External regulation and firm ESG disclosure from the perspective of Greentrans formation Game analysis of

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ABSTRACT: From a domestic perspective, the development of iron and steel firms in the past has caused excessive energy consumption and ecological and environmental pollution, among other problems. Therefore, under the current "double carbon" strategy, it is urgent to change the development approach. As the basis of ESG rating, ESG information disclosure plays a fundamental role in the process of ESG investment. However, ESG information disclosure by listed firms is mainly voluntary, and the macro-mandatory effect is insufficient. False disclosure and non-disclosure often occur. From the perspective of game theory, this paper discusses the equilibrium game strategy between Nangang steel firm's ESG information disclosure and regulatory authorities and puts forward suggestions for regulatory authorities to supervise ESG information disclosure of listed firms from the perspectives of reducing regulatory costs, increasing penalties, improving public opinion monitoring and strengthening punishment for regulatory negligence

KEYWORD: Iron and steel firms; External supervision; ESG information disclosure; Game theory
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I. INTRODUCTION AND LITERATURE REVIEW
1.1 Research background and significance
1.1.1 Research background

Since 2021, driven by a series of policies such as double carbon and common prosperity, the ESG ecosystem in China has taken initial shape, and the popularity of ESG concepts has exploded. ESG requires firms to pay attention to environmental protection, fulfill social responsibilities, and improve firm governance during development. Firm ESG governance is conducive to strengthening the management of environmental and social risks, promoting sustainable development, and improving firms' ability to operate sustainably. Effective ESG information disclosure can enable the market to judge a firm's ability to achieve sustainable development and manage risks more accurately. In addition, firms with better ESG performance can gain more trust from stakeholders.

With the deepening of the concept of sustainable development, investors are not only focusing on the economic benefits of investment but also on the social benefits. Therefore, the concept of socially responsible investment and the continuous development of ESG investment are deepening. ESG investment is an investment philosophy and method that evaluates and screens firms based on environmental protection, social responsibility, and firm governance.

The ESG rating system is the basis for implementing the ESG investment concept. Promoting the ESG investment concept can only be achieved by establishing a sound, scientific, and reasonable ESG evaluation system. The ESG rating system mainly includes three dimensions: ESG information disclosure, evaluation and rating methods, and investment guidance. As the foundation of the ESG investment concept, ESG information disclosure refers to the proactive or passive disclosure of a listed firm's environmental, social responsibility, and firm governance information to investors and regulatory authorities, according to relevant requirements, before and after listing. This facilitates regulatory supervision of the firm's actual situation and helps investors fully understand the firm's situation for making informed investment decisions. However, despite being the most basic ESG information disclosure, there are still cases of non-disclosure, false disclosure, and other issues.

The steel firm selected for this paper is Nanyang Iron and Steel Co., Ltd. Nanyang Iron and Steel Co., Ltd. was listed as one of China's TOP50 Industrial Firms for Sustainable Development by Forbes in 2022. Furthermore, Nangang received three awards: the "2022 Wind ESG A-Share Best Practice Award", the "2022 Wind ESG A-Share Best Practice Award (Social)", and the "2022 Wind ESG A-Share Industry Best Practice Award (Materials)". It is the only listed steel firm to receive these awards. From a game theory perspective, this paper provides suggestions for improving the ESG information disclosure of Nangang Steel Firm from the perspective of external supervision.

In general, the ESG evaluation index system reflects the sustainable development performance of firms from three aspects: environment, society, and firm governance. Under these three core aspects, eight themes and thirty key evaluation indicators are established.

1.1.2 Research Significance
1.1.2.1 Practical significance
The 20th National Congress of the Communist Party of China has set the direction for China's future development. The report highlights the construction of a modern industrial system and emphasizes that economic development should focus on the real economy. As a traditional industry with great potential in the real economy, the steel industry plays a crucial role. The development of the real economy is inseparable from the basic manufacturing industry. As a key industry, the iron and steel industry is an essential pillar supporting the international market competitiveness of China's major manufacturing countries and industries. Nangang actively or passively discloses environmental, social responsibility, and firm governance information to regulatory authorities by relevant requirements, allowing investors to make informed decisions about the firm's performance and sound investment decisions.

