

The Relationship between Corporate ESG Performance and Green Innovation: An Empirical Analysis Using Stata's Basic Regression Model

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Abstract:

This study uses data from Chinese A-share listed companies (2012–2021) and a multi-period difference-in-differences (DID) model to examine the relationship between corporate ESG (Environmental, Social, and Governance) performance and green innovation. Results show that higher ESG ratings significantly promote the growth of green patents, indicating a positive effect on corporate green transformation. The study also highlights the significant impact of control variables, such as firm size and listing duration, on green innovation. Regression analysis and parallel trend tests confirm the robustness of the model. These findings provide policy implications for governments, firms, and investors to foster green innovation and sustainable development.

Keywords:

ESG Performance, Green Innovation, Difference-in-differences Model, A-share Listed Companies, Sustainable Development

1. Introduction

Under the goals of “carbon neutrality” and “carbon peaking,” corporate Environmental, Social, and Governance (ESG) performance has become a focal point in both management practice and academic research. ESG disclosures have had positive effects on firms, with existing literature exploring the impact of ESG performance on investment, corporate performance, and other economic factors. As the concept of green sustainable development gains traction, more companies are proactively disclosing ESG reports. Third-party rating agencies have also developed ESG ratings based on these disclosures, leading to extensive academic research on ESG itself and its economic consequences. However, the effectiveness of ESG performance remains debated. Scholars such as Deng argue that ESG ratings help mitigate information asymmetry between companies and stakeholders, thereby attracting greater stakeholder support, leading to better financial performance and higher market value [1]. Most studies focus on the relationship between ESG

performance and financial performance or market reactions, with Flammer's review of over 2,000 studies showing that around 90% of empirical research supports a non-negative correlation [2]. However, little research has explored how ESG ratings influence sustainable investment, especially in terms of corporate green innovation.

The literature on the relationship between ESG performance and corporate value is divided, partly due to differences in ESG evaluation standards across countries. Most international ESG research focuses on developed nations, with limited studies on emerging markets. Additionally, there is a lack of systematic analysis on how ESG performance affects corporate green innovation in China. This study, using data from Chinese A-share listed companies (2012-2021), investigates the relationship between ESG performance and green innovation through empirical analysis using Stata.

2. Research Design

This study follows Hu Jie's work [3] on ESG ratings and corporate green transformation using a difference in-differences (DID) approach, applying Stata for regression analysis. The model is specified as follows:

$$GT_{it} = \lambda_0 + \lambda_1 ESG_{it} + \gamma X_{it} + u_i + \eta_t + \varepsilon_{it}$$

The dependent variable, GT_{it} , represents the green transformation of firm i in year t . The key explanatory variable, ESG_{it} , is set to 1 if the company's ESG rating is published by the China Securities Index (CSI) for year t , otherwise 0. X_{it} represents a set of control variables; u_i is the individual fixed effect; η_t is the time fixed effect; and ε_{it} is the random error term.

The ESG data is sourced from the Wind database, following methodologies from scholars like Xiao Fang [4] and Tan & Zhu [5]. Parallel trend tests are conducted, with firms receiving ESG ratings being classified as the treatment group and others as the control group. The dependent variable for corporate green innovation is the number of green patents granted, sourced from the China National Research Data Service platform (CNRDS). Control variables include firm size (Size), leverage (Lev), revenue growth (Growth), largest shareholder's ownership (Top1), cash flow (Cashflow), board size (Board), proportion of independent directors (Indep), CEO-chair duality (Dual), shareholder power balance (Balance2), firm age (FirmAge), and management shareholding (Mshare), sourced from the CSMAR database.

Considering ESG ratings by CSI were first released in 2015, the sample includes A-share listed companies from 2012 to 2022. The sample processing steps are as follows: (1) Exclude financial firms and companies listed as ST, ST*, or PT; (2) Exclude newly listed companies to avoid disclosure bias; (3) Remove firms with significant missing data, resulting in 34,315 observations. (Table 1)

Table 1. Variable Definitions.

