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Empirical Evidence of ESG Development, Enterprise Innovation, and Carbon Emission Intensity Based on Text Analysis

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Abstract

For the double carbon enterprise sustainable development ability and the relationship between carbon emissions, the first screening China a-share listed companies 2011-2018 annual report information, using text analysis to establish ESG development level index, followed by the benchmark regression model, learned that ESG development level and carbon intensity of inverted U type, and the robustness test and tool variable regression method, again using the ESG for green technology innovation of nonlinear relationship, technology innovation U-type effect will lead to carbon intensity before reduction. Finally, further heterogeneity test shows that the ESG development effect of eastern provinces is better than the central and western provinces; the ESG development in low market areas does not bring synchronous reduction of carbon intensity; the ESG development effect of large-scale enterprises is inferior to that of small-scale enterprises. It is concluded that China has exceeded the inverted U-shaped extreme value point on the average level, and enterprises and governments should continue to practice ESG to promote the realization of the "carbon neutral" goal.

Keywords

Green technology innovation; Benchmark regression model; ESG; Carbon neutral; Text Analysis.

1. Introduction

In the past 40 years, global climate change has led to a significant increase in the frequency and intensity of extreme weather. The international community has reached a consensus on carbon reduction and negotiated relevant institutional arrangements and action plans under the framework of the United Nations. From the United Nations Framework Convention on Climate Change reached in 1992, the Kyoto Agreement in 1997, to the Paris Agreement formally signed in 2016, countries have jointly built the political and legal foundation for tackling climate change. In 2020, China officially proposed the goal of aking carbon emissions by 2030 and achieving carbon neutrality by 2060 to address the common climate change risks of human society. China is under more pressure compared with the emission reduction targets of other major developed economies. Due to the different stages of development, major developed countries have passed the peak emissions and only need to continue the previous levels to achieve the 2050 net zero emissions target; China's total carbon emissions are still increasing, need to peak emissions at a low per capita GDP by 2030 and neutralize emissions within 30 years. In terms of realization years, China is more urgent than developed countries; in terms of reduction intensity, the annual emission reduction rate is 8-10%, and carbon emissions fall faster. As the main body of carbon emission and the main body of carbon neutral target, the production activities of enterprises affect the realization path of the target. How to achieve green transformation and reduce carbon emission under the current situation of high pressure and multiple challenges has become an important issue under the "30 . 60" goal.

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The sustainable development ability of an enterprise directly affects the ecological and environmental protection performance of an enterprise, and the social responsibility concept with sustainable development as the core is changing its business philosophy. In the neoclassical theory, the maximization of owner profit is the only social responsibility of an enterprise (Friedman et al., 1971), but the concept of taking shareholders' interests as the development goal cannot solve the social problems brought by the externality of enterprise activities. At present, environment (Environment), society (Social) and governance (Governance) are regarded as the most important dimensions in the sustainable development capacity of enterprises. ESG is being considered by the public sector and external investors as a three dimensions, and is becoming the key to the low-carbon transformation of enterprises.

The concept of ESG originates from ethical investment and socially responsible investment (Michelson et al., 2004), which is the investment philosophy produced by investors for the purpose of personal religious concept or creating positive benefits for the society. In 1992, the United Nations Conference on Environment and Development (UNCED) was held and adopted Agenda 21, advocating environmental protection and sustainable development. Environmental factors gradually expanded to the production, investment side and consumer demand side in public activities, expanding the boundary of enterprise performance evaluation. In 2004, the proprietary concept of ESG was first proposed in the Who Cares Wins report of the UN Global Compact. In 2006, the United Nations Organization for Responsible Investment Principles (PRI) was established to help investors incorporate environmental, social and corporate governance elements into their corporate value assessment, and ESG has become the internationally accepted measure of green and sustainable development of enterprises.

The ESG evaluation system comprehensively measures the ability of enterprises to address climate change and achieve carbon neutral goals, and is also a comprehensive measure of the level of corporate social responsibility fulfillment. With the setting of the target of "carbon peak and carbon neutral & quot. ESG has increasingly increasing attention in China. Financial institutions and governments have carried out a wide range of practices in related fields, including specific activities, information disclosure norms and evaluation of target subjects. In the investment and financing activities led by the ESG concept, green finance and transformation finance are parallel and benign interactive, and the market stock of financial products such as green credit, bonds and asset-backed securities has steadily increased. In the ESG regulatory policies for listing entities, the government departments play a programmatic and normative role, and the exchange is responsible for refining the guidelines and requirements, and the regulatory trend is constantly strengthened.

Enterprise ESG performance is of great significance to climate change mitigation, and the consistency of social responsibility and the development of low carbon economy exist (Lv et al, 2010; An Guojun, 2021). Whether enterprises can improve their ESG performance to achieve the "win-win" of individual sustainable development ability and social environmental issues is the internal power of enterprise business development under the goal of carbon neutral. But in practice, ESG or enterprise sustainability does not directly mean improved environmental performance. Specifically, the improvement of multi-dimensional ESG level may only result from the growth of a single dimension, and the level of environmental dimension will lag behind the change of ESG level; the constant cost of environmental investment is huge, which is likely to be squeezed out by other dimensions, and the improvement of the overall sustainable development level of the enterprise will lead to the decline of environmental performance.

In order to explore the actual effect of enterprise ESG performance and sustainable development ability on carbon emissions under the background of peak carbon reach, carbon neutrality and carbon target, this paper systematically combs the relevant literature, and builds an empirical model with the data of a-share listed enterprises from 2011 to 2018 and provincial panel data. The keywords were selected from the three dimensions of environment, society and

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governance, and the text analysis method was used to count the keyword frequency, and the enterprise ESG development level indicators and provincial ESG development level indicators were constructed, and the relationship between ESG development and carbon emission intensity was tested. The possible marginal contributions are as follows: first, we use the text analysis method to minimize the subjectivity of the existing ESG evaluation and the analysis framework from macro phenomenon to micro mechanism, examine the nonlinear relationship between the provincial enterprises, discuss the two paths of energy saving and energy substitution in the ESG development; third, according to the results of the benchmark, this paper proposes development suggestions to realize the carbon neutral goal.

2. Literature Review

2.1. Enterprise ESG and sustainable development

Since the formation of the ESG concept, many scholars have conducted research around it. Most of the literature in the field of corporate finance examines the ESG performance within the enterprise boundary from three sub-dimensions, and examines the close correlation between ESG and governance ability, risk and performance (Gillan et al., 2021). ESG represents the social responsibility of the enterprise in social, economic and environmental aspects, and is an intangible asset of the enterprise, which can bring good social reputation and establish a good image. The "moral capital" formed by ESG can bring long-term value growth to the enterprise (John et al., 1998; Godfrey et al., 2009).

It is generally believed that the ESG system composed of three dimensions represents the sustainable development ability of enterprises. The ESG performance of companies constitutes the most important source of social responsibility information, enabling companies to link sustainability contributions to financial market decisions (Torres te al., 2019). Specifically, the relationship between sustainable development and ESG is two-way (Ho et al., 2019), and the performance of social responsibility represented by ESG drives sustainable development. As a non-standardized form of guarantee, ESG promotes efficiency and reduces market fluctuations and risks, and strengthens the development of enterprise investment and advanced technology, so as to further optimize the development of enterprise and economic growth. At the same time, ESG has achieved the effect of reducing information asymmetry and consolidating the sustainable operation of enterprises by enhancing the trust relationship between investors and stakeholders (Martinez-Ferreroet al., 2016). In the context of increasingly strict social responsibility challenges brought by sustainable development requirements, the sustainable development goals will promote them to pay attention to environmental, social and governance factors, and gradually accumulate and establish specific ESG advantages in the practice of ESG concept (Xie Hongjun and Lu Xue, 2022). However, there is no unified conclusion on how to measure the ESG performance level of enterprises, and China has not yet issued a standardized evaluation framework and evaluation standard. There are different processing methods in the selection of dimension indicators, the quantification of indicators and the construction of evaluation framework.

