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Environmental Regulation and Corporate Social Responsibility: The Impact of Executive Authority and Equity Concentration Ratio on Technological Innovation

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During the 75th session of the United Nations General Assembly, the Chinese government presented a proposal indicating its commitment to enhance its independent national contribution by implementing robust policies and measures, with the objective of achieving carbon neutrality by 2060. As the main energy consumption and pollutant emission enterprises, manufacturing enterprises should also take the initiative to grasp the opportunity of carbon neutral development and respond to the national call. In addition, technological progress as a potential solution to environmental pollution, how should enterprises promote technological innovation? These problems need further study. In view of this, this study selects 2011-2020 China a-share manufacturing listed enterprises, using fixed effects model, analyse the impact of environmental regulation, corporate social responsibility, CEO Power and equity concentration on corporate technological innovation. Research shows that environmental regulation, corporate social responsibility, CEO Power and equity concentration all have a significant positive impact on technological innovation, CEO Power and equity concentration play a positive moderating role in the impact of environmental regulation and corporate social responsibility on technological innovation.

Keywords: *Environmental Regulation; Corporate Social Responsibility; Technological Innovation; Executive Authority; Ownership Concentration.*

Introduction

Subsequent to the commencement of the reform and opening up in the late 1970s, China initiated notable strides in economic development. The manufacturing economy, as a key driver of economic growth, has experienced substantial expansion in China. Nevertheless, the expeditious growth of the manufacturing sector has also led to grave environmental pollution concerns. In light of heightened environmental consciousness, mounting emphasis has been placed on the ecological problems stemming from the manufacturing industry's growth. The remediation and amelioration of the ecological environment hinge on various means, such as technological advancement, technological transformation, comprehensive utilization and deep processing, dust suppression, energy conservation, emission reduction, social oversight, among others. Among these means, ecological modernization theory posits that environmental problems can be addressed through technological progress, rendering enterprises no longer responsible for pollution production, and enabling technological innovation within enterprises to be considered a potential panacea to environmental pollution (Desheng *et al*., 2021). On the external front, governments across the world have instituted environmental laws and regulations to constrain enterprises' conduct and encourage them to engage in innovative practices to address environmental problems (Shi & Xu, 2018). Moreover, the Porter Hypothesis notes that rational environmental control may effectively stimulate and facilitate enterprises' technological innovation, thereby enhancing their competitiveness (Desheng *et al*., 2021). In addition, as a major energy consumer and pollutant emitter in China, manufacturing enterprises represent a crucial target of environmental regulations (Li & Ramanathan, 2018). Meanwhile, on the internal front, numerous scholars at home and abroad have verified that enterprises can advance sustainable development goals by actively exercising social responsibility and reinforcing technological innovation to maximize the environmentally-friendly development across the whole spectrum of society (Ruan *et al*., 2022). However, some scholars have likewise contended that environmental oversight and corporate social responsibility can have detrimental effects on enterprise innovation (Yang *et al*., 2022; Chu *et al*., 2022). As a result, it is both theoretically and practically significant to appraise the environmental regulation and CSR influence on the technology innovation of manufacturing firms, specifically for the context of China.

Enterprise innovation constitutes a crucial metric for evaluating an enterprise's long-term value, and is a critical factor for its sustained profitability and longevity. It is a multifaceted process, which entails substantial economic input-output, and necessitates a significant number of high-intensity R&D investments. Relative to other investment activities, technological R&D innovation is notably more responsive to the long-term strategic decision-making of enterprises, and exceedingly arduous to secure external financial support due to its complexity, specificity, and the heightened risks, accumulations, and uncertainties of innovation revenues stemming from R&D operations (Han & Fu, 2022). In their capacity as enterprise operators, CEOs serve as the primary planners and architects of enterprise innovation strategies, and are therefore instrumental in making strategic decisions that have a profound impact on

the long-term value of firms (Sheikh, 2019). Notwithstanding, the power distribution among top executives of different enterprises is subject to significant differences, and consequently, not all CEOs possess identical levels of power and influence. In certain enterprises, the CEO is exclusively responsible for rendering strategic decisions, whereas in others, such decisions are made jointly with the board of directors. Researchers, such as Sheikh (2018) (Chiu *et al*., 2021) and Chiu (2021) (Sun & Xia, 2022), assert that a potent CEO can expedite decision-making and promptly adapt to fluctuations in the market environment. Moreover, as proprietors of the enterprise, concentration of shares is linked to greater compliance with environmental legislation and regulations, and a stronger commitment to corporate social responsibility, since major shareholders relentlessly seek to maximize profits, and encourage innovation through socially responsible corporate practices (Bi & Li, 2020). Conversely, other scholars contend that commanding CEOs and top managers are liable to exhibit overconfidence. This inclination often leads to disregarding the counsel of other experienced team members, and engenders an elevated risk of incurring costly errors. Moreover, when factoring in complications such as the expense of technological innovation, they are more likely to impede corporate technological progress (Sun & Xia, 2022). The divergent perspectives of scholars upon effects of Executive Authority and ownership concentration on enterprise technological innovation demonstrate that their impact may be either advantageous or detrimental, and as such, it represents an empirical issue that necessitates testing within a specific context.

In light of China's strategic goal of achieving "carbon neutrality" by 2060, it is urgent for Chinese manufacturing enterprises to prioritize technological innovation to meet environmental protection targets. Against this backdrop, it becomes crucial to assess the environmental laws and policy impact, as well as corporate social responsibility, on promoting technological innovation within the Chinese management context. Additionally, this study seeks to explore the function of Executive Authority and ownership concentration in affecting technological innovation, and their influence on the correlation between environmental supervision, CSR, and technological innovation.To address these issues, the present study focuses on the following four parts: first, the theoretical analysis and assumptions of the relationship between environmental regulation, corporate social responsibility, CEO Power and equity concentration, and technological innovation in enterprises, the second is to build a relational model, obtain data, define variables, and the third is to use a fixed-effects model to analyze the impact of environmental regulation, corporate social responsibility, and corporate technological innovation, fourth, we use the proportion of R & D investment to revenue to measure the explained variable, and use the fixed effect model to test the stability. This study deepens the understanding of the impact mechanism of technological innovation in manufacturing enterprises from both external and internal perspectives, and enriches the explanatory power of agency theory in Enterprise Innovation Research from the perspective of corporate governance, it proves that the incentive theory is compatible with the research on the impact of technological innovation of manufacturing enterprises.

