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The long-term and short-term effects of green strategy on corporate performance: evidence from Chinese listed companies

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Abstract:

While a growing body of literature has examined the link between green strategy and firm performance, little attention has been paid to distinguishing short-term from long-term effects, and the underlying mechanisms through which green strategy takes effect are also rarely discussed. This paper leverages the context of implementing a green strategy among Chinese listed companies to examine how the green strategy impacts the company's short-term and long-term financial performance. Drawing from the resource-based view (RBV), we argue that the implementation of the green strategy facilitates the company's long-term performance but inhibits short-term performance due to the mediating effects of firms' debt ratio. The current research makes substantial contributions to the literature and provides important implications for policymakers and firm managers.

Keywords green strategy, long-term and short-term, firm performance, moderating effect, Resource-based view

1 Introduction

Along with rapid industrialization, China has long been plagued by a deteriorating natural environment and climate change. Given the public health caused by severe pollution, the Chinese government has continuously deepened the environmental management system, optimized environmental supervision methods, and partially alleviated the environmental pollution problem (Huang and Chen 2015). Despite the benefits of passive environmental supervision in improving environmental quality, it has been challenging to develop an endogenous motivation for polluters to solve environmental problems (Chang et al. 2021). In addition to driving changes in social and environmental conditions, corporate behavior is a significant source of pollution (Zhang et al. 2020). Therefore, promoting green strategies among companies is essential to sustainable development (Bassetti et al. 2021).

Porter (1996) first proposed the green strategy, which stressed that businesses no longer achieve economic gains at the expense of the external environment. To achieve this goal of win-win economic and environmental benefits, businesses must redistribute their internal resources, upgrade their green technologies, and develop green products that differentiate their competitive advantage, then create a corporate green image, expand their original

market demand, and experience long-term profit growth (Olson 2008; Zhang et al. 2011). Despite this, business managers in an agency relationship tend to pay more attention to short-term profits during their tenure since the owner and manager are separated (Goktan 2014). Moreover, the green strategy is risky. Companies face conflict and ambiguity in implementing green strategies because the commercial success and sustainability benefits are uncertain, constantly evolving, and dynamically complex (Sharma 2014; Wijethilake et al. 2018). We believe the first step in implementing the green strategy is to distinguish between the impacts of the green strategy on the company's short- and long-term performance.

Moreover, the literature holds varying views on how green strategies perform in the short and long run. Some studies conclude that green strategies improve corporate performance over time (Chakrabarty and Wang 2012; Leyva et al. 2019), but others report mixed or even adverse outcomes in the short-run (Wagner 2005; Ramanathan et al. 2010). The inconsistent findings of the literature are primarily due to differences in research settings, sample data structures, and quantification methods of green strategy. Specifically, there are differences in the conclusions drawn from the research background of developed versus developing countries and cross-sectional analysis using survey data versus panel data. Additionally, different indicator systems will impact green strategy measurement. More importantly, most studies have not examined the mechanisms through which green strategy operates when a negative correlation is reached. Therefore, further study is required to provide a more empirically sound picture of the connection between green strategy and corporate performance.

Due to the implementation of the green strategy occupying production resources short-term, especially the occupation of production funds, the company's debt structure will be affected (Leyva et al. 2019). Moreover, the company's debt structure will influence its financial performance in terms of debt costs, debt risk, and other factors, so this study explores the impact of green strategy on corporate financial performance via the mediating effect of the debt ratio and suggests ways to improve the short-term performance.

Our research focuses on the impact of green strategy implementation among Chinese firms to test the association between green strategy and long empirically- and short-term performance of enterprises. China has been implementing green and sustainable development from top to bottom since the 12th Five-Year Plan, so green strategies are commonplace.

Our sample includes 3869 Chinese listed firms with 32468 firm-year observations. The observing time window is from 2008 to 2019. Panel data have a changing trend over time compared to cross-sectional data, so they are more appropriate for analyzing the short- and long-term effects of the study subject. In addition, we use a semi-supervised clustering algorithm to estimate the implementation of the company's green strategy; the algorithm is based on the partially clear input-output correspondences, which makes the result more reliable than the Index Aggregation method in most of the literature. To comprehensively measure an enterprise's financial performance, we take account of both accounting and market-based variables. Subsequently, we deploy various empirical techniques, including long-term and short-term performance analysis, moderating effect, and heterogeneity analysis, which support our arguments.

The current research seeks to make the following contributions. First, although there is some evidence on the relationship between green strategy and corporate performance, this paper is the first to evaluate both long-term and

short-term effects on corporate performance using panel data. Second, this article probes into the underlying mechanisms of how green strategy has an inhibitory effect on the short-term financial performance of a company. Third, we propose a double-check method for measuring the effectiveness of green strategies. The first procedure is based on semi-supervised clustering algorithms; then, we conduct a second check using ISO4001 certification and environmental scores of corporate social responsibility.

The rest of the paper is organized as follows. In Section 2, we develop the conceptual framework and hypotheses based on extant literature. Section 3 presents related methodologies and data. In section 4, we tested the hypotheses and further examined the validity of the results. Section 5 concludes the paper.

2 Literature review and hypothesis

Resource-based views (RBVs) assume that firms are the integration of resources and that resources determine the performance of firms, especially non-substitutable resources (Barney 1991; Hart 1995). Despite the relationship between resources and firms' performance being widely discussed, RBV has been criticized for its inability to uncover firms' resource management processes due to insufficient data (Priem and Butler 2001). However, the green activities of a firm will shape its tangible and intangible resources, which in return affect its performance (He and Shen 2019). Following the literature, we ground our research on the RBV, summarize various green activities of enterprises as the implementation of green strategy, and investigate how green strategy affects enterprises' short-term and long-term performance. Figure 1 summarizes the conceptual framework and the proposed hypotheses in the study.

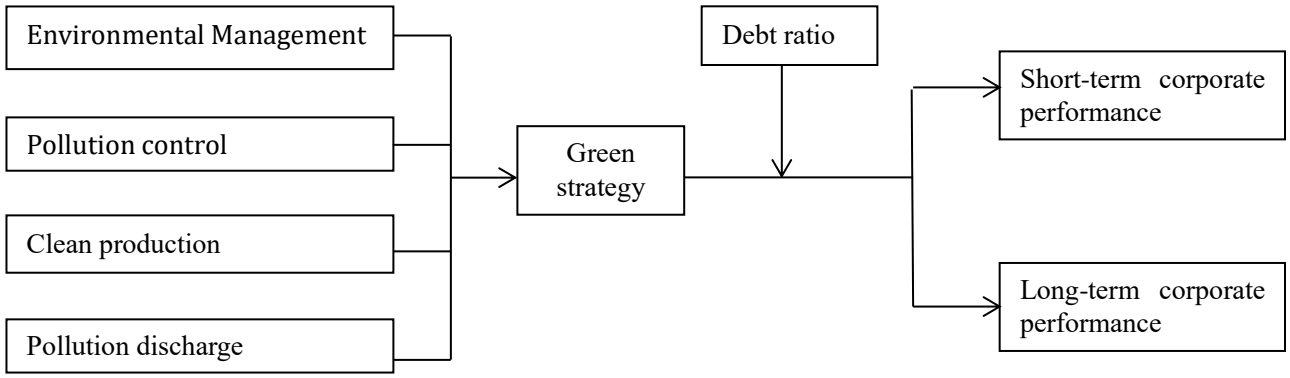

Fig 1 Conceptual framework

2.1 Green strategy

Porter (1996) proposed green strategy, and its definition and content have been continually developed and improved by subsequent scholars. Sharma (2000) emphasized that environmental protection measure was the crucial component of the green strategy. Additionally, Banerjee (2001) proposed a green business strategy, which meant that business areas such as R&D, procurement, production, and sales should consider environmental factors. Based on concept development, the definition of green strategy focuses more on the implementation process of the strategy, including environmental action, green innovation, and emission reduction control (Bansal 2005; Montiel and Delgado 2014; Duque et al. 2019).

