Supplementary Material

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# Table S1. Spatial weight matrix.

|  |  |
| --- | --- |
| Types | Calculation formula |
| Economic geography nested matrix (W1) |  |
| Inverse square geographic distance matrix (W2) |  |
| Geographical adjacency matrix (W3) |  |

Note: In the economic geography nested matrix (W1), *PGDPi* and *PGDPj* represent the per capita GDP of province *i* and province *j*, respectively. In the inverse square geographical distance matrix (W2), *dij* indicates the geographical distance between provinces, *R* is the earth's radius, *φi* and *φj* are the dimension and longitude of the province, respectively, and *τ* is the longitude difference between the two provinces.

# Table S2. Specific explanations of green finance-related indicators.

|  |  |
| --- | --- |
| Explanation | Basis for selection |
| Six major high energy-consuming industries | The six major high-energy-consuming industries are classified according to the explanation in the “Industrial Statistics” of the National Bureau of Statistics of China as follows: Electric power and heat production and supply industry, Non-metallic mineral products industry, Ferrous metal smelting and calendaring, Non-ferrous metal smelting and calendaring, Chemical raw materials and chemical products manufacturing industry, Petroleum processing, coking, and nuclear fuel processing. |
| Environmental protection-listed companies | Based on the stock concept label of the Wind database and concerning the “Green Industry Guidance Catalog 2019”, this paper finally selects environmental protection-listed companies from 16 green concept sectors such as Wind power industry stocks, Wind power generation, Clean development mechanism, Charging piles, Geothermal energy, Solid waste treatment, Environmental protection along the Yangtze River, Energy conservation and environmental protection, Energy-saving lighting, Waste sorting, Beautiful China, Mainland low-carbon components, Hydrogen energy, Biomass energy, Hydropower, Carbon neutrality. |
| Green insurance | Green insurance should be measured by the proportion of environmental liability insurance. However, due to the late introduction of environmental liability insurance and the lack of data, agricultural insurance, which is more relevant to the environment, was chosen as a substitute for environmental liability insurance. |
| Total carbon emissions | Total carbon emissions are calculated by summing up the products of coal, oil, and natural gas consumption and their respective carbon emission factors. |

# Table S3. Descriptive statistics and Multicollinearity test.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | Observation | Mean | Std. dev | Min | Median | Max | VIF | 1/VIF |
| Eco-efficiency (*Ee*) | 390 | 0.389 | 0.286 | 0.168 | 0.265 | 1.139 | — | — |
| Green finance (*Gf*) | 390 | 0.185 | 0.114 | 0.064 | 0.153 | 0.885 | 4.30 | 0.233 |
| Industrial structure (*Is*) | 390 | 0.465 | 0.098 | 0.309 | 0.457 | 0.810 | 3.32 | 0.301 |
| Urbanization rate (*Ur*) | 390 | 0.583 | 0.128 | 0.347 | 0.569 | 0.893 | 4.65 | 0.215 |
| Environmental regulation (*Er*) | 390 | 0.009 | 0.003 | 0.004 | 0.009 | 0.018 | 1.21 | 0.826 |
| Technological innovation (*Rd*) | 390 | 0.017 | 0.011 | 0.005 | 0.014 | 0.062 | 4.77 | 0.210 |
| Trade openness (*To*) | 390 | 0.270 | 0.303 | 0.017 | 0.138 | 1.447 | 3.13 | 0.319 |
| Environmental awareness (*El*) | 390 | 9.126 | 0.950 | 7.029 | 9.064 | 12.66 | 3.67 | 0.272 |

Table S3 shows that the mean variance inflation factor (Mean VIF) for the model is 3.579, with none of the variables exceeding the critical value of 5. Therefore, it can be concluded that the model does not exhibit severe multicollinearity issues.

# Table S4. Traditional Markov transition probability matrices of green finance and eco-efficiency types from 2009 to 2021.

|  |  |  |  |
| --- | --- | --- | --- |
| t/(t+1) | Green finance |  | Eco-efficiency |
| n | 1 | 2 | 3 | 4 | n | 1 | 2 | 3 | 4 |
| 1 | 96 | 0.781 | 0.219 | 0.000 | 0.000 | 96 | 0.854 | 0.135 | 0.010 | 0.000 |
| 2 | 95 | 0.010 | 0.790 | 0.200 | 0.000 | 91 | 0.022 | 0.824 | 0.154 | 0.000 |
| 3 | 88 | 0.000 | 0.011 | 0.830 | 0.159 | 87 | 0.000 | 0.035 | 0.873 | 0.092 |
| 4 | 81 | 0.000 | 0.000 | 0.000 | 1.000 | 86 | 0.000 | 0.000 | 0.023 | 0.977 |

