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Corporate social responsibility and green supply chain efficiency: conditioning effects based on CEO narcissism

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Accelerating the construction of the green supply chain system and improving the efficiency of the green supply chain is the key to promoting the high-quality development of enterprises. In view of this, based on stakeholder theory, higher order theory and expectancy theory, this study focuses on the impact of corporate social responsibility (CSR) on corporate green supply chain efficiency (GSCE) and the moderating role of chief executive officer (CEO) narcissism. A regression analysis of the observed sample reveals that CSR significantly enhances GSCE. Further decomposing CSR into internal CSR and external CSR to reveal the impact of different types of CSR on GSCE, we find that internal CSR fulfillment has a significant positive impact on GSCE, and this relationship is strengthened when CEOs are narcissistic. Furthermore, external CSR has a significant negative impact on GSCE, and this relationship is also strengthened by CEO narcissism. The main contribution of this paper is to study the relationship between CSR and green supply chain efficiency, decompose CSR into internal and external CSR, enrich the research on the intrinsic mechanism of value creation of CSR. It also enriches the research in the context of CSR from the perspective of CEO personality traits, providing new ideas and suggestions for manager selection and corporate greening governance in practice.

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Introduction

The report of the Twentieth Party Congress states that "we will accelerate the construction of a new development pattern and strive to promote high-quality development". The report of the 19th National Congress proposed for the first time that "China's economy has shifted from a stage of high-speed growth to a stage of high-quality development". The Proposal of the Central Committee of the Communist Party of China on the Formulation of the Fourteenth Five-Year Plan for National Economic and Social Development and the Vision and Goals for the 23rd Five-Year Plan, which was adopted at the Fifth Plenary Session of the 19th CPC Central Committee, explicitly proposed that economic and social development during the 14th Five-Year Plan period should be "based on the theme of promoting high-quality development". Enterprises, as important microeconomic subjects, play a pivotal role in the transformation and development of the national economy at this important historical stage. High-quality development of the national economy requires the promotion of high-quality enterprises, and accelerating the construction of a green supply chain system and improving the efficiency of the green supply chain is the key to promoting the high-quality development of enterprises.

Green supply chain is a kind of supply chain development method that balances environmental and economic benefits (Meng et al., 2021). In recent years, the green transformation of supply chain in China has achieved certain results, but there are still problems such as low level of green supply chain management and low efficiency of green supply chain. Therefore, it is a long way to go to strengthen green supply chain management. Efficient green supply chain management is not only an important embodiment of sustainable development of society, but also enables enterprises to obtain sustainable competitive advantages, which has positive effects on both society and enterprises. The improvement of green supply chain efficiency lies in the satisfaction of stakeholders' needs (Kitsis and Chen, 2021). The stakeholder view of corporate social responsibility (CSR) argues that stakeholder theory clarifies the object of responsibility of CSR, and CSR embodies the fulfillment of a company's responsibility to its stakeholders (Kim et al., 2018), reflecting the extent to which the company satisfies the needs of its stakeholders. Based on this analysis, CSR should have a certain influence on green supply chain efficiency. Efficient green supply chain management is the cornerstone of the healthy and sustainable development of enterprises, therefore, this paper investigates whether CSR can improve the efficiency of enterprises' green supply chain, which is of great significance to the management of green supply chain.

Modern enterprise theory suggests that an enterprise is an open system that is responsible to all stakeholders with the aim of achieving economic efficiency and corporate social value. Driven by economic globalization, the concept of CSR has gradually been accepted by all walks of life in society. The fulfillment of CSR will not only affect the development of the enterprise itself, but also the long-term sstability of the whole society, so the issue of CSR has always been one of the topics of widespread concern in all walks of life. CSR is a comprehensive indicator of an enterprise's due diligence towards stakeholders such as shareholders, employees, suppliers, customers, consumers and the environment. The traditional view of business believes that companies should be oriented to the interests of shareholders and aim to maximize profits. However, the resulting environmental pollution, lack of social responsibility and a series of other problems have made enterprises realize that a single responsibility to shareholders cannot achieve healthy and sustainable development. Only by balancing the interests of all stakeholders and achieving "Pareto optimization" can enterprises achieve long-term green development (Epstein and Widener, 2011). Based on this, this paper shifts the attention to the deconstruction of CSR, focusing on internal CSR and external CSR based on the stakeholder theory, and further investigating the impact of corporate responsibility fulfillment to different stakeholders on the efficiency of green supply chain, which is of great significance in enriching the research topic of CSR.

Expectancy theory states that human decision-making behavior is based on perceptions of goals (Flake et al., 2015). Whether or not the level of CSR fulfillment can have an impact on green supply chain efficiency will be influenced by stakeholders' perceptions of CSR. CEOs are ultimately in charge of a company's decision-making by reacting to changes in the environment, and as the most influential person in the center of power of a company they will have a great impact on a company's green supply chain efficiency. As the most influential person in the center of power of the company, they will have a great impact on the company's green supply chain efficiency. In addition, CEOs are the promoters and executors of the company's development, and stakeholders can understand the fulfillment of CSR by knowing the CEOs, and CEOs can improve stakeholders' perception of CSR, so CEOs should have a certain moderating role in the process of CSR's influence on GSCE. The high echelon theory suggests that "a firm is a reflection of the characteristics of its executives, and the personal characteristics of managers are one of the most important influences on corporate decision-making". Studies have focused more on the demographic background and statistical characteristics of executives such as CEOs, such as explicit characteristic variables such as age, gender, and race (Serfling, 2014; Faccio et al., 2016; Guo et al., 2021), or implicit characteristic variables such as education level and culture (Lin et al., 2014; Boubaker et al., 2020). In modern society, one of the most distinctive traits of CEOs, CEO narcissism, has received increasing attention in business management (Al-Shammari et al., 2019). Therefore, this paper examines the moderating role of CEO narcissism in the process of CSR's influence on GSCE from the perspective of CEO's psychological traits and explores whether CEO narcissism plays a facilitating or inhibiting role in the process of the two influences?