The evaluation of the green strategy takes place in two stages. An evaluation index system is constructed in the first stage, while in the second stage, the evaluation method must be determined. The selection and construction of green strategy indicators generally come from existing survey databases and questionnaires; among them, the Thomson Reuters database includes financial, environmental, social, corporate governance, and international data on over 6000 firms globally in all sectors. It includes over 400 measures grouped into more than 70 indicators, which is an invaluable tool for studying the green development strategy of enterprises and creating evaluation items for green strategy. Green strategy can be measured in two ways, the first being the index validity analysis based on the questionnaire data, the second being the comprehensive evaluation including the fuzzy comprehensive evaluation and cluster analysis. The relevant literature about the determination and evaluation methods of green strategy indicators is listed in Table 1.

Table 1 Literature review about the items and methods of evaluating green strategy

Study	Sample	Object	Data sources	Measure items	Methods
Yang et al. (2019)	134 listed companies in China	Proactive environmental strategy	Survey data	Five items (pollution management)	Confirmatory factor analysis
Leonidou et al.(2017)	153 small Cypriot manufacturer	Green business strategy	Survey data	7 indicators (environmental management)	Confirmatory factor analysis
Chen et al. (2015)	China, 198 manufacturing firms	Environmental strategy	Survey data	4 indicators (environmental management)	Confirmatory factor analysis
Chen et al. (2020)	Printed circuit boards (PCBs) in Taiwan	environmental protection strategy	Google Trends	7 strategies along 5 dimensions	T_w fuzzy importance-performance analysis
Digalwar, et al. (2020)	one Indian automobile organization	Sustainable strategy	Production and operation data of the company	5 items (environment production)	fuzzy analytical network process (ANP)
Buysse and Verbeke (2003)	Belgium, 197 firms	Proactive environmental strategy	Survey data	10 items (reactive strategy, pollution prevention and environmental leadership)	cluster analysis
Migdadi (2018)	23 airlines from different regions	green operations strategy	Survey data	12 items (energy use and pollutant	cluster analysis

				emission)	
Scarpato et al. (2020)	Italian , fisheries industry	Sustainable strategy	Survey data	7 factor (sustainable development)	principal component analysis Cluster analysis
Longoni and Cagliano (2015)	725 firms from 21 countries	Environmental sustainability priorities	International Manufacturing Strategy Survey (2009)	2 items (environmental products and social responsibility)	K-means cluster analysis

Validity analysis of the indicators based on the questionnaire data can retain the data information altogether, but the cost of collecting the data, the non-public nature, and the non-verification characteristics present significant obstacles to the questionnaire survey method (Morgan and Sonquist 1963; Loosveldt et al. 2004). Similarly, the fuzzy comprehensive evaluation method lacks further verification of the evaluation results (Wang and Wang 2007). Nevertheless, semi-supervised clustering can make up for these shortcomings. Specifically, clustering analysis can verify the effectiveness of the clustering results in training set through semi-supervised learning and further expand to extensive sample clustering analysis, which indirectly verifies the reliability of clustering analysis (Schmiedeberg 2010; Bynen 2012).

2.2 Green strategy and performance

Incorporate environmental literature during the last two decades, one of the most studied issues has been the nature of the relationship between environmental activity, like implementing a green strategy, and financial performance (King and Lenox 2001; Etzion 2007). Nevertheless, the vast majority of studies examined whether this relationship was positive (win-win) or negative (win-lose) have yielded contradictory results. It is mainly due to the differences between long and short periods and the heterogeneity of the data that led to the opposite conclusion (Cordeiro and Sarkis 1997; Chakrabarty and Wang, 2012; Lin et al. 2021). The related literature and main conclusions are listed in Table 2.

A stream of studies has found a negative, win-lose relationship between green strategy and financial performance in the short term. The main reason for this is that implementing a green strategy will occupy production resources and create a crowding-out effect on corporate investment (Ramanathan et al. 2010; Busch and Hoffman 2011; Lin et al. 2021). Additionally, environmental management (e.g., ISO14001 certifications) requires additional capital and support, which increases the cost of production and operation for firms even further (Wagner 2005; López et al. 2007; Trumpp and Guenther 2017). Based on the arguments above, we propose the following Hypotheses1:

Hypotheses1: The implementation of green performance will have a short-term negative effect on financial performance.

Another stream of studies has found a positive, win-win relationship between green strategy and financial performance in the long run. An organization's ability to innovate products and services compatible with changes in the environment can assist in achieving long-term benefits over competitors (Sharma 2014). Such organizations may

also benefit from a first-mover advantage in the long run by establishing superior brand recognition and customer loyalty. In general, green strategy enhances organizational performance as it (i) promotes efficient use of resources (Shu et al. 2016), (ii) converts wastes into recyclable outputs (Chen and Chang 2013), (iii) reduces emissions (Menguc et al. 2010), (iv) helps to develop a competitive advantage (Chakrabarty and Wang 2012). Taken together, we come up with the following Hypotheses 2:

Hypotheses 2: The implementation of green performance will be conducive to corporate financial performance in the long run.

Table 2 Literature review on the relation between green strategy and corporate performance

Study	Sample	Theory	Independent variable	Moderate variables	Dependent variable	Key finding
Cordeiro and Sarkis (1997)	Event study	N/A	Corporate environmental proactivism	N/A	Short-term Financial performance	negative
Wagner(2005)	Survey data from paper-manufacturing industry in four European countries	N/A	Corporate environmental strategies (measured by the amount of pollution emissions and energy use of enterprises)	N/A	Economic performance (ROA, ROE, ROS)	negative
López, et al. (2007)	110 firms from 55 European countries	N/A	Corporate social responsibility(measured by Dow Jones Sustainability Index)	N/A	Corporate financial performance(profit)	Negative
Menguc, et al. (2010)	325 manufacturing firms in New Zealand	RBV and Institutional theory	Proactively environmental strategy (measured by pollution prevention and top management support)	N/A	Firm's performance (sales growth and profit growth)	positive
Ramanathan, et al. (2010)	UK industrial sector	N/A	Environmental regulation (measured by pollution control expenditure)	N/A	Corporate innovation performance (production and process innovation)	negative
Busch and Hoffman (2011)	174 firms from US in 2006	Stakeholder theory RBV	Corporate Environmental performance (Carbon emission)	N/A	Corporate financial performance (ROA, ROE,	negative