Variable Type	Variable Name	Variable Symbol
Independent Variables	ESG Performance	SynTao Green Finance ESG
Dependent Variable	Green Innovation	ln green innovation unite
Control Variables	Control variables include firm size	Size
	leverage	Lev
	revenue growth	Growth
	largest shareholder's ownership	Top1
	cash flow	Cashflow
	board size	Board
	proportion of independent directors	Indep

	CEO-chair duality	Dual
	shareholder power balance	Balance2
	firm age	FirmAge
	management shareholding	Mshare

3. Regression Analysis

3.1. Descriptive Statistics

This study uses two measures of corporate green innovation: the total number of independent green patent applications (green innovation independence) and the total number of joint green patent applications (green innovation unite), both of which are logged. The mean values for these variables are 0.119 and 0.044, with standard deviations of 0.430 and 0.288, respectively. The range between the maximum and minimum values is 5.852 and 6.676, indicating that while the overall level of green innovation among sample firms is relatively low, there is considerable variation across firms. The average ESG score is 0.122, suggesting that 12.2% of the sample firms have an ESG rating. (Figure 1)

Variable	Obs	Mean	Std. dev.	Min	Max
SynTao ~ ESG	35,325	.1224628	.3278243	0	1
Ingreen ~ dence	35,286	.1194243	.4298087	0	5.852202
Ingreen ~ unite	35,286	.0440729	.2879339	0	6.675823
Size	35,325	22.19912	1.337533	14.94164	28.63649
Lev	35,325	.4147035	.2095876	.0079691	1.956558
Cashflow	35,322	.0468396	.075476	-.8877293	.875945
Board	35,284	2.113416	.199336	1.098612	2.890372
Indep	35,284	.3770653	.0558208	.1428571	.8
Dual	35,325	.3061571	.4609023	0	1
Top1	35,287	.3390513	.1493068	.002863	.89991
Balance2	35,287	.7740964	.631307	0	4.000007
FirmAge	35,325	2.93042	.3291182	1.098612	4.174387
Mshare	34,370	.1539904	.3083077	0	20.17084

Figure 1. Descriptive Statistics.

Among the control variables, the average firm size (Size) is approximately 22.199, with a maximum value of 28.636 and a minimum of 14.941, indicating a diverse range of firm sizes in the sample. The average total asset-liability ratio is about 41.4%, showing that most firms have a debt ratio close to 50%, which is considered a reasonable leverage level. Other variables also fall within reasonable value ranges.

3.2. Correlation Analysis

Figure 2 presents the correlation analysis results for the main variables. The correlation coefficient between corporate ESG performance and green innovation is 0.146, which is statistically significant, providing preliminary evidence that green innovation has a positive effect on ESG performance. No correlation coefficient exceeds 0.8, indicating that there is no multicollinearity among the variables.

	Ingreen ~ ite	SynTao ~ ESG	Size	Lev	ROA	ATO	Cashflow
Ingreen ~ ite	1.000						
SynTao ~ ESG	0.146***	1.000					
Size	0.205***	0.530***	1.000				
Lev	0.057***	0.110***	0.493***	1.000			
ROA	0.007	0.088***	-0.001	-0.366***	1.000		
ATO	0.008	0.022***	0.046***	0.122***	0.141***	1.000	
Cashflow	0.031***	0.124***	0.076***	-0.159***	0.403***	0.082***	1.000
Growth	-0.001	-0.002	-0.003	0.005	0.000	0.001	0.000
Board	0.060***	0.109***	0.267***	0.144***	-0.001	0.014***	0.036***
Indep	0.012**	0.043***	0.005	-0.005	-0.014***	-0.020***	-0.007
Dual	-0.020***	-0.051***	-0.183***	-0.140***	0.050***	-0.020***	-0.011**
Top1	0.049***	0.092***	0.187***	0.035***	0.134***	0.066***	0.100***
Balance2	-0.015***	-0.020***	-0.113***	-0.120***	0.003	-0.045***	-0.017***
FirmAge	0.017***	0.115***	0.177***	0.182***	-0.096***	-0.008	0.003
Mshare	-0.037***	-0.065***	-0.227***	-0.200***	0.120***	-0.008	0.019***

	Growth	Board	Indep	Dual	Top1	Balance2	FirmAge
Growth	1.000						
Board	0.003	1.000					
Indep	-0.004	-0.548***	1.000				
Dual	-0.003	-0.177***	0.104***	1.000			
Top1	0.006	0.019***	0.038***	-0.048***	1.000		
Balance2	-0.004	0.007	-0.026***	0.063***	-0.684***	1.000	
FirmAge	0.002	0.053***	-0.008	-0.113***	-0.082***	-0.035***	1.000
Mshare	-0.003	-0.137***	0.051***	0.159***	-0.045***	0.155***	-0.158***

	Mshare
Mshare	1.000

Figure 2. Correlation Analysis.

