentives, including personal carbon accounts, ecological credit reward systems, subsidies for replacing household appliances with energy-efficient alternatives, incentives for purchasing new energy vehicles, and subsidies for green home renovation. These measures help offset the price premium associated with green products, reduce the cost of green consumption for households, and encourage voluntary adoption of green consumption practices.

Nevertheless, the effectiveness of these policy mechanisms is likely to depend on regional socioeconomic conditions. Given the substantial differences among the three pilot provinces in terms of economic development, industrial structure, and the existing level of green consumption, the effects of NECPZ construction on green consumption are expected to vary across provinces.

Based on the above analysis, the following hypothesis is proposed:

H1

The construction of National Ecological Civilization Pilot Zones contributes to improving regional green consumption, and the policy-induced increase in green consumption exhibits provincial heterogeneity.

2.2 Mechanisms Through Which National Ecological Civilization Pilot Zone Construction Promotes Green Consumption

Compared with the immediate direct effects of policy intervention, the indirect effects of National Ecological Civilization Pilot Zone construction on green consumption are more long-term and pervasive. They are expected to reshape the broader socioeconomic environment within which production and consumption decisions are made.

(1) Industrial structure upgrading and increased supply of green products. Industrial structure upgrading represents the primary production-side mechanism through which environmental governance may influence consumption. Through stringent environmental access requirements and emission quota controls, pilot zones encourage the transformation and upgrading of traditional energy-intensive and highly polluting industries while fostering the development of green industries such as ecological agriculture, circular manufacturing, renewable energy, and eco-tourism.

(2) Improvement of environmental quality and enhancement of green consumption willingness. A second mechanism operates through improvements in environmental quality. National Ecological Civilization Pilot Zone construction has significantly improved environmental quality, creating a physical and social environment that is more conducive to environmentally responsible consumption. Improved environmental quality is expected to increase consumers' willingness to adopt environmentally friendly and low-carbon lifestyles, thereby indirectly promoting green consumption. In this way, environmental improvements reinforce the behavioural effects generated by institutional reforms and production-side transformation, jointly supporting the transition towards more sustainable consumption patterns.

Based on the above analysis, the following hypothesis is proposed:

H2

National Ecological Civilization Pilot Zone construction improves regional green consumption by promoting industrial structure upgrading (H2a) and improving environmental quality (H2b).

Taken together, these two hypothesises represent complementary pathways through which NECPZ construction promotes green consumption. Industrial structure upgrading expands the supply and accessibility of green products, while improvements in environmental quality strengthen consumers' willingness to adopt sustainable behaviours.

3. Methodology

Among the multiple channels through which environmental governance may influence consumption, this study focuses on two system-level mechanisms that are consistently highlighted in the sustainable production and consumption literature: production-side structural transformation and improvements in environmental quality.

3.1 Regression Control Model and Research Method

This study employs the Regression Control Method (RCM) proposed by Hsiao et al. (2012) [15] to empirically evaluate the causal effect of National Ecological Civilization Pilot Zone construction on regional green consumption. Compared with widely used Difference-in-Differences (DID) and the Synthetic Control Method (SCM), RCM does not require random assignment between treatment and control groups, and allows control-unit weights to take either positive or negative values. These features make RCM particularly suitable for evaluating policy interventions involving a small number of treated units (Chen and Wu, 2015 [16], Abadie et al., 2010 [17]; Shen et al., 2022 [18], Hsiao & Zhou, 2019 [19]; Li & Bell, 2017 [20]).

The analytical framework is introduced below. Following Hsiao et al. (2012) [15], suppose the observed panel data are denoted by $\{y_{it}\}(i=1,\cdots,N;t=1,\cdots,T)$, Let T_0denote the number of pre−treatment periods, with policy intervention beginning at period T_0+1. Let y_{it}^1 represent the outcome for unit $i$at time $t$under policy intervention, and y_{it}^0 represent the potential outcome in the absence of the policy. The policy effect for unit i can therefore be expressed as: $\triangle y=y_{it}^1-y_{it}^0$. Within the context of this study, the objective is to estimate the unobservable green consumption trajectory that would have occurred in the absence of National Ecological Civilization Pilot Zone construction.

This study focuses on the first batch of National Ecological Civilization Pilot Zones, namely Fujian, Jiangxi, and Guizhou Provinces. Owing to the uniqueness of policy implementation, only the observed outcome under policy intervention y_{it}^1can be observed, whereas the counterfactual outcome without policy intervention y_{it}^0 is unobservable. Consequently, the net policy effect cannot be directly estimated.

To estimate this unobservable counterfactual, the Regression Control Method constructs an appropriate control group and estimates the counterfactual trajectory of green consumption in the absence of National Ecological Civilization Pilot Zone implementation. The untreated outcome is assumed to follow the factor model shown in Eq. (1):

$$y_{it}^0=\alpha_i+\beta X_{it}'+b_i'f_t+\epsilon_{it}(i=1,\cdots,N;t=1,\cdots,T)$$

1

Where $\alpha_i$denotes the individual fixed effect, $X_{it}$is an $F\times 1$vector of observed covariates, f_t is a $K\times 1$ vector of unobserved common factors, b_i denotes the corresponding $K\times 1$ factor loadings, ϵ_{it} is the random error term.