					Tobin's Q)	
Chakrabarty and Wang (2012)	panel data from Kinder, Lydenberg, and Domini database, Compustat fundamentals database, and Compustat segments database in the USA	RBV	Sustainability practices (including environment, commubity, Employee, diversity, government and technology)	N/A	R&D intensity and Internationalization	Long-term positive
Walker and Wan (2012)	100 top performing Canadian firms in 2008	N/A	Green talk And green washing	N/A	Financial performance (ROA)	negative
Wang and Bansal (2012)	148 firms in 2008 in Canada	N/A	Corporate social responsibility activities (including coumunity, employee, environment, production)	CSR disclosure	Financial performance (Sale level, Market share, Sales growth, Cash flow, ROA, ROE, ROS)	negative
Chen and Chang (2013)	254 valid questionnaires from Taiwan's electronics industry	N/A	Green dynamic capabilities (measured by green knowledge, and technology)	Green creativity	Green product development performance	positive
Shu, et al. (2016)	490 Chinese firms in 2010	Institutional theory	Green management (related to environment, resources and energy)	Government support and social liegitimacy	Production innovation	positive
Shin et al. (2018)	EPA's Fortune 500 Top Green Power Partners List in US	NRBV	Renewable energy utilization	N/A	Firm financial performance (ROE, Tobin's Q, Operating margin)	positive
Brulhart et al. (2019)	188 questionnaires in France.	RBV	environmental proactivity (environmental issues, and efforts)	N/A	Firm profitability: (ROE, ROA, ROS)	positive

Leyva, et al. (2019)	Panel data from 1989 to 2009	Agency theory	Environmental innovation (measured by the frequency of focused knowledge)	Slack resources (R&D investment)	Financial performance (Tobin's Q)	Long-term positive
Yang et al. (2019)	126 listed firms in China	N/A	Environmental strategy (energy utilization and environment management)	State ownership and government administrative control	Innovation capability	positive
Lin, et al. (2021)	384 firms from CSRHub list and ESG database	Stakeholder theory	corporate sustainability strategy performance	N/A	Company's performance (ROA, ROE, ROIC, Tobin's Q)	negative

Abbreviation: NRBV, natural-resource-based view; ROA, return on asset; ROE, return on equity; ROS, return on sale; ROIC, return on invested capital.

2.3 Mediating role of debt ratio

The implementation of the green strategy will squeeze the capital and labor originally used for production, thereby increase the short-term debt burden of the company (Horváthová 2012; Leyva et al. 2019). In this regard, with specific requirements and documented standard, implementation of green strategy drives firms to set environmental goals and adjust the resource allocation plan of the production department and the non-production department. According to the RBV theory, the principal production resource (the capital used for production) will decrease, therefore, more capital investment will be required to maintain the current output level, thus the debt ratio of enterprises will increase.

As a result, the company's financial performance is restrained by the improvement in the company's debt ratio (Enekwe et al. 2014). Specifically, Furthermore, high-debt companies mean not only higher funding and interest costs (Van et al. 2010), but also higher financial risks, which negatively impact the company's solvency, corporate credit, and refinancing (Allayannis et al. 2003). In short, the above-mentioned negative effects are not conducive to improving short-term financial performance.

Given that firm's resources are limited in supply at a certain time point and that implementation of the green strategy needs a significant amount of capital investments, the company implementing green strategy will have a higher debt ratio and therefore inhibit financial performance. Based on the arguments above, we propose the following hypothesis 3:

Hypotheses 3: Companies with green strategies will need to deal with higher debt problems, which will negatively impact short-term performance.

3 METHODOLOGY AND VARIABLES

3.1 Green strategy

Evaluating green strategies is particularly challenging due to the complexities inherent in the evaluation process and unverifiable evaluation results (Hrebiniak 2006). Therefore, this section adopts a double-check evaluation procedure to evaluate the implementation of the green strategy of Chinese listed companies. Our first step is to introduce a clustering algorithm and then implement a system for evaluating green strategy indicators. Based on this, we cluster large samples using the semi-supervised algorithm. In the last step, we evaluate the clustering results.

3.1.1 wkFCM algorithm

The process of dividing a collection of physical or abstract objects into multiple classes composed of similar objects is called clustering. The cluster generated by clustering is a set of data objects similar to the objects in the same cluster and different from the objects in other clusters. The first time the clustering method was used for strategic evaluation was by Harrigan (1985), who used factor analysis and simple clustering to distinguish strategic groups. In subsequent studies, Fuzzy-C-Means (FCM) in clustering algorithms was further expanded and studied by Budayan et al. (2009)

However, the traditional FCM clustering algorithm has two defects: 1) the constraint condition of membership sum of 1 makes it sensitive to outliers and noises; 2) it is an iterative descent algorithm, making the initial clustering center sensitive and challenging to converge to the global optimum. Therefore, we improve the FCM algorithm.

With the improved FCM algorithm based on the kernel, the original points are mapped into the feature space via kernel functions. Since the original space cannot be divided by a linear function, it can be transformed into a higher-dimensional space, and a linear function can be found in the higher dimensional space, so the original data can easily be divided. This high latitude space is called feature space, and the inner product of the mapping function from low latitude to high dimension space is called kernel function. Furthermore, introducing kernel functions into machine learning is a meaningful way to increase computing performance when the number of features in feature space is large, and the computation of kernel functions is relatively tiny compared to the inner product of feature space. Therefore, the kernel-based FCM (kFCM) algorithm improves the clustering performance and makes the algorithm robust to noise and outliers.

Consider nonlinear mapping function $\phi: \mathrm{x} \longrightarrow \phi(\mathrm{x}) \in R^{D_k}$, where D_k is the dimension of the eigenvector x, we do not need to know x's transformation explicitly, just its dot product instead, which is $\phi(\mathrm{x}) \cdot \phi(\mathrm{x}) = \kappa(\mathrm{x}, \mathrm{x})$. Kernel functions can take many forms, including polynomials and radial basis functions (RBF). Given a kernel function κ, kernel-based FCM is usually defined as a constraint minimization problem, and the objective function is as follows:

$$J_m(U,\kappa) = \sum_{j=1}^{c} \left(\sum_{i=1}^{n} \sum_{k=1}^{n} (u_{ij}^m \, u_{kj}^m d_\kappa(x_i, x_k)) / 2 \sum_{l=1}^{n} U_{ij}^m \right)$$

Where $d_\kappa(x_i, x_k) = \kappa(x_i, x_i) + \kappa(x_\kappa, x_\kappa) - 2\kappa(x_i, x_\kappa)$ is the distance based on kernel between the i eigenvector kernel and the k eigenvector, which can been calculated by kernel matrix, define $\tilde{u}_k = \frac{u_k^m}{\sum_i |u_{ik}^m|}$, and $u_k^m = (u_{1k}^m, u_{2k}^m, \dots u_{nk}^m)^T$, we can get the following after simplification:

$$d_\kappa(x_i, v_k) = \tilde{u}_k^T K \tilde{u}_k + K_{ii} - 2(\tilde{u}_k^T K)_i$$

Similar to fuzzy c-means algorithm, clustering centers can be linearly combined by eigenvectors:

$$\phi(v_j) = \frac{\sum_{l=1}^{n} u_{lj}^m \phi(x_l)}{\sum_{l=1}^{n} u_{lj}^m}$$

Where u_{ij} is defined as:

$$u_{ij} = [\sum_{k=1}^{c} (\frac{\left||X_j - V_i|\right|^2}{\left||X_j - V_k|\right|^2})^{\frac{2}{m-1}}]^{-1}$$

Traditional FCM believes that every object is equally important, but in reality this is not the case. Therefore, to make sure that each object's relative importance is shown, the eigenvector weights serve as clustering centers, which is calculated as:

$$\phi(v_j) = \frac{\sum_{l=1}^{n} w_l u_{lj}^m \phi(x_l)}{\sum_{l=1}^{n} w_l u_{lj}^m}$$

Where, w_l is a set of pre-determined weights, which is used to define the weight influence of each eigenvector. Furthermore, cluster centers are also more influenced by objects with a high weight.