In terms of environmental evaluation index selection, Lv Jun (2012) selected qualitative indicators, to enterprise excessive emissions or not and whether by environmental penalties to measure environmental performance, Cai Chun (2021) combined with qualitative and quantitative indicators, select environmental compliance, environmental operation efficiency, environmental expenses of six dimensions such as comprehensive evaluation of enterprise environmental performance. In the selection of social responsibility indicators, Li Zhenghe Xiang Rui (2007) believes that corporate social responsibility information basically includes six categories: environment, energy, employees, community, products and services, and other categories. Because the criteria for measuring social assets, social liabilities, social costs and

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social benefits cannot be unified, the data obtained by different companies is not highly comparable. From the perspective of stakeholders, Wen Subin and Fangyuan (2008) selected A series of secondary indexes according to the responsibility of enterprise to the government. Yin Kaiguo (2014) directly adopted the rating results of a-share social responsibility report issued by the third-party rating agency RLCCW as the proxy variable of corporate social responsibility. However, due to the numerous research background, the selection of indicators is more diversified, including operators, equity concentration, institutional investors, state-owned shareholding ratio, etc. (Feng Genfu and Wen Jun, 2014). Although there are some differences in the selection indexes of the existing literature, they still have some commonalities. Enterprises with outstanding performance in one dimension may not be equally prominent in the other dimension, and the comprehensive level of ESG will improve due to weighted synthesis; the negative externality of the environment and society includes both production level (such as carbon intensity, water consumption, etc.) and management level, ESG needs to consider the inhibitory effect of management system on external risks (Qiu Muyuan and Yin Hong, 2019).

In terms of ESG research methods, some scholars simultaneously use independent indicators of three sub-dimensions or comprehensive indicators calculated by comprehensive evaluation method to represent ESG level (Sun Dong et al., 2019), but the literature directly using agency rating results accounts for the majority, such as: MSCI Mingsheng (Zhang Cankun, 2021), Commercial Ronglu (Zhang Lin and Zhao Haitao, 2019; Xiaofang, et al., 2021; Li Jin et al., 2021), China Securities Index (Gao Jieying et al., 2021; Wang Linlin et al., 2022; Song Ke et al., 2022). In industry practice, the rating results of the agency depend on the disclosure of corporate ESG information, and there are large differences between the assessors. Specifically, compared with the broad consensus of financial information disclosure, there is no consensus on ESG information on which exact indicators to evaluate the company's ESG performance, or how to explain and judge the significance of different indicators for the company's ESG performance (Lamont, 2012). In the absence of clear evaluation rules, companies with less ESG information are more likely to evaluate based on simple rules of thumb, so they are more likely to reach an agreement; for companies that disclose more ESG information, rating agencies may use different indicators to evaluate ESG performance, which may disagree on whether ESG performance is good or bad. Therefore, because more disclosure would provide more divergent information to rating agencies (Cookson and Niessner, 2020). The empirical study was verified by Christensen et al. (2022) based on information from MSCI, TR, Sustainalytics and Bloomberg, Considering that the rating agencies are based on the enterprise ESG outcome indicators (the indicators reflecting the actual performance results of the enterprise ESG, Such as carbon emission intensity, etc.), compared to the ESG ratings based on the ESG input index (reflecting the efforts of enterprises to achieve the expected results, Such as the adoption of relevant policies, target setting, etc.), the ESG rating is more divergent (Christensen et al., 2022). Domestic third-party institutions also pointed out the problems from the perspective of data, such as: high inconsistency of original data, strong randomness of reference benchmark selection, great uncertainty of replacement value estimation, etc., which led to the huge difference in ESG ratings of domestic companies.

2.2. Corporate social responsibility and carbon emissions

At present, there are few direct studies on the relationship between social responsibility and carbon emission intensity. Most of the literature related to carbon emissions examines the determinants of per capita carbon dioxide emission level and the peak of carbon dioxide emissions when GDP reaches its value (Yu Yihua et al., 2011).

More relevant literature discusses the relationship between corporate social responsibility and environmental performance. There are various channels and ways for enterprises with social

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responsibility awareness to improve their environmental performance (Wang Xiaolu and Ni Danyue, 2018).one side, The carbon dioxide emissions of the production sector can be achieved through the technological innovation of the production of enterprises (Diamond, 2009); With the increasing development of green finance, Companies tend to implement carbon emission reduction strategies to establish a good image, Thus dispersing risks and reducing financing costs (Shahbaz et al., 2013); Making low-carbon green products and participating in carbon emission reduction projects bring additional tax relief to enterprises while easing the policy pressure and public pressure of the external environment (Sprinkle, 2010); A developed financial system is more conducive to corporate carbon trading, As the main body of carbon trading, Carbon emission enterprises constitute the "carbon sink" demand side, It has also become a carbon sink supplier (Tan Zhixiong, 2012).

At the same time, some studies point out that environmental performance when companies intend to improve their environmental, social, and corporate governance performance, or their sustainable development capabilities, may get worse. The research of Chen Yutao and Feng Jian (2020) found that the efficiency of green investment of enterprises is generally low, which is mainly caused by the problem of investment redundancy. The management only extensively invests heavily in the environmental dimension, ignoring the effective allocation of resources and the use of value creation. The research of Chen Guan and Zhang Xuan (2016) found that the fulfillment of social responsibility to the community (environmental protection) has no positive effect on the innovation performance of enterprises. Li Wenqian et al. (2018) found that social responsibility has an inverted U-shaped impact on the technological innovation performance of enterprises, which further has a non-linear impact on the pollution emission of enterprises.

3. Theoretical Analysis and Research Hypothesis

ESG, as the leader of green finance and the core of the sustainable development capacity of enterprises, may have an uncertain relationship with the carbon emission intensity. Based on the environmental Kuznetz curve (Environmental Kuznets Curve) in the field of environmental economics, this paper analyzes the relationship between ESG development level and carbon emission intensity in stages.

Stage 1: In the early stage of ESG development, the path of green finance development and enterprise knowledge stock depends on increasing the carbon emissions per unit of GDP.

The inclusive promotion of green finance provides an opportunity for the improvement of ESG level. Green finance represented by ESG investment can effectively promote the investment and financing activities of enterprises and ease the financing constraints of enterprises. Companies can use green assets as collateral, or use green financial instruments to obtain external funds. The ESG principal rating will directly send a positive signal to the market, which will reduce credit transaction costs and increase the availability of foreign capital (Qiu Muyuan, Yin Hong, 2019; Zhang Lin and Zhao Haitao, 2019). The easing of financing constraints brings to the expansion of production scale. Due to the path dependence of knowledge production function in the early stage of development and the high constant cost investment of enterprises, the external funds are not effectively used in RESEARCH and development activities, and the green production technology is not deepened accordingly. Under the premise of a certain stock of knowledge, the carbon emission level per unit of output increases with the expansion of the production scale (Wu Yanbing, 2006).