1.1.2.2 Practical Significance
Using game theory, this paper explores the equilibrium game strategy between ESG information disclosure of heavily polluting firms in the iron and steel industry and regulatory authorities. The game is played through the review process of external supervisory agencies and whether steel firms disclose their information truthfully. Based on the game's equilibrium, optimal solutions exist between steelmakers and regulators. Furthermore, recommendations are made for regulatory agencies to supervise ESG information disclosure of listed firms, which include reducing regulatory costs, increasing penalties, improving public opinion monitoring, and strengthening punishment for regulatory negligence.

1.2 Literature Review
1.2.1 System research under the ESG concept
The main financial statements in the traditional firm financial reporting system are the balance sheet, income statement, statement of changes in shareholders' equity, and cash flow statement. Most of the data is based on the "accrual basis" confirmed by accounting. Therefore, the historical cost is an important measurement attribute in the financial statements to reflect the firm's financial condition, operating results, and cash flow. However, Lee (2006) pointed out that establishing a multi-asset portfolio cannot eliminate systemic risk, i.e., market risk. He also stated that the current financial report has limitations and cannot solve the firm's inherent risks. To overcome these issues, Serafeim (2015) analyzed the correlation between portfolio reports, investor composition, and the negative correlation between risk factor β coefficient and the ESG index. The findings suggest that firm social responsibility disclosure can effectively reduce market risks.

With the deepening of the ESG concept, more and more scholars propose that ESG reports supplement traditional financial statements. Huang Shizhong (2021) believes that firm financial statements are built based on "shareholders' interests first", and investment, financing, distribution, and evaluation are all based on whether they can bring value to shareholders. According to Weston (2021), this shareholder-centered value creation is incompatible with the ESG concept that advocates stakeholders. Qian Longhai (2020) believes that with the vigorous development of ESG reports, the concept of value creation will undergo three major changes: the orientation of value creation will be diversified from a single value orientation, and the maximization of shared value will replace the maximization of shareholders' equity; the scope of value creation extends from connotation to the external, emphasizing the unity of economic value, social value, and environmental value. The motivation for firm value creation expands from the inside to the outside, and society, the environment, and other aspects will influence the firm value creation ability.

Huang Shizhong (2021) discovered that the increasing demand for ESG reports from investors, creditors, and other stakeholders has led to a rapid growth in the number of ESG reports submitted by firms. Peng Xiaofeng et al. (2021) believe that the implementation of ESG reports can complement the comprehensive reflection of the current situation of firms. Zhang Qiaoliang and Sun Ruijuan (2015) point out that ESG information can also reflect the development trend of firms, and poor ESG performance can cause great trouble for investors. Lu Ming (2021) emphasizes that ESG reports can collect relevant information about a firm's environment, social responsibility, and management and evaluate the firm according to ESG standards. This enables investors to see the firm's overall performance more comprehensively, not only its financial performance but also its operating conditions.

Based on existing literature, foreign scholars have conducted various studies on the path of ESG information disclosure. Ruth (2019) believes that the significance of ESG information should be explored and emphasizes that significant ESG information of listed firms should be published promptly and dynamically

adjusted in real-time on the rating system. Roberta S Karmel (2016) conducted an empirical analysis of the ESG information disclosure reform of American stock exchanges and proposed suggestions on improving the path of ESG information disclosure and infrastructure, combining it with the actual situation of the American stock market.

In contrast, domestic research on ESG information disclosure mainly includes the following aspects. Huang Jinbo et al. (2021) empirically tested the mechanism of social responsibility disclosure of listed firms during the stock market crash. They found that the social responsibility disclosure of listed firms could effectively reduce the stock market crash risk. Liu Huihao and Feng Yongjia (2020) studied the relationship between economic uncertainty and firm social responsibility information disclosure. They found that firms tend to increase consumers' attention by disclosing relevant responsibility information when economic uncertainty increases. However, this is not the internal factor driving firms to make social responsibility disclosure. They suggested that supervision from the regulatory department is a long-term solution for firms to strengthen social responsibility disclosure. Through empirical testing and analysis, Tan Wenshuang et al. (2021) believe that promptly proactive disclosure of social responsibility information can improve a firm's reputation. As its intermediary transmission mechanism, the media will pay attention to firms, thus improving firm performance. Qian Yudong (2021) believes that domestic research mainly focuses on the influence of ESG information disclosure on various aspects of firms but does not discuss the factors that drive firm ESG disclosure. This paper will contribute to improving research on ESG information disclosure.