3.1.2 indicators for green strategy

Green strategy indicators are primarily selected from two directions: existing survey databases and questionnaire surveys based on specific purposes. One of them, Thomson Reuters' (Duque et al. 2020; Lin et al. 2020; Lartey et al. 2020) database, relates to enterprise green development strategy, environment, and resource management, and green product production forms the basis for researching enterprise green strategy indicators. In addition, Mendonca and Zhou (2019) and Lin et al. (2020) expand the scope of the green strategy indicator system to varying degrees. By combining the environmental disclosure content of listed companies in China using the CSMAR database, we developed 25 indicators that can be used to evaluate green strategies for Chinese listed companies, which are environmental management, pollution control, clean production, and pollution discharge. The content and definition of the evaluation indicators are shown in Table 3. The sample contained 3869 listed firms with 32468 firm-year observations, and the descriptive statistics of each indicator are shown in Appendix 1.

Table 3 Green strategy index system of Chinese listed companies

Category	Indicators	Description
Environmental management	1. Does the company have the concept of environmental protection?	If the company's environmental protection philosophy, environmental policy, environmental management organization structure, circular economy development model, green development are disclosed, the index is assigned a value of 1, otherwise it is 0.
	2. Does the company have environmental protection goals?	If the company's past environmental protection targets are fulfilled and future environmental targets are disclosed, the indicator is assigned a value of 1, otherwise it is 0.
	3. Does the company have an environmental management system?	If the disclosure company has formulated a series of management systems such as related environmental management systems, systems, regulations, responsibilities, the indicator is assigned a value of 1,

		otherwise it is 0.
	4. Has the company organized environmental education and training?	If the company's participation in environmental protection education and training is disclosed, the indicator is assigned a value of 1, otherwise it is 0.
	5. Does the company have special environmental protection expenditure?	If the company's participation in environmental protection special activities, environmental protection and other social welfare activities are disclosed, the indicator is assigned a value of 1, otherwise it is 0.
	6. Has the company established an emergency mechanism for environmental incidents?	If it is disclosed that the company has established an emergency response mechanism for major environmental-related emergencies, the emergency measures it has taken, and the handling of pollutants, the indicator is assigned a value of 1, otherwise it is 0.
	7. Has the company established a "three simultaneous" system?	If the company's implementation of the "three simultaneous" system is disclosed, the indicator is assigned a value of 1, otherwise it is 0.
	8. Has the company established the environmental information disclosure system?	If a listed company separately discloses environmental reports or discloses environmental-related information in the social responsibility report, the indicator is assigned a value of 1, otherwise it is 0.
Pollution control	9. Has the company established a waste gas treatment system?	0 = no description; 1 = qualitative description; 2 = quantitative description (currency / numerical description).
	10. Has the company established a wastewater treatment system?	0 = no description; 1 = qualitative description; 2 = quantitative description (currency / numerical description).
	11. Has the company established a dust treatment system?	0 = no description; 1 = qualitative description; 2 = quantitative description (currency / numerical description).
	12. Has the company established a solid waste recycling system?	0 = no description; 1 = qualitative description; 2 = quantitative description (currency / numerical description).
	13. Has the company established noise, light pollution and radiation treatment system?	0 = no description; 1 = qualitative description; 2 = quantitative description (currency / numerical description).
Cleaner production	14. Has the company established a cleaner production system?	0 = no description; 1 = qualitative description; 2 = quantitative description.
	15. Is the company up to standard in pollutant discharge?	Assign a value of 1 if the pollutant discharge reaches the standard, otherwise it is 0.
	16. Is there any sudden environmental accident in the production process of the company?	If there is no sudden major environmental pollution incident, assign a value of 1, otherwise it is 0.

	17. Does the company have any environmental violations in the production process?	If there is no environmental violation, assign a value of 1, otherwise it is 0.
	18. Does the company have environmental petition cases in the production process?	There is no environmental petition event, assign a value of 1, otherwise it is 0.
	19. Is the company a key pollution monitoring unit?	If the company is a key monitoring unit, assign a value of 1, otherwise it is 0.
Pollution discharge	20. Has the company's wastewater discharge volume been disclosed?	0 = no description; 1 = qualitative description; 2 = quantitative description.
	21. Has the company's chemical oxygen demand (COD) emissions been disclosed?	0 = no description; 1 = qualitative description; 2 = quantitative description.
	22. Has the company's sulfur dioxide (SO2) emissions been disclosed?	0 = no description; 1 = qualitative description; 2 = quantitative description.
	23. Has the company's carbon dioxide (CO2) emissions been disclosed?	0 = no description; 1 = qualitative description; 2 = quantitative description.
	24. Has the company's dust emissions been disclosed?	0 = no description; 1 = qualitative description; 2 = quantitative description.
	25. Has the company's solid waste emissions been disclosed?	0 = no description; 1 = qualitative description; 2 = quantitative description.

3.1.3 Comparison of clustering methods

Compared with factor analysis based on questionnaire data and fuzzy comprehensive evaluation, semi-supervised learning has the following characteristics. Based on the small samples with labels in the samples of semi-supervised learning, we train appropriate classifiers that consider the relationship between input and output variables and then apply them to other large sample classification, which makes the clustering process and clustering method reliable.

The first step of the semi-supervised clustering algorithm is to select the algorithm with the highest clustering accuracy based on the data with the existing labels. Our training set is the IRIS data set, consisting of 150 iris characteristics with four dimensions: calyx length, calyx width, petal length, and petal width and each iris variety (Setosa, Versicolor, Virginia). In this case, the wkFCM algorithm based on the Iris data set results in a better clustering, which means that the range of differences between comparing the four-dimensional feature data with the natural varieties is minimal, thus increasing the accuracy clustering. After calculation, the accuracy of the FCM algorithm is 89.33%, and that of wkFCM is 91.33%. Therefore, the validity of wkFCM clustering algorithm is verified.

3.1.4 Clustering results

Second, the wkFCM algorithm is applied to the clustering analysis of large samples. In Figure 2 and Figure 3 illustrate how the wkFCM clustering algorithm is used to distinguish whether a company implements a green

strategy using green strategy indicator data from Chinese listed companies.