Note: * indicates $p < 0.1$, ** indicates $p < 0.05$, *** indicates $p < 0.01$

3.3. VIF Test

The variance inflation factor (VIF) values for all variables are below 3, indicating that multicollinearity is not an issue in the model. (Figure 3)

Variable	VIF	1/VIF
Size	2.16	0.462970
Top1	2.04	0.489076
Balance2	2.01	0.498326
Board	1.62	0.615583
Lev	1.50	0.665274
Indep	1.49	0.669914
SynTao ~ ESG	1.46	0.682953
Mshare	1.13	0.888047
FirmAge	1.10	0.912592
Dual	1.08	0.927184
Cashflow	1.07	0.932984
Mean VIF	1.52	

Figure 3. VIF Test.

3.4. Fixed Effects Model

Using a two-way fixed effects approach with individual and time-fixed effects, a regression with clustered robust standard errors is performed. The R-value between corporate ESG and green innovation is 0.617, which is close to 1, further suggesting a strong correlation between the two variables and supporting the use of a multi-period DID model. (Figure 4)

Fixed-effects (within) regression			Number of obs = 34,332		
Group variable: stkcd			Number of groups = 4,910		
R-squared:			Obs per group:		
Within = 0.0141			min = 1		
Between = 0.0339			avg = 7.0		
Overall = 0.0289			max = 11		
corr(u_i, Xb) = 0.0953			F(21,4909) = 7.33		
			Prob > F = 0.0000		
(Std. err. adjusted for 4,910 clusters in stkcd)					
Ingreen~unite	Coefficient	Robust std. err.	t	P> t	[95% conf. interval]
SynTao~ ESG	.0341572	.0084175	4.06	0.000	.0176552 .0506593
Size	.0099741	.0036119	2.76	0.006	.0028932 .0170551
Lev	-.0155959	.0100911	-1.55	0.122	-.0353789 .0041871
Cashflow	.0045391	.0151029	0.30	0.764	-.0250693 .0341475
Board	-.0143447	.0197899	-0.72	0.469	-.0531417 .0244522
Indep	.0145313	.0502896	0.29	0.773	-.0840588 .1131215
Dual	-.0024764	.0049298	-0.50	0.615	-.0121411 .0071883
Top1	-.0160766	.0340459	-0.47	0.637	-.0828218 .0506687
Balance2	-.00934	.0073346	-1.27	0.203	-.0237191 .0050391
FirmAge	-.017257	.0386218	-0.45	0.655	-.092973 .058459
Mshare	.0028815	.0046211	0.62	0.533	-.0061779 .0119409
year					
2013	.0092364	.0043755	2.11	0.035	.0006585 .0178142
2014	.0074206	.0061938	1.20	0.231	-.004722 .0195633
2015	.0106904	.0081985	1.30	0.192	-.0053823 .0267631
2016	.0191479	.0105326	1.82	0.069	-.0015007 .0397964
2017	.0270404	.0125345	2.16	0.031	.0024672 .0516136
2018	.0174355	.0141731	1.23	0.219	-.0103501 .0452211
2019	.0201487	.0156986	1.28	0.199	-.0106275 .0509249
2020	.0224035	.0178709	1.25	0.210	-.0126316 .0574385
2021	.0392471	.0196712	2.00	0.046	.0006829 .0778114
2022	.0547071	.0214599	2.55	0.011	.0126362 .0967781
_cons	-.1114302	.1233454	-0.90	0.366	-.3532424 .1303819
sigma_u	.21566528				
sigma_e	.16991691				
rho	.61700048	(fraction of variance due to u_i)			

Figure 4. Fixed Effects Model.