With the initial popularization of ESG concept and the improvement of ESG attention, financial institutions have carried out green financial innovation for the consumer end, which will produce a rebound effect in energy consumption (Shao Shuai et al., 2013). Green payments and green credit relatively reduce consumers' consumption costs and increase their actual disposable income. This demand expansion will simultaneously stimulate production and

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investment, driving the demand for energy factors. Total carbon emissions continue to grow because of the total consumption trend, and carbon emissions per unit of output increase.

Stage 2: In the later stage of ESG in-depth development, ESG investment and enterprise practice will promote enterprise technological innovation and regulatory mechanism reform from many aspects to reduce carbon emissions per unit of GDP.

On the level of product demand and production factor demand, low-carbon orientation is more concerned by the market. The living standard of consumers will improve synchronously with the regional ESG level, and consumers' awareness of environmental protection will increase, and they will pursue a higher quality of life, and be more inclined to consume low-carbon and environmentally friendly products. In addition, the higher the regional ESG level, the more perfect the development of green finance in its jurisdiction, the higher the degree of environmental regulation, the low financing cost and high environmental regulation will change the energy demand through the carbon trading market, the comparative cost of high carbon energy increases, the dependence of enterprises on it decreases, and the carbon emission reduction at the production end has become a trend (Muhammad et al., 2013; Qiu Muyuan and Yin Hong, 2019).

At the level of technology and capital, they support each other and jointly promote the reduction of carbon emission intensity. On the one hand, with the further development of ESG, there are broad positive incentives for the research and development of pollution reduction and energy efficiency improvement technologies. Enterprises have a more sensitive perception of new innovative ideas and technical level, which will further promote the improvement of their technological innovation ability, change the traditional and extensive production mode, and have an inhibitory effect on environmental pollution. At the same time, the government's policy preference and social green preference will promote the technological innovation of enterprises in the region, improve the utilization rate of resources, and reduce unit energy consumption and pollution (Qu Xiao' e and Luo Haiyan, 2019). On the other hand, the ESG development goals set up by the enterprises themselves are more mature, and the ESG investment strategies of external investors will be concentrated in the industries and enterprises that conform to the green development prospects (An Guojun et al., 2022). The market will have more stringent requirements for carbon emission subjects, and the capital agglomeration effect and leading role of enterprises with high ESG development level will be more significant, which will further lead the green technology upgrading of enterprises in the same industry and reduce the energy consumption and carbon emission per unit of economic output.

At the level of industrial structure and policy, ESG rating system and investment and financing concept can guide the transfer of financial resources between industries, and ESG under the intervention of the public sector will become an important leader for the industrial development in the future. Under the "30·60" target, financial institutions and external investors will gradually change the investment wind direction, which is conducive to the formation of an environment-friendly and resource-saving industrial structure, promote the reform of industrial structure, and promote the development of clean and low-energy consumption industries. Production in highly polluting industries will be limited, and high-carbon production capacity will be phased out. In addition, the policy and regulatory adjustment will effectively promote the green transformation. ESG standards will be used as an important support for industrial regulation and guiding policy formulation, ESG concept will run through the governance practice of "double carbon" target, the overall carbon dioxide emissions will gradually decrease, and with the expansion of economic volume, the carbon emission intensity will continue to decline (Chen Ning and Sun Fei, 2019; Wang Jing, 2019).

It can be seen that ESG development and carbon intensity do not have a definite linear correlation, and there is a relationship between the marginal gain (carbon reduction effect)

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growth is stronger than the marginal loss (carbon emission effect). As shown in Figure 2: In the early stage, the directional adjustment of capacity and strategy makes the development of ESG have a fixed carbon emission cost, the increase effect over the inhibition effect, and the carbon dioxide emission intensity will increase with the development of ESG; in the later mature stage, the carbon emission inhibition effect of ESG grows faster than the increase effect, and the sustainable development ability of enterprises and regions is released, indicating that the carbon dioxide emission intensity will decrease with the development of ESG. The research hypothesis of this paper is proposed:

H1: The development of ESG has an inverted U-shaped effect on carbon emissions

Macroscopically, the relationship between ESG development level and carbon emission is similar to the inverted U-shaped relationship presented by the environmental Kuznez curve. The implied micro mechanism is realized by ESG practice subject, that is, individual enterprises.

Technological progress of enterprises is the most important driving force to reduce carbon emissions (Liza Yang et al., 2019), among which green technology innovation is more sustainable and of innovative significance than other technological changes (Shao Xingyu, Fan Desheng, 2022). Green technology innovation is an innovation in energy consumption, pollution emission, pollution control and other aspects, which can directly improve energy efficiency and reduce carbon emissions per unit of output (Wang Xiaoping, 2018). Green technology innovation directly expands the market supply of green products for enterprises. Green products have comparative advantages such as high technology content and low carbon footprint, and have a deeper profit space than traditional products. Under the action of the market mechanism, the backward production capacity will be eliminated simultaneously (Yan Zheming et al., 2016). Further, enterprise green technology innovation will affect the energy demand structure, and change change renewable clean energy, nuclear energy, wind energy and the traditional high emission fossil energy, adjust the price of energy consumption structure, promote green energy replace high carbon pollution energy, realize the transformation and upgrading and the whole society in the field of carbon reduction (Snow White, etc., 2021). The development of ESG will affect carbon emissions simultaneously through energy substitution and technological progress. Therefore, this paper puts forward a second research hypothesis from two aspects to explore the micro mechanism after the macro phenomenon:

H2: ESG development affects carbon emissions through enterprise green technology innovation

4. Empirical Strategies and Variables

4.1. Model design

To investigate the relationship between ESG development and carbon emissions, a fixed-effect regression equation was established:

$$\ln\left(\frac{CO_2}{GDP}\right)_{jt} = \beta_0 + \beta_1 Provesg_{jt} + \beta_2 Provesg2_{jt} + \gamma Controls_{jt} + \lambda_j + \lambda_t + \varepsilon_{jt} \quad (1)$$

Where, the explained variable is the logarithm of the CO 2 emission intensity, which is the CO 2 emission per unit GDP in province t year j. The core explanatory variable is the total number of provinces and regions with selected ESG keywords, which is used to represent the regional ESG development level. As CO 2 emissions are also influenced by other factors, a set of control variables was introduced. It is a fixed effect of provinces, indicating the differences between provinces that do not change with time, such as energy endowment, human preference and regulation differences. It is an annual fixed effect, indicating the common development trend of each province every year, such as policy impact, international energy market changes, technological progress, etc. For the disturbance term, the main changes of the model in this study are from the province-year level. In order to handle the possible heteroscedasticity and

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sequence autocorrelation, the standard was mistakenly cluster-adjusted at the province-year level. The coefficient before the square term is the ESG development effect of the study. When it is significantly positive or significantly negative, there is a U-type or inverted U-type relationship between ESG development and carbon emission intensity.

4.2. Data source and pre-processing

The main data sources are from China Carbon accounting database, wind, Juchao Information network and related statistical yearbooks.

Among them, the carbon emissions data are obtained from the China Carbon Accounting Database (CEADs). CEADs is in the national natural science foundation committee, Ministry of Science and Technology international cooperation projects and key research program, the research council, gathered nearly thousands of Chinese and foreign scholars with the raise data collection, check, jointly compiled covering China and other developing economies multi-scale carbon accounting list and social economy and trade database, and provide free data sharing download for academic research.