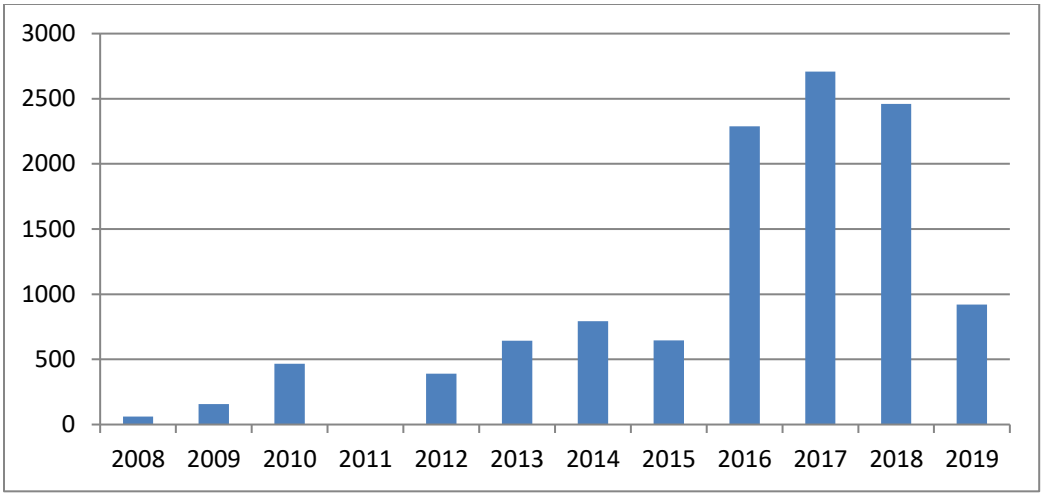

Fig 2 Number of listed companies implementing green strategy

In Figure 1, it can be seen that companies are implementing green strategies at an increasing rate. The number of companies implementing green strategies has increased significantly in the 13th Five-Year Plan (2016-2020) than the 12th Five-Year Plan (2011-2015). Due to the apparent time effect of the number of companies implementing green strategies, it is appropriate to analyze the company-level green strategy issues using the panel data structure. Figure 2 shows the industry distribution of the number of companies implementing green strategies, which indicates that most of these companies are in the manufacturing industry. It is, therefore, essential to take into account the heterogeneity of industries when discussing green strategy and company performance.

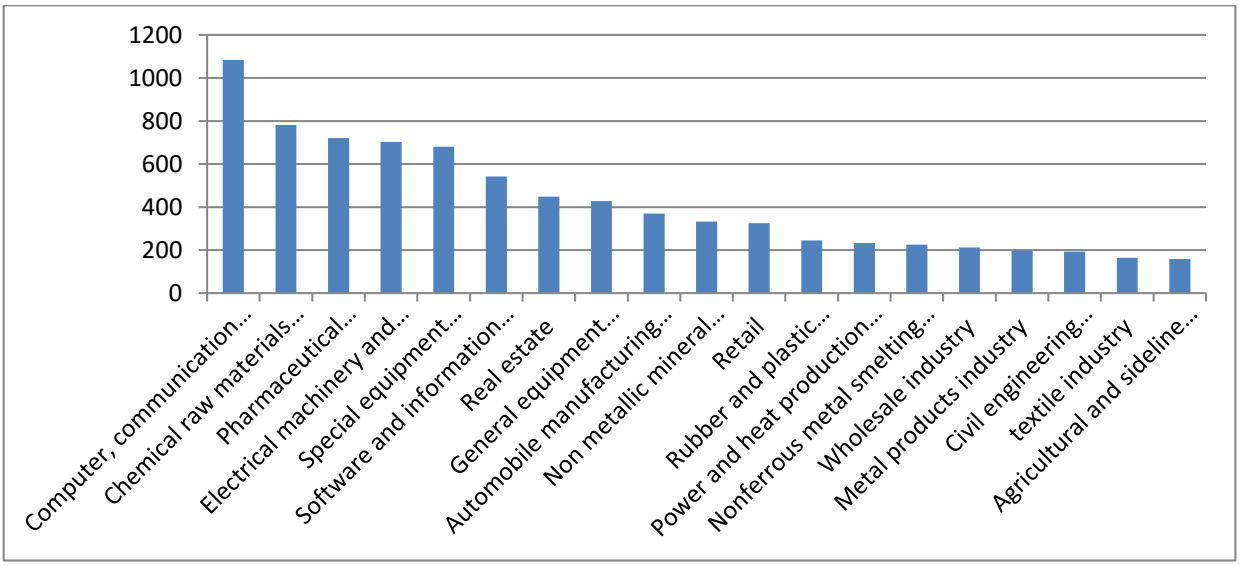

Fig 3 Number of listed companies implementing green strategy in various industries

3.1.5 Validity tests of clustering results

Given that the cluster analysis method for green strategy is new, it is essential to validate clustering results using well-established markers for best practices in the corporate world. To that end, we employ proxy variables that have appeared in the literature for green strategy. ISO4001 certification and environmental scores in corporate social

responsibility (CSR) are the relevant proxy variables of green strategy (He and Shen, 2019; Kraus et al. 2020). Table 4 presents the results of validation tests for our primary measure. Columns (1) and (2) show that the green strategy obtained by the clustering method is positively and significantly associated with ISO 14001 certification and that this positive association remains after controlling for industry and year fixed effects. Column (3) and (4) shows that green strategy is also positively and significantly associated with environmental scores in CSR, and the positive correlation is robust after controlling the industry and year fixed effects. In summary, the validation tests reported in Table 4 reassure us that our cluster estimation is correlated with the concept of green strategy in the existing literature and has performed as expected.

Table 4 Validity test of clustering results

	(1)	(2)	(3)	(4)
VARIABLES	*Green_strategy*	*Green_strategy*	*Green_strategy*	*Green_strategy*
ISO4001	0.0345***	0.0211*		
	(0.0126)	(0.0112)		
CRS_Environment			0.00205**	0.00196**
			(0.00101)	(0.000899)
Constant	0.476***	0.399***	0.481***	0.402***
	(0.00433)	(0.134)	(0.00366)	(0.134)
Company FE	YES	YES	YES	YES
Industry FE	NO	YES	NO	YES
Year RE	NO	YES	NO	YES
Observations	23,832	23,832	23,832	23,832
R-squared	0.001	0.223	0.001	0.223
Number of Symbol	3,734	3,734	3,734	3,734

Standard errors in parentheses

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

3.2 Data and variables

The data of this study is mainly from the CSMAR database, which includes 3980 listed firms in China. Specifically, we first retrieved firm and related green strategy indicators from the Environment research font in CSMAR (https://cn.gtadata.com). In the next step, we followed Graves and Pedrycz (2010) and developed a computer program, which is based on the research of Bezdek, Ehrlich and Full (1984), to makes a cluster analysis on whether the listed companies implement the green strategy according to the green strategy index. Thirdly, we use the ISO4001 environmental certification data (from CSMAR) and the environmental score in the CSR report (https://stockdata.stock.hexun.com) to verify the validity of the clustering results. In the final step, we collected and sorted the explained variables and other control variables from CSMAR.