Based on this factor representation, the model can be transformed into an estimable regression specification by eliminating the unobserved common factors under the required regularity conditions. For a given period t, stacking the equations across all units and applying appropriate mathematical transformations under the required regularity conditions removes the unobserved common factors f_t(Li & Bell,2017 [20], yielding the following time-series regression model in Eq. (2):

$$y_{1t}^0=\delta_1+\delta'Z_t+\nu_{it}(t=1,\cdots,T_0)$$

2

which includes both the outcome variables and covariates of all control units. Eq. (2) is estimated using Ordinary Least Squares (OLS) based on the pre-policy observations. Once the regression model has been estimated using the pre-policy observations, the estimated coefficients can be used to generate the counterfactual outcomes for the post-treatment period. The estimated parameters are then used to predict the counterfactual outcome of unit 1 after policy implementation in Eq. (3):

$$\hat{y}_{1t}^0=\hat{\delta}_1+\hat{\delta}'Z_t^*(t=T_0+1,\cdots,T)$$

3

where Z_t^* represents a subset of $Z_t$selected for predicting the potential outcome y_{1t}^0. Comparing the observed post-policy outcomes with these estimated counterfactual trajectories provides an estimate of the causal policy effect. Based on the estimated counterfactual outcome, the policy treatment effect is calculated in Eq. (4):

$$\hat{\triangle} y=y_{1t}^1-\hat{y}_{1t}^0(t=T_0+1,\cdots,T)$$

4

This modelling strategy provides a reliable basis for evaluating both the overall impact of NECPZs construction on green consumption and the mechanisms through which regional environmental governance contributes to sustainable production and consumption. When estimating Eq. (2) using pre-treatment observations, including an excessive number of control units and covariates may lead to model overfitting.

Following Li and Bell (2017) [20], this study first applies the Least Absolute Shrinkage and Selection Operator (LASSO) to select relevant variables, after which the Regression Control Model is estimated using Ordinary Least Squares. Cross-validation is employed to determine the optimal tuning parameter, thereby improving model fit and enhancing the accuracy of policy effect estimation.

3.2 Variable Selection

Based on the empirical strategy outlined above, this section introduces the variables used to evaluate the policy effects of NECPZs construction. The variable selection is designed to capture the multidimensional nature of green consumption, identify the policy intervention of interest, and control for other factors that may influence regional green consumption.

(1) Outcome Variable: Green Consumption

A review of the various definitions of green consumption in the existing literature indicates that it is a systemic concept with multi-level and multi-dimensional characteristics. Grounded in the theory of environmental economics, this study defines green consumption as a whole-process, green and low-carbon consumption practice in which all actors involved in consumption—seeking to reconcile the competing constraints of economic development and environmental protection—advance the green transition on both the production (supply) side and the consumption (demand) side, underpinned by a supportive green consumption environment.Green consumption encompasses behavioural, environmental, and production-related dimensions, its evaluation requires a multidimensional measurement framework rather than a single indicator. This study follows Xie et al. (2022) [8], Yi et al. (2025) [21], and Gan et al. (2026) [22] in constructing a comprehensive evaluation index system (Table 1).

Accordingly, the evaluation system captures green consumption from three complementary perspectives: green production consumption, green household consumption, and the supporting green consumption environment. Each dimension is measured by some indicators, respectively.

Green Production Consumption: industrial sulfur dioxide emissions per unit of GDP, energy consumption per unit of GDP, comprehensive utilization rate of industrial solid waste, and the number of green patent applications.

Green Household Consumption: annual public transport passenger volume per 10,000 people, daily domestic water consumption per capita, urban population using natural gas, and the harmless treatment rate of municipal solid waste.

Green Consumption Environment : the green coverage rate of built-up areas, per capita park green space, the centralised treatment rate of urban sewage, the share of investment in environmental pollution control in GDP and the average number of days on which air quality met or exceeded the Grade II standard in provincial capitals and municipalities directly under the central government—are employed to characterise the green consumption environment.

Table 1
Green Consumption Evaluation Indicator System

Dimension	Indicator	Unit	Direction
Green Production Consumption	Industrial SO_2 emissions per unit of GDP	tons/10,000 yuan	Negative
	Energy consumption per unit of GDP	tons of standard coal/10,000 yuan	Negative
	Comprehensive utilization rate of industrial solid waste	%	Positive
	Number of green patent applications	Number	Positive
Green Household Consumption	Annual public transport passenger volume per 10,000 people	Person-times	Positive
	Daily domestic water consumption per capita	Liters	Negative
	Urban population using natural gas	10,000 persons	Positive
	Harmless treatment rate of municipal solid waste	%	Positive
Green Consumption Environment	Green coverage rate in built-up areas	%	Positive
	Park green space per capita	m^2/person	Positive
	Centralized urban sewage treatment rate	%	Positive
	Environmental pollution control investment as a share of GDP	%	Positive
	Average number of days with air quality meeting or exceeding Grade II in provincial capitals and municipalities	days	Positive

Having established the multidimensional indicator system, since individual indicators contribute differently to the overall evaluation system, objective weights are required to aggregate these indicators into a comprehensive measure of provincial green consumption. Existing weighting approaches are generally classified into subjective methods (e.g., Delphi method, Analytic Hierarchy Process, and comparative scoring) and objective methods (e.g., entropy weighting, principal component analysis, and factor analysis). Compared with subjective weighting, objective methods reduce subjective bias. The procedure for measuring the green consumption levels of China's 29 provinces (municipalities and autonomous regions) over the period 2004–2023 (excluding Hong Kong, Macao and Taiwan of China, as well as the Tibet Autonomous Region and Hainan Province) is as follows(Zhou and Ma,2024[23]):

(a) Standardisation of indicators

Because the raw data of the various indicators are not dimensionally consistent, they must be preprocessed prior to evaluation. This study applies range (min–max) standardisation to each indicator; the specific formulae are as follows.

$$V_{ij} = \frac{X_{ij} - min\left(X_j\right)}{max\left(X_j\right) - min\left(X_j\right)} + A$$

5

where X_{ij} denotes the raw value of the *j*-th indicator for the *i*-th sample, min(X_j) and max(X_j) denote the minimum and maximum values of the *j*-th indicator, respectively, and *A* is a translation constant (set to 0.01) that prevents zero values after standardisation from invalidating subsequent calculations. This treatment effectively eliminates the influence of dimensional differences on the measurement results.