ESG level data structure is from the keyword frequency statistics of listed companies, and the annual report source is Juchao Information network. Juchao Information Network is an information disclosure website for listed companies designated by the China Securities Regulatory Commission. It is the first large-scale securities professional website in China to fully disclose the announcement information and market data of more than 2,500 listed companies in Shenzhen and Shanghai. In the process of data processing, this paper excluded ST, ST* and financial industry enterprises, and eliminated the enterprises with missing values and incomplete information, and finally obtained 29,472 annual reports of A-share listed companies.

Data of GDP, industry and urban population are obtained from China Statistical Yearbook; data of foreign direct investment are obtained from China Foreign Economic Statistical Yearbook and China Foreign Economic Statistical Yearbook; agricultural insurance premium income data are obtained from wind database; energy structure is calculated from China Energy Statistical Yearbook; development intensity is calculated from China Statistical Yearbook of Science and Technology and statistical Yearbook of provinces. Limited by data availability and missing values, the provincial panel data for this model spans from 2011 to 2018, with a total of 248 sample sizes.

4.3. Variable construction

⑴ Interpreted variable: ln (CO2 / GDP)

The logarithm of carbon dioxide emissions per unit of GDP. Due to the differences in industrial structure and energy consumption characteristics of different provinces and regions, it is not of economic significance to directly compare the total CARBON dioxide emission intensity, referring to Zhao Rongqin et al. (2010). When carbon dioxide emissions peak, energy consumption per unit of carbon dioxide will decrease, and ESG development plays an important role in promoting this process.

⑵ Enterprise ESG level index: Firmesg and core explanatory variable: Provesg

① Enterprise ESG level index

As mentioned above, there are great differences in the ratings of the same company among different ESG rating companies. Taking China Resources Micro and CNPC as an example, four rating agencies, Wind, Micro, CSI Index and Commercial, gave different results (Appendix Table 1). In order to avoid the difference of results brought by the same text information, as well as the measurement error caused by the subjective factor interference and evaluation framework, this paper chooses to use the text analysis method for quantitative research on the enterprise ESG level.

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In the enterprise level research, many literature adopts text analysis methods based on the descriptive information of the company's annual report (Zhao Chenyu, 2021; Hu Nan et al., 2021; Wu Fei et al., 2021). In the field of sustainable development and corporate social responsibility, many foreign scholars have applied the text mining method (text mining-based analysis).

Modapothala and Issac (2009) used a data mining approach to assess corporate environmental reports based on 10 sustainability criteria (variables), such as the CEO's statement on sustainability, carbon dioxide emissions, human rights, etc. Shahi et al. (2011) developed an intelligent software system that uses machine learning and text classification to analyze and score sustainability reports within the framework of the Global Reporting Initiative. The most relevant study is the 2020 study by Kiriu and Nozaki 2, which divided corporate disclosed information into containing quantitative and qualitative information. In order to solve the evaluation limitations of qualitative information, they developed a text mining model to visualize corporate ESG activities using the word structure related with ESG in CSR reports. Text-mining models process corporate disclosures in a consistent manner, thereby minimizing human subjectivity.

At present, there are multiple types of ESG evaluation frameworks and evaluation systems at home and abroad. Through text analysis of the annual reports of target A-share listed companies, keywords to measure ESG level are constructed and keyword frequency is counted, so as to reflect the ESG development level of enterprises. The specific steps are described as follows:

(I) Refer to the relevant literature to give the range of possible keywords, as shown in Table 1, which can be divided into three categories: environment, society and governance;

(Ii) Climbing the annual report of a-share listed enterprises from 2011 to 2018 from the Juchao Information website;

(Iii) Text analysis and statistics of the word segmentation frequency in the annual report of each company, the total number of statistical keyword word frequency, defined as Firmesg;

(Iv) According to the text partitioning of the corresponding evaluation framework, the Apriori association analysis method was used to select the frequent item set of keywords, narrow the range of keywords, and get the frequent keywords as shown in Table 1. The total number of frequent keyword word frequency, defined as Scrfirmesg.

② The core explanatory variable

Because the carbon accounting data is difficult to obtain at the enterprise level, the data quality cannot be unified, so this paper adds up the micro data to the provincial level, transforms the micro problems to the provincial level, and verifies the research hypothesis. According to the information of $Provesg_{jt}$the registration location of all a-share listed companies provided by wind, the esg keywords of the enterprise are obtained by logarithm by region and year, and it is used to represent the provincial esg development level directly summarized in the t year of the j province.

$$Provesg_{jt} = \ln\left(\sum_{t}\sum_{j} Firmesg_{ijt}\right)$$

In terms of rationality, listed enterprises play a representative role in realizing carbon neutrality and promoting green transformation. Their level can reflect the development level of provincial ESG, that is, the overall level of sustainable development of the province. At present, the industry has also carried out corresponding practices in provincial ESG evaluation, such as the Caixin think tank and the provincial index compiled by Caixin according to the performance of the government and enterprises, and the ESG List of Mainland Cities released

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by Securities Times according to the ESG report of enterprises. The treatment method of this paper has certain practical significance.

At the effectiveness level, the aggregated provincial ESG development level was processed annually in 2011-2018 and visualized using Python. There is a positive correlation between the ESG development level and the level of economic development, and the carbon emission intensity is consistent with the differences in energy structure.

At the technical implementation level, This article collects the annual reports of all A-share listed enterprises of Shanghai Exchange and Shenzhen Exchange from the Juchao Information website through the Python crawler function, And refer to the central university of finance and economics green finance ESG rating criteria, Bloomberg ESG rating, the Shanghai stock exchange listed company environmental information disclosure guidelines, the stock exchange of Hong Kong environmental, social and governance report guidelines, China insurance regulatory commission on strengthening the opinions of banking financial institutions social responsibility, the international organization for standardization ISO26000 the social responsibility guide (2010), Ming sheng (MSCI) ESG index rating guidance, Using the classic Apriori association analysis method in the field of data mining to select important frequent keywords, Therefore, the variables constructed by them can more objectively reflect the ESG development level of enterprises.

③ Controls the set of variables

The existing literature has comprehensively studied the factors affecting the carbon dioxide emission level and emission intensity. This paper refers to Li Kai and Qi Shaozhou (2011) to introduce the level of openness (LnOpen), industrial structure (Indstructure) and urbanization level (Urban).

The above variables mainly target the carbon emissions in industrial production activities. This paper also uses the proportion of agricultural insurance premium income to the total premium income (Agrinsurance) to reflect the carbon emissions level in the agricultural production field. Although the greenhouse gases emitted by agricultural activities are mainly methane and nitrous oxide, and the emission intensity of agricultural activities is lower than that of the whole economic activities, China, as a traditional agricultural country, is necessary to consider the dynamic effect of agricultural production on carbon intensity in research. In agricultural production activities, the development of agricultural insurance has negative effects on agricultural carbon emission density and agricultural carbon emission intensity. Agricultural insurance has the function of dispersing and transferring risks. Through the risk guarantee mechanism, it can enhance the confidence of producers and operators, and enhance the enthusiasm of farmers to improve their technology for low-carbon production (Ma Jiujie, Cui Hengyu, 2021).