The possible research contributions of this paper are: First, based on stakeholder theory, this paper analyzes and empirically tests the promotion effect of CSR on green supply chain efficiency, which helps to enrich the content of green supply chain efficiency influencing factors. Current research on green supply chain efficiency influencing factors focuses on government subsidies (Meng et al., 2021), internal environmental management (Dai et al., 2015), eco-design (Coskun et al., 2016), and consumer collaboration (Ghosh and Shah, 2015). The improvement of green supply chain efficiency lies in the fulfillment of stakeholders' needs, and CSR reflects the fulfillment of corporate responsibility to stakeholders, therefore, it is important to study the impact of CSR on GSCE. Second, this paper deconstructs CSR into internal CSR and external CSR, and explores the impact of CSR on GSCE by dimension. Existing research on CSR focuses on the economic consequences of CSR. For example, many scholars have explored the impact of CSR on increasing the long-term value of firms (Nguyen et al., 2020), improving corporate transparency (Jizi et al., 2014), alleviating financing constraints (Hao and He, 2022), and promoting green innovation (Gillan et al., 2021), reducing corporate risk (He et al., 2022). While previous literature has studied CSR as a whole, this paper categorizes CSR into internal and external CSR, and suggests that internal and external CSR may have different impacts on firms' green supply chain efficiency, which will help to better understand the scope and deconstruction of CSR. Third, based on expectation theory, this paper analyzes the moderating role of CEO narcissism in the

process of CSR's impact on green supply chain efficiency and empirically tests it, enriching the research on the intrinsic mechanism of CSR's value creation. Existing studies focus more on the demographic background and statistical characteristics of executives such as CEOs, and as CEOs' personality traits and psychological behaviors are receiving more and more attention in corporate management, this paper investigates the impact of CEO narcissism as a moderating variable on CSR and GSCE, which enriches the research on the economic consequences of CSR, and also provides ideas and suggestions for the selection of CEOs in reality.

The rest of the paper is structured as follows: the second part is the theoretical analysis and research hypotheses, the third part is the research design, the fourth part is the empirical analysis, and the last part is to summarize the conclusions and implications of this paper.

Theoretical analysis and research hypothesis

Corporate social responsibility and green supply chain efficiency. Stakeholder theory suggests that the essence of a firm is a multilateral contract concluded between stakeholders (Horisch et al., 2014). Stakeholders invest in the enterprise and also have demands on the enterprise, and the enterprise can only realize healthy and sustainable development if it satisfies the demands of stakeholders (Schaltegger et al., 2019). A green supply chain balances economic and environmental benefits and involves stakeholders such as suppliers, production plants, sellers and final customers (Roh et al., 2022). The aim is to minimize the environmental impact and maximize the resource utilization of products throughout the entire process from raw material acquisition, processing, packaging, warehousing, transportation, use to end-of-life disposal (Agyabeng-Mensah et al., 2022). Enterprises fulfill their social responsibility, take the initiative to assume responsibility for environmental protection, increase the environmental benefits of enterprises (Adnan et al., 2018), and satisfy the needs of stakeholders in the green supply chain, which in turn improves the efficiency of the green supply chain. The improvement of green supply chain efficiency enables enterprises to gain competitive advantage and promotes enterprise green innovation and green development (Yang and Roh, 2019; Roh et al., 2021; Ghaderi et al., 2023).

Most scholars in the "shareholder primacy" theory believe that CSR is driven by economic interests (Ullah and Sun, 2021). Scholars believe that the goal of the company is to create wealth for shareholders, and that active CSR will harm the interests of shareholders and adversely affect performance because of information asymmetry, which makes it difficult for shareholders to manage CSR behaviors (Glavas and Piderit, 2009). Stakeholder theory, on the other hand, suggests that CSR brings certain benefits to the firm, such as creating a good social image that enhances the firm's reputation, and obtaining a better internal and external reputation is conducive to operational efficiency and sustainable performance (Lee and Roh, 2023). At present, China's CSR activities in full swing, by the government, the media and the public and other social parties are widely concerned about government departments are highly concerned about corporate "green development", "sustainable development", "coordinated development", "responsible and responsible" and other issues. Government departments are highly concerned about enterprises' "green development", "sustainable development", "coordinated development", "responsibility and commitment" and other issues. If enterprises make achievements in social responsibility, they will have more opportunities to get incentives from the government in terms of reputation, promotion, and funds (Guo et al., 2023), which will improve the efficiency of green supply chain (Fahimnia et al., 2018). In addition, the positive signals sent by enterprises due to their social responsibility help them to obtain advantageous resources such as excellent talents and cooperative investment, which positively affects the improvement of enterprises' green supply chain efficiency (Carvalho et al., 2017). Therefore, this study proposes the following hypothesis:

H1: CSR fulfillment has had a positive impact on GSCE.

Heterogeneous corporate social responsibility and green supply chain efficiency. CSR can be categorized into internal CSR, which is the responsibility to employees, suppliers, customers, etc., and external CSR, which is the responsibility to external stakeholders such as the government, community, and ecosystem. Companies use internal and external CSR practices to meet green supply chain management needs. When a company fulfills internal CSR, the company's employees have a stronger sense of sustainability for the company's long-term development to ensure that the company improves its green supply chain efficiency. Companies that actively fulfill internal CSR incorporate greening sustainability into their corporate strategy, which has a positive impact on improving green supply chain efficiency. When a company fulfills external CSR, the company will always pay attention to the changes in government policies and social current events, therefore, narcissistic CEOs will be more likely to choose the social responsibility activities that can bring social attention and benefits to the company in the short term (Lin et al., 2020), and will reduce other investments that can bring long-term benefits to the company. The improvement of green supply chain efficiency has to consider both economic and environmental aspects at the same time, which is a long-term endeavor that may not be effective in the short term (Tseng et al., 2014). Therefore, the fulfillment of external CSR has a negative impact on the improvement of green supply chain efficiency. Based on this, the following hypothesis is proposed:

H2a: The fulfillment of internal CSR has a positive impact on the improvement of green supply chain efficiency.