(b) Calculating the proportion P_{ij} of the j-th indicator for the i-th sample

$$P_{ij} = \frac{V_{ij}}{\sum_{i=1}^{n} V_{ij}}$$

6

where *n* is the number of samples.

(c) Calculating the information entropy e_j of the j-th indicator

$$e_j = -k\sum_{i=1}^{n} P_{ij}\ln\left(P_{ij}\right),\ k = \frac{1}{\ln n}$$

7

The information entropy e_j reflects the degree of dispersion of the indicator data: the smaller e_j is, the greater the dispersion of the indicator and the larger its influence on the evaluation results.

(d) Calculating the divergence coefficient (information utility value) d_j

$$d_j = 1 - e_j$$

8

(e) Calculating the indicator weight W_j

$$W_j = \raisebox{1ex}{\$}d_j\$ \Big/ \raisebox{-1ex}{\$}\sum_{j=1}^{m} d_j\$$$

9

where *m* denotes the number of indicators.

(f) Calculating the composite score C_i of the green consumption level

$$C_i = \sum_{j=1}^{m} W_j V_{ij}$$

10

where C_i denotes the composite green consumption score of the *i*-th sample.

(2) Core Explanatory Variable: NECPZs Construction

The core explanatory variable is a treatment indicator representing implementation of the NECPZs policy. Fujian, Jiangxi, and Guizhou Provinces constitute the treatment group. Regions with substantially different policy implementation schedules or limited data availability, including Hainan, Tibet, Hong Kong, Macao, and Taiwan, are excluded from the analysis.

(3) Control Variables

To isolate the policy effect from other socioeconomic factors that may simultaneously influence green consumption, a series of control variables is incorporated into the empirical analysis. Following Shao et al. (2019) [24] and Long et al. (2023) [10], six control variables are included.

1. Urbanization level, measured by the proportion of the urban resident population.

2. Economic development, measured as the natural logarithm of GDP per capita.

3. Trade openness, measured by total imports and exports as a share of GDP.

4. Financial development, measured by the ratio of total deposits and loans of financial institutions to GDP.

5. Human capital, proxied by the average years of schooling.

6. Government fiscal support, measured by general fiscal expenditure as a share of GDP.

Together, these variables account for differences in regional socioeconomic development, thereby improving the reliability of the estimated policy effects.

3.3 Data Sources

After defining the variables, the corresponding data sources are introduced below. This study employs panel data for 29 Chinese provinces from 2004 to 2023.

The data used to construct the green consumption indicator system are obtained from “the China Statistical Yearbook”, “China Energy Statistical Yearbook”, “China Environmental Statistical Yearbook”and “China Science and Technology Statistical Yearbook”from 2005 to 2024.Data for the remaining control variables are collected from national statistical yearbooks and provincial statistical yearbooks. To maintain a balanced provincial panel over the study period, missing observations for a small number of years are completed using linear interpolation. Descriptive statistics for all variables are reported in Table 2.

Table 2
Descriptive statistics of the variables

Variable	Symbol	Observations	Mean	Std. dev.	Minimum	Maximum
green consumption	lsxf	580	1925.512	3118.465	22.4330	19766.52
urbanisation level (%)	czsp	580	56.0718	14.7355	14.88	89.6
economic development	jjfz	580	10.5568	0.7356	8.3628	12.2075
Trade openness	dwkf	580	0.2986	0.3426	0.0071	1.6406
financial development	jrfz	580	3.1167	1.0648	1.4696	7.5446
human capital endowment	rlzb	580	8.9486	1.0657	6.378	12.782
government fiscal support (%)	czfc	580	22.0653	9.8533	1.9328	64.3011

4. Empirical Results and Analysis

Building upon the conceptual framework and empirical strategy presented in the previous sections, the following analysis evaluates whether National Ecological Civilization Pilot Zone construction promotes green consumption and examines the mechanisms through which regional environmental governance influences sustainable production and consumption.

The empirical analysis proceeds in three stages. First, we estimate the overall policy effect of NECPZ construction on green consumption. Second, we examine the robustness of the estimated treatment effects. Finally, we test the proposed transmission mechanisms.

4.1 Trends in Green Consumption in the Pilot Provinces

The evolution of green consumption in the pilot provinces is examined to provide descriptive evidence regarding potential policy effects. Figure 1 illustrates the evolution of green consumption in Fujian, Guizhou, and Jiangxi Provinces during 2004–2023.