In addition, considering the management activities of the public sector, this paper uses the environmental protection capacity building fund (LnFunds) at the corresponding level in the financial expenditure to express the environmental governance efforts of local governments. The environmental protection capacity building funds will be directly invested in the pollution prevention and control platform and related infrastructure construction, which will have a direct impact on the social carbon emission intensity. The investment of government funds has a strong demonstration role, which can explore the emerging industries related to environmental protection and strengthen the environmental awareness of industrial enterprises, so as to encourage industrial enterprises to build a green industrial chain and reduce the energy consumption per unit output.

Table 1. Implications and construction methods of the main variables of Equation I

variable name	Implications and construction method

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Ln(CO2/GDP)	Carbon emission intensity: the log of the ratio of regional carbon emissions to regional GDP
Provesg	Provincial ESG level: the total number of keyword frequency selected by listed companies within the jurisdiction is one logarithm
Provesg2	Squared term of the Provesg
Scresg	Listed companies frequent keyword word frequency of the provincial and regional summary
Scresg2	Scr _ esg
LnOpen	Level of opening-up: the logarithm of actually utilized foreign direct investment
LnFunds	Government governance efforts: the logarithm of the total funds used for environmental protection capacity building at the regional level
Indstructure	Industrial structure: the year-on-year growth rate of industrial added value
Urban	Population structure: urban population proportion
RD	R & D intensity: the ratio of provincial R & D expenditure to GDP

In China's future energy application transformation, the role of technological progress and the combination of industry, university and research will become increasingly prominent. This paper introduces the variable of R & D intensity (RD) to measure the potential of technology upgrading. In the process of industrialization and urbanization, technological progress will change the elastic relationship between economic growth and carbon emissions, change the structure of energy consumption, and improve the energy saving rate per unit output (Lin Boqiang, Liu Xiying, 2010). The above variable names and calculation methods are shown in Table 2.

4.4. Descriptive statistics and scatter plots

Table 3 shows the relevant description statistics for all variables in this paper, and Sumesg is the original provincial summary value when the logarithm was not taken. It can be seen that there are great provincial differences in ESG level and carbon dioxide emission intensity between provinces and cities, and the average ESG at the provincial level is about 9.83. The difference in ESG level is related to the level of economic development in different regions, while the difference in carbon dioxide emission intensity is related to the economic scale, demographic structure and industrial structure.

Table 2. Descriptive statistics of each variable in equation I

Variable	observed value	average value	standard deviation	least value	crest value
lnCO2GDP	248	9.609	0.564	7.903	11.087
Sumesg	248	33700.	44815	2282	314600
Provesg	248	9.832	1.049	7.733	12.659
Scresg	248	8.344	1.016	5.919	10.923
Urban	248	56.133	13.252	22.71	89.6
Agrinsurance	248	6.339	5.503	0.34	24.5
LnFunds	248	11.222	1.181	7.741	15.394
LnOpen	248	12.836	1.719	7.311	15.589
Industructure	248	9.456	5.058	-15.2	22.7
RD	248	1.577	1.111	0.41	6.17

Use Provesg as the horizontal axis and ln (CO2 / GDP) as the ordinate axis. It can be seen that the relationship between ESG level and Ln (CO2 / GDP) is not strictly linear, but inverted U-

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shaped relationship, which is consistent with the hypothesis and subsequent regression analysis.

5. Empirical Results

5.1. Benchmark regression results

This part examines the actual effect of ESG development on provincial carbon emission intensity, and uses regression analysis using equation I to test the hypothesis. Column (1) and (2) of Table 4 report the coefficient estimates after no control variables and inclusion, respectively. The results show that the quadratic term coefficient is significantly negative at 1%, and not changes after adding the control variable; the extreme point is 9.54, within the range of sample data. It can be preliminarily considered that there is a significant inverted U-shaped relationship between regional ESG level and carbon dioxide emission intensity, showing the effect of increasing first and then decreasing, which verifies the research hypothesis of this paper H1. However, this judgment is not rigorous. When the real relationship between ESG development level and regional carbon emission intensity is convex and monotonous, the estimation of model I will mistakenly produce an extreme point and inverted U-shaped relationship.

Table 3. Equation I benchmark regression results

explained variable	lnCO2GDP	lnCO2GDP
	(1)	(2)
Provesg	1.212***	1.418***
	(0.287)	(0.359)
Provesg2	-0.0655***	-0.0743***
	(0.0123)	(0.0170)
fixed effect	Y	Y
controlled variable	—	Y
Observations	248	248
Adj R-squared	0.962	0.965

Note: report clustering robust standard error for province-year level in brackets; Table * * *, * * and * are significant at 1%, 5% and 10% respectively, the same below

Referring to Lind and Mehlum (2010), this paper continues to test the above estimated non-monotonic relationship (U test) to investigate whether there is a true inverted U-type relationship in the interval. The null hypothesis is that there is no U-type relationship. The reporting results are shown in Table 5. The calculated extreme points are within the sample interval, and the P value is 0.0189, that is, the null hypothesis can be rejected at 95% confidence level, and the inverted U-type relationship in model I is statistically significant.

The median of ESG development level in the sample was 9.62. Compared with the extreme points, more than 50% of the samples have exceeded the extreme point and are in the right half arc of the inverted U-shaped curve. The higher the level of ESG development level in most provinces in the observation window, the lower the average carbon emission intensity is. At present, China has passed through the "painful period" when the marginal carbon emission effect is greater than the marginal carbon emission reduction effect. The sustainable ability of enterprises and green finance development represented by the ESG concept are giving full play to the role of carbon reduction and emission reduction. Enterprises also need to continue to improve the capacity building of ESG, promote industrial upgrading and energy transformation; the government should formulate supporting financial and fiscal policy tools, improve the supervision mechanism and unified evaluation framework, ensure that the capital

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is invested in green, the target subject and the production behavior, and realize the carbon emission reduction under the synchronous development of ESG.

Table 4. Results of the equation IU type test

Part A: Section test results		
variable	Lower bound	Upper bound
Interval	7.733	12.659
Slope	0.269	-0.462
t-value	2.101	-3.609
P>| t |	0.018	0.001
Part B: Overall U-type test results		
t-value = 2.10	P>| t | = 0.0184	
Extreme point 95% confidence interval: [7.89; 10.87]		

5.2. Robustness test

This section uses multiple methods to test the robustness to verify whether the conclusions of the benchmark model still hold under certain specific model settings.

First, the frequent keyword frequency obtained by correlation analysis is used to replace ESG keyword frequency to construct a new provincial ESG development level variable (Scresg). Compared with the keyword list, frequent keywords obtained based on association rules can more objectively reflect the importance enterprises attach to environment, society and corporate governance.

Second, alternative regression using the new ESG index. CSR score data using Oriental Fortune Choice data instead of the original core explanatory variables. The rationality of this substitution lies in: CSR represents the social responsibility of enterprises, reflects the sustainable development ability of enterprises, and is the core concept of the capital market focusing on business for good; ESG is the further business practice of CSR and the quantification of sustainable development level driven by stakeholders. In terms of data processing, this paper takes the average value of the province where the enterprise is located, and constructs a new provincial ESG development level (CSR) according to the year, and conducts the robustness test.

Table 6 reports the regression results for the above two robustness recommendations. The inverted U-shaped relationship between ESG level and carbon emission intensity remains at the significance level of 1%, which is basically consistent with the results in the benchmark regression, indicating that the results in the benchmark regression are robust.