3.2.1 Dependent variables

Typically, accounting-based and market-based metrics are used to analyze financial performance. Specifically,

accounting-based indicators display the owners' interests in terms of the rate of return on capital, while business-based indicators display the managers' operating performance, indicating profitability. Accounting-based parameters can be further divided into two categories: return on assets (ROA) and return on equity (ROE) (Busch and Hoffman 2011; Walker and Fang 2012; Lin et al., 2020). Meanwhile, market-based parameters can be best characterized by return on sale (ROS) and net profit ($NetProfit$) (Shin et al. 2018; Brulhart et al. 2019).

According to several researchers, such as Barnett and Salomon (2012) and Waddock and Graves (1997), accounting-based and market-based determinants are used together. For our calculations, we employ ROA and ROE as accounting-based determinants of firm's financial performance and ROS and net profit as the market-based quantifier of firm's financial performance. ROA is the value obtained after dividing earnings before interest and tax by all the company's assets; ROE is the value obtained after dividing net income by the company's equity capital, and ROS represents the company's earnings by sale revenue. Finally, net profit is obtained by subtracting operating costs and related taxes from operating revenue, then we take the logarithmic form of net profit.

4.2.2 Independent Variable

To identify the effect of the green strategy, we use a dummy variable $Green\_Strategy$ calculated by the wkFCM method, where 1 means the firm implemented the green strategy, and 0 means the firm did not. The validity of the clustering results was verified by the correlation test with ISO 14001 green certification and the environmental score in the CSR, as shown in Table 4.

4.2.3 Mediating Variables

Based on our conceptual framework, we propose that a company's debt ratio mediates the effect of green strategy on corporate performance in the short term. To measure the debt ratio, we deploy the ratio of total debts to total assets for the firm in a given year as the moderator variable $Debt\_Ratio$.

4.2.4 Control Variables

For all analyses, we control for $Size$, which is measured as the logarithm of the number of an employee of the focal firm in a given year, also we control the Age of the company (He, & Shen, 2019; Yang et al. 2019). Besides, we also consider the annual capital investment K, which has been found to affect corporate performance (Kahle and Shastri 2005). Moreover, we select the Herfindahl-Hirschman index (HHI) to measure industry concentration. Furthermore, we control for RD, which is measured as the ratio of R&D expenditure to total sales of the focal firm in a given year. In addition, we control for the industry-level characteristics of industry distribution of green strategy implementation since some industries are more involved in implementing green strategy than others (Figure 2). Last but not least, we include a complete set of firm and year dummies to control for any fixed, unobserved firm heterogeneity, as well as macroeconomic factors that may affect a firm's performance. Table 5 provides the descriptive statistics for the variables examined in the study and bivariate correlation coefficients.

Table 5 Descriptive statistics and correlation

Variable	Mean	SD	1	2	3	4	5	6	7	8
1. ROA	0.0292	0.8151	1							
2. $Green\_Strategy$	0.4819	0.4997	-0.0029	1						
3. Age	16.38	5.8822	-0.0097	0.0171*	1					

4. $Size$	21.96	1.5217	-0.0022	-0.0049*	0.0559*	1				
5. K	22.11	1.4958	0.0171*	0.0492*	0.1868*	0.3286*	1			
6. RD	4.6019	5.4081	-0.0677*	0.0399*	-0.1090*	-0.0795*	0.0709*	1		
7. HHI	0.0887	0.1108	-0.0198*	-0.0103	-0.0385*	0.0313*	-0.2269*	-0.1228*	1	
8. $Debt\_Ratio$	2.605	4.26	0.0068*	0.0015	-0.1157*	0.0585*	-0.2189*	-0.0037	0.2518	1

Note: * represents correlation significant is p<0.1.

4.3 Empirical model for Hypothesis

We predict that the implementation of green strategy may inhibit short-term corporate performance (Hypothesis 1), but that it may promote long-term corporate performance (Hypothesis 2). We also propose that the debt ratio has a moderating effect on the short-term performance, which means that green strategy implementing enterprises will bear higher debt, which will negatively affect their short-term performance (Hypothesis 3). To sum up, we establish the following empirical model.

$$Y_{it} = \alpha + \beta Green\_strategy_{it} + \gamma X_{it} + \mu_t + \theta_i + \varepsilon_{it} \quad (1)$$

$$\begin{cases} Y_{it} = \alpha + \beta Green\_strategy_{it-2} + \gamma X_{it} + \mu_t + \theta_i + \varepsilon_{it} \\ Y_{it} = \alpha + \beta Green\_strategy_{it-4} + \gamma X_{it} + \mu_t + \theta_i + \varepsilon_{it} \end{cases} \quad (2)$$

$$Y_{it} = \alpha + \beta Green\_strategy_{it} + Moderator_{it} + \gamma X_{it} + \mu_t + \theta_i + \varepsilon_{it} \quad (3)$$

Where Y_{it} is a dependent variable, representing ROA, ROE, ROS, and net profit. $Moderator_{it}$ stands for a moderating variable, which obtains by multiplying the variable $Green\_Strategy$ and the variable $Debt\_Ratio$. X_{it} is a vector of control variables for firm *i* in year *t*, μ_t is a set of year fixed effects, θ_i is a set of firm fixed effect. Because firm fixed effects have already captured fixed industry differences, industry dummies cannot be include (He, & Shen, 2019).

4. Green strategy and corporate performance

4.1 Green strategy and short-term corporate performance

First, we examine Hypothesis 1, which predicts that a green strategy will inhibit corporate performance in the short term. To get practical estimation, we deal with heteroscedasticity, autocorrelation, and cross-section correlation simultaneously and adopt Driscoll-Kraay standard errors; the results are reported in Table 6. Column (1) regress $Green\_Strategy$ on ROA, the estimated coefficient is negative and statistically significant at the p<0.01 level, indicating that green strategy significantly restrains corporate's ROA. Similarly, column (2) - column (4) also verifies the negative correlation between green strategy and ROE, ROS, and net profit, thus supporting our prediction in Hypothesis 1.

Table 6 Green strategy and short-term corporate performance

	(1)	(2)	(3)	(4)
Dependent variable	ROA_{it}	ROE_{it}	ROS_{it}	$NetProfit_{it}$
$Green\_Strategy_{it}$	-0.0104***	-0.0110***	-0.0469*	-0.104***
	(0.00302)	(0.00315)	(0.0250)	(0.0167)
Age_{it}	-0.00906***	-0.00705***	0.00331	-0.181***

	(0.00129)	(0.00130)	(0.0150)	(0.0542)
$Size_{it}$	0.129**	0.134**	0.274**	1.024***
	(0.0424)	(0.0441)	(0.0900)	(0.0745)
K_{it}	-0.103**	-0.108**	-0.319**	-0.152**
	(0.0346)	(0.0354)	(0.135)	(0.0622)
HHI_{it}	-0.0315	-0.0361*	0.0973***	0.525*
	(0.0177)	(0.0196)	(0.0237)	(0.252)
RD_{it}	-0.00201***	-0.00191***	-0.0475**	-0.0157***
	(0.000412)	(0.000457)	(0.0179)	(0.00289)
Constant	-0.399	-0.433	1.311	2.691**
	(0.219)	(0.237)	(1.297)	(1.181)
Company FE	YES	YES	YES	YES
Year RE	YES	YES	YES	YES
Observations	14,101	14,101	14,100	12,799
Number of groups	3,099	3,099	3,099	3,080
R-squared	0.1560	0.1588	0.2783	0.2898

Standard errors in parentheses

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

4.2 Green strategy and long-term corporate performance

Then, we verify whether implementing a green strategy will improve the company's financial performance over time (Hypothesis 2). To visualize the time effect of green strategy implementation, we distinguish between the current effect, the medium and long-term effect (lagging two years of $Green\_Strategy$), and the long-term effect (lagging four years of $Green\_Strategy$). Four groups of panel data (Panel A-Panel D) are established with ROA, ROE, ROS, and net profit as explanatory variables. The results are reported in Table 7.