Consistent with the timing of National Ecological Civilization Pilot Zone implementation, beginning in 2016, the green consumption levels of all three pilot provinces exhibit an overall upward trend with greater growth than that observed before policy implementation. Among them, Fujian records the strongest increase in green consumption, followed by Jiangxi, while Guizhou shows the smallest increase. These preliminary observations suggest that the implementation of the National Ecological Civilization Pilot Zone policy has effectively promoted green consumption in the pilot provinces.

However, descriptive trends alone cannot establish a causal relationship, making the counterfactual analysis presented in the following section necessary to quantify the policy effects and identify the underlying mechanisms.

Source

Compiled by the authors based on the China Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, and China Science and Technology Statistical Yearbook.

4.2 Regression Control Results

The first stage of the empirical analysis estimates the overall policy effect of National Ecological Civilization Pilot Zone construction on regional green consumption by comparing the observed post-policy outcomes with their estimated counterfactual trajectories. The first batch of National Ecological Civilization Pilot Zones (NECPZs) included Fujian, Jiangxi, and Guizhou Provinces. Using panel data from the 26 control provinces prior to the establishment

of the pilot zones, this study estimates the counterfactual trajectories of green consumption for each of the three pilot provinces. Following Li and Bell (2017) [20], the Least Absolute Shrinkage and Selection Operator (LASSO) is first employed for variable selection, after which Ordinary Least Squares (OLS) estimation is conducted. The results are reported in Tables 3–5.

Table 3
Actual values, predicted values, and treatment effects of the green consumption level (Fujian Province).

Year	Actual value	Predicted value	Treatment effect
2016	2204.5667	1567.3500	637.2167
2017	2569.8107	1874.8843	694.9264
2018	3177.8321	2102.1250	1075.7072
2019	3244.7284	2253.5864	991.1420
2020	3483.9019	2765.4844	718.4175
2021	3141.3535	2562.3782	578.9753
2022	3097.2762	2491.3137	605.9625
2023	3270.3291	2627.2620	643.0672
Mean	3023.7248	2280.5480	743.1769

Source: Obtained from the Lasso–OLS regression of the regression control model performed in Stata/MP 17.0.

Table 4
Actual values, predicted values, and treatment effects of the green consumption level (Jiangxi Province).

Year	Actual value	Predicted value	Treatment effect
2017	1272.8212	1090.9542	181.8670
2018	1488.4062	1341.2346	147.1716
2019	1654.5635	1210.4657	444.0978
2020	2056.7008	1523.0673	533.6335
2021	1755.9976	1427.8008	328.1968
2022	1680.5567	1526.5974	153.9593
2023	1949.1808	1666.6155	282.5653
Mean	1694.0324	1398.1051	295.9273

Source: Obtained from the Lasso–OLS regression of the regression control model performed in Stata/MP 17.0.

Table 5
Actual values, predicted values, and treatment effects of the green consumption level (Guizhou Province).

Year	Actual value	Predicted value	Treatment effect
2017	717.4875	542.1052	175.3823
2018	933.0903	538.8824	394.2079
2019	922.4311	522.9016	399.5295
2020	1108.6368	621.2195	487.4172
2021	939.0470	660.9360	278.1110
2022	931.1111	689.3944	241.7167
2023	1127.8080	668.0181	459.7899
Mean	954.2303	606.2082	348.0221

Source: Obtained from the Lasso–OLS regression of the regression control model performed in Stata/MP 17.0.

The results are presented in Fig. 2, where the horizontal axis represents the year and the vertical axis represents the level of green consumption.

(2a)Fujian Province 2b Guizhou Province 2c Jiangxi Province

Figure 2. Policy Effects of National Ecological Civilization Pilot Zone Construction on Green Consumption in the Pilot Provinces

Notes

The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.

Figure 2 first illustrates the results for Fujian Province. Using panel data for all variables from the 26 control provinces during 2004–2015, the LASSO-OLS estimator is employed to generate the counterfactual trajectory of green consumption. The estimated coefficient of determination (R^2) reaches 0.9997, indicating that before the establishment of the pilot zone (2004–2015), the counterfactual estimates closely match the observed values. This suggests that the selected control provinces accurately capture the dynamic evolution of green consumption in Fujian Province. Following the establishment of the National Ecological Civilization Pilot Zone in 2016, however, the observed and counterfactual trajectories begin to diverge. The observed level of green consumption exceeds its counterfactual prediction, with an average treatment effect of 743.1769, indicating a positive net policy effect. This finding suggests that the establishment of the National Ecological Civilization Pilot Zone significantly promoted green consumption in Fujian Province.

To examine whether the policy effect is consistently observed across different pilot provinces, the same estimation procedure is subsequently applied to Guizhou and Jiangxi Provinces. Similarly, Guizhou and Jiangxi Provinces established National Ecological Civilization Pilot Zones in 2017. Their counterfactual green consumption trajectories were estimated using observations from the 26 control provinces during 2004–2016. The LASSO-OLS estimation produced goodness-of-fit values of 0.9946 for Guizhou and 0.9976 for Jiangxi, indicating that the estimated counterfactual values closely approximate the observed pre-treatment values. After policy implementation, the observed and counterfactual trajectories gradually diverge in both provinces. The estimated average treatment effects are 348.0221 for Guizhou and 295.9273 for Jiangxi, respectively, both indicating positive policy effects (Fig. 2).

Overall, the construction of National Ecological Civilization Pilot Zones significantly improved green consumption in all three pilot provinces, although the magnitude of the policy effect differed across provinces. These findings support Hypothesis H1 and provide initial empirical evidence that regional environmental governance contributes to promoting green consumption, although the magnitude of the policy effect differs across provinces.