Table 5: The robustness test

explained variable: ln(CO2/GDP)	Replace it with frequent keywords	Replace it with a social responsibility score
	(1)	(2)
Scresg	0.897***	—
	(0.275)	—
Scresg2	-0.0556***	—
	(0.0165)	—
CSR	—	1.537***
	—	(0.475)
CSR2	—	-0.0796***
	—	(0.0250)
fixed effect	Y	Y

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controlled variable	Y	Y
Observations	248	248
Adj R-squared	0.970	0.605

5.3. Endogeneity analysis and treatment

(1) Endogenicity analysis

To some extent, there is a reverse causality relationship between carbon intensity and ESG level (i. e., vertical bias), and the explanatory variables contain information about the explained variables, that is, the ESG level may indirectly reflect the carbon emission intensity of the province, making the coefficient estimation wrong. Specifically, carbon emission intensity can quantitatively measure the risk of climate change. Provinces with higher carbon intensity will introduce more stringent environmental emission indicators or a more comprehensive economic development evaluation system, which causes enterprises to increase their investment in environmental and social dimensions and improve their ESG performance level.

Moreover, the benchmark equation may also lose the estimation consistency because of the unobservable missing variables. Carbon emission per unit GDP is not only influenced by enterprises, but also affected by unobservable factors, such as individual operators, catering and manufacturing industries, and carbon dioxide emissions; Influenced by regional culture and official characteristics, different regions may have different energy preferences and regulation intensity, these factors will affect economic output and pollution emission. The above factors can not be reflected by the ESG defined in this study, and it is difficult to include them in the regression equation using quantitative methods, but these cases are universal, so the unobserved missing variables cannot be ignored.

(2) Tooling variable method and two-stage regression

Although the time fixed effect and individual fixed effect are controlled in the benchmark regression model, which can eliminate the influence of unobservable factors that do not change with time and with individuals, the endogeneity problem cannot be fully addressed. Due to the sequence correlation of ESG level, the treatment method commonly used in panel data is not suitable for this study. In view of this, this paper chose to use the instrumental variable approach to further alleviate the above possible endogenity and estimate parameters using 2 SLS regression to examine the robustness of the benchmark regression equation I results.

Referring to Hering and Poncet (2014), Chen Shiyi and Chen Dengke (2018), Sun Weizeng et al. (2019), Shi Dan and Li Shaolin (2020), this paper uses the air flow VC_{jt}coefficient () during the observation period of various provinces in China as the tool variable of regional ESG development level. A qualified instrument variable should meet the correlation and extrinsic requirements, that is, related to the endogenous explained variable, can represent the exogenous information in the endogenous variable; unrelated to the random disturbance term, and have an effect on the explained variable through the endogenous variable.

Table 6. Endogenicity analysis

explained variable	The first stage of the return	The second stage of the return
	Provesg	LnCO2/GDP
	(1)	(2)
LnVC	4.699**	—
	(2.226)	—
LnVC2	-0.336**	—
	(0.153)	—
Provesg	—	17.92***

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	—	(2.521)
Provesg2	—	-0.958***
	—	(0.125)
fixed effect	Y	Y
controlled variable	Y	Y
Observations	240	240
Adj R-squared	0.720	0.973
Phase 1 F statistic	196.67	—

In the problem of this study, the air flow coefficient can satisfy the correlation well. In areas with a smaller air circulation coefficient, the greater the monitoring concentration of pollutants, local governments will have incentives to pursue green GDP, and will tend to introduce more stringent policy regulations and comprehensive economic development goals. While paying attention to economic growth, the government will increase its attention to the sustainable development performance of enterprises within its jurisdiction, provide them with corresponding public services, provide more support tools in conjunction with financial institutions, and optimize the system design. Under the guidance of the government's green GDP and the guidance of policies, enterprises will set sustainable development goals, get more support from the government, improve the performance of ESG level, focus on optimizing the performance of environmental dimension, and promote the reduction of individual carbon emissions and energy consumption. Therefore, the action path of air circulation coefficient can be expressed as: "Air circulation coefficient pollutant detection concentration local government green GDP incentive enterprise availability of external resources and environmental binding ESG level carbon emission".

The air flow coefficient also satisfies the exophytic assumption. The air circulation coefficient is only determined by the local geographical environment and meteorological conditions, which is highly exogenous and has nothing to do with human activities such as carbon emissions. Based on the ERA-INTERIM grid meteorological data provided by the European Center for Medium-term Weather Forecast (ECMWF), the ArcGIS software was used to analyze the atmospheric boundary layer height and 10 meters height wind speed from 2011 to 2018, the product of the air circulation coefficient. There is no direct relationship with carbon emission intensity.

Model I actually contains two endogenous variables (Provesg and its square term), and at least two instrumental variables are required to meet the order conditions for subsequent identification. Since the exotics of VC as an instrumental variable has been discussed, the VC square term is used as the second instrumental variable in this paper.

Conduct a two-stage least-squares regression:

$$Provesg_{jt} = \varphi_0 + \varphi_1 LnVC_{jt} + \varphi_2 LnVC_{jt}^2 + \Omega Controls + \lambda_j + \lambda_t + \varepsilon_{jt}$$

$$Ln\left(\frac{CO2}{GDP}\right)_{jt} = \pi_0 + \pi_1 \widehat{Provesg}_{jt} + \pi_2 \widehat{Provesg2}_{jt} + \zeta Controls + \lambda_j + \lambda_t + \varepsilon_{jt} \quad (2)$$

In the first stage of regression, the air circulation coefficient and its square term coefficient are significant, and the F value is greater than 10, indicating that the air flow coefficient meets the correlation hypothesis. In the second stage of the regression, the provincial ESG performance level and its square term were still significant, without a large change in the coefficients, indicating that the regression results of the benchmark model were not caused by endogenous bias.

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6. Further Analysis: Mechanistic Testing and Heterogeneity

6.1. Overall effect: progress in green technology

(1) Model setting and regression

According to the above theoretical hypothesis, the green innovation capacity can directly affect the enterprise emissions at the micro level, and eventually transmit to the carbon emission intensity at the provincial level. Here, the number of green patent application granted is introduced to measure the green technology innovation ability of the enterprise, and it is used as the explained variable to regress the ESG level of the enterprise and its square term, so as to explain the influence mechanism. Set the fixed effect regression equation (3) to verify the hypothesis H2:

$$LnGreeninvent_{it} = \alpha_0 + \alpha_1 LnFirmesg_{it} + \alpha_2 LnFirmesg2_{it} + \theta Controls_{it} + \eta_i + \eta_t + e_{it} \quad (3)$$

Among them, it is the logarithm of the number of green patent invention $LnGreenapply_{it}Firmesg_{it}\alpha_2$ granted, and the data comes from CnOpenData, CSMAR green patent research database and CNRDS database. It is the frequency of ESG keywords disclosed by a single enterprise in a certain year to represent the ESG level of enterprise i in the t year, using its logarithmic form. Controls Is a series of enterprise characteristics, including corporate financial indicators and corporate governance variables, including: enterprise asset scale, TobinQ value, asset-liability ratio, R & D investment (Qi Shaozhou, et al., 2018), proportion of fixed assets, operating income, return on assets, the combination of chairman and CEO, the size of the board of directors (Wang Xin, Wang Ying, 2021). Descriptive statistics of each variable are presented in Appendix Table 3. Table 8 reports the regression results, and the square term coefficient is significantly positive, and the extreme point is 5.94, which is within the sample ESG level, that is, the enterprise has a positive U-shaped relationship between ESG performance level and green technology innovation.