Theoretical Analysis and Research Hypothesis

Environmental Regulation and Technological Innovation

The correlation between environmental regulation and technological innovation remains controversial in existing research. Currently, the dominant perspective posits that environmental regulations impede enterprises' technological innovation from a static standpoint. With the expansion of the research scope, some scholars' empirical studies indicate that environmental regulatory measures have a dynamic impact on technological innovation, firstly suppressing and subsequently promoting it. Figure 1 demonstrates two prevailing views among domestic and foreign scholars regarding the influence of environmental regulations upon enterprise technological innovation. The first perspective pertains to the inhibition theory, which suggests that environmental regulations will exert a cost-inhibition impact upon enterprise innovation. This theory is based on the static perspective of neoclassical economics, which maintains that environmental regulation can compensate for market failures, but it also increases the production cost of enterprises. The implementation of green production and the reduction of three wastes, as required by environmental supervision, increase entry barriers, hinder the initial growth for small and medium-sized enterprises with limited capital, thus decrease market vitality (Shu & Zou, 2022). Moreover, environmental laws and regulations entail additional expenses for pollution control by enterprises, resulting in decreased capital investment in production factors such as technology R&D and high-quality labor force, as demand for products and capital increases (Yu & Li, 2021). Hence, environmental laws and regulations exhibit a crowding-out effect on enterprises' technological innovation investment (Jiang *et al*., 2021). Conversely, the incentive theory advocates for the incentive impact of environmental regulation on technology innovation and Porter hypothesis in a dynamic standpoint. It contends that environmental regulation aimed at improving environmental performance represents a potential source of competitive advantage for enterprises by promoting process improvement, increasing production and operations efficiency, reducing compliance costs, and expanding market opportunities. Under environmental supervision, enterprises tend to transform their production mode by reducing resource inputs or enhancing efficiency (Qiu, 2020; Chen & Deng, 2021). Consequently, they improve production compliance, reduce production costs, and even innovate to develop new marketable products. These technological innovations can counterweigh the expense of complying with environmental laws and regulations. Although data availability often impacts the testing of Porter hypothesis, it has been tested by several scholars, especially the hypothesis that environmental supervision stimulates innovation. Utilizing a quasi-natural experiment, Chen Yi Li and Deng Yu Wei (2021) found that the new Environmental Protection Act enhances productivity by reducing the attractiveness of physical capital accumulation, thereby compensating for underinvestment in human capital (Rubashkina *et al*., 2015). Similarly, Rubashkin *et al*. (2019) selected the European manufacturing industry as their research sample and

discovered that appropriate environmental laws and regulations benefit enterprise technological innovation (Daddi *et al*., 2021). Daddi *et al*. (2021) demonstrated that strict environmental regulations positively contribute to investment in high-tech equipment, product innovation, and firm performance (He *et al*., 2019). He *et al*. (2022) employed structural equation modeling based on a questionnaire survey of 220 green manufacturing enterprises in China's Pearl River Delta and revealed no direct environmental regulations impact on green innovation performance (Chen *et al*., 2022). Meanwhile, Chen Hewang (2022) conducted an empirical study using the OLS model and Poisson regression model with panel data of China Shanghai and Shenzhen A-share listed enterprises between 2005 and 2019 to test the positive impact of environmental regulation on enterprise green innovation (Yu & Cui, 2019). The majority of studies conducted domestically and abroad are based on the above two theories and have yielded varying results. The ongoing debate surrounding environmental regulation and technological innovation suggests that the relationship between the two is influenced by the characteristics of the environmental regulation instrument itself as well as the internal and external factors of the enterprises themselves. In addition, scholars have conducted empirical research on the distinctive mechanisms underlying different types of environmental supervision and technological innovation (Su & Zhou, 2019; Ye *et al*., 2018; Yuan & Zheng, 2017). Meanwhile, others have analyzed the role of government intervention (government subsidies and fiscal decentralization) (Wu & You, 2018; Liao & Tsai, 2019) and customer interests (Hu *et al*., 2020) in environmental supervision and technological innovation. Building upon these findings, the below assumptions are put forth:

H1. *Environmental regulation significantly and positively affects on firms' technological innovation*.

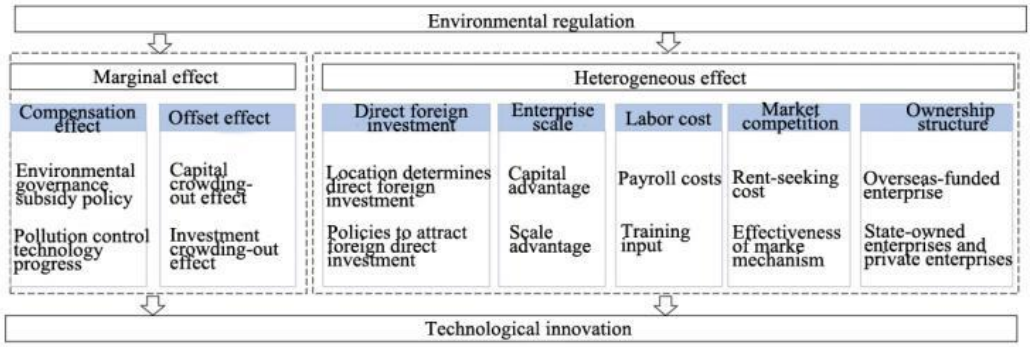

Figure 1. Association between Environmental Regulation and Technological Innovation

CSR and Technology Innovation

In the past three years, social responsibility innovation (RSI) has garnered extensive attention from both foreign scholars and governments. Considered as contributing to sustainable development, technological innovation and corporate social responsibility (CSR) have become focal points in this area (Wu *et al*., 2020) RSI has emerged as a top priority in the European Union's Horizon 2020: Innovation Framework Program Study. Numerous large multinational corporations view technological innovation as a crucial component of their CSR practices, aimed at showcasing their sustainable development advantages. As commercial competition intensifies, innovation has become a critical factor for enterprises' long-term survival (Li & Liu, 2017; Shahzad *et al*., 2020; Lins *et al*., 2017). Developed countries such as the European Union have expressed great interest in technological innovation to maintain their competitiveness in the globalized world economy. The development of new technologies and engineering skills, as well as the demands of consumers, are not the only factors that influence technological innovation. The promotion of CSR in a country or region also plays a crucial role. For a enterprises to achieve success in technological innovation, it must consider its operational impacts upon society and the environment, encourage the creativity of its employees, and collaborate with suppliers, customers, and other business partners to develop innovative products and services. The function of CSR for driving technological innovation has emerged as a significant topic in relevant research fields. Research conducted by Lins *et al*. (2017) on SMEs revealed that enterprises adopt either proactive or reactive models of socially responsible practices and technological innovation (Bacinello *et al*., 2020). Studies indicate that advanced enterprises tend to adopt proactive strategies, which are often accompanied by the highest level of social responsibility practices. Moreover, enterprises that are proactive in their social responsibility are more likely to innovate compared to enterprises that adopt passive social responsibility practices. For enterprises looking to enhance their position in the industry without taking on excessive risks, practicing corporate social responsibility can serve as a starting point for active innovation. Innovation often involves risk, and CSR can be a way to mitigate that risk. For instance, practicing CSR can help enterprises reduce the risk associated with legislation or stakeholders, and support long-term innovation. The positive relationship between CSR and technological innovation is illustrated in Figure 2.

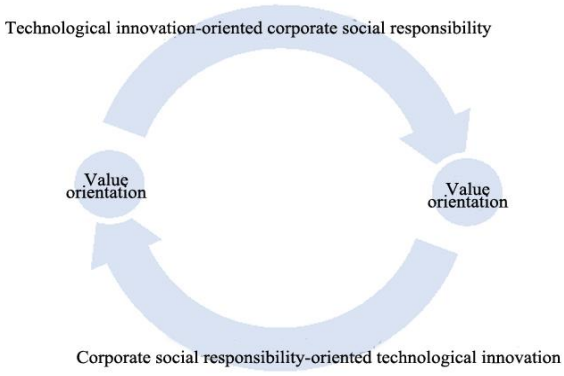

Figure 2. Association between CSR and Technological Innovation

The literature has established the contribution of CSR practices to innovation. Bacinello *et al*. (2020) conducted a study on Brazilian enterprises and demonstrated that the three dimensions of CSR (economy, society, and environment) positively impact sustainable innovation in enterprises (Gallego-Álvarez *et al*., 2011). Briones *et al*. (2018) investigated Spanish agribusinesses and revealed that social responsibility positively affects innovation, with cooperation playing a mediating role in this relationship (Costa & Fonseca, 2022). However, some studies have reported a reversed or unclear relation between CSR and enterprise innovation. Gallego-Álvarezd *et al*. (2011) discovered a reversed impact of CSR on innovation performance by studying enterprises listed in the Dow Jones Sustainability Index. They noted that this impact was influenced by industry (Hu, 2015). Costa *et al*. (2022) conducted a study on enterprises in Portugal and discovered a unclear set of facts upon the impact of CSR concerning innovation (Ding *et al*., 2020). Thus, on which basis, the below hypothesis is proposed:

H2. *CSR significantly and positively affects corporate technology innovation.*

Executive Authority and Technological Innovation

The CEO is commonly recognized as a crucial figure in firm management, responsible for overseeing the day-to-day business activities of the enterprise (Bian *et al*., 2018). According to agency theory, a strong CEO may clash with management and assert their dominance over other managers, potentially affecting the innovation decisions of the enterprises (Zhao *et al*., 2016). However, Upper Echelons Theory argues for the positive role of a strong CEO in enterprise technological innovation. Firstly, a strong CEO holds a significant position in the company, and can use their leadership skills to increase wealth through innovative practices and improve staff member satisfaction and the enterprises' public perception (Hirshleifer et al., 2012). Secondly, enterprise innovation leads to the development of new products, which can automatically expand the scale of the company and its portfolio. In this case, to achieve enterprise innovation, a strong and confident CEO is necessary to make decisive decisions. Additionally, a CEO with professional knowledge can help reduce the risk associated with innovation (Chen, 2014). Hirshleifer *et al*. (2012) support this idea by suggesting that confident CEOs are more willing and capable of investing in corporate research and development (R&D) projects to drive innovation (Galasso & Simcoe, 2011). Chen (2014) conducted a study on listed enterprises on the Taiwan Stock Exchange and found that strong CEOs can encourage board members in investments of corporate innovation (Xu, 2015). Galasso and Simcoe (2011) explored the correlations between CEO overconfidence and innovation, finding that overconfidence are positively related to the number of intellectual property rights (Shi & Gao, 2019). Based on the literature, the below hypothesis is put forth:

H3. *Executive Authority significantly and positively affects corporate technology innovation.*

Ownership Concentration and Technological Innovation

In general, it can be argued that a higher proportion of investment by major shareholders in an enterprise is indicative of a stronger interest in strategies that would maximize the enterprise's value. In this regard, enterprise innovation represents a preferred method for achieving this goal, and thus, major shareholders are likely to endorse and support such innovation practices (Yi *et al*., 2018; Cheng, 2018). When equity is highly concentrated, enterprises often feature a small number of controlling shareholders who are better positioned to negotiate and agree on the strategic direction of the enterprise. As such, they are also more likely to support innovation initiatives by the enterprise. Moreover, in enterprises with high ownership concentration, major shareholders have greater oversight and control over management, which in turn, leads to more effective resource allocation, and provides a range of resources to facilitate the implementation of innovative activities. However, some scholars have highlighted that major shareholders, when allocating resources, may rely on their personal risk preferences to weigh risks and benefits. Consequently, the concentration of company equity can foster a tendency among major shareholders to pursue private benefits instead (Wang *et al*., 2017). In the case of enterprises with centralized equity, investment patterns tend to be more centralized and singular, which prevents major shareholders from effectively dispersing investment risks. As a result, they are more likely to pursue short-term returns, and avoid high-risk and high-uncertainty innovation behaviors, which in turn, can hinder enterprise innovation (Muttakin *et al*., 2018). Building on these observations, the below hypothesis is put forth:

H4. *Ownership concentration significantly and positively affects corporate technological innovation.*

The Moderating Role of Executive Authority

The primary responsibility of the CEO is to manage corporate uncertainties, both internal and external in nature. Internal uncertainty stems primarily from the board of directors and other senior executives, while external uncertainty emanates from the broader external environment of the enterprise. Based on the organizational

structure and legal provisions of the enterprise, the CEO is vested with the necessary authority to ensure that the enterprise's regular business activities are successfully carried out (Xu & Chen, 2022). As the key figure in corporate governance, the CEO consolidates the powers of both the chairman and the general manager, and wields ultimate executive power within the enterprise (Pucheta-Martínez & Gallego-Alvarez, 2021). The level of CEO authority is directly related to his or her level of control over the enterprise, as well as the extent of his or her role and influence in the decision-making process, which decisively affects the continuation and expansion of the enterprise (Zou *et al*., 2021). At present, CSR serves not only as a functional strategy to manage stakeholders but also has the potential to cultivate corporate responsibility competitiveness as a strategic function. The power of the CEO is a critical factor in determining the level of implementation of corporate sustainability strategies, and the CEO's ability to allocate resources and power is crucial to successfully implementing CSR initiatives (Li *et al*., 2018). In particular, CEOs with greater power wield more decision-making authority in determining the direction of resource allocation, which enables them to more effectively address social problems. Moreover, CEOs with accumulated experience can gain insights into potential business opportunities and threats, and identify the business value inherent in social and environmental issues more acutely, allowing them to apply CSR more effectively. In addition, some empirical studies offer supporting confirmation for the relationship between CSR and corporate innovation (Huang *et al*., 2019).

The effect of CSR and environmental supervision can be greatly influenced by a powerful CEO (Cao & Lin, 2019). The CEO's environmental awareness and dedication to sustainable development can stimulate enterprises to actively comply with environmental regulations. In addition, the agent theory endorses the significant function of top management in environmental performance, as executive compensation has been considered the most effective approach to incentivize senior management to achieve long-term sustainability and development goals while adhering to environmental regulations. Compliance with environmental laws and regulations and sustainable development goals is a critical factor for a company's long-term survival and growth, and an authorized CEO is expected to ensure that the organization operates in accordance with these principles. In addition, a CEO who is committed to adhering to environmental laws and regulations can drive technological innovation in enterprises, thereby mitigating the rising costs of pollution control (Xiao, 2016). Moreover, a CEO with greater power is also likely to possess greater knowledge in R&D and exercise more control over the enterprise's innovation projects. As such, a strong CEO with a solid understanding of environmental regulations is essential to drive innovation in enterprises. In general, if a CEO is deeply invested in environmental policies, he or she will exert pressure on the enterprise's management to implement such regulations, which in turn can catalyze innovation (Li *et al*., 2016). Building upon this premise, the following hypothesis is put forward in this study:

H5. *Executive Authority exhibits a positive moderating role in the relationship between environmental regulation and technological innovation.*

H6. *Executive Authority has a positive moderating role in the relationship between CSR and technological innovation.*

The Moderating Effect of Shareholding Concentration

The allocation of enterprise resources and strategic decisions are largely determined by the will and cognition of shareholders, who are the owners of such resources and income. The influence of equity owners varies depending on their respective stakes in the enterprise (Calza *et al*., 2016). As the most fundamental component of corporate governance, the ownership structure significantly impacts the development and management of enterprises. Ownership concentration, which reflects the degree of ownership concentration and controlling power of major shareholders (Liu *et al*., 2019), is a crucial aspect of the ownership structure. Evidence suggests that equity concentration can serve as an important mechanism for enhancing an enterprise's social practices and performance. When major shareholders are committed to investing in environmental governance and social practices, they will monitor the management's adherence to environmental regulations and fulfillment of corporate social responsibility. Calza and Profumo (2016) further underscore the substantial decision-making power wielded by major shareholders, which can determine the extent to which an enterprise engages in environmental and social practices (Hegde *et al*., 2020). Addtionally, minority shareholders primarily seek immediate profits and are less concerned with the enterprise's long-term development, whereas major shareholders prioritize the enterprise's sustained growth and profitability. They are more invested in the environment and social practices, in accordance with the agency theory's assertion that major shareholders play an active role in improving enterprise performance by participating in environmental and social practices. Liu *et al*. (2019) demonstrated that ownership structure positively affects the environmental performance of manufacturing enterprises. Enterprises with higher ownership concentration tend to engage more actively in environmental actions than those with lower ownership concentration (Milosevic *et al*., 1997). The Porter Hypothesis further suggests that enterprises that comply with environmental laws and regulations tend to prioritize environmental concerns more than those that do not engage in such practices. By engaging in environmental practices, enterprises can develop innovation strategies that foster enterprise innovation. On this basis, the following below is put forth:

Moreover, equity concentration has been found to positively correlate with both stock returns and corporate innovation (Wang *et al*., 2021), and incentivizes management to implement environmental protection measures. As major shareholders are primarily focused on long-term profits, they exert pressure on enterprises to engage in social practices. The concentration of stock rights is also an effective means of preserving shareholders' power, as they can partake in enterprise's social practices (Li *et al*., 2022). Based on our understanding, no clear research has delved into the role of ownership concentration in the

correlation between environmental supervision, CSR, and enterprise innovation. Thus, the following hypothesis is proposed:

H7. *There is a positive moderating role of ownership concentration between environmental regulation and technological innovation.*

H8. *Ownership concentration positively moderates the relationship between CSR and technological innovation.*

Research Design

Data Source

The research conducted from 2011 to 2020 is based on an initial sample of manufacturing enterprises publicly traded on A-share in the Shanghai and Shenzhen Stock Exchanges. The choice of manufacturing enterprises is due to the fact that they are subject to more stringent environmental laws and regulations and are obligated to engage in more social responsibility activities compared to other industries. Additionally, listed enterprises in the manufacturing sector tend to disclose more information regarding their production processes and environmental impact, and such data can be easily obtained for research purposes. Moreover, the International Organization for Standardization's ISO 14001 environmental management system certification is a standard that involves third-party certification bodies assessing conformity to the ISO 14001 standard. This certification applies to all types of organizations, including enterprises, institutions, and relevant government entities. ISO 14001 certification is a crucial indicator of an organization's adherence to international environmental management standards, pollutant treatment processes and can help establish a positive social image for the enterprise. Consequently, the study manually screened for A-share listed manufacturing enterprises that had received ISO 14001 certification, as these enterprises are likely to be more impacted by environmental regulations. In addition, the sample was screened according to the following criteria: (1) enterprises in delisting, suspension, and termination of listing; (2) enterprises with missing data and changing rights and interests. Finally, the study recorded an effective sample of 748 enterprises, resulting in a total sample size of 7480.

Definition of Variables

Explained Variables

The technological innovation of enterprises in this study is determined by the amount of patent applications. Firstly, the patent data of enterprises is registered and published using the Patent Cooperation Treaty (PCT), which is internationally accepted, in the China National Intellectual Property Administration (SIPO) patent database. This ensures the consistency and comparability of patent data. Secondly, the number of enterprise patent applications is a commonly used statistical indicator that reflects domestic and international innovation (Sun *et al*., 2022). This indicator suggests the substantial innovation achievements of enterprises and more accurately reflects the final outcomes of their R&D activities (Li & Yu, 2018). Sun Zhongjuan *et al*. (Chen *et al*., 2021) and Li Chuyang and Yu Minggui (Zhang *et al*., 2019) have explored this measure in their research on innovation. Additionally, the amount of patent applications is classified into categories of: invention, utility model, and design. This study considers the sum of these patent applications to investigate the innovation output behavior of enterprises. The distribution of patents is skewed to the right, and the natural logarithm of the patent number is utilized as the primary innovation index in the analysis. To prevent the exclusion of enterprises with no patents in a given year, the actual value was included in the calculation of the natural logarithm (Dun *et al*., 2021).

Explanatory Variables

This study utilizes the ratio of environmental protection investment to the total assets of enterprises as a means to evaluate their environmental governance behavior. Environmental investment serves as a prompt response to environmental protection decisions that companies can implement in a brief period, following the implementation of environmental regulations, thus objectively reflecting the impact of such regulations on enterprises (Cui & Jiang, 2019). Investment in environmental protection generally encompasses asset-based and expense-based expenditures. Asset-based expenses comprise the expenses incurred in the purchase and refurbishment of pollution control equipment, and the implementation of environmentally-friendly production processes, which are predominantly reflected in the financial statements as "projects under construction". Expense-based expenditures, on the other hand, are those that are reflected in the financial statements as "management expenses" and include costs such as those associated with landscaping, sewage charges, and certification fees for environmental management systems. Environmental policies implemented by local governments vary depending on the actual conditions of different regions and industries. As economic development levels, resource endowment, and ecological conditions differ significantly among regions, the intensity of government environmental control imposed on enterprises may display substantial regional variations (Yan & Kong, 2022). To accurately reflect the environmental regulation situation, this study adopts the approach of Cui Guanghui and Jiang Yingbing (Liu & Wang, 2021) and uses the ratio of environmental protection investment to total assets of enterprises as a metric. CSR is determined by the corporate social responsibility score of Techinform listed enterprises in this study. After considering the objectivity, professionalism, and accessibility of data, the CSR score of Techinform listed enterprises is selected as a measure of corporate social responsibility (Liao *et al*., 2022). Thus, this study uses the CSR score of Techinform listed enterprises as an indicator for evaluation.

Adjustment Variables

To measure the power of the CEO, the ratio between the CEO's annual salary and the combined annual salaries of the

top three executives is adopted in this study. Given the risky and intricate nature of investing in technological innovation, the chief executives make innovative decisions by considering their own interests and the risks associated with decision-making. The CEO's remuneration typically consists of short-term pay, such as salary and bonuses, which may lead to a lack of proper incentive, thereby causing the CEO to abandon the decision to invest in innovation [71]. Finkelstein (1992) also underscored that the higher a CEO's salary, the greater the power they wield within the organization. Besides, Galasso and Simcoe (2011) contended that a CEO's salary level and proportion in the overall top management could reflect their position and role in the top management team. They also posited that this indicator is unaffected by other factors within the industry or enterprise and thus provides a more accurate reflection of the CEO's power relative to other executives. Henceforth, the measure selected to determine the ratio of the annual remuneration of the CEO to the overall annual compensation of the top three executives of the organization is drawn from the empirical research of Liu Dong and Wang Jingda. Similarly, the concentration of equity can be calculated through selecting the shareholding ratio of the top five shareholders, which has been established as a standard indicator in extant literature, and serves to reflect the distribution of the company's equity. Notably, the shareholding ratio of shareholders occupying the topmost positions is used as a judgement criterion. Therefore, drawing on the study of Shilong Liao *et al* [72], the shareholding ratio of the top five shareholders is selected as the metric for measuring ownership concentration.

Control Variables

According to the extant literature on technological innovation in enterprises, the following potential variables that could impact enterprise innovation are controlled:

These variables comprise the size of intangible assets, age of the enterprises, balance sheet ratio, return on net assets, and total asset turnover.

(1) Scale of intangible assets: The measurement of the intangible assets of an enterprise is represented by the natural logarithm of the total value of such assets. This measure serves to reflect the intangible assets of the enterprise, which, in turn, have an effect on the enterprise's investment in technological innovation and patent output. Consequently, in this study, the scale of intangible assets is included in the control variables to test its impact.

(2) The age of an enterprise is defined as the duration between the year of its establishment and the year of analysis, and is considered an indicator of the enterprise's survival. Moreover, the age of an enterprise also often reflects the overall quality of its business management. Empirical evidence suggests that, on one hand, the longer an enterprise has been in operation, the more it is capable of stabilizing its operations and minimizing risks associated with decisions on technological innovation. On the other hand, the extended operation of an enterprise signifies its better overall performance, higher corporate governance standards, and a propensity towards innovative decisions. Thus, in this study, the age of the enterprise is included as a control variable.