4.3 Robustness Tests

The preceding analysis demonstrates substantial divergence between the observed and counterfactual levels of green consumption following the establishment of the first batch of National Ecological Civilization Pilot Zones. However, whether these effects can be attributed solely to the policy requires further verification, additional analyses are required to confirm that these effects are attributable to National Ecological Civilization Pilot Zone construction rather than alternative explanations. To eliminate the influence of potential confounding factors and ensure the robustness of the empirical findings, two additional robustness tests are conducted.

(1) Time Placebo Test

Because policy implementation intensity differs across provinces and green consumption exhibits an overall upward trend over time, a spatial placebo test cannot adequately address potential endogeneity concerns. Furthermore, as the National Ecological Civilization Pilot Zone policy was implemented only in designated provinces, a time placebo test is employed instead.

Specifically, a fictitious policy implementation year of 2014 is assigned, and the green consumption levels of the three pilot provinces are re-estimated. The results are presented in Fig. 3.

(3a)Fujian Province 3b Guizhou Province 3c Jiangxi Province

Figure 3. Results of the Time Placebo Test

Notes

The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.

As shown in Fig. 3, prior to the fictitious intervention year, the observed and synthetic counterfactual trajectories closely coincide for all three pilot provinces. Even during the period between the fictitious intervention year and the actual implementation year, the observed and counterfactual trajectories remain highly consistent, exhibiting only minor deviations, which may be attributable to China's Ecological Civilization Demonstration Zone initiative launched in 2014. After the actual policy implementation, however, the divergence between the observed and counterfactual trajectories becomes substantial, with the observed green consumption levels consistently exceeding the counterfactual estimates. These findings indicate a positive policy effect and suggest that the observed increase in green consumption can indeed be attributed to the exogenous policy shock generated by the establishment of the National Ecological Civilization Pilot Zones. Therefore, the empirical conclusions remain robust.

(2) Selection of the Optimal Variable Subset Using Information Criteria

To further assess whether the estimated policy effects are sensitive to model specification, an additional robustness test based on alternative variable selection criteria is conducted. Following Hsiao et al. (2012) [15], the optimal subset of explanatory variables is selected using information criteria. Three selection criteria, AIC, BIC, and the corrected Akaike Information Criterion (AICc), are employed to identify the subset that provides the best fit between the observed and counterfactual outcomes. For all three pilot provinces, AICc is selected as the optimal criterion.

The corresponding results are presented in Fig. 4.

(4a)Fujian Province 4b Guizhou Province 4c Jiangxi Province

Figure 4. Robustness Test Based on the AICc Criterion

Notes

The regression control model was estimated using the OLS procedure implemented in Stata/MP 17.0.

Figure 4 shows that, following the establishment of the National Ecological Civilization Pilot Zones, substantial divergence remains between the observed and counterfactual trajectories of green consumption in all three pilot provinces. Moreover, the observed values continue to exceed the counterfactual estimates, indicating that the positive treatment effect remains statistically meaningful under the alternative model specification.

Taken together, the robustness tests indicate that the positive effect of National Ecological Civilization Pilot Zone construction on green consumption is not driven by model specification or spurious policy timing. Having established the robustness of the overall policy effect, the following analysis examines the mechanisms through which this effect is generated.

4.4 Mechanism Analysis

Building upon the theoretical framework developed above, the Regression Control Method is employed to examine whether the establishment of National Ecological Civilization Pilot Zones promotes industrial structure upgrading and improves environmental quality in the three pilot provinces. These analyses provide empirical evidence regarding the production-side and environmental pathways proposed in Hypothesis H2. **(1) Industrial Structure Upgrading**

To examine whether the National Ecological Civilization Pilot Zones promote industrial upgrading, this study follows Zhou et al. (2020) [25] and adopts the ratio of value added in the tertiary industry to that in the secondary industry as a proxy for industrial structure upgrading.

The estimation results are reported in Fig. 5.

(5a)Fujian Province 5b Guizhou Province 5c Jiangxi Province

Figure 5. Effects of National Ecological Civilization Pilot Zone Construction on Industrial Structure Upgrading

Notes

The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.

As shown in Fig. 5, after the establishment of the National Ecological Civilization Pilot Zones, the ratio of tertiary to secondary industry value added increased substantially in Fujian, Guizhou, and Jiangxi Provinces. The estimated average treatment effects are 0.1893, 0.2594, and 0.0515, respectively. These findings indicate that the establishment of National Ecological Civilization Pilot Zones significantly promoted industrial structure upgrading in the pilot provinces. Therefore, Hypothesis H2a is supported.

(2) Improvement in Environmental Quality

While industrial structure upgrading represents the primary production-side pathway through which environmental governance may influence consumption, improvements in environmental quality provide an additional mechanism by strengthening the conditions that encourage sustainable consumer behaviour. To examine whether National Ecological Civilization Pilot Zone construction improves environmental quality, this study follows Chu and Cheng (2023) [26] and Shu et al. (2021) [27] by using the comprehensive utilization rate of industrial solid waste as a proxy for production-related environmental pollution. This indicator is employed to assess whether the pilot zone policy effectively reduces industrial pollution and improves overall environmental quality. Improved environmental quality is expected to strengthen residents' willingness to engage in green consumption, thereby promoting regional green consumption.

The results are reported in Fig. 6.