Our country still has room for improvement compared to the well-developed research on ESG information disclosure abroad. For example, Zhu Kebing et al. (2017) argue that foreign countries have explored the necessity and path of ESG information disclosure and the problems that arise during the process. However, due to the relatively recent emergence of ESG investment and the lack of related infrastructure, there has been less research on the disclosure of ESG information among listed firms. Therefore, this paper makes a modest contribution to the regulatory research on listed firms' ESG information disclosure.

II.   RELATED THEORETICAL BASIS

2.1 Economic Externality theory

Based on Marshall's external economic foundation in Welfare Economics, Pigou, an economist, proposed the theory of economic externality. The theory states that economic externalities occur when the marginal private output differs from the marginal net social output. Pigou categorized economic externalities into positive and negative externalities according to the relationship between marginal private interests and marginal social interests generated by business activities.

The theory of economic externalities provides valuable insights into ESG. Ecological and environmental resources are public resources that lack specific property rights and require government intervention and regulation. The prerequisite for government intervention and regulation is that firms fully disclose environmental information to promote the government's comprehensive understanding of environmental information. However, although a firm's operational activities can produce significant positive and negative externalities crucial for assessing a firm's value creation ability and sustainable operation, financial reports often fail to reflect these externalities."

To fully reflect the impact of economic externalities, the ESG reporting system was created. Firms releasing ESG data can provide a decision-making basis for the government and significantly reduce regulatory costs associated with government intervention and regulation. Moreover, the ESG report should reveal the negative external factors in the firm's behavior and its positive external factors. While punishing negative externalities of firms can correct their environmental behaviors, supervision and correction costs are usually high. On the other hand, measures taken for positive externalities of firms are mainly incentives, which can better guide firms to realize low-carbon and green transformation.

Additionally, due to the influence of economic externality theory, the ESG reporting system does not limit the scope of the disclosure to the business operations of firms but also involves indirect environmental impacts, such as water and air pollution in the production process of raw materials, carbon emissions, and energy consumption caused by fuel procurement. Suppose the environmental impact of disclosure is confined to the firm's business operations. In that case, it may underestimate the environmental pollution caused by the firm's behavior and thus affect the accuracy of disclosure despite its convenience, low cost, and ease of verification.

2.2 Shared value creation theory

For a long time, financial management in our country has focused solely on maximizing after-tax income for shareholders, neglecting social welfare and the ecological environment. As a result, assessing a firm's sustainable operation ability has mainly centered on the economic aspect while ignoring other stakeholders. This value orientation prioritizes shareholder value while neglecting social and environmental

benefits, is not conducive to sustainable development, and can even lead to public skepticism of a firm's legitimacy. To address this issue, Professor Porter, an expert in competitive strategy at Harvard University, and John Kramer, a senior scholar at the Harvard Kennedy School of Government, proposed a model of shared value creation in their works "Strategy and Society: Competitive Advantage and Firm Social Responsibility" and "Creating Shared Value: How to Transform Capitalism and Unleash Innovation and Growth."

Shared value enhances a firm's competitiveness by developing policies and operational measures to improve its community's economic conditions and social environment. The shared value creation model advocates for transforming from "value creation exclusively owned by shareholders" to "shared value creation equally shared by interests". Based on this point of view, the shared value creation model is more aligned with the value proposition of sustainable development theory. The scope of a firm's value creation should expand from economic value to social and environmental value, considering the legitimate rights and interests of shareholders and other stakeholders.

The theoretical basis of shared value creation originates from the "triple bottom line" theory. The economic bottom line refers to the ability of firms to obtain profits. The social bottom line means that firms should attach importance to human capital, create a fair and just business environment as far as possible, and improve the well-being of "people", such as providing medical insurance, reforming work environments, providing tuition subsidies for technical education, etc. Finally, the environmental bottom line refers to making daily business decisions that minimize environmental impact and strives to become an environmentally friendly firm. Firms can achieve healthy and sustainable development only by meeting the triple bottom line requirements."