H2b: The fulfillment of external CSR has a negative impact on improving green supply chain efficiency.

The moderating effect of CEO narcissism. Narcissism is a complex and multidimensional psychological state. Raskin and Terry's (1988) generalization of narcissistic traits has gained consensus, finding that narcissism includes seven dimensions of attribute characteristics, such as authority, exhibitionism, superiority, vanity, exploitativeness, subjective power and conceit. The narcissist needs a continuous supply of sustenance to satisfy and support the ego (i.e., 'narcissistic supply'). Narcissistic supply can come from internal sources, such as the narcissist's ability to strengthen self-identity by asserting authority and power and exploiting and demeaning others. It can also come from external sources, such as sustained attention, approval and praise from others (Al-Shammari et al., 2019). "Getting bigger and stronger" is the goal of many companies and even appears in the company's articles of incorporation. The narcissistic attributes of CEOs make them more keen on fulfilling CSR (Dabbebi et al., 2022), and the fulfillment of CSR meets the needs of the relevant stakeholders in the green supply chain, which in turn improves the green supply chain efficiency of the company (Wang et al., 2020). If the CEO of a company has narcissistic characteristics, when performing internal CSR, in order to show their ability in front of their employees and customers and get more honor and admiration, they will focus their attention on how to achieve high quality and sustainable development of the company (Lassoued and Khanchel, 2022). Improving the efficiency of the green supply chain is key for firms to achieve high quality growth (Petrenko

et al., 2016). Therefore, CEO narcissism reinforces the positive impact of internal CSR on green supply chain efficiency. When fulfilling external CSR, narcissistic CEOs will have a stronger than average desire to gain external attention and to gain as much recognition and praise from external stakeholders as possible by undertaking external CSR. They are more likely to choose CSR activities that can bring attention to the organization in the short term and neglect activities that can bring long-term benefits to the organization (Lin et al., 2020). Whereas the improvement of green supply chain efficiency is a long-term endeavor that can only be seen in the long term, CEOs will neglect to invest in this long-term endeavor in order to obtain timely feedback from the outside world (Tseng et al., 2014). Therefore, CEO narcissism reinforces the negative impact of external CSR on green supply chain efficiency. In summary, the following hypotheses are proposed:

H3a: CEO narcissism strengthens the positive impact of internal CSR on green supply chain efficiency.

H3b: CEO narcissism strengthens the negative impact of external CSR on green supply chain efficiency.

Study design

Sample selection and data sources. This study selects Chinese A-share non-financial listed companies as the research sample. Given that the promulgation of regulations in various aspects of China's green supply chain was completed in 2013, this study sets the time frame of the study as 2014–2021. The sample data are mainly obtained from the CSMAR database, stock exchange website and company's official website, and some data are compiled by manual excerpt. To ensure the quality of the study, the sample was screened: excluding companies with special treatment status, companies with abnormal financial status and samples with extreme or serious missing data. The sample variables were winsorize processed at the 1% level. Finally, 6105 observations were obtained. DEAP 2.1 software was used in the data processing process, and the data were processed with Stata 16.0. The quantity table is shown in Table 1.

Variable definition

Dependent variable: green supply chain efficiency (GSCE). This study adopts the DEA method to measure GSCE. Since capital and labor are still the main input factors of manufacturing enterprises, this study refers to Fang and Yang (2017) to select input indicators: net fixed assets, green supply chain personnel costs. Output indicators: reutilization rate of raw materials and energy, inventory turnover rate. Environmental variable indicators: years of enterprise establishment, asset size. The rationale for the selection is as follows:

The net value of fixed assets is used to reflect the level of capital investment of an enterprise. Facilities, plants, warehouses and means of transportation can be considered as the most important capital inputs in the business process of an enterprise. Therefore, fixed assets can be said to be the material guarantee of the enterprise to create economic value. At the same time, the effectiveness of an enterprise's utilization of assets will directly affect its economic efficiency. Therefore, the net value of fixed assets is regarded as one of the input indicators. According to the connotation of green supply chain, it is known that green supply chain is to integrate suppliers, manufacturers, distributors, retailers and final customers into a chain to facilitate subsequent integrated management. The aim is to minimize the environmental impact (negative effect) of the whole production process of the enterprise and maximize the efficiency of resource utilization. Green supply chain personnel can coordinate the relationship of each node company and promote the willingness of each company to make efforts for green supply chain operation. Therefore, the green supply chain personnel cost is selected as one of the input indicators.

Table 1 Quantity table.

Samples	Number
raw data	7559
Enterprises in special treatment status	251
Enterprises with abnormal financial status	436
Samples with extreme or missing data	479
Sample variables winsorized at the 1% level	378
Excluded data	1544
Remaining data	6015
Number of firms	752

The reuse rate of raw materials and energy refers to the degree of reuse of raw materials and energy per unit of raw materials and energy consumption, and the higher the ratio coefficient, the better the reuse of raw materials and energy. This output index is an important reflection of the word "green" in green supply chain efficiency. Inventory is the focal point of various problems in the supply chain. Inventory turnover rate is like a thermometer of the health of business operation, and the good or bad business operation will eventually be reflected in the inventory turnover rate. Therefore, the reutilization rate of raw materials and energy and the inventory turnover rate are selected as output indicators.

The choice of environmental variables must meet the "separation assumption", that is, the green supply chain efficiency will be affected in a short period of time, but will not be affected or changed by the sample. To a certain extent, the establishment period of an enterprise determines the comprehensive strength of its development, and different establishment periods have different effects on the efficiency of its green supply chain. Asset size can also affect the construction of green supply chain system to different degrees, and has a direct impact on green supply chain efficiency. Therefore, the number of years of establishment and the scale of assets are selected as environmental variables. The specific indicators are listed in Table 2.