The results of the traditional Markov chain test, as shown in Table S4, indicate that: (1) All the transition probability values on the diagonal were significantly greater than those off the diagonal. Moreover, transitions between different levels of green finance and eco-efficiency generally maintained an upward or downward shift by one stage, making abrupt changes across types relatively rare. This suggests the overall stability of green finance and eco-efficiency. (2) For moderate-level types (k=2 and k=3), the probabilities of maintaining stability in green finance and eco-efficiency were 79.0%, 83.0%, 82.4%, and 87.3%, respectively. The chances of downward transitions were 1.0%, 1.1%, 2.2%, and 3.5%, while the probabilities of upward transitions were 20.0%, 15.9%, 15.4%, and 9.2%, respectively. The likelihood of upward transitions was higher than that of downward transitions, indicating that moderate-level green finance and eco-efficiency demonstrated positive momentum for upward changes. However, transitioning to high-level types posed even greater challenges and encountered specific developmental difficulties. (3) Both green finance and eco-efficiency exhibited the “Matthew effect.” The probability of downward transitions for high-level green finance and eco-efficiency types was as low as 0% and 2.3%, respectively. Additionally, the likelihood of upward changes for low-level green finance and eco-efficiency types was only 21.9% and 13.5%, respectively. This indicates a clear polarization and club convergence phenomenon in green finance and eco-efficiency.

# Table S5. Spatial panel econometric model suitability test.

|  |  |  |  |
| --- | --- | --- | --- |
| Statistics | W1 | W2 | W3 |
| LM-error | 16.558\*\*\* | 9.480\*\*\* | 15.230\*\*\* |
| Robust LM-error | 17.513\*\*\* | 8.877\*\*\* | 0.019 |
| LM-lag | 6.337\*\* | 3.553\* | 19.762\*\*\* |
| Robust LM-lag | 7.293\*\*\* | 2.951\* | 4.550\*\* |
| LR-spatial lag | 57.18\*\*\* | 28.41\*\*\* | 58.34\*\*\* |
| LR-spatial error | 54.71\*\*\* | 20.62\*\*\* | 41.55\*\*\* |
| Wald-spatial lag | 61.21\*\*\* | 29.69\*\*\* | 64.01\*\*\* |
| Wald-spatial error | 58.92\*\*\* | 21.63\*\*\* | 44.14\*\*\* |
| Hausman | -26.60 | 37.26\*\*\* | -13.39 |
| Both-Ind | 60.58\*\*\* | 30.48\*\* | 52.92\*\*\* |
| Both-Time | 692.26\*\*\* | 657.30\*\*\* | 647.75\*\*\* |

Note: (1) \*, \*\*, and \*\*\* indicate significant levels at 10%, 5%, and 1%, respectively. (2) The negative value in the Hausman test can be considered as a signal to choose the fixed-effects.

The results of the suitability test for the spatial panel econometric model, as shown in Table S5, indicate that: (1) The *LM* test indicated that the spatial panel lag models (SPLM) with the economic geographical nesting matrix (W1), inverse square geographical distance matrix (W2), and geographical adjacency matrix (W3) were all suitable for examining the causal relationship between green finance and eco-efficiency. (2) The results of the *Wald* and *LR* tests, conducted under the three types of spatial weight matrices, passed the significance test. This implies that the spatial panel Durbin model (SPDM) cannot be simplified into the spatial panel error model (SPEM) or SPLM. (3) The negative result of the *Hausman* test indicated that the fixed-effects model was superior to the random-effects model, and the joint significance of spatial fixed effects and time fixed effects was observed, at least at the 5% level. Therefore, this study ultimately employed the SPDM with both spatial and time fixed effects for parameter estimation.

# Table S6. Endogeneity treatment results.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| IV | Stage I | Stage Ⅱ |  | DSPDM |  | SDID |
| Variables | (1) *Gf* | (2) *Gf2* | (3) *Ef* | Variables | (4) *Ef* | Variables | (5) *Ef* |
| *L·Gf* | 0.900\*\*\*(0.061) |  |  | *L.Ef* | 0.753\*\*\*(0.051) | *Did* | 0.076\*\*\*(0.025) |
| *L·Gf2* |  | 0.978\*\*\*(0.087) |  | *L.WEf* | -0.375\*\*\*(0.129) | *Wx.Did* | 0.101\*(0.058) |
| *Gf* |  |  | 3.095\*\*\*(0.865) | *Gf* | 0.794(0.510) |  |  |
| *Gf2* |  |  | -2.426\*\*\*(0.639) | *Gf2* | -0.717\*(0.399) |  |  |
| *U-test* | *P>|t|*=0.009\*\*\* | *Wx·Gf* | 2.988\*\*\*(1.142) |  |  |
| *Underidentification test*78.411\*\*\* (0.000) | *Wx·Gf2* | -1.905\*\*(0.836) |  |  |
| *Weak identification* 338.761 (7.030) | *Spatial rho* | 0.354\*\*\*(0.081) | *Spatial rho* | 0.475\*\*\*(0.063) |
| *Overidentification test*0.000 | *Direct* | *Gf* | 1.095\*\*(0.538) | *Direct* | *Did* | 0.092\*\*\*(0.028) |
| *Gf2* | -0.916\*\*(0.402) |
| *Covariate* | Yes | *Indirect* | *Gf* | 4.812\*\*\*(1.808) | *Indirect* | *Did* | 0.238\*\*(0.096) |
| *Gf2* | -3.149\*\*(1.335) |
| *Province fixed*  | Yes | *Total* | *Gf* | 5.907\*\*\*(2.158) | *Total* | *Did* | 0.330\*\*\*(0.113) |
| *Gf2* | -4.065\*\*(1.585) |
| *Time fixed* | Yes | *Covariate/Province/Time fixed* | Yes | *Covariate/Province**/Time fixed* | Yes |
| *R-squared* | 0.550 | *R-squared* | 0.808 | *R-squared* | 0.086 |
| *N* | 360 | 360 | 360 | *N* | 360 | *N* | 390 |