III. IS THE GAME MODEL OF EXTERNAL SUPERVISION AND FIRM ESG DISCLOSURE

3.1 Game between external supervision and firm ESG disclosure

First, participants: It is assumed that the regulatory authorities and the management of listed firms are rational players in the game model, understand the game's structure, and can choose strategies to maximize their interests.

Second, policy: assume that the external regulatory department can choose a policy set as J={ A_1, A_2 }, which A_1 represents review and A_2 no review; The strategy set that the listed firm can choose is S={ B_1, B_2 }, where it B_1 represents untrue disclosure and B_2 true disclosure.

Third, information: It is assumed that both sides do not know each other's strategies before making decisions, and both choose strategies simultaneously.

Fourth, choice: there are four major strategic situations in this game:

First, when the listed firm chooses to disclose green investments, it cannot obtain additional income. To disclose green investment information, the administrator must pay the related costs recorded as C_1 (C_1 mainly the fees paid by relevant ESG information disclosure).

Secondly, when listed firms choose not to disclose green investment information, the regulatory authorities will face review and non-review. When the regulatory department does not review, the management will get additional revenue and mark it as E. However, when the regulatory department conducts a review, the listed firm will get 0 additional revenue and will face a fine from the regulatory department, mark it as D, and must comply with the regulatory department's order for rectification. The cost of rectification is denoted as C_2 (assuming that the rectification cost is equal to the cost paid by the administrator, $C_1 = C_2$)

Thirdly, when the regulatory authorities examine the disclosure information of listed firms, two situations may arise: listed firms disclose green investments and do not disclose green investments. When listed firms disclose green investments, the effect of regulatory review and non-review is the same, so the review will result in a waste of costs C_3; When the listed firm does not disclose the green investment information, the regulatory department will impose a penalty income D (equal to the amount of penalty paid by the listed firm) and require the listed firm to make rectification at the cost of C_2.

Finally, when the regulatory authorities do not strictly supervise the listed firms, there will be two types of disclosure. When the listed firm discloses information, the regulatory authorities will not incur any losses. However, when the listed firm does not disclose green investments, the disclosure of false ESG information by the listed firm may lead to decision-making errors in the portfolio investment process. If the regulatory authorities do not actively perform their review duty, they will lose out on penalties and income. Additionally, they may face penalties for dereliction of duty (P) and criticism from public opinion (S), and the loss is denoted

as L(D, P, S), where D, P, and S are positively correlated. The payoff matrix for both sides of the game is shown in Table 1.

Table 1: Payment matrix of both sides of the game

Listedfirm	Regulatory authorities	
	Review（α）	Noreview（1-α）
Failuretodisclose greeninvestments（1-β）	-(D+C_2),D-C_3	E, -L(D, P, S)
DiscloseGreen investments（β）	-C_1,-C_3	-C_1, 0

3.2 Equilibrium solution of the game between regulatory authorities and firms

There is no pure strategy Nash equilibrium in the game between regulators and firms, so a mixed strategy equilibrium is mainly used here. In this game model, the probability of strict supervision by regulatory authorities is denoted as α, and the probability of not strictly performing supervision is 1-α. Similarly, the probability of true disclosure of ESG information by listed firms is denoted as β, while the probability of false disclosure is 1-β. The expected utility function between the regulatory department and the firm is, respectively U_1 and U_2:

Let the expected utility function of the supervision department be expressed U_1, then

$$U_1 = \alpha[(D-C_3) \times \beta + (-C_3) \times (1-\beta)] + (1-\alpha) \times [-L(D,P,S) \times \beta + 0] \qquad (3.1)$$

Take the partial derivative of equation (3.1) concerning α and set it equal to zero, then the utility
The maximized first-order condition is:

$$\partial U_1/\partial\alpha = \beta[D+L(D, P, S)] - C_3$$

$$\beta[D+L(D, P, S)] - C_3 = 0$$

$$\beta^* = C_3/D+L(D, P, S) \qquad (3.2)$$

$$\text{known}: 0 \le \beta \le 1$$

$$0 \le C_3 \le D+L(D, P, S)$$

There are three situations when listed firms choose to examine or not examine:

E.g., If When β ＜/D+L(D, P, S), the optimal strategy of the supervision department is no review.