In Panel A, the first column represents the impact of implementing a green strategy on the current financial performance of enterprises, which is consistent with the results of Table 6. Column (2) represents the medium-and long-term impact of implementing green strategy on enterprise ROA after two years, whose estimated coefficients are negative at the p<0.05 level and smaller than Column (1), which indicates that the negative impact of going green will weaken over time. Further, Column (3) also came to a similar conclusion, four years after the implementation of the green strategy, the financial performance of the company has been improved. In addition, Panel B-Panel D confirms the relationship between green strategy implementation and ROE, ROS, and net profit, supporting our hypothesis in Hypothesis 2.

Table 7 Green strategy and long-term corporate performance

Panel A			
Dependent variable:ROA_{it}	(1)	(2)	(3)

$Green\_Strategy$	-0.0104***		
	(0.00296)		
$Green\_Strategy_{it-2}$		-0.00827**	
		(0.00287)	
$Green\_Strategy_{it-4}$			0.00770**
			(0.00233)
Constant	YES	YES	YES
Control Variable	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	14,049	8,662	4,364
Number of groups	3,083	2,523	1,956
R-squared	0.1560	0.1838	0.2602
Panel B			
Dependent variable: ROE_{it}			
$Green\_Strategy$	-0.0109***		
	(0.00307)		
$Green\_Strategy_{it-2}$		-0.00774**	
		(0.00290)	
$Green\_Strategy_{it-4}$			0.00799**
			(0.00225)
Constant	YES	YES	YES
Control Variable	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	14,049	8,662	4,364
Number of groups	3,083	2,523	1,956
R-squared	0.1588	0.1944	0.2833
Panel C			
Dependent variable: ROS_{it}			
$Green\_Strategy$	-0.0479*		
	(0.0250)		
$Green\_Strategy_{it-2}$		-0.0939***	
		(0.0186)	
$Green\_Strategy_{it-4}$			0.0247**

			(0.00895)
Constant	YES	YES	YES
Control Variable	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	14,049	8,662	4,364
Number of groups	3,083	2,523	1,956
R-squared	0.2783	0.2582	0.2486
Panel D			
Dependent variable: $\mathrm{NetProfit_{it}}$			
$Green\_Strategy$	-0.104***		
	(0.0167)		
$Green\_Strategy_{it-2}$		-0.104***	
		(0.0230)	
$Green\_Strategy_{it-4}$			0.127*
			(0.0542)
Constant	YES	YES	YES
Control Variable	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	12,799	7,733	3,854
Number of groups	3,080	2,488	1,866
R-squared	0.2898	0.2647	0.2418

Standard errors in parentheses

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

4.4 Moderating analysis

According to Hypothesis 1, the implementation of the green strategy will not benefit the short-term financial performance of enterprises; this conclusion seriously hinders the managers from implementing green strategy independently. However, it has become inevitable that green upgrading and sustainable development will be implemented in all industries, so exploring the critical obstacles to implementing a green strategy will be essential for its successful implementation.

According to Hypothesis 3, adopting a green strategy leads to higher debt, negatively affecting the short-term performance of enterprises. To test Hypothesis 3, the cross-product of green strategy and corporate debt ratio was examined, and the results are shown in Table 8. Column 1 to column 4 of Table 8 shows that companies pursuing green strategies do have higher debt levels and negative coefficients at the 5% level for cross-product items. Nevertheless, the implementation of green strategies will positively affect the financial performance of enterprises if

debt ratios are controlled, indicating that debt problems are a significant obstacle to businesses implementing green strategies. To encourage enterprises to implement green strategies independently, government support is needed, such as green subsidies and credit incentives. In addition, we plot the interaction effect as illustrated in Figure 4, so Hypothesis 3 is supported.

Table 8 Moderating effect- the level of debt ratio

	(1)	(2)	(3)	(4)
Dependent variable	ROA_{it}	ROE_{it}	ROS_{it}	$NetProfit_{it}$
$Green\_Strategy_{it}$	0.0168***	0.0147***	0.0758***	-0.0202
	(0.00288)	(0.00280)	(0.0230)	(0.0135)
$leverage$	-0.344***	-0.389***	-0.745***	-1.462***
	(0.0232)	(0.0243)	(0.108)	(0.253)
$Green\_Strategy * Debt\_ratio_{it}$	-0.253***	-0.275***	-0.696***	-0.606***
	(0.0548)	(0.0605)	(0.195)	(0.173)
Constant	YES	YES	YES	YES
Control Variable	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	14,101	14,101	14,100	12,799
Number of groups	3,099	3,099	3,099	3,080
R-squared	0.3599	0.4002	0.2807	0.3130

Standard errors in parentheses

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

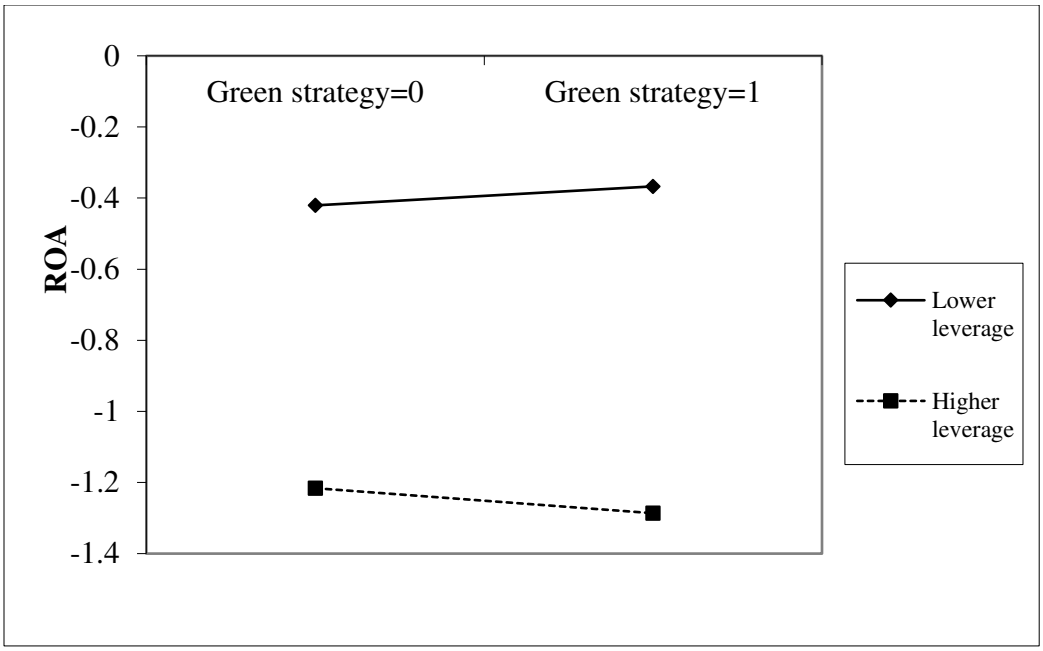

Figure 4 Interactive effects of green strategy and leverage on performance

4.3 Further study

In our empirical analysis, we verify the impact of the implementation of green strategy on the long-term and short-term performance of enterprises. However, the anti-incentive effect of short-term performance will adversely impact the strategic decision-making of enterprise decision-makers, as well as the policy support of the government. Hence, this section will examine the robustness of the short-term effect of green strategy based on estimation method, outlier processing, and industry heterogeneity.