Note: (1) \*, \*\*, and \*\*\* indicate significant levels at 10%, 5%, and 1%, respectively. (2) Cluster-robust standard errors are in parentheses. (3) Underidentification test result is the Kleibergen-Paap rk LM statistic, with its P-value in parentheses. Weak identification test result is the Kleibergen-Paap rk Wald F statistic, with the corresponding critical value from the Stock-Yogo test at a 10% significance level in parentheses. Overidentification test result is the Hansen J statistic, with a result of 0, indicating exact identification. (4) The results of the parallel trends test and placebo test for SDID are shown in [Figure S1](#FigureS1) and [Figure S2](#FigureS2), respectively.

# Table S7 Robustness test results.

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | Replace matrix | Exclude pilot provinces | Adjust time frame |
| Eco-civilization | Green finance |
| *Gf* | 3.947\*\*\* | 3.115\*\*\* | 2.869\*\*\* | 3.767\*\*\* |
| (0.554) | (0.508) | (0.580) | (0.919) |
| *Gf2* | -3.378\*\*\* | -2.687\*\*\* | -2.413\*\*\* | -2.808\*\*\* |
| (0.452) | (0.404) | (0.470) | (0.734) |
| *Wx.Gf* | 12.353\*\*\* | 6.583\*\*\* | 3.445\*\* | 3.716\*\* |
| (3.766) | (1.128) | (1.350) | (1.745) |
| *Wx.Gf2* | -10.592\*\*\* | -4.847\*\*\* | -2.073\* | -3.120\*\* |
| (2.633) | (0.908) | (1.093) | (1.383) |
| *Spatial rho* | 0.146\*\*\* | 0.470\*\*\* | 0.124\*\* | 0.236\*\*\* |
| (0.071) | (0.083) | (0.110) | (0.086) |
| *Direct* | *Gf* | 4.100\*\*\* | 3.887\*\*\* | 2.985\*\*\* | 4.097\*\*\* |
| (0.583) | (0.563) | (0.613) | (0.977) |
| *Gf2* | -3.516\*\*\* | -3.282\*\*\* | -2.499\*\*\* | -3.086\*\*\* |
| (0.475) | (0.462) | (0.500) | (0.794) |
| *Indirect* | *Gf* | 15.754\*\*\* | 11.998\*\*\* | 3.696\*\*\* | 6.067\*\*\* |
| (5.094) | (2.299) | (1.425) | (2.224) |
| *Gf2* | -13.435\*\*\* | -9.122\*\*\* | -2.342\*\* | -4.931\*\*\* |
| (4.029) | (1.938) | (1.190) | (1.867) |
| *Total* | *Gf* | 19.854\*\*\* | 15.885\*\*\* | 6.682\*\*\* | 10.164\*\*\* |
| (5.332) | (2.611) | (1.774) | (2.712) |
| *Gf2* | -16.951\*\*\* | -12.404\*\*\* | -4.841\*\*\* | -8.017\*\*\* |
| (4.243) | (2.225) | (1.511) | (2.366) |
| *Covariate* | Yes | Yes | Yes | Yes |
| *Province fixed*  | Yes | Yes | Yes | Yes |
| *Time fixed* | Yes | Yes | Yes | Yes |
| *R-squared* | 0.039 | 0.158 | 0.130 | 0.186 |
| *N* | 390 | 351 | 325 | 210 |

Note: (1) \*, \*\*, and \*\*\* indicate significant levels at 10%, 5%, and 1%, respectively. (2) Cluster-robust standard errors are in parentheses.

Figure S1. Parallel trend test.



The parallel trend test, as shown in Figure S1, indicates that the experimental and control groups followed the same development trend before the implementation of the pilot policies (before 2018). After 2018, the effects of the pilot policies gradually became significantly positive, thereby meeting the requirements of the parallel trend test.

Figure S2. Placebo test.



The placebo test, as shown in Figure S2, indicates that the virtual estimate coefficients were concentrated around 0, with a noticeable gap from the real estimate coefficients. Additionally, they followed a normal distribution, ruling out interference from other random factors.