(3) The capital-liability ratio of an enterprise represents the proportion of its liabilities to its total assets, which serves as an indicator of its debt level and leverage. In general, when an enterprise has a higher leverage, it faces greater pressure to repay its debts as it borrows more funds, and may be less inclined to allocate significant resources towards expenditures such as technological innovation. Hence, this study incorporates the asset-liability ratio as a control variable for analysis.

(4) Return on equity (ROE) is calculated as the ratio of an enterprise's annual net profit to its shareholders' equity, and serves as a reliable measure of its profitability. In general, higher profitability of an enterprise is perceived positively by shareholders, who may then display a greater inclination towards holding the enterprise's shares for longer periods of time, favoring innovative R&D projects, and investing in the R&D activities of the enterprise. As a result, this study will examine the ROE as a control variable.

(5) The turnover rate of total assets is determined as the ratio of total sales to total assets, which is indicative of the scale of asset investment in relation to sales level, reflecting the business capabilities of an enterprise. Typically, higher turnover rates of total assets signify stronger sales abilities of the enterprise, better returns on asset investments, and greater inclination towards investing in technological innovation. Consequently, the turnover rate of total assets will be examined as a control variable in this study. The detailed specifications of the variables and data sources are presented in Table 1.

Table 1

Variable Structure and Data Sources

Variable type	Variable name	Measurement indicators	Data source
Explanatory variable	Environmental regulation	Environmental protection investment amount/total assets of the enterprise	Annual reports of various enterprises
	Corporate Social Responsibility	CSR rating	Techinform
Explained Variable	Enterprise technological innovation output	Ln (number of patent applications+1)	China Research Data Service Platform (CNRDS): Innovation Patent Database
Moderator variable	Executive Authority	The ratio of CEO's annual salary to the total annual salary of the top three executives of the company	CSMAR Solution: Company Research Series - Governance Structure - Executive Dynamics
	Ownership concentration	Shareholding ratio of the top five major shareholders	CSMAR Solution: Company Research Series - Shareholders - Equity Information

Variable type	Variable name	Measurement indicators	Data source
Control variable	Scale of intangible assets	Natural logarithm of total value of intangible assets	CSMAR Solution: Company Research Series - R&D Innovation of Listed Companies - Financial Situation
	Asset liability ratio	Total liabilities/total assets	CSMAR Solution: Company Research Series - Financial Indicator Analysis
	Return on assets	The ratio of net profit after tax divided by total assets	CSMAR Solution: Company Research Series - Financial Indicator Analysis
	Asset turnover	Total sales/total assets	CSMAR Solution - Company Research Series - Financial Indicator Analysis
	Enterprise age	Year t minus year of establishment of the enterprise	CSMAR Solution - Company Research Series - Basic Information of Listed Companies

Model Construction

Drawing upon the preceding literature review and the correlation analysis conducted between variables, this study has developed a model, depicted in Figure 3, aimed at investigating the impact of environmental regulation, CSR, executive authority, and ownership concentration on corporate technological innovation.

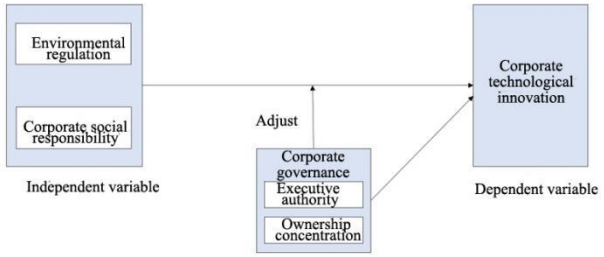

Figure 3. Theoretical Model of Environmental Regulation and CSR Affecting Technological Innovation

Research Methods

This study adopts fixed-effect model to analyze the impact of environmental regulation, corporate social responsibility, executive authority and ownership concentration on enterprise technology innovation. This model was chosen because it can control unobserved heterogeneity that does not change over time, thus reducing missing variable bias. The definitions and measurements of all variables in the model have been described in detail above, and the model setup and estimation methods have been described transparently. In addition, a series of model diagnostic tests were performed, including the Durbin-watson test to detect sequence correlation and the Breusch-Pagan test to assess heteroscedasticity, and Hausman test to determine the applicability of the fixed-effects model and the random-effects model. To ensure the robustness of the results, this article performed a variety of sensitivity analyses and, where possible, used instrumental variables to address potential endogeneity issues.

Descriptive Statistics

This paper sampled 7480 manufacturing firms publicly trade on A-share in Shanghai and Shenzhen stock markets for analysis of descriptive characteristics of key variables. The statistical analysis in Table 2 demonstrates that the average number of patent applications for the entire sample is 3.375, where the minimum and maximum values are 0 and 9.591. These results indicate that the technological innovation capability of listed manufacturing enterprises varies significantly and is relatively dispersed, with most enterprises having a low level of innovation capability. The average environmental adjustment of the entire sample is 0.0008, where the minimum and maximum values are 0 and 0.629. This suggests that the environmental protection investment level of listed manufacturing enterprises is inadequate and requires improvement. Furthermore, there exists significant variation in the importance of environmental protection investment by different listed manufacturing enterprises, with most enterprises having a low level of investment. The results reveal that the minimum score of corporate social responsibility is -13.86, while the maximum score is 90.87. These scores illustrate the significant differences among listed manufacturing enterprises in fulfilling corporate social responsibility. The average score of corporate social responsibility is 25.05, which is far below the passing level. This finding indicates that the development of corporate social responsibility of listed manufacturing enterprises is unbalanced. The average value of the CEO's power for the entire sample is 0.411, where the minimum and maximum values are 0.333 and 1. This finding suggests that the CEO's power in listed manufacturing enterprises is generally significant, and some enterprises are under the complete control of the CEO in terms of management decision-making power. The average ownership concentration for the entire sample is 51.30, where the minimum and maximum values are 6.908 and 94.05. The above result exhibits that the equity of listed enterprises in the manufacturing industry is generally concentrated.

Table 2

Descriptive Statistics

Variable	Observations	Average value	Minimum value	Maximum value
Y	7480	3.375	0	9.591
X_1	7480	0.008	0	0.629
X_2	7480	25.05	-13.86	90.87
X_3	7480	0.411	0.333	1
X_4	7480	51.30	6.908	94.05
Z_1	7480	18.97	7.090	23.96
Z_2	7480	17.25	2	39
Z_3	7480	0.428	0.0140	2.471
Z_4	7480	0.010	-72.15	16.89
Z_5	7480	0.682	0.014	8.601

Empirical Analysis

Environmental Regulation and Corporate Technology Innovation

The present study employs a fixed effects model for assessing the impacts by environmental regulations, CSR, and enterprise technological innovation, and the regression findings are presented in Table 3. Based on the first column of Table 3, the coefficient of environmental regulation is significantly positive at the 10 % level of significance, suggesting that the government's implementation of environmental regulations favorably affects the technological innovation level of firms. These findings support the first hypothesis in this paper and the Porter hypothesis, which posits that environmental regulations significantly and positively affect the technological innovation of enterprises. While the enactment of environmental laws and regulations by the government may result in additional expenditure on pollution control by enterprises, the adoption of innovative production methods under environmental regulations may enhance production compliance, reduce production costs, and even facilitate the creation of new marketable products, thereby offsetting the compliance cost of environmental regulation.