Is U type extreme value point is 5.94, higher than the sample level of ESG average (5.75), namely the most of ESG level of green technology innovation, is still in the early development of the "throes", in the ESG dimension infrastructure investment increase, ESG level gradually increase at the same time, the green technology innovation due to extrusion effect, the ESG index quantitative ability is in the preliminary construction training stage, has not yet reached the efficient profit output level. With the accumulation of enterprise investment in the early stage, the ESG sub-dimension foundation is constantly improved, reaching the extreme value point. At this time, green technology innovation is placed by enterprises to achieve the expectation of reducing environmental pollution, maintain the ESG evaluation level, and enterprises also expect to get corresponding economic benefits. (Yang Dong, Chai Huimin, 2015), there are obvious incentives in green investment and research and development. The improvement of ESG level in the later stage shows a positive correlation with green technology innovation.

Table 7. Model (3) Regression results

explained variable	Greeninvent
LnFirmesg	-0.195**
	(0.0931)
LnFirmesg2	0.0164**
	(0.0340)
fixed effect	Y
controlled variable	Y
Observations	14,083
Adj R-squared	0.782

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⑵ Micromechanism

In terms of more specific mechanism of action, this paper explains the U-shaped influence of enterprise ESG level in green technology innovation from the perspective of politics, resources, technology, cost and stakeholders.

① Before the extreme value point, the enterprises' investment in ESG will have a negative impact and inhibit the green technology innovation of the enterprises

Due to the dual "negative externalities" of the environment (Jia Jun, Zhang Wei, 2014), enterprises lack the incentive to invest in environmental technology, and the market forces have an insufficient impact on the promotion of green technology innovation. Generally, the stock of non-green technology knowledge is larger than that of green technology knowledge. Enterprises still invest a large amount of R & D funds in the innovation of non-green technology, and the path dependence effect will lock in the pollution emissions in economic development (Acemoglu D, 2002). Specifically speaking, the technological innovation is facing the pressure in three aspects.

One is the political pressure. With the corresponding adjustment of the government's environmental policies and the increasing change of investors' ideas, enterprises to maximize profits will consciously maintain the relationship between government and business and expand the space of rent-seeking in order to obtain political connections. Political correlation reduces the transaction cost of enterprises in order to obtain public resources and property rights protection, and helps enterprises to obtain more credit support. (Yu Wei et al., 2012). However, political correlation will form the "political resource curse effect", rent-seeking cost and excessive investment behavior will squeeze out technological innovation investment, and non-market competition reduces the active incentive, which reduces the efficiency of independent innovation of enterprises and intensifies the extensive development (Yuan Jianguo et al., 2015).

Second, resource pressure. Under the constraint of limited resources, enterprises will extract part of the limited resources for social responsibility investment, which will squeeze out other types of expenditure. This "crowding out effect" is more significant for the long periodicity, uncertainty and high adjustment cost of research and development innovation (Shuxin, 2020). In addition, as a sub-dimension of social responsibility and sustainable development capacity, technology research and development has higher opportunity costs compared with other dimensions (such as information disclosure). When allocating resources, enterprise managers are easy to show irrational behaviors such as short-sighted or lazy. Choosing dimensions with smaller risks for investment will also "squeeze out" or inhibit R & D investment.

Third, the cost pressure. On the one hand, the development of ESG requires enterprises to make simultaneous efforts in environmental governance, fulfilling social responsibilities, and building a good governance system, which will consume the resources used to directly improve the economic interests of shareholders, increase additional costs, and reduce the profit space of the company (Qiu Muyuan, Yin Hong, 2019). In the ESG, on the other hand, such factors with strong externality on any spending can not bring monetary benefits for the enterprise, but also make creditors think managers for personal reputation and excessive investment social responsibility, take up the application to the core technology research and development or product innovation upgrade resources, thus produce certain negative effects in the aspect of debt cost (shi, etc., 2017).

② After the extreme value point, enterprises can improve their ESG performance, which is conducive to promoting green technology innovation

One is the technical compensation. When ESG develops to a higher level, the company will increase investment in R & d and innovation, make efficiency improvements and redistribute internal resources. Enterprises have corresponding incentives to cope with the increasingly

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high environmental costs, improve the production process and improve the utilization rate of resources, and actively carry out green innovation, so as to compensate for the green technology research and development that was squeezed out in the early stage. Outside the enterprise, the public sector will use strict and appropriate environmental regulations under the "two-carbon" goal to implement the "Porter hypothesis".

Second, resource compensation. Enterprises with high ESG level convey the signal of sustainable profit and comprehensive risk resistance to the outside, and ESG has become a trust endorsement of enterprises to the society. This signal effect can help enterprises to obtain government support and public recognition, enhance investor confidence, so as to obtain more innovation funds, social relations and political connection resources, in order to maintain a sustainable competitive advantage, enterprises will spontaneously promote technological innovation.

In summary, as shown in the figure below, at the micro level, the green technology innovation of individual enterprises and ESG show a positive U-shaped relationship: before the extreme point, increasing the investment of ESG will increase political, resource and cost pressure, and reduce innovation; after the extreme point, enterprises will obtain political, resource and benefit compensation, and innovation improves. Green technology has a negative correlation between carbon and carbon emissions per unit of GDP, that is, the application of green technology can be produced at a smaller environmental cost, and the carbon emissions of the same unit of output decrease. At the macro level, listed companies, as an important subject of ESG practice, can represent the regional ESG development level on the whole. After the level increases, the provincial ESG level will show an inverted U-shaped relationship with the carbon emission intensity.

6.2. Heterogeneity analysis

This part will explore the heterogeneity at both the macro and micro levels. At the macro level, this paper studies the influence of ESG development on carbon emission intensity under different geographical locations and market levels; at the micro level, it discusses the influence of enterprises with different attributes and sizes on the influence of innovation on carbon emissions per unit output on the basis of ESG level on micro innovation.

(1) Regional differences between the east and the west

Referring to the regional division in the China Statistical Yearbook, the whole country is divided into the eastern and central and western regions. The descriptive statistics of the main variables in the east and west are shown in Table 9, and the visualization results are shown in Appendix Figure 1 and Figure 2. The average level of ESG emission in eastern provinces is higher than that in western provinces, but the average emission intensity of western provinces is higher than that in eastern China, which is consistent with the differences in industrial structure, population density and social and economic development level in China. As an economic bridgehead and technological innovation highland, the east pays attention to green and sustainable development under high economic development level, ESG level is higher, the energy consumption per unit output is lower; the density of energy mining industry and smelting industry in the central and western provinces is higher than that in the east, and the energy use efficiency is insufficient, so the carbon dioxide emission intensity is higher than that in the east.

Table 8. Comparison of the main variables in the eastern, central and western provinces

variable	area	average value	standard deviation	crest value	least value	median
Sumesg	midwest	15083	11026	62125	2282	11834
	east	67549	60693	314600	5241	54220

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CO2/GDP	midwest	20700.94	11587.65	65312.22	6906.651	16499.52
	east	11732.79	6076.331	29556.5	2705.332	10273.79

Table 9 columns (1) and (2) report the regression results of the eastern and central and western provinces, respectively. The results showed an inverted U-shaped relationship between ESG development level and carbon emission intensity in the two subsamples. The inverted U-shaped extreme value point in the eastern province is 8.81, and the extreme value point in the western province is 9.71. In the western region, there are more industries with high pollution and energy consumption, and the development level of green finance is relatively low. In order to realize the inhibitory effect of ESG on carbon emissions, more investment and construction are needed than those in the eastern region.