The basic idea of the DEA method is as follows: First, the relationship between input and output data is analyzed using the traditional DEA model to obtain the enterprise's efficiency and input difference values. Second, the influence of the selected environmental variables on the difference value was analyzed, and the SFA model was applied to adjust the input terms of the sample enterprises to eliminate the errors caused by the influence of environmental and error factors on the analysis results. Finally, the DEA model was used to compare the adjusted input data with the original output data. As environmental factors and random error effects were excluded, the efficiency value derived at this point was the pure management efficiency value. This method can be divided into three stages.

Stage 1: BC^2 model. The expressions are:

$$\begin{aligned} &\operatorname{Max}\{\theta\} \\ \text{s.t.}\begin{cases} \sum_{j=1}^{N} X_j\lambda_j \le X_{j0} \\ \sum_{j=1}^{N} Y_j\lambda_i \ge \theta Y_{j0}, j = 1, 2, \ldots N \\ \sum_{j=1}^{N} \lambda_j = 1 \\ \lambda \ge 0 \end{cases} \end{aligned}$$

In this equation, X and Y denote each decision unit's input and output indicator matrices, respectively, N denotes the number of

Table 2 Green supply chain efficiency input, output, and environmental variables indicator system.

Types	Name	Meaning
Input Indicators	Net value of fixed assets	Original value of fixed assets less accumulated depreciation
	Green supply chain personnel costs	Total salary of all personnel involved in green supply chain operations
Output Indicators	Reuse of raw materials and energy	Unit raw materials and energy consumption about the degree of reuse of raw materials and energy
	Inventory turnover rate	Speed of enterprise inventory turnover
Environmental Variables Indicators	Year of business establishment	Year of establishment of listed company
	Asset Size	Total company assets

DUM units, λ_i denotes the weight of each input indicator, and θ is the first stage efficiency measurement value of each decision unit.

Stage 2: SFA model.

Since the enterprise efficiency values calculated in the first stage may be affected by factors such as management ineffectiveness, environmental variables, and random errors, the SFA model needs to be further used to de-interfere with the results of the first-stage measurement, and analyze the difference between the ideal and actual input quantities to adjust the input values.

If there are N decision units, M inputs for each decision unit, and k environmental factors, the SFA-specific formula is

$$S_{ni} = f^n(Z_i;\beta_n) + v_{ni} + u_{ni}$$

$$n = 1, 2, \ldots, M$$

$$i = 1, 2, \ldots, N$$

where S_{ni} denotes the difference between the nth actual input and the target input of the ith decision unit. $f^n(Z_i;\beta_n)$ is the degree of influence of environmental factors on S_{ni}, and $f^n(Z_i;\beta_n) = Z_k\beta_{nj}V_{ni}$ is a random disturbance term. u_{ni} is the management inefficiency, v_{ni} and u_{ni} are independent, and $v_{ni} \sim N(0, \sigma_{ni}^2)$.

The input variables are then adjusted for the next stage of efficiency analysis, and the adjustment formula is as follows:

$$XA_{ni} = X_{ni} + \left[\max_i(Z_k\beta_n) - Z_k\beta_n\right] + \left[\max_k(v_{ik}) - v_{ik}\right]$$

Stage 3: The processed DEA model.

The original output value in the first stage is replaced by the adjusted output value of the second stage with the removal of environmental disturbances and random error disturbances, and calculated again with the BC^2 model. The resulting efficiency value is the real efficiency level that excludes the influence of environmental factors and random disturbance terms, and can objectively reflect enterprises' green supply chain efficiency.

Independent variable: corporate social responsibility (CSR). This study establishes the CSR disclosure index by analysing each enterprise's information, such as social responsibility reports and financial reports, with specific indicators referring to the social responsibility rating system on Hexun.com. The professional evaluation system of social responsibility reports of listed companies examines five items from shareholder responsibility, employee responsibility, supplier, customer and consumer rights responsibility, environmental responsibility and social responsibility, each of which sets up secondary and tertiary indicators for a comprehensive evaluation of social responsibility, among which 13 secondary indicators and 38 tertiary indicators are designed. In this study, CSR is divided into internal and external CSR, where internal CSR includes shareholder responsibility, employee responsibility, supplier, customer and consumer rights responsibility, external CSR includes environmental and social responsibility. If the annual financial report or social responsibility report of the enterprise has the disclosure of these 56 items, it is assigned a value of 1, otherwise it is assigned a value of 0. Then the value of all the three levels of indicators under the first level of the index is summed up and divided by the number of tertiary indicators to get the final score of CSR and internal and external CSR.

Moderating variable: CEO narcissism (Ceonar). Chatterjee and Hambrick (2007) proposed five indicators based on the concept of narcissism: ① The amount of space the CEO's photo occupies in the corporate annual report. ② The prominence of the CEO in corporate publications. ③ The difference between the CEO's cash compensation and the executive just below him. ④ The difference between the CEO's non-cash compensation and the executive just below him. ⑤ The frequency of "I" and "we" used by the CEO in his/her statements. In view of the fact that the annual reports of domestic listed companies seldom print the CEO's photo and that domestic databases do not disclose executive compensation data in great detail, this study proposes to select the 2nd and 5th indicators to indicate the degree of CEO narcissism. Among them, the 2nd indicator (CEO's prominence in corporate publications), the original method is expressed by the frequency of CEO's name appearing in publications. However, since the subjunctive pattern in the Chinese context is more complex compared to the English context, this indicator was modified to measure the ratio of news items about the CEO to the total news items in the reports on the corporate official website. The CEO narcissism data were obtained from the interview transcripts of the financial website and the corporate official website. The data collected in this study were taken from the 2nd and 3rd year of the CEO's tenure due to the fact that in the year of the CEO's tenure, there may be environmental discomfort as well as job transition factors that affect performance. After obtaining the two-year means of the two indicators, this study took the average to obtain the CEO narcissism value. Given that the distribution of the narcissism value is skewed, it was made to conform to a normal distribution after taking the logarithm.