Eg. If When β ＞/D+L(D, P, S), the optimal strategy of the supervision department is examination;

If β=/D+L(D, P, S), "review" and "no review" are random.

The expected utility function of the listed firm is U_2, then:

$$U_2 = \beta \times [-(D+C_2) \times \alpha + E \times (1-\alpha)] + (1-\beta)[(-C_1) \times \alpha + (-C_1) \times (1-\alpha)] \qquad (3.3)$$

Take the partial derivative of equation (3.3) concerning β and set it equal to zero, then the first-order condition of utility maximization is:

$$\partial U_2/\partial\beta = E + C_1 - \alpha(E+C1+D)$$

$$\text{Then}, E + C_1 - \alpha(E + C_1 + D) = 0$$

$$\alpha^* = (E+C_1)/(E+C_1+D) \qquad (3.4)$$

$$\text{known}: 0 \le \alpha \le 1$$

$$0 \le E+C_1 \le E+C_1+D$$

Then: when α<E+C_1/E+C_1+D, the optimal strategy of the listed firm is the disclosure of violation;

When α>E+C_1/E+C_1+D, the optimal strategy of listed firms is no violation of disclosure;

When α=E+C_1/E+C_1+D, listed firms' "non-violation disclosure" and "non-violation disclosure" are random.

From Equations (3.2) and (3.4), it can be concluded that the mixed Nash equilibrium is:

S*=(S1*,S2*), 即：(E+C_1)/(E+C_1+D), C_3/D+L(D, P, S) （3.5）

The equilibrium solution in Equation 3.5 shows that when the regulatory authorities randomly select certain firms for inspection, listed firms with a ratio of C_3/D+L(D, P, S) will disclose relevant ESG information in violation of regulations; When the regulatory authorities randomly investigate and punish, there will be an (E+C_1)/(E+C_1+D) listed firms without false disclosure of information.

IV. CASE ANALYSIS

As the main initiator, Nanjing Iron & Steel Co., Ltd. is a joint-stock firm jointly initiated and established by the Twentieth Metallurgical Construction Firm of China, Beijing Iron & Steel Design and Research Institute of Metallurgical Group of China, China Metallurgical Import & Export Jiangsu Firm, and Jiangsu Metallurgical Materials Supply & Marketing Co., LTD. The case of Nangang Co., LTD. (600282) selected in this paper is based on studying the game between external supervision and firm ESG disclosure. The sustainable development report of firms will be particularly important for firms that invest heavily in environmental protection. In contrast, heavily polluting firms will be more inclined to invest in green technologies. The selection of firms mainly focuses on the environmental expenditure data in firm social responsibility, firm sustainable development reports, and firm annual reports. Generally, the investment data of firms in green environmental protection is not obvious. Although some firms are heavy polluters, they do not disclose much about the expenditure on green environmental protection. The firm's environmental protection investment is mainly used in facilities and equipment, as well as low-carbon transformation and site upgrading. The disclosure of green environmental protection expenditure and whether the firm truly discloses the data are important factors in calculating the probability of the game between the iron and steel firms and the regulatory authorities.

Table 4-1 Investment in key environmental protection projects of Nangang in 2021

Project/year	Project amount	Reporting period input	Cumulative input
Environmental protection closed the renovation project of the original material yard	32678.10	14355.83	29978.96
Raw material Transformation Project (Phase II)	45921.90	20097.27	22138.31
Coke storage closed technology renovation project	36896.94	13213.47	31688.61
Sintering machine reform	20000.00	243.30	243.30
Technical reform of the pellet desulfurization project	80000.00	2111.66	7100.00
Sintering machine flue gas desulfurization and denitrification engineering	39000.00	3484.30	34371.79

C_1 for firms to truly disclose the cost paid, and in the heavily polluting steel firms, the firm sustainability report focuses on the green investment of firms:

C_1=14355.83+20097.27+13213.47+243.30+2111.66+3484.30=53588Ten thousand yuan

Table4-2 Calculationofinputcostofenvironmentalprotectionfrom 2017 to 2021

Unit:Tenthousandyuan

Project/year	2017	2018	2019	2020	2021
Expensing cost	7925.61	71437	23926	167611	117443
Capitalized cost	10904.7	10511.16	47950.6	119194.2	159250.32
Environmental protection cost	18830.31	81948.16	71876.6	286805.2	276693.32

Environmental protection cost rate	0.5	0.58	0.63	0.62	0.6
Contribution to the cost of environmental protection	3962.81	41433.46	15073.38	103918.82	70465.8
Contribution of capitalized environmental costs	5452.35	6096.47	30208.88	73900.4	95550.19

E represents the firm's additional income when external supervision is not reviewed. Based on the environmental protection expenditure, there are two types of costs: operating and capitalized. The investment cost in green environmental protection projects represents the additional income earned by the firm when external supervision is not reviewed.

