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## The Impact of Executive Academic Experience on Green Innovation in Manufacturing Corporations

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### ABSTRACT

Green innovation, as a sustainable development approach, can synergistically promote high-quality economic and social development. We select China's A-share-listed manufacturing corporations from 2011 to 2021 as the research sample to empirically study the impact of executive academic experience on green innovation in manufacturing corporations. Further, we test the relationship between executive academic experience and green innovation in manufacturing corporations under the mediating role of corporate social responsibility and the moderating role of heterogeneous environmental regulations. The study shows that (1) executive academic experience helps to promote green innovation in manufacturing corporations; (2) executive academic experience is conducive to promoting the fulfillment of social responsibility by manufacturing corporations; (3) corporate social responsibility plays a mediating role between executive academic experience and green innovation in manufacturing corporations; (4) environmental regulation positively moderates the relationship between executive academic experience and green innovation in manufacturing corporations, and both formal environmental regulation and informal environmental regulation positively moderated the promotion of green innovation in manufacturing corporations by executive academic experience.

### KEYWORDS

Green innovation; Executive academic experience; Corporate social responsibility; Environmental regulation

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## 1. Introduction

As an important participant in market economic activities, corporations are an indispensable and important part of social and economic development. The manufacturing industry is an important pillar of China's national economic development. It is also a major energy consumer in the economic operation and the main force responsible for carbon emission reduction. Accelerating the promotion of green innovation in manufacturing corporations is of great significance for the realization of economic structural transformation (Jin et al., 2020). The theoretical category of green innovation was first proposed by Braun (1994) in the concept of Green Technology Innovation (GTI), advocating the realization of resource conservation and environmental protection in the process of production and operation. Green innovation is an innovative activity that focuses on environmental protection and long-term development, involving multiple dimensions such as process, technology, and product, and can minimize environmental impact and maximize economic benefits (Li et al., 2013). This is also an innovative activity for corporations to achieve product design, production, use, and recycling under the guidance of sustainable development goals, oriented towards energy conservation, emission reduction, and product quality improvement (Li et al., 2014). Based on the development needs of manufacturing corporations, this paper uses the main content of green innovation, that is, green technology innovation to define this concept (Qi et al., 2018). Under the background of the era of green development, the requirements for corporation production are increasing day by day. Transformation and upgrading, quality improvement and efficiency increase have become the criteria pursued by many corporations. Undoubtedly, how to promote the green innovation of manufacturing corporations is an important topic to achieve sustainable social and economic development, which deserves special attention.

## 2. Literature review

According to the upper echelon theory (Hambrick & Mason, 1984), the personality traits of corporate executives affect corporate decision-making. Among them, executives with academic experience can use their solid theories to guide their practice, thus helping corporations to make more accurate and effective business decisions and significantly contributing to corporate performance improvement (Jiang et al., 2007). The academic experience of executives is a unique human capital of corporations. Executives who have usually undergone academic experience have strong specialized technical knowledge, which can provide technical support for the formulation and implementation of corporate innovation decisions (Zhu et al., 2017; Yu et al., 2018). Moreover, directors with academic experience are better able to acquire and incorporate useful external knowledge, which is conducive to enhancing the corporate competitive advantage (Audretsch et al., 2006). Academic experience makes executives pay more attention to personal self-worth perception and social responsibility awareness. The environmental awareness of executives is important to the green innovation strategy of corporations (Peng et al., 2015), and the support of executives has a significant role in promoting the environmental innovation activities of corporations (Li et al., 2013). Especially for executives with forward-looking thinking, when the corporation encounters environmental problems, they will take the environmental protection concept as an important idea for corporate development, actively implement green innovation activities, and realize the win-win situation of economy and environmental protection (He et al., 2016). In particular, the academic experience of executives plays a role in the green innovation of corporations. Individual executives can establish a rich social network in institutions of higher learning or scientific research institutions through their academic work experience, strengthening the connection between the company and outside knowledge institutions, bringing important knowledge resources and other social capital to the corporation, which is conducive to the introduction of more complex green products and technologies (Wagner, 2007). This kind of social capital comes from outside the corporation, which is of great significance in promoting the corporation to build an industry-university-research cooperation platform and realize

the corporate green innovation and development (Yin et al., 2023). Other scholars have explored the link between the education level of the executive team and corporate green innovation, and found that the number of executives with academic experience positively promotes corporate green innovation (He et al., 2021). The more educated the executive team is, the more likely they are to choose innovative solutions (Carmen et al., 2005), and the more active the corporation will be in undertaking green innovation activities. However, it has also been suggested that more highly educated executive teams may face problems such as over-analysis, insufficient information collection, and concerns about venture capital (Flood et al., 1997).