Control variables. This study screens the control variables following Fang et al. (2014): ① The level of economic development of the area where the enterprise is located (Area). The higher the level of economic development in the area where the enterprise is located, the more beneficial to the green supply chain system construction. ② The size of assets (Size). The size of the enterprise's assets will affect the enterprise's investment in green supply chain management, which directly impacts the efficiency of green supply chain. ③ Return on total assets (Roa). The stronger the profitability, the stronger the environmental awareness, the higher the GSCE. ④ Nature of property rights (Soe). Compared with non-Soe, Soe are more responsive to policies, have stronger green awareness and have higher GSCE. ⑤ Age of the enterprise (Age). To a certain extent, the age of an enterprise can reflect the comprehensive strength of the enterprise. The definition of the variables is shown in Table 3.

Table 3 Variable definition.

Variable Type	Variable Name	Variable Symbols	Variable Definition
Explained variables	Green Supply Chain Efficiency	*GSCE*	DEA three-stage method
Explanatory variables	Corporate Social Responsibility	*CSR*	The sum of the values of all three levels of indicators under the first level of CSR, divided by the number of three levels of indicators.
	Internal Corporate Social Responsibility	*Incsr*	The sum of the values of all three levels of indicators under the first level of internal CSR, divided by the number of three levels of indicators.
	External Corporate Social Responsibility	*Excsr*	The sum of the values of all three levels of indicators under the first level of external CSR, divided by the number of three levels of indicators.
Adjustment variables	CEO Narcissism	*Ceonar*	Ln (the average proportion of news about CEOs in official website news and the proportion of "I" and "we" used in speeches or interview statements)
Control variables	The level of economic development of the region where the company is located	*Area*	Real GDP as a share of total population
	Asset Size	*Size*	Natural logarithm of total assets
	Profit Level	*Roa*	Net income divided by total assets balance
	Nature of ownership	*Soe*	state-owned enterprise (Soe)=1, otherwise 0
	Year of business establishment	*Age*	Natural logarithm of the age of a company going public
	Industry Effect	*Industry*	Industry Control Variables
	Year Effect	*Year*	Annual control variables

Model construction

This study develops a regression model (1) to test the effect of CSR on GSCE (i.e., to test H1).

$$GSCE = \alpha + \beta_1 CSR_{it} + \beta_2 Area_{it} + \beta_3 Size_{it} + \beta_4 Roa_{it} + \beta_5 Soe_{it} + \beta_6 Age_{it} + \varepsilon_{it} \quad (1)$$

Where, the dependent variable GSCE is the corporate green supply chain efficiency, the independent variable CSR denotes the CSR index, ε represents the random error term of the model, and the rest are control variables.

Based on the heterogeneity of CSRs, this study divides CSR into internal CSR and external CSR. This study develops regression model (2) to test the effects of internal CSR and external CSR on GSCE (i.e., H2a and H2b).

$$GSCE = \alpha + \beta_7 Incsr_{it} + \beta_8 Excsr_{it} + \beta_9 Area_{it} + \beta_{10} Size_{it} + \beta_{11} Roa_{it} + \beta_{12} Soe_{it} + \beta_{13} Age_{it} + \varepsilon_{it} \quad (2)$$

Where, the dependent variable GSCE is the firm's green supply chain efficiency, the independent variable Incsr is the internal CSR index, Excsr is the external CSR index and ε denotes the random error term of the model. The rest are control variables.

This study develops regression model (3) to test the effect of H3, CEO narcissism, on the moderating effect of the main effect.

$$GSCE = \alpha + \beta_{14} Incsr_{it} \times Ceonar + \beta_{15} Excsr_{it} \times Ceonar + \beta_{16} Area_{it} + \beta_{17} Size_{it} + \beta_{18} Roa_{it} + \beta_{19} Soe_{it} + \beta_{20} Age_{it} + \varepsilon_{it} \quad (3)$$

Where, GSCE is the dependent variable. The interaction terms of CEO narcissism with internal CSR and external CSR are $Incsr_{it} \times Ceonar$ and $Excsr_{it} \times Ceonar$ respectively. ε denotes the random error term of the model. The rest are control variables.

Empirical analysis

Descriptive statistics and correlation analysis. Table 4 shows the results of descriptive statistics. The mean value of GSCE is 0.419, the standard deviation of GSCE is 0.202, the minimum GSCE is 0.184, and the maximum GSCE is 0.898, indicating a significant difference in GSCE among different enterprises. The CSR mean is 0.218, the standard deviation is 0.275, the minimum value was 0, and the maximum value was 0.924, indicating significant differences in the fulfillment of social responsibility among enterprises. The mean internal CSR is 0.213 and the standard deviation of the internal CSR is 0.361 with a minimum value of 0.092 and a maximum value of 0.911. The mean external CSR is 0.236, which is higher than the mean internal CSR. The standard deviation of external CSR is 0.249, the minimum external CSR is 0, and the maximum external CSR is 0.879. The mean value of CEO narcissism is 0.156, the standard deviation of CEO narcissism is 0.278, and the minimum value of CEO narcissism is 0.278. Narcissism has a minimum value of 0.113 and a maximum of 5.069 for CEO narcissism, which reflects the unevenness of CEO narcissism among companies.

Table 4 Descriptive statistics results.

Variables	Number	Mean	SD	Min	Max
Gsce	6105	0.419	0.202	0.184	0.898
Csr	6105	0.218	0.275	0.000	0.924
Incsr	6105	0.213	0.361	0.092	0.911
Excsr	6105	0.236	0.249	0.000	0.879
Ceonar	6105	0.156	0.278	0.113	5.069
Area	6105	0.329	0.054	0.285	0.781
Size	6105	22.341	1.286	19.870	26.431
Roa	6105	0.032	0.075	−0.475	0.213
Soe	6105	0.627	0.469	0.000	1.000
Age	6105	2.051	0.941	0.131	3.296

Regarding the main control variables, the minimum value of enterprise size is 19.870, and the maximum value is 26.431, indicating some variability in enterprise size. The nature of the enterprise Soe is a 0–1 variable with a mean value of 0.627, indicating that more than half of the enterprises are state-owned enterprises. The minimum value of Age of enterprise establishment is 0.131, and the maximum value is 3.296, indicating a certain disparity in the establishment of enterprises.