Using the pooled OLS model and the clustered robust standard error, we evaluate the overall effect of green strategy implementation on enterprise financial performance comprehensively. In Panel A of Table 9, the regression results show that the implementation of green strategies does not result in improved corporate financial performance after controlling the fixed effects of time and individual, and the conclusion is consistent both under the cross-sectional and panel data structures. According to Coles et al. (2001) extreme values of the sample have an impact on the estimation results, so we remove outliers less than 1% and greater than 99%, then verify the relationship between green strategy and short-term performance, and the negative effect is robust as shown in Panel B of Table 9.

Table 9 Robust test

Panel A: pooled OLS method	(1)	(2)	(3)	(4)
Dependent variable	ROA_{it}	ROE_{it}	ROS_{it}	$NetProfit_{it}$
$Green\_Strategy_{it}$	-0.00644***	-0.00749***	-0.0443**	-0.0559***
	(0.00158)	(0.00159)	(0.0209)	(0.0195)

Constant	YES	YES	YES	YES
Control Variable	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	14,101	14,101	14,100	12,799
R-squared	0.139	0.136	0.027	0.584
Panel B: remove outliers of sample				
Dependent variable	ROA_{it}	ROE_{it}	ROS_{it}	$NetProfit_{it}$
green_strategy_Fuzzy_c_means	-0.0104***	-0.0299***	-0.0192***	-0.103***
	(0.00302)	(0.00765)	(0.00449)	(0.0161)
Constant	YES	YES	YES	YES
Control Variable	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	14,101	13,193	14,100	12,799
Number of groups	3,099	3,031	3,099	3,080
R-squared	0.1560	0.1527	0.1808	0.2968

Standard errors in parentheses

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

5 CONCLUSION AND DISCUSSION

5.1 Conclusion

New development patterns must harmonize economic growth with ecosystems, and the implementation of green strategy by enterprises is essential for sustainable development models (Olson, 2008). Additionally, quantifying the benefits of executing a green strategy is a significant factor in making a company's strategic choice (Shin et al., 2018). Based on the theory of RBV, we investigate how the adoption of green strategy by firms affects their short-term and long-term financial performance. Leveraging the environmental disclosure data of Chinese listed companies for multi-index cluster analysis, we find that implementing a green strategy will lead to the inconsistent effect of short-term growth performance. In particular, green strategy inhibits the short-term financial performance of firms, instead, stimulates the long-term performance. Moreover, the results reveal that leverage acts as the crucial mechanism through which green strategy may take short-term effect.

5.2 Implications for policymakers

This study provides policymakers with significant implications. Specifically, as hypothesized, the implementation of green strategies will impede short-term enterprise financial performance but allow for long-term financial performance. We explore short-term barriers to green strategy implementation by focusing on corporate debt and find that companies that implement the green strategy will have higher debt, meaning higher debt costs and

financial risk, which will negatively impact short-term performance (Horváthová 2012; Leyva et al. 2019). Accordingly, policymakers are suggested to incentivize firms to implement green strategies by subsidizing the green products and technologies or providing green credit support for the green development of enterprises (Zhang et al. 2021).

5.3 **Implications for firm managers**

As well, the current study conveys essential ethical and economic incentives for firm managers. Notably, a company's development is often constrained by limited resources and underdeveloped management skills, and implementing a non-market strategy is risky (Sharma 2014). Thus, firms managers are hesitant to reallocate limited resources to implement a green strategy and ponder how it can benefit them (Chakrabarty and Wang 2012). We have removed some concerns of managers by showing that a green strategy will provide a long-term benefit. Moreover, sustainability-oriented strategic goals shift the firm's focus to competitive advantage, resource allocation efficiency, and sustainable development. Therefore, firm managers are suggested to actively formulate and implement green strategies, especially for managers of the energy industry.

5.4 Limitations and future research

Although our study provides new insights into the differences between long-term and short-term performance when implementing green strategies, the following limitations provide avenues for further research. First, the term “green strategy” is a vague concept, including the designation, implementation, and feedback evaluation, which differs from ISO4001 certification and CSR, as ISO4001 certification is a part of the green strategy, and CSR is the consequence of implementing green strategy. Limited by the unavailability of information and data, the scientific evaluation of green strategy will further rely on text mining and extensive sample analysis to explore the whole process of strategy implementation. Second, although debt ratios moderate the interaction between green strategy and short-term performance, additional studies should be conducted to examine debt structures, debt costs, and debt risk of firms to understand the financial constraints of implementing green strategies. Last but not least, as a short-term obstacle to the implementation of green strategies is the lack of funds, the policy effects of government subsidies, taxes, and credit policies are further discussed.

Appendices

Appendix 1 statistical description of the company's green strategy indicators

variable	N	mean	sd	min	max
Indicator 1	32468	0.334	0.472	0	1
Indicator 2	32468	0.119	0.324	0	1
Indicator 3	32468	0.287	0.452	0	1
Indicator 4	32468	0.0880	0.284	0	1
Indicator 5	32468	0.152	0.359	0	1
Indicator 6	32468	0.214	0.410	0	1
Indicator 7	32468	0.107	0.309	0	1
Indicator 8	32468	0.00700	0.0810	0	1
Indicator 9	32468	0.339	0.474	0	1
Indicator 10	32468	0.351	0.477	0	1
Indicator 11	32468	0.193	0.395	0	1
Indicator 12	32468	0.283	0.450	0	1
Indicator 13	32468	0.184	0.387	0	1
Indicator 14	32468	0.152	0.359	0	1
Indicator 15	32468	0.995	0.0680	0	1

Indicator 16	32468	0.00100	0.0250	0	1
Indicator 17	32468	0.00800	0.0890	0	1
Indicator 18	32447	0	0.0170	0	1
Indicator 19	32468	0.219	0.414	0	1
Indicator 20	32468	0.458	0.659	0	2
Indicator 21	32468	0.244	0.634	0	2
Indicator 22	32468	0.206	0.583	0	2
Indicator 23	32468	0.0940	0.380	0	2
Indicator 24	32468	0.277	0.594	0	2
Indicator 25	32468	0.0350	0.211	0	2

Declarations

(1) Ethics approval and consent to participate

Not applicable

(2) Consent for publication

Not applicable

(3) Availability of data and materials

The datasets generated are available in https://cn.gtadata.com

(4) Competing interests

The authors declare that they have no competing interests

(5) Funding

Not applicable

(6) Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Weihua Yu and Xin Jin. The first draft of the manuscript was written by Xin Jin and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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