(6a)Fujian Province 6b Guizhou Province 6c Jiangxi Province

Figure 6. Effects of National Ecological Civilization Pilot Zone Construction on Environmental Quality

Notes

The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.

As shown in Fig. 6, following the establishment of the National Ecological Civilization Pilot Zones, the comprehensive utilization rate of industrial solid waste increased substantially in Fujian and Guizhou Provinces. The estimated average annual treatment effects are 9.6528 and 10.5444, respectively, indicating significant improvements in production-related environmental performance. In contrast, Jiangxi Province experienced only a modest increase, with an average annual treatment effect of 0.2813. One possible explanation is that Jiangxi is a major industrial province with abundant mineral resources, including Asia's largest copper and tungsten reserves, while also ranking among China's leading producers of rare earth elements and non-ferrous metals. Consequently, large quantities of industrial solid waste are inevitably generated during production, resulting in a comparatively lower utilization rate and limiting improvements in environmental quality. Accordingly, Hypothesis H2b is supported.

Overall, the mechanism analysis demonstrates that National Ecological Civilization Pilot Zone construction promotes green consumption through complementary structural pathways. Industrial upgrading expands the supply and diversity of green products, while improvements in environmental quality strengthen the conditions that encourage environmentally responsible consumption. Together, these findings provide empirical support for the conceptual proposition that regional environmental governance facilitates sustainable production and consumption through coordinated transformations in production systems and environmental conditions.

5. Conclusions and Policy Implications

This study investigates whether regional environmental governance can promote sustainable consumption and, if so, through which mechanisms such policy effects are realized. By examining the NECPZs as a place-based environmental governance initiative, the study seeks to better understand how institutional reforms can simultaneously reshape production systems, environmental conditions, and consumption behaviour. Using panel data for 29 Chinese provinces covering the period 2004–2023, this study empirically examines both the policy effects of the pilot program on regional green consumption and its underlying transmission mechanisms. The empirical findings collectively demonstrate that the effects of regional environmental governance extend beyond environmental protection and are reflected in both the evolution of green consumption outcomes and the structural conditions that support sustainable consumption.

The establishment of the pilot zones significantly enhanced green consumption, and the estimated policy effects remained robust. Mechanism analysis indicates that the policy promotes green consumption primarily through facilitating industrial structure upgrading and improving environmental quality in the pilot provinces.

These findings suggest that policies aiming to promote green consumption should move beyond isolated consumer-oriented interventions and instead adopt integrated approaches that simultaneously strengthen environmental governance, production transformation, and market development. Based on the above findings, the following policy recommendations are proposed to promote regional green consumption and advance ecological civilization construction.

• First, the integrated regional environmental governance should continue to be strengthened. The experience of the NECPZs suggests that coordinated institutional reforms can effectively promote sustainable consumption while supporting broader sustainability objectives. Future policy expansion should therefore emphasise the replication of successful governance practices.

• Second, the heterogeneous policy effects observed across provinces indicate that policy expansion should be region-specific. Differentiated policy measures tailored to local conditions should account for regional differences in economic development, industrial structure, and environmental conditions rather than adopting a uniform policy approach.

• Third, governments should strengthen production-side transformation, supporting green industries, and expanding the supply of certified green products. Improving the availability and competitiveness of green products can reinforce the effectiveness of demand-side policies and support sustainable consumption.

Overall, this study highlights that promoting green consumption requires more than encouraging environmentally responsible consumer behaviour. Sustainable consumption is more likely to emerge when regional environmental governance simultaneously transforms production systems, improves environmental quality, and creates institutional conditions that support greener market choices. The experience of China's NECPZs, therefore, provides broader insights into how integrated environmental governance can contribute to sustainable production and consumption transitions.

Declarations

Supplementary information

The supplementary materials are available at https://doi.org/10.6084/m9.figshare.34936821

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical clearance was not required for this study, as it did not involve animal subjects or human participants.

Informed consent

Not applicable. The study relies exclusively on secondary data obtained from publicly available sources and does not involve human participants.

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Author Contribution

Author contributions Yongyuan Guo: Writing-original draft, Funding acquisition, Conceptualization, Model and indicator design, Project administration; Linbo Yuan: Writing-review&editing, Methodology, Validation, Data curation, Resources; All authors reviewed the manuscript.

Data Availability

Data availability The datasets and analysis code used in this study are provided in the Supplementary Information as a compressed “Data and Code” package. The package contains the underlying datasets for the green consumption, control variables, and the Stata analysis code (Analysis_Code.do). The data are derived from publicly available sources, including the China Statistical Yearbook, the China Energy Statistical Yearbook, the China Environmental Statistical Yearbook ,the China Science and Technology Statistical Yearbook, and Provincial Statistical Yearbooks .