E= 704.658 million Yuan

D represents the penalty paid by the firm for not disclosing information during regulatory inspections. The selected data relates to the firm's environmental protection administrative penalties in 2021. For example, the mixing yard of Raw Material Factory No.2 violated environmental regulations by not using the high-pressure spray gun during stacking and taking operations, resulting in a fine of 100,000 yuan. D=100,000 yuan.

C_3 cost of external review for true disclosure of ESG information. The selected data is from the firm's sustainable development report of the firm. In 2021, the firm will steadily promote energy conservation and emission reduction and invest about 439.2743 million yuan in the "construction of the integrated wisdom Center" to help achieve the goal of energy conservation and efficiency. C_3 = 439.2743 million yuan

L refers to the inauthentic disclosure of information about Nangang Stock, which will lead to investors' decision-making mistakes in portfolio investment, loss of penalty income D, penalty P for dereliction of duty, and accusation S from public opinion.

The data comes from the firm's annual social responsibility and sustainable development reports.

L=4.06+70465=70469.06 Ten thousand yuan

From Equations (3.2) and (3.4), it can be concluded that the mixed Nash equilibrium is:

S*=(S1*,S2*), that is(E+ C_1)/(E+ C_1 +D), C_3 / D+L(D, P, S)

Then it can be concluded that the probability of Nangang' s non-disclosure or illegal disclosure of firm ESG is:

C_3 / D+L(D, P, S)=43927.43/10+70469.06=62.33%

Probability of regulatory review of Nangang ESG:

(E+ C_1)/(E+ C_1 +D)= （70465+53588） / （70465.8+53588+10） =99.9%

As Nangang is a heavily polluting firm with relatively high carbon emissions, its investment in environmental protection is also relatively large, indicating a higher probability of regulatory review by the authorities on heavily polluting steel firms.

Regarding the game equilibrium between external supervision and listed firms, Formula (3.5) indicates that the probability of Nangang Stock not truly disclosing the information is C_3 /D+L(D, P, S), and the regulatory department has a probability of (E+ C_1)/ (E+ C_1 +D) to conduct reviews so that both parties can achieve the maximization of expected utility, which is the equilibrium solution of the game. Therefore, the optimal profile solution of listed firms changes positively with C_3 and inversely with L(D, P, S) and D; the optimal probability solution of regulatory authorities changes positively with E and C_1 inversely with D.

V.   A SUMMARY AND PROSPECT

Based on the game equilibrium solution, there is an optimal solution between Nangang Stock, a steel firm, and the regulatory department. To reduce the probability of illegal disclosure by listed firms, the regulatory department should effectively reduce the cost of supervision. Reducing the cost of supervision does not mean reducing the number of supervisors but rather improving the efficiency of supervision. For example, advanced supervision equipment can be introduced for random inspections to reduce the expenditure of human costs in supervision. Additionally, penalties for violations of firm information disclosure should be increased. During the information disclosure process, firms compare costs and benefits. When the cost of illegal disclosure by listed firms exceeds the benefits, listed firms will be forced to disclose the information under the actual earnings to reduce information disclosure mistakes.

Conversely, when a listed firm discloses information in violation of regulations, if the income from the illegal disclosure of the information is higher than the cost, the listed firm will choose to disclose information in violation of regulations, even at the risk of being punished, based on the comparison of cost and income, which weakens the effectiveness of external supervision. Moreover, the intensity of punishment for regulatory personnel dereliction of duty should be increased to reduce regulatory errors effectively. With the development of internet technology and improving information accessibility, public and network media supervision plays an increasingly important role in the information disclosure of listed firms. Therefore, it is crucial to fully play the role of social supervision and reduce the inauthenticity of ESG information disclosure by listed firms.

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