Table 3

Regression Results of Environmental Regulation, CSR and Corporate Technological Innovation

	(1)	(2)
X_1	1.296*	
	(1.77)	
X_2		0.00212***
		(2.98)
Z_1	0.268***	0.313***
	(11.14)	(21.89)
Z_2	0.0213***	0.00439
	(2.95)	(0.91)
Z_3	-0.229	-0.0506
	(-1.46)	(-0.51)
Z_4	0.0129	0.0160**
	(0.91)	(2.38)
Z_5	-0.00995	0.0336
	(-0.15)	(0.69)
_cons	-2.529***	-3.068***
	(-5.66)	(-11.80)
Annual fixed effect	control	control
Individual fixed effects	control	control
Observations	7480	7480
R^2	0.829	0.806

*Note: The values in parentheses are t; *, **, *** represents the significance levels of 10 %, 5 %, and 1 %, respectively*

Corporate Social Responsibility and Technological Innovation

Based on the findings in the column 2 of Table 5.3, CSR exhibits a statistically significant positive impact at the 1% level of significance. This implies that enterprises that proactively engage in corporate social responsibility initiatives are likely to enhance their technological innovation capabilities. These results lend support to the second hypothesis of this study, which posits that corporate social responsibility has a significant positive effect on enterprises' technological innovation. Consequently, enterprises that embrace social responsibility are more inclined to adopt innovative strategies and are thus more likely to innovate compared to those that only undertake social responsibility in a passive manner. For enterprises, the adoption of corporate social responsibility practices helps to address stakeholders' demands, fosters communication and connectivity between enterprises and various parties, enhances the accumulation of corporate social capital such as markets, talents, and capital, and provides a motivational support and resource base for conducting technological innovation. Regarding the control variables, the scale of intangible assets is positively significant at the 1 % level of significance, indicating that the greater the intangible assets of an enterprise, the more it contributes to its technological innovation capability. Moreover, the turnover rate of total assets is also positively significant at the 5% level, implying that faster turnover of production and operation funds leads to better utilization rates of funds and, in turn, strengthens the technological innovation abilities of enterprises.

Executive Authority and Enterprise Technological Innovation

This study adopts a fixed effects model for appraising impacts of Executive Authority and ownership concentration on technologiy innovation within enterprises. The regression outcomes are presented in Table 4. Based on the first column of Table 4, the coefficient for Executive Authority is positive, but insignificantly so, thereby suggesting that Assumption 3 is invalid. Although the CEO is an essential executive of the enterprise, possesses ultimate executive power, and is involved in decision-making on company matters, his impact on technological innovation is not significant. The CEO is also subject to interference and supervision by shareholders and the board of directors, and as such, their preferences should be considered.

Table 4

Regression Results of Executive Authority, Ownership concentration ratio and Enterprise Technological Innovation

	(1)	(2)
X_3	0.0195	
	(0.12)	
X_4		0.0037***
		(2.68)
Z_1	0.317***	0.312***
	(22.04)	(21.75)
Z_2	0.00131	0.00494
	(0.28)	(1.01)
Z_3	-0.0791	-0.0427
	(-0.79)	(-0.42)
Z_4	0.0161**	0.0169**
	(2.39)	(2.52)
Z_5	0.0373	0.0589
	(0.76)	(1.21)
_cons	-3.023***	-3.217***
	(-11.24)	(-11.83)
Annual fixed effect	control	control
Individual fixed effects	control	control
Observations	7480	7480
R^2	0.806	0.806

*Note: The values in parentheses are t; *, **, *** represents the significance levels of 10 %, 5 %, and 1 %, respectively*

Ownership Concentration and Enterprise Technological Innovation

According to the findings presented in column 2 of Table 4, the concentration of ownership exhibits a significant positive relationship with the technological innovation ability of listed manufacturing enterprises, with statistical significance at the 1% level. These results corroborate the fourth hypothesis of the study, which posits that the ownership concentration has a considerable positive impact on the technological innovation of firms. In cases where the equity is highly concentrated, the enterprise is typically controlled by a dominant shareholder or a group of major shareholders who exert absolute control. A moderate level of ownership concentration could facilitate decision-making and governance consensus among management. Moreover, as the proportion of shareholders' investments in the enterprise increases, their interest in maximizing enterprise value grows, and enterprise innovation becomes the best means to achieve this goal. Consequently, major shareholders are inclined to support innovative enterprise practices. In enterprises with highly concentrated equity, shareholders are better equipped to supervise and control management, enhance capital allocation efficiency, and provide robust financial backing for innovation activities.

The Moderating Effect of Executive Authority

This study employs the ratio of the CEO's annual salary to the total of the first three executives' yearly salaries as a proxy variable for Executive Authority for assessing impacts by Executive Authority upon the correlation between environmental control, CSR, and enterprise technological innovation, as presented in Table 5. The high Executive Authority company group consists of samples with Executive Authority greater than the average value, while the low Executive Authority company group comprises samples with Executive Authority lower than the average value. The columns 1 and 2 of Table 5 reveal that environmental regulation's regression coefficients are positive in both the high-Executive Authority enterprise group and the low-Executive Authority enterprise group but are statistically insignificant. Therefore, Hypothesis 5 is not supported, indicating that Executive Authority does not exert a significant regulatory effect on the correlation between environmental regulation and enterprise technological innovation. This finding could be attributed to the fact that CEOs, following the implementation of environmental regulations, often resort to end-of-pipe governance decisions instead of prioritizing technological innovation, altering production methods, and adopting environmentally-friendly practices.

Based on the data presented in the third and fourth columns in Table 5, regression coefficient of CSR is positively significant at a 5% level of significance only in the enterprise group characterized by high Executive Authority. Conversely, in the enterprise group with low Executive Authority, the coefficient is positive but not significant. This finding confirms Hypothesis 6, which postulates that a greater Executive Authority results in a more significant impact of CSR on enterprise technological innovation. One possible explanation for this result is that the CEO, when actively undertaking corporate social responsibility, must consider the needs of all stakeholders and adopt a long-term perspective when it comes to R&D and innovation activities. It further suggests that the CEO can function as a capable steward in innovative R&D activities by leveraging their power to facilitate the smooth implementation of R&D projects, effectively address any obstacles in the innovation process, and exert a powerful influence on the technological innovation activities of their enterprise.

Table 5

The Moderating Effect of Executive Authority

	(1)	(2)	(3)	(4)
	Low Executive Authority	**High Executive Authority**	**Low Executive Authority**	**High Executive Authority**
X_1	1.475	0.511		
	(1.25)	(0.51)		
X_2			0.00120	0.00181**
			(0.93)	(2.02)
Z_1	0.249***	0.195***	0.286***	0.278***
	(8.66)	(3.73)	(9.13)	(15.16)
Z_2	0.0296***	0.0112	-0.00956	0.0125**
	(3.24)	(0.82)	(-1.06)	(2.05)
Z_3	-0.149	-0.251	0.172	-0.0209
	(-0.72)	(-0.83)	(0.89)	(-0.16)
Z_4	0.0177	-0.133*	0.0124	0.0185**
	(1.17)	(-1.86)	(1.08)	(2.23)
Z_5	0.00205	-0.0589	0.342***	0.00304
	(0.02)	(-0.38)	(3.38)	(0.05)
_cons	-2.300***	-1.019	-2.662***	-2.482***
	(-4.25)	(-1.07)	(-4.68)	(-7.44)
Annual fixed effect	control	control	control	control
Individual fixed effects	control	control	control	control
Observations	4987	2493	2426	5054
R^2	0.838	0.874	0.840	0.819

*Note: The values in parentheses are t; *, **, *** represents the significance levels of 10 %, 5 %, and 1 %, respectively*

The Moderating Effect of Ownership Concentration

The present paper employs the shareholding ratio of the top five shareholders as a proxy variable for ownership concentration. Samples with ownership concentration higher than the mean are categorized as the high ownership concentration group, while samples with ownership concentration lower than the mean are classified as the low ownership concentration group, to investigate the impact of ownership concentration on the linkages between environmental regulation, CSR, and corporate technological innovation, as depicted in Table 6. The results presented in the columns 1 and 2 of Table 6 reveal that the regression coefficients of environmental regulation are positive but statistically insignificant in both the high and low ownership concentration groups of enterprises. These findings suggest that ownership concentration does not significantly moderate the impact of environmental regulations on enterprises' technological innovation, thereby rejecting Hypothesis 7. One possible explanation for this result is that,

following the introduction of environmental regulations, major shareholders may prefer to allocate resources towards pollution control measures rather than focusing on enhancing the technological innovation capabilities of their enterprises to address environmental concerns at the production level.