Table 5 provides the correlation analysis of the variables, and the table shows that the absolute values of the relative coefficients are below 0.5, indicating no multicollinearity problem between the variables.

Table 5 Results of correlation analysis.

Variables	GSCE	CSR	Incsr	Excsr	Ceonar	Area	Size	Roa	Soe	Industry	Age
GSCE	1										
CSR	0.153***	1									
Incsr	0.125**	0.492***	1								
Excsr	0.032*	0.387***	0.421***	1							
Ceonar	0.041	0.261	0.037***	−0.172**	1						
Area	−0.113**	−0.154**	−0.071	−0.043*	−0.135**	1					
Size	0.257***	0.054**	0.061**	0.132*	0.241*	0.113***	1				
Roa	0.31**	0.082**	0.135***	−0.037*	0.032*	0.216*	0.193**	1			
Soe	−0.381*	0.098*	0.297*	−0.218**	0.013**	−0.381**	−0.185*	−0.152*	1		
Industry	0.201	0.169**	−0.219*	0.204**	0.105***	−0.136**	0.031***	0.194*	0.021**	1	
Age	0.091	0.171**	−0.032*	0.135**	−0.210**	0.148**	0.137*	0.173**	−0.083*	0.108**	1

***, **, and * indicate 1%, 5%, and 10% significance levels, respectively.

Table 6 Regression results of corporate social responsibility and green supply chain efficiency.

Variables	(1) GSCE	(2) GSCE
CSR	0.091** (1.98)	0.063*** (2.95)
Area		0.858*** (2.81)
Size		0.058*** (2.73)
Roa		0.031*** (3.31)
Soe		0.591 (1.16)
Age		−0.055* (−1.77)
Constant	−0.165*** (−5.21)	−0.156*** (−4.93)
Company FE	Yes	Yes
Industry FE	Yes	Yes
Year FE	Yes	Yes
N	6105	6105
Adj_R2	0.682	0.694

t-values in parentheses, ***, **, * denote 1%, 5%, and 10% significance levels, respectively.

Table 7 Regression results of heterogeneous CSR and green supply chain efficiency.

Variables	(1) GSCE	(2) GSCE
Incsr	0.116*** (3.52)	0.196*** (5.21)
Excsr	−0.163*** (−4.36)	−0.237*** (−4.89)
Area		0.158*** (5.42)
Size		0.072*** (4.23)
Roa		0.031*** (3.94)
Soe		0.631*** (4.42)
Age		−0.021*** (−5.02)
Constant	−1.145*** (−6.92)	−1.201*** (−6.13)
Company FE	Yes	Yes
Industry FE	Yes	Yes
Year FE	Yes	Yes
N	6105	6105
Adj_R2	0.512	0.594

t-values in parentheses, *** denote 1% significance levels.

Empirical testing

Basic regression analysis. As shown in Table 6, column (1) is the regression analysis without the addition of control variables, and column (2) is the regression analysis with the addition of control variables. As shown in column (1) of Table 6, CSR has a positive effect on GSCE ($\beta = 0.091$, $p < 0.05$). In column (2) of Table 6, CSR significantly and positively affects GSCE at the 1% level ($\beta = 0.063$, $p < 0.01$), indicating that CSR has a significant incentive effect on the green supply chain efficiency. Thus, H1 is supported by the empirical results.

Regression analysis based on heterogeneous CSR. Most existing literature studies CSR as a composite indicator, and little literature decomposes CSR into internal and external CSR for research. This study explores the impact of internal and external CSR on GSCE. As shown in Table 7, column (1) is the regression result without control variables, while column (2) has control variables added. Column (1) shows that internal CSR fulfillment has a positive impact on the improvement of GSCE ($\beta = 0.116$, $p < 0.01$), while external CSR fulfillment has a negative impact on the improvement of GSCE ($\beta = -0.163$, $p < 0.01$). In column (2) of Table 7, the effect of internal CSR on GSCE is positive and significant ($\beta = 0.196$, $p < 0.01$), which indicates that the higher the degree of internal CSR fulfillment, the higher the GSCE. The effect of external CSR on GSCE is negative and significant ($\beta = -0.237$, $p < 0.01$), which indicates that the higher the degree of external CSR fulfillment, the lower the GSCE.

This indicates that the fulfillment of CSR can improve corporate green supply chain efficiency, but the impact of CSR on green supply chain efficiency varies among different stakeholders. Among them, the fulfillment of internal CSR to shareholders, employees, suppliers and consumers can promote the improvement of green supply chain efficiency, while the fulfillment of external CSR to the environment and society can reduce the green supply chain efficiency of enterprises. The possible reason is that the fulfillment of responsibilities to shareholders, employees, suppliers and consumers, as important internal stakeholders of an enterprise, can directly improve the efficiency of all aspects of the enterprise, including the efficiency of the green supply chain. For example, the fulfillment of responsibilities to shareholders can promote the efficiency of investment and financing; the fulfillment of responsibilities to employees can help improve the productivity of the enterprise, the fulfillment of responsibilities to suppliers can promote the operational efficiency of the enterprise's procurement channel, and the fulfillment of responsibilities to consumers can reduce the transaction costs of the sales channel and improve the efficiency of marketing. The fulfillment of external CSR on environment and society reduces the enterprise's green supply chain efficiency may be due to the fact that the improvement of green supply chain efficiency is a long-term work, and the reputation effect generated by the enterprise's fulfillment of external CSR is not enough to compensate for the cost and expense it consumes in the short term, resulting in the reduction of green supply chain efficiency. H2 is supported by the empirical results.