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Figures

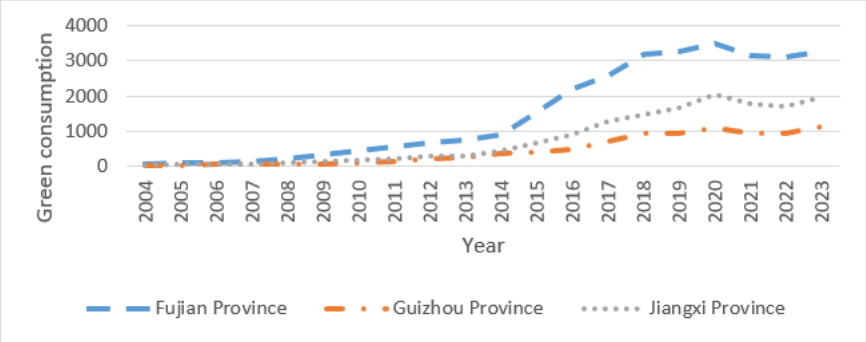

Figure 1

Trends in Green Consumption in the Three National Ecological Civilization Pilot Provinces (2004–2023)

Source:*Compiled by the authors based on the China Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, and China Science and Technology Statistical Yearbook.*

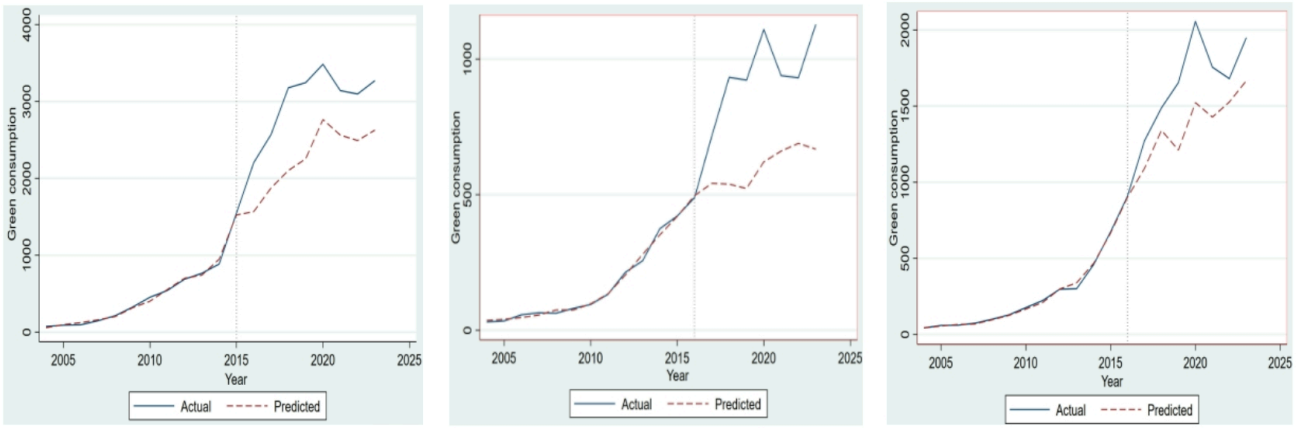

Figure 2

Policy Effects of National Ecological Civilization Pilot Zone Construction on Green Consumption in the Pilot Provinces