⑵ Regional marketization level

Regional degree of marketization of ESG development and carbon emission intensity has significant influence, Grossman et al (2004) research shows that strong market competition environment will effectively drive enterprises to follow the market order and attaches great importance to the business relationship, and the mutual competition between enterprises for this follow and value provides the internal guarantee mechanism (OrgZ, 1997). For areas with low marketization, first, the government has relatively stronger environmental control, and the government will pay more attention to the implementation and implementation of the policy goal of reducing carbon emission, and give more social welfare and security to green enterprises; second, the market and related investment institutions will also pay more attention to the performance of enterprises in terms of environmental, social responsibility and sustainability. The tives from the government and the market make enterprises pay more attention to ESG construction, so as to improve the ESG level of the whole province, implement low-carbon environmental protection policies, and finally achieve the policy goal of reducing carbon emissions.

Referring to Zuo Xiang and Li Huiwen (2017), this paper uses the Fan Gang index to measure the marketization process of regions. In the process of data processing, since the index has different base periods from 2008-2016 and 2016-2018, it cannot be directly compared, so the provinces and regions are divided into high marketization areas according to the average value of the index each year. On this basis, the heterogeneity of the regional marketization level is investigated. The definition variable Highmarket, 1 above the mean, indicates a high market area, otherwise 0.

The results of the sub-sample regression are shown in Table 10. In the low-market area, the inverted U-shaped effect of the provincial ESG level on carbon emissions is significant, which is in line with the previous analysis. This is also consistent with the current situation of China. In Ningxia, Qinghai, Gansu and other areas with low market, the industries with high pollution and high energy consumption are intensive, and the carbon emission pressure is large, so the reduction of marginal carbon emission intensity brought by the improvement of ESG development level is more significant.

Table 9. Results of provincial subsample regression

	Eastern provinces and central and western provinces		High marketization and low marketization	
sample book	east	midwest	High marketization	Low marketization
	(1)	(2)	(3)	(4)
Provesg	1.139	1.238***	-0.245	0.921*
	(0.700)	(0.430)	(0.610)	(0.514)
Provesg2	-0.0646**	-0.0637***	-0.00868	-0.0481*

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	(0.0286)	(0.0224)	(0.0235)	(0.0264)
fixed effect	Y	Y	Y	Y
controlled variable	Y	Y	Y	Y
Observations	88	160	117	129
Adj R-squared	0.981	0.968	0.961	0.965

(3) scale

According to Schumpeter's corporate scale hypothesis, innovation activities need to be lasting and institutionalized, while large enterprises can afford r & d projects, and the harvest of innovation results also requires enterprises to have some market control ability. Therefore, large enterprises are significantly better than small and medium-sized enterprises in terms of innovation investment and the quality and quantity of innovation results.

This paper uses the average of total enterprise assets as the basis to distinguish large-scale (d_Size=1) and small and medium-sized (d_Size=0) enterprises. Table 11 reports the results of sample regression. The ESG level of large enterprises and small and medium-sized enterprises have inverted U-shaped and U-shaped effects on enterprise green technology innovation respectively. The extreme points are 5.92 and 5.84 respectively, and the group mean values are 5.758 and 5.755. At present, there is a difference of enterprise size on the impact of ESG level, which plays a role in blocking the green technology innovation of large enterprises, and plays a positive role in promoting small and medium-sized enterprises.

Enterprise scale is small, environmental protection, social responsibility, corporate governance investment is larger, the basic capacity will squeeze out green technology research and development of investment, when ESG level progress and keep stable, small-scale enterprises will take the initiative to improve research and development efficiency to seek competitive advantage, so as to improve the quantity and quality of green innovation output. Large enterprises have perfect governance system and management system, strong ESG basic capacity, high preliminary construction efficiency and less investment; With the increase of enterprise scale, the complex organization system and growing production scale will gradually increase the difficulty of ESG construction, and the input and output of green innovation are affected by various factors, and the efficiency will gradually decrease. It is contrary to the theory of enterprise scale: ① R & D investment intensity decreases and then decreases with the enterprise scale (Jin Lingdi and Chen Guohong, 2001); ② enterprise scale has significant effect on innovation, but the positive relationship of enterprise scale on innovation is mainly reflected in non-state-owned enterprises (Feng Genfu et al., 2021); ③ enterprise technology innovation investment is less than 1, which indicates that the larger the better, and the influence of scale factor is not simple and linear on innovation (Jafferson, 1998).

The impact of enterprise scale on innovation is very significant. Large-scale enterprises can provide more capital and talents, and have more technological accumulation. Compared with small-scale enterprises, they have more innovative advantages. When the scale of an enterprise is close to the level of market monopoly, the enterprise lacks the sense of crisis caused by the pressure of market competition, lack of competitive incentive, reduce the tendency of research and development willingness, and is unwilling to invest capital and energy in technological innovation. In addition, large-scale enterprises have mature and stable product production system and marketing service network, if a product fundamental innovation, may break the structure of the product and production system, make enterprises need to pay extra costs in the production and marketing, enterprise interests temporarily damaged, it may make decision makers to fundamental innovation inertia, thus not put forward higher requirements for innovation output quantity and quality.

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Table 10. Results of enterprise subsample regression

sample book	medium and small-sized enterprises (1)	large-lot producer (2)
LnFirmesg	-0.533***	0.353*
	(0.113)	(0.207)
LnFirmesg2	0.0450***	-0.0303
	(0.0122)	(0.0258)
fixed effect	Y	Y
controlled variable	Y	Y
Observations	12,002	2,014
R-squared	0.771	0.850

7. Conclusion and Recommendations

This paper uses qualitative information to construct ESG development level index through text analysis method, to some extent to avoid the measurement error caused by evaluation subjectivity and evaluation framework differences. Benchmark regression identified an inverted U-shaped relationship between ESG development and carbon emissions, and persisted after robustness regression and endogenous treatment. At present, China has passed the inverted U-shaped inflection point at the average level. The development of ESG level can continue to promote the reduction of carbon emission intensity, and ESG investment and ESG practice can further promote the early realization of the "carbon neutral" goal. Heheterogeneity analysis shows that the ESG development effect of the central and western regions and the low marketization provinces are not consistent: the central and western regions still need to continue to increase investment in sustainable capacity building and play the role of green finance and corporate social responsibility; due to the government environmental regulation and market incentives, ESG can effectively promote carbon reduction, while the low marketization provinces need to further implement relevant policies to promote the improvement of environmental performance in the region. In addition, the scale of enterprises has different effects on the development of ESG. The government should introduce corresponding policies to encourage enterprises to research and develop environmental technologies to avoid green R & D investment being squeezed out.

This paper still has many places to improve: first, change the acquisition and measurement of ESG indicators, further use machine learning method to optimize the statistical results of word frequency, further reduce the subjective intervention, and compare the sample effectiveness with the mainstream rating data; second, further improve the robustness test and mechanism analysis, discuss the development effect of ESG from the two dimensions of energy substitution and energy saving and efficiency improvement; and third, to optimize the time window, expand the sample size, and investigate the effect of ESG on carbon emission intensity after the introduction of "carbon neutral" target is formally proposed.

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