Adjustment effect test. As shown in Table 8, column (1) is the regression results without the addition of control variables, and column (2) is the regression results with the addition of control variables. In column (1) of Table 8, the effect of Ceonar on GSCE was significantly positive at 1% level ($\beta = 0.521$, $p < 0.01$), and the impact of the cross term between CSR and Ceonar on GSCE is positive and significant, indicating that CEO narcissism has a moderating effect. Column (2) shows that the effect of the Ceonar×Incsr on GSCE is positive and significant ($\beta = 1.378$, $p < 0.01$). This result indicates that the propulsive effect of internal CSR fulfillment on GSCE is significantly enhanced when CEO narcissism is present (i.e., H3a is empirically supported). The effect of the Ceonar × Excsr on GSCE is negative and significant ($\beta = -1.432$, $p < 0.01$), indicating that the inhibitory effect of external CSR fulfillment on green supply chain efficiency is enhanced when CEO narcissism is present (i.e., H3b is empirically supported). The above provides strong support for Hypothesis 3.

The empirical results in Table 8 indicate that CEO narcissism helps to promote the positive impact of CSR on GSCE, while the role in the process of CSR on GSCE for different stakeholders is different, and Hypothesis 2 is partially supported. CEO narcissism significantly positively moderates the process of CSR on GSCE for internal CSR on shareholders, employees, suppliers, and consumers. This may be due to the fact that narcissistic CEOs can reduce the information asymmetry between the firm and these stakeholders, which leads to an increase in their awareness of CSR, and thus positive supportive behaviors that lead to the enhancement of the firm's green supply chain efficiency. CEO narcissism has a strengthened moderating effect on the negative influence process of external CSR on GSCE, which may be due to the fact that narcissistic CEOs may reduce their influence on green supply chain management in order to obtain timely feedback from the outside world. The possible reason is that narcissistic CEOs may reduce their investment in the long-term work of green supply chain management in order to obtain timely feedback from the outside world.

Table 8 Regression results of CEO narcissism and green supply chain efficiency.

Variables	(1) *GSCE*	(2) *GSCE*
Ceonar	0.521*** (4.42)	0.613*** (4.46)
Ceonar×Incsr	1.369*** (5.75)	1.378*** (5.93)
Ceonar×Excsr	−1.392*** (−5.23)	−1.432*** (−5.72)
Area		0.426*** (4.32)
Size		0.182* (1.78)
Roa		0.421*** (2.75)
Soe		0.318*** (3.42)
Age		−0.321*** (−3.81)
Constant	−1.327*** (−5.34)	−1.532*** (−5.91)
Company FE	Yes	Yes
Industry FE	Yes	Yes
Year FE	Yes	Yes
N	6105	6105
Adj_R2	0.621	0.653

t-values in parentheses, *** and * denote 1% and 10% significance levels respectively.

Robustness tests. To ensure the robustness of the results, this study tested the endogeneity of the model by PSM method, changing the CSR measure and treating the main explanatory variables with time lags. The methods are described in detail as follows.

Endogeneity test: PSM method. The PSM method is used to test this study for the endogeneity problem that may be caused by sample self-selection. The entire sample is grouped according to whether the firms fulfill CSR or not, and firm size, age, nature of ownership, industry and year are used as covariate matching variables to find control groups with similar characteristics for the treatment groups based on the principles of nearest neighbor matching, radius matching and kernel matching. The balance tests performed on all covariates before PSM regression estimation was passed, and the average treatment effects of firms performing social responsibility under multiple matching principles were positive and significant at the 1% level. The post-matching estimation results presented in columns (1)–(6) of Table 9 remain consistent with the hypothesis testing regression results, demonstrating that the study findings remain robust after overcoming the problem of sample self-selection bias.

Substitution test for CSR. This study, which refers to Illich et al. (2022), uses the CSR score of Runlin Global (RKS), a third-party authoritative assessment organization, as a proxy variable for CSR. The RKS social responsibility score is mainly composed of three aspects: technical, holistic and content aspects, which can comprehensively reflect the fulfillment of CSR, and is defined as the core independent variable Csr1. As shown in Table 10, column (1) is the regression result without control variables, while column (2) has control variables added. Column (1) indicates the effect of CSR1 on GSCE is positive and significant ($\beta = 0.793$, $p < 0.05$), while column (2) also confirms this ($\beta = 0.853$, $p < 0.01$), and this empirical result supports Hypothesis 1.

Table 9 Endogeneity test: PSM method.

Variables	Nearest Neighbor Matching		Radius Matching		Nuclear matching	
	(1) GSCE	(2) GSCE	(3) GSCE	(4) GSCE	(5) GSCE	(6) GSCE
CSR	0.0932*** (2.77)		0.152*** (2.96)		0.141*** (2.89)	
Ceonar		0.731*** (2.86)		0.481*** (3.32)		0.615*** (3.81)
Ceonar× Incsr		1.532*** (3.74)		1.631*** (4.05)		1.175*** (5.02)
Ceonar × Excsr		−1.512*** (−3.02)		−1.367*** (−4.31)		−1.381*** (−3.95)
controls	−0.316*** (−2.59)	0.421*** (2.66)	0.046*** (2.59)	0.051*** (2.67)	−0.052*** (−2.81)	−0.042*** (−3.78)
Constant	0.523*** (3.09)	0.241*** (3.62)	−0.431*** (−4.97)	−0.164*** (−6.04)	0.528*** (3.98)	0.573*** (4.07)
Industry & Year	Control	Control	Control	Control	Control	Control
Adj - R^2	0.281	0.438	0.538	0.621	0.327	0.381
N	6105	6105	6105	6105	6105	6105
ATT	Difference = 0.073***; $T = 6.170$		Difference = 0. 063***; $T = 6.390$		Difference = 0.069***; $T = 6.470$	

t-values in parentheses, *** denote 1% significance levels.

Table 10 Robustness tests: alternative tests of CSR.