Notes:*The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.*

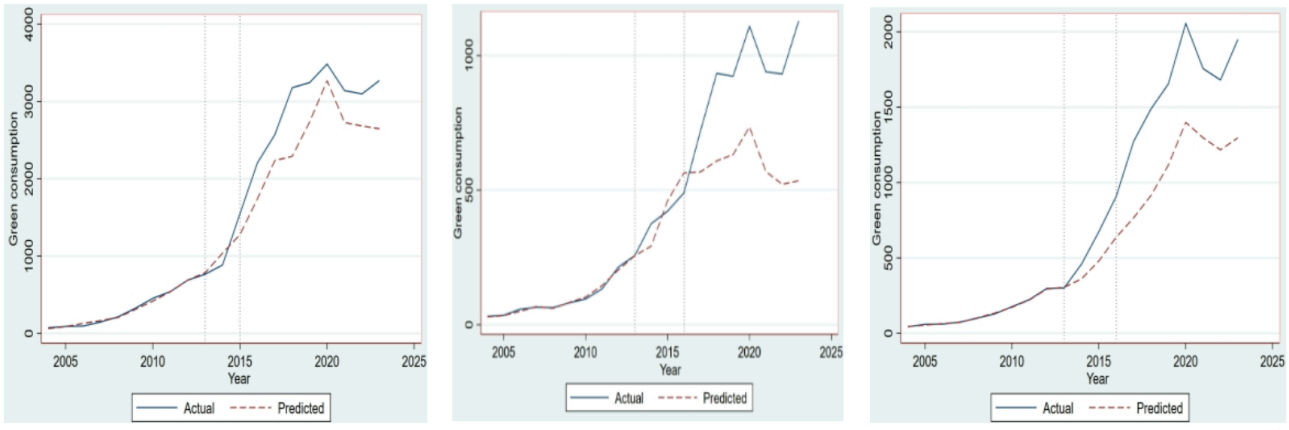

Figure 3

Results of the Time Placebo Test

Notes:*The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.*

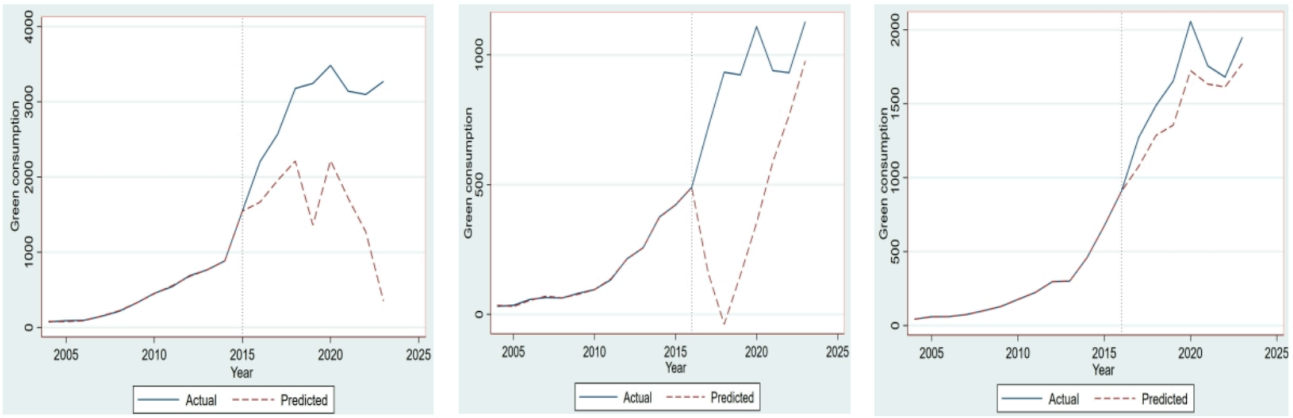

Figure 4

Robustness Test Based on the AICc Criterion

Notes:*The regression control model was estimated using the OLS procedure implemented in Stata/MP 17.0.*

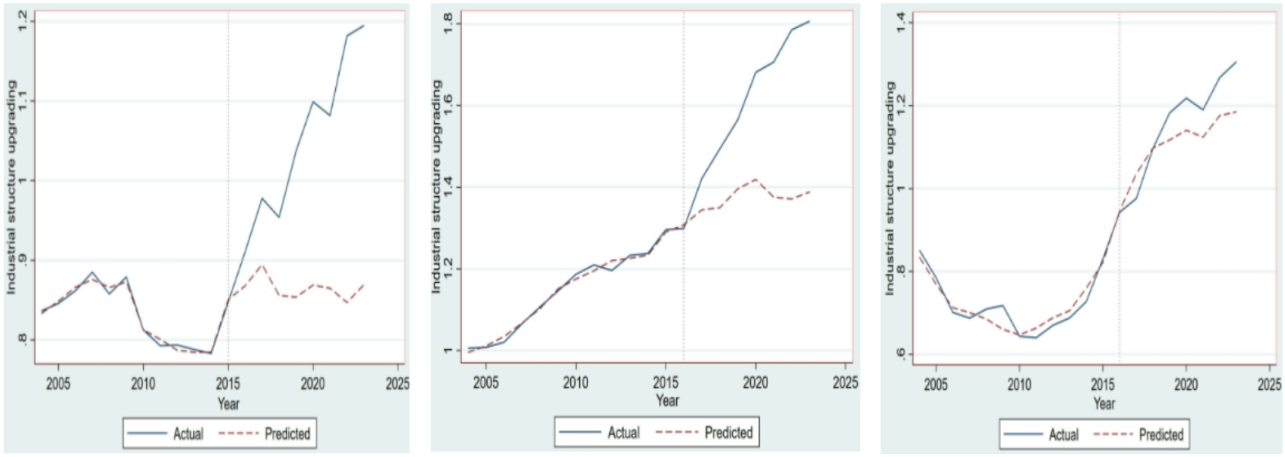

Figure 5

Effects of National Ecological Civilization Pilot Zone Construction on Industrial Structure Upgrading

Notes:*The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.*

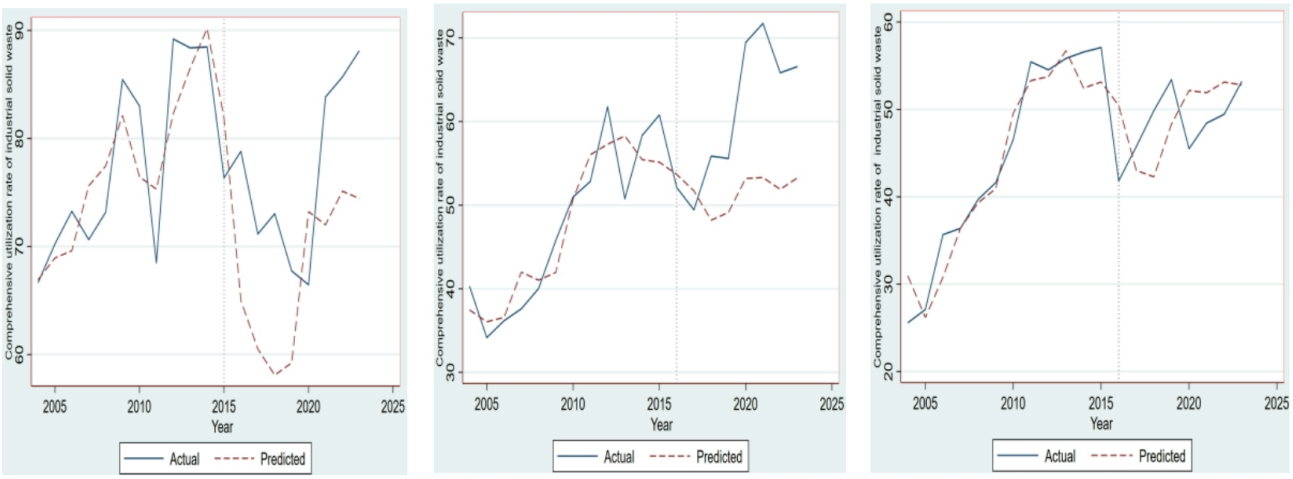

Figure 6

Effects of National Ecological Civilization Pilot Zone Construction on Environmental Quality

Notes:*The regression control model was estimated using the LASSO-OLS procedure implemented in Stata/MP 17.0.*

Supplementary Files

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- Appendixwithexplanations.docx