The results presented in the columns 3 and 4 of Table 6 reveal that the regression coefficient of corporate social responsibility is significantly positive at a 1% level of significance in the high ownership concentration group, while it is positive but not statistically significant in the low ownership concentration group. This empirical finding provides support for Hypothesis 8, suggesting that higher ownership concentration strengthens the link between CSR and technological innovation. One possible explanation for this finding is that major shareholders, who hold significant ownership stakes in the enterprise, tend to focus on the long-term growth and development of the enterprise. They may therefore take a proactive approach towards corporate social responsibility, engage in social practice activities, and promote technological innovation within the enterprise.

Table 6

The Moderating Effect of Ownership Concentration

	(1)	(2)	(3)	(4)
	Low Executive Authority	High Executive Authority	Low Executive Authority	High Executive Authority
X_1	1.650	0.366		
	(1.14)	(0.40)		
X_2			0.00939	0.00272***
			(0.91)	(2.64)
Z_1	0.209***	0.244***	0.339***	0.221***
	(6.59)	(5.72)	(15.98)	(10.05)
Z_2	0.0390***	0.000600	-0.0125*	0.0235***
	(3.62)	(0.06)	(-1.79)	(3.13)
Z_3	-0.0520	0.00394	0.159	0.00337
	(-0.22)	(0.02)	(1.06)	(0.02)
Z_4	0.0127	0.000383	0.0212**	-0.00852
	(0.33)	(0.02)	(2.44)	(-0.71)
Z_5	-0.00746	0.0178	0.160**	0.0653
	(-0.07)	(0.17)	(2.20)	(0.81)
_cons	-1.694***	-1.873**	-3.467***	-1.604***
	(-2.79)	(-2.40)	(-8.87)	(-4.00)
Annual fixed effect	control	control	control	control
Individual fixed effects	control	control	control	control
Observations	3795	3685	3813	3667
R^2	0.846	0.847	0.827	0.825

*Note: The values in parentheses are t; *, **, *** represents the significance levels of 10 %, 5%, and 1 %, respectively*

Premised upon the preceding analysis, this study arrives at the conclusion that environmental regulation is critical in advancing technological innovation in corporations. Furthermore, corporate social responsibility also significantly contributes to this phenomenon, while Executive Authority and ownership concentration act as positive moderating factors. Lastly, ownership concentration has a noteworthy impact on driving corporate technology innovation.

Robustness Test

This study employs the R&D investment to operating income ratio as the explanatory variable to gauge enterprise technological innovation, as opposed to patent application, and utilizes the fixed effect model to conduct calculations. Table 7 presents the regression results. As evidenced in Table 7, both environmental regulation and corporate social responsibility have significantly advanced enterprise technological innovation, which aligns with the previous regression findings. This attests to the comprehensive and robust conclusion of this study.

Table 7

Robustness Test

	(1)	(2)
X_1	4.177***	
	(3.62)	
X_2		0.00667***
		(4.17)
Z_1	-0.0976**	0.0839**
	(-2.38)	(2.35)
Z_2	0.0969***	0.106***
	(5.95)	(7.88)
Z_3	-1.129***	-1.181***
	(-4.40)	(-5.13)
Z_4	-0.000564	-0.0546***
	(-0.03)	(-3.10)
Z_5	-0.974***	-1.779***
	(-8.59)	(-15.58)
_cons	4.695***	2.573***
	(6.00)	(3.96)
Annual fixed effect	control	control
Individual fixed effects	control	control
Observations	7480	7480
R^2	0.839	0.806

Note: The values in parentheses are t; *, **, *** represents the significance levels of 10 %, 5 %, and 1 %, respectively

Conclusions and Recommendations

Conclusion and Discussion

The main cause of environmental issues lies in the market failure resulting from the opportunistic conduct of enterprises. The negative externalities of the environment, coupled with the public nature of goods, impede the definition of property rights, and market mechanisms alone are inadequate to achieve effective supervision. To this end, governments around the globe have established environmental laws and regulations to monitor the behavior of enterprises and address environmental concerns. In light of China's strategic objective of achieving "carbon neutrality" by 2060, it has become urgent for Chinese manufacturing enterprises to realize their environmental protection objectives through technological innovation. However, R&D activities present significant challenges for enterprises, owing to the high investment, slow return, and substantial uncertainty involved. In light of the growing emphasis on social responsibility, enterprises have gradually undertaken social practice activities and fulfilled their social responsibility. Active fulfillment of social responsibility by enterprises not only helps maintain their

reputation and improve external relationships, but also provides the impetus for sustained and healthy development. Therefore, the present paper primarily centers upon studying the impact of environmental regulations as well as CSR on technology innovation within enterprises. Drawing upon relevant literature, this study formulates research hypotheses, and utilizes Chinese publicly traded manufacturing firms on A-share from 2011 to 2020 as its research subjects to explore the relationship and specific impact paths of environmental regulation and CSR on technology innovation. The study finally draws the following research conclusions:

(1) The promotion of enterprise technological innovation is significantly influenced by environmental regulation. Enterprises tend to enhance their technological innovation as a means of adhering to environmental regulations. Upon the issuance of environmental protection laws and regulations by the government, enterprises may adjust their production mode and reduce production costs through technological innovation. This can compensate for the costs of compliance imposed by environmental protection laws and regulations. Additionally, through technological innovation, enterprises may develop end-of-pipe environmental management technologies and proactively utilize environmental regulations as a driving force to achieve leading competitive advantages in environmental technology. Despite influences from environmental regulation upon the technology innovation of enterprises, the positive effects of Executive Authority and equity concentration adjustments are found to be insignificant. Empirical evidence indicates that after implementing environmental regulations by the government, CEOs and major shareholders tend to allocate more resources towards direct investment in end-of-pipe pollution control, as opposed to adopting a production concept that emphasizes the enhancement of the enterprise's technological innovation capability to mitigate environmental pollution at its source.

(2) The contribution of corporate social responsibility to enterprise technological innovation is significant, as enterprises tend to improve their technological innovation capability in order to fulfill their social responsibility. Corporate social responsibility encompasses various stakeholders, including shareholders, employees, and consumers. Through active fulfillment of corporate social responsibility and meeting the expectations of all stakeholders, enterprises can enhance communication and relationships with all parties, cultivate a positive corporate image, integrate social capital such as talent, markets, and capital, and promote technological innovation. Therefore, the active fulfillment of corporate social responsibility is beneficial for enterprises to engage in innovation activities and enhance their technological innovation capability.

(3) The effect of ownership concentration on an enterprise's technological innovation is positive. Specifically, higher levels of ownership concentration are associated with stronger technological innovation capabilities. This suggests that as the proportion of shareholder investment in an enterprise increases, so does their interest in maximizing the enterprise's value and attention to sustainable development, as well as their willingness to support innovative activities. In addition, concentrated equity ownership in enterprises allows shareholders to strengthen management supervision and control, mitigate information asymmetry and agency problems, and ensure accurate implementation of innovation activities. Therefore, enterprises should scientifically design the ownership structure and improve the technological innovation ability.