Variables	(1) *GSCE*	(2) *GSCE*
CSR1	0.0793** (2.17)	0.0853*** (3.62)
Area		0.953*** (3.93)
Size		0.093*** (4.12)
Roa		0.041*** (5.08)
Soe		0.375*** (6.01)
Age		−0.063*** (−4.97)
Constant	−0.462*** (−5.82)	−0.513*** (−4.21)
Company FE	Yes	Yes
Industry FE	Yes	Yes
Year FE	Yes	Yes
N	6105	6105
Adj_R2	0.286	0.381

t-values in parentheses, *** and ** denote 1% and 5% significance levels respectively.

Table 11 Robustness test: core variables lagged one period.

Variables	(1) *GSCE*	(2) *GSCE*
L. CSR	0.168*** (6.25)	
L. Incsr		0.192*** (6.93)
L. Excsr		−0.189*** (−5.97)
Area	0.422*** (3.52)	0.329*** (3.76)
Size	0.132*** (4.91)	0.093*** (3.05)
Roa	0.467*** (4.86)	0.532*** (5.16)
Soe	0.538*** (4.96)	0.531*** (4.75)
Industry	0.324*** (2.97)	0.265*** (3.54)
Age	−0.735*** (−4.23)	−0.632*** (−3.64)
Constant	−1.953*** (−3.86)	−1.731*** (−4.29)
Company FE	Yes	Yes
Year FE	Yes	Yes
N	6105	6105
Adj_R2	0.437	0.449

t-values in parentheses, *** denote 1% significance levels.

Time lag treatment of explanatory variables. Considering that a certain time interval from input to output of GSCE, the effect of explanatory variables CSR, Incsr and Excsr on GSCE may be lagged. Therefore, this study adopts a lagged explanatory variable approach to verify the robustness. As shown in column (1) of Table 11, L.CSR is the CSR lagged by one year, and its effect on GSCE is positive and significant ($\beta = 0.168$, $p < 0.01$). In column (2) of Table 11, the effect of L.Incsr on GSCE was positive and significant ($\beta = 0.192$, $p < 0.01$), and the effect of L.Excsr on GSCE was negative and significant ($\beta = -0.189$, $p < 0.01$). In summary, the results remain robust after the time lag treatment of the explanatory variables, as shown above.

Conclusions and implications of the study

The high-quality development of the national economy needs to be fueled by enterprises, and accelerating the construction of a green supply chain system and improving the efficiency of the green supply chain is the key to promoting the high-quality development of enterprises. CSR is of great significance to the high-quality development of enterprises. This paper investigates the impact of CSR (further deconstructed into internal CSR and external CSR) on green supply chain efficiency and the moderating role of CEO narcissism in the process of the two impacts from both theoretical and empirical perspectives. The results of the study show that, firstly, the fulfillment of CSR activities helps to improve green supply chain efficiency. Second, the fulfillment of internal CSR positively affects the improvement of green supply chain efficiency; the fulfillment of external CSR negatively affects the improvement of green supply chain efficiency. Finally, CEO narcissism helps to strengthen the positive impact of CSR on GSCE. That is, the more narcissistic characteristics a corporate CEO has, the more he or she can enhance the promotion of CSR on green supply chain efficiency.

The findings of this study have some practical implications for motivating firms to achieve quality development: Firstly, companies can actively participate in CSR activities to develop a competitive advantage, thus promoting long-term and stable development. This study finds that internal CSR can improve employee motivation and satisfy customers' needs, thus providing a favorable internal environment for GSCE. External CSR can make companies incline their resources to short-term goals and neglect long-term sustainable development to gain more attention from external stakeholders, such as the government and community. Therefore, companies need to participate actively in internal CSR and establish good relationships with internal stakeholders, such as employees and customers, to promote the efficiency of their green supply chains. Secondly, the trait of CEO narcissism has both positive and negative sides. When a company's CEO has the trait of narcissism, on the one hand, it can strengthen the CEO's connection with employees and customers, thus enhancing the efficiency of the green supply chain; on the other hand, if the CEO focuses excessively on external CSR, more attention and resources on external relationships will be used, thus neglecting the long-term and stable development of the company itself. Therefore, narcissistic CEOs should be encouraged to perform more internal CSR and less external CSR. Thirdly, this study provides new ideas and suggestions for selecting managers in practice and managing managerial opportunism. This study examines the moderating effect of CEO narcissism on the relationship between CSR and GSCE and provides ideas and suggestions for the selection of CEOs in reality and what should be done to restrain and avoid the negative impact of narcissistic CEOs on enterprises.

Limitation and future research

This paper explores the impact of CSR on firms' green supply chain efficiency in terms of theoretical development and empirical evidence, but there are still some limitations. Due to the fact that Chinese CEOs are more reluctant to disclose information than their Western counterparts, the fact that CEO photos are rarely printed in the annual reports of domestic listed companies, and the lack of detailed disclosure of executive compensation data in domestic databases, this study only selects two indicators to measure CEO narcissism, namely, the degree of prominence of the selected CEOs in corporate publications and the percentage of frequency of the use of the words "I" and "we" in their statements. Although these two indicators, when combined to measure narcissism, are able to characterize the four dimensions of narcissism proposed by Emmons (1987), i.e., leadership/authority, superiority/arrogance, self-absorption/self-admiration, and utility/power, the small number of indicator items selected may have caused a small bias in our study.

Although this paper puts CSR, CEO narcissism and green supply chain efficiency into the same framework for research, more detailed research remains to be further deepened in the future. This paper adopts empirical research, and future research can adopt case study methodology, selecting single or multiple enterprises as research objects, and further deepening the research on CSR and green supply chain efficiency through longitudinal single-case study or in-depth cross-case study, in order to realize exploratory deepening and validation support for

the research perspectives and main conclusions presented in this paper.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Author contributions

All authors in the equal proportion collected and analyzed the data, designed the study, interpreted the results, carried out the implications, did the literature review, and wrote the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

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