3.5. Benchmark Regression

From Columns (1) and (2) of Table 2, the regression results indicate a significantly positive coefficient for ESG ratings, suggesting that ESG ratings significantly enhance corporate green patent output. Column (2) further demonstrates that, after incorporating a series of control variables, the coefficient for ESG ratings is 0.0452, which is significant at the 1% level. This implies that ESG ratings lead to an average 4.52% increase in the total number of green patents granted in the following year. These findings support Hypothesis 1, confirming that ESG ratings have a significant positive effect on firms' green transition.

Among the control variables, firm size (Size) and listing age (FirmAge) both exhibit significantly positive coefficients, indicating that larger and more established firms are more likely to engage in green transition. This is consistent with the notion that

green transition involves high risk and substantial investment, which larger and older firms are better positioned to undertake.

Table 2. Basic Regression.

	(1)	(2)	(3)	(4)
	ln green innovation unite	ln green innovation unite	ln green innovation unite	ln green innovation unite
SynTao Green Finance ESG	0.128***	0.0452***	0.0358***	0.0378***
	(27.65)	(8.38)	(6.51)	(6.78)
Size		0.0383***	0.0449***	0.0433***
		(28.98)	(29.12)	(26.03)
Lev			-0.0695***	-0.0641***
			(-8.28)	(-7.31)
Cashflow				-0.00292
				(-0.14)
Board				0.0267***
				(2.78)
Indep				0.0908***
				(2.77)
Dual				0.00881***
				(2.63)
Top1				0.0310**
				(2.16)
Balance2				0.00572*
				(1.71)
FirmAge				-0.00918*
				(-1.93)
Mshare				-0.00184
				(-0.36)
_cons	0.0284***	-0.812***	-0.928***	-0.975***
	(17.54)	(-27.95)	(-28.80)	(-23.13)
N	35286	35286	35286	34332
R2	0.021	0.044	0.046	0.046
adj. R2	0.021	0.044	0.046	0.046
F	764.6	811.2	564.7	150.9

Note: *t* statistics are in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

3.6. Parallel Trend Test

To further examine the dynamic effects of ESG ratings and validate the model's robustness, a parallel trend test was conducted (see Figure 5). The results show that prior to the ESG rating, the regression coefficients are not significantly different from zero, indicating minimal impact of ESG on green innovation. After the ESG rating, the coefficients exhibit a clear upward trend and become statistically significant, demonstrating that ESG ratings have a sustained positive effect on firms' green transition. The parallel trend test confirms the validity of the model established in Figure 5.

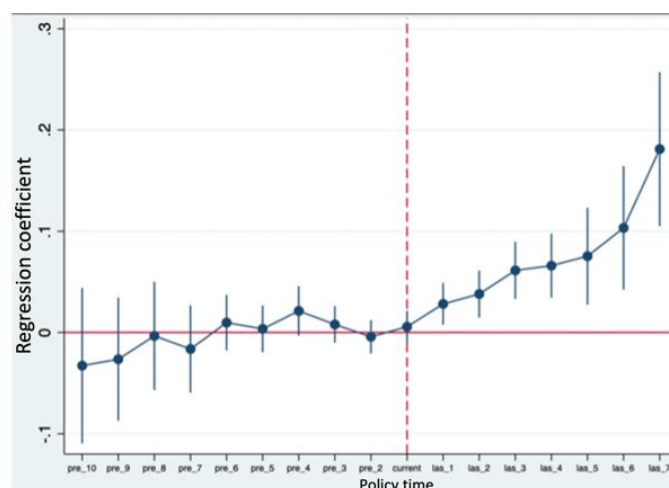


Figure 5. Parallel Trend Test.

4. Conclusions

Promoting green economic transition has become a global priority. For China to achieve green development, corporate green transformation is essential. Using ESG ratings from SynTao Green Finance and a multi-period difference-in-differences model, this study empirically investigates the impact of ESG ratings on corporate green innovation. The findings reveal that ESG ratings significantly enhance firms' green innovation. Based on these insights, the following recommendations are proposed: For Governments: Establish ESG management and evaluation standards to guide and regulate corporate ESG practices. For Corporations: Strengthen ESG awareness and actively pursue green transformation. For Investors: Adopt responsible investment strategies focused on ESG to promote ESG-driven investments. A collaborative effort between governments, corporations, and investors can create a positive feedback loop for ESG development, fostering corporate green transformation and driving high-quality growth.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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