(4) In the context CSR impacts upon technological innovation within organizations, the effect of concentrated equity on this relationship has been explored. The results indicate that within enterprises characterized by a higher level of shareholder concentration, corporate social responsibility exerts a more robust influence on promoting technological innovation. This finding underscores the heightened interest of major shareholders in the long-term development of the enterprise, which translates into greater involvement in social activities, increased acceptance of corporate social responsibility, and ultimately, enhanced technological innovation capacity.

Research at home and abroad generally believes that environmental regulation is the key factor to promote enterprise technological innovation. Porter (1991) proposed the baud hypothesis that environmental regulation can promote enterprise innovation, which is consistent with the conclusion of this study. However, this study further explores how environmental regulation can promote technological innovation by influencing the internal decision-making process, which is an important supplement to the existing literature. The conclusions of this study are consistent with those of Orlitzky et al. (2003) and McWilliams & Siegel (2001), both of which emphasize the positive impact of CSR on enterprise technological innovation. The innovation is that this study provides a more detailed explanation of how CSR promotes technological innovation by improving corporate social image and market opportunities. This study provides a new perspective on the impact of executive authority and ownership concentration on technological innovation. Although some studies suggest that concentrated ownership may lead to managerial myopia (Shleifer & Vishny, 1986), this study finds that executive authority and equity concentration can promote technological innovation under specific conditions. This indicates that the relationship between internal governance structure and technological innovation may be more complex than the existing literature reveals.

The results of this study are consistent with the existing literature in many aspects, but also provide new insights. Environmental Regulation and CSR implementation are regarded as important factors to promote enterprise technological innovation. Executive Authority and ownership concentration play a complex moderating role in this process, which indicates that the interaction between internal governance structure and external pressure has an important impact on technological innovation. These findings highlight the importance of how firms can innovate through internal governance and external responses in the context of globalization and sustainable development.

Research Suggestions

(1) To address the issue of high energy pollution from homogeneous manufacturing enterprises, the government should enhance environmental propaganda and raise the environmental awareness of business owners and managers. To achieve this, the government must develop environmental laws and regulations to restrain pollution behavior and stimulate a shift in the production mindset of these enterprises. It has been observed that CEOs and major shareholders often respond to environmental laws and regulations by investing in terminal governance. However, while this approach can reduce environmental pollution, it may also add to the financial burden of enterprises, thereby limiting their long-term development prospects. In this context, the government should actively utilize new media platforms to disseminate information related to environmental protection to business owners and managers, with the aim of enhancing their environmental awareness and promoting a paradigm shift in production and development. Such measures can also promote technological innovation within these enterprises.

(2) To enhance technological innovation and promote the progress of society, the government should perfect the incentive system for technological innovation and reinforce the assessment of its incentive effect. Specifically, the government should refine the policies that encourage and support technological innovation, allocate financial resources for R&D activities of enterprises based on their unique characteristics, and enhance the monitoring of government subsidies to ensure they are directed towards technological innovation. In addition, enterprises are urged to engage in fundamental research that is subjected to international peer evaluation, extend the evaluation cycle as appropriate, establish a long-term evaluation mechanism that aligns with industry responsibilities and innovation demands, and promote the technological innovation of enterprises.

(3) The promotion of social responsibility among enterprises should be prioritized by the government. This can be first achieved through the establishment of a CSR supervisory body, which can develop an effective management system and define the areas, contents, and methods of enterprise management. A smooth-running social responsibility management organization system should also be established. Second, the government should accelerate the progress of social responsibility legislation and transform some popular social responsibilities into laws and regulations. This can enhance the binding and standardized behavior of enterprises in fulfilling their responsibilities. Third, the social responsibility report publishing system should be improved, with enterprises being required to regularly compile CSR reports. The report content and treatment should be continuously improved, and a platform for stakeholder participation should be established, along with an improved stakeholder participation mechanism. Finally, new media and other tools can be utilized to encourage enterprises to actively fulfill their social responsibility, and to broaden the channels of social public supervision.

(4) To improve their innovation capability and optimize external relations, enterprises must proactively fulfill their corporate social responsibility. By actively undertaking social responsibility, enterprises can reduce conflicts with stakeholders, enhance employee cohesion, expand their market scale, and promote continuous innovation in products and technologies. Therefore, it is essential for enterprises to shift their focus from being market subjects in economic trade to becoming important subjects of social citizenship, and participate in social services to solve social problems while striving to create comprehensive values of the economy, environment, and society. To achieve this, first, it is crucial for enterprises to change their approach and integrate social responsibility into their corporate strategies and major decisions. They must consider social responsibility fully as they develop growth stratagems while executing critical decisions, factoring in their own objectives as well as needs by other parties involved and the affordability of the environment. Second, CSR should be wholly institutionalized in all facets in business operation, including daily operations and administration. Third, CSR performance should be included in performance appraisals as an important responsibility indicator.

(5) To enhance corporate governance, enterprises should improve their governance structure and rationally allocate the power of the CEO. The CEO's management ability and moral quality should be reasonably evaluated, and background investigation of the CEO should be strengthened to enhance trust in him. In the process of corporate governance, the CEO should be reasonably empowered to enhance his independent decision-making ability and be urged to take the initiative to undertake social responsibility. Additionally, enterprises should promote the CEO to actively carry out technological innovation activities. Given the characteristics of R&D activities, such as high investment, slow returns, and strong uncertainty, the CEO bears greater supervision and management risks. Therefore, enterprises should establish a fault-tolerant mechanism, set up an incentive mechanism during the R&D process, and encourage the CEO to actively implement innovative behavior.

(6) There is a need to improve the ownership structure and rationally distribute ownership. In China's listed manufacturing enterprises, the high concentration of shares has improved the ability of large shareholders to supervise managers and promote long-term development. However, such concentration may also lead to related party transactions that could encroach on the interests of small and medium shareholders. Therefore, it is important to adopt a dialectical approach to equity concentration and formulate a reasonable equity structure. To achieve this, enterprises should consider the actual development and industry characteristics and continuously adjust the ownership structure. Shareholders should be encouraged to focus on technological innovation and promote the long-term development of the enterprise.

Contributions and Prospects

Theoretical Contributions

Firstly, this study deepens the understanding of the impact mechanism of technological innovation in

manufacturing enterprises from both external and internal perspectives, the government promulgates the environmental regulation and other systems to restrict the enterprise behavior, impels it to carry out the innovation behavior actively. Within enterprises, they can contribute to the achievement of sustainability goals by actively implementing social responsibility and promoting technological innovation. Secondly, from the perspective of corporate governance, it enriches the explanatory power of agency theory in the study of enterprise innovation. This study examines the mediating effect of CEO Power and equity concentration on the impact of environmental regulation and corporate social responsibility on technological innovation. Finally, this study confirmed that the incentive theory and the impact of technological innovation of manufacturing enterprises fit well. Although incentive theory and inhibition theory are the main theories of the research on the impact of enterprise environmental regulation and technological innovation, this research has confirmed the innovation research on manufacturing industry, especially when considering the impact of environmental regulation on the technological innovation of manufacturing enterprises, the incentive theory is more suitable.

Research Limitations and Prospects

This study reveals the mechanism of environmental regulation and corporate social responsibility on technological innovation of manufacturing enterprises, but there are still some deficiencies. On the one hand, the study was conducted on China's a-share listed manufacturing companies. In order to prove the universality of the research results, we can consider the research design for other types of enterprises or small and medium-sized enterprises in the future. On the other hand, this study only uses the number of patent applications as the index to measure the technological innovation of enterprises. In the future, we can take into account the technological m & A Behavior of the enterprise and the absorption effect of the technology acquired by the enterprise when we measure the technological innovation of the enterprise.

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