Social responsibility, as an important influence on corporate green innovation, has also been studied by numerous scholars. With regard to corporate social responsibility, especially in the manufacturing industry, it helps corporations to formulate and implement innovation decisions based on the guidance of green concepts, and to minimize the negative impacts of environmental pollution and resource waste in the innovation process. Corporations assume environmental responsibility and increase environmental protection investment, although it will increase operating costs, but in the long run, positive social responsibility performance is conducive to the green development of corporations, winning the support of resources from external forces such as the government and environmental protection organizations, which in turn is conducive to the enhancement of the innovation performance of the corporation (Xiong et al., 2020). Specifically in terms of technological innovation, research has found that corporate active fulfillment of social responsibility has a positive promotion effect on technological innovation (Luo et al., 2015). In terms of green innovation, when corporations fulfill their social responsibility, they will take into account the needs and interests of stakeholders in terms of environmental protection and other aspects, which in turn will promote corporate green innovation in order to achieve sustainable development (Wang et al., 2021).

Environmental regulation is an effective means of influencing the green development of manufacturing corporations. In terms of a category of environmental regulation represented by government subsidies, it has been argued that R&D subsidies, as a government policy tool to support innovation, can incentivize corporations to carry out green innovation, and its mechanism lies in the fact that the government encourages corporations to increase their green inputs and actively carry out green innovation research and development activities through the provision of subsidies of financial resources (Bai et al., 2019; Xiang et al., 2022; Wang et al., 2023). High-intensity environmental regulatory pressure will force corporations to carry out more green activities, invest more in environmental attention and resource allocation, and create a good internal and external foundation for corporate green innovation (Berrone et al., 2013; Li et al., 2017). However, some scholars consider that environmental regulation is not conducive to promoting corporate green innovation. Environmental regulation increases corporate environmental investment and operational costs (Testa et al., 2011), making corporate disposable resources less available and crowding out R&D investment (Chintrakarn, 2008). This increases the financial burden on corporations and crowds out available resources for green innovation (Palmer et al., 1995; Petroni et al., 2019), which in turn negatively affects green innovation in corporations (Nath et al., 2010).

To sum up, the existing literature research mainly has the following three characteristics. First, there are abundant studies on the impact of executive academic experience on corporate green innovation, but less attention has been paid to the relationship between green innovation in manufacturing corporations. There is still much exploration space on the role and relationship mechanism of executive academic experience characteristics in green innovation of manufacturing corporations. Second, the fulfillment of corporate social responsibility has been highly valued by scholars, and it is generally agreed that the fulfillment of corporate social responsibility will promote green innovation in corporations. However, corporate social responsibility fulfillment, as a major decision about corporate effectiveness, is directly affected by corporate executive characteristics. We consider that a study

combining social responsibility, executive academic experience and corporate green innovation can further identify the role of corporate social responsibility between executive academic experience and green innovation in manufacturing corporations. Third, research on the impact of environmental regulation on corporate green innovation focuses on two aspects. On the one hand, there is the promotion effect, which believes that environmental regulation will promote the green innovation of corporations. On the other hand, it is the inhibition effect, which environmental regulation will inhibit corporate green innovation. The impact of environmental regulation on corporate green innovation has not yet formed a unified conclusion. In this connection, we will consider the effects of formal and informal environmental regulation on corporate green innovation to enrich the research value.

The possible contributions of this paper are: (1) To explore the driving factors of green innovation in manufacturing corporations from the perspective of executive academic background characteristics, enriching the research on the driving factors of green innovation in manufacturing corporations. (2) Considering the factors of corporate social responsibility and heterogeneous environmental regulation, expanding the mechanism of green innovation in manufacturing corporations from both internal and external aspects. (3) Under the requirements of the national green economy development plan, provide certain ideas for the government to reasonably promote the green and high-quality development of local manufacturing corporations and comprehensively improve the level of green manufacturing of corporations.

The rest of the paper is organized as follows: Section 3 presents the research hypotheses; Section 4 presents the source of research data and model construction; Section 5 presents the empirical analysis process; and Section 6 presents the research conclusions.

### **3. Research Hypothesis**

#### *3.1. The relationship between executive academic experience and green innovation in manufacturing corporations*

According to the upper echelon theory, executives' personal philosophies and personality traits influence corporate decisions and behaviors. Academic experience has a cultivating effect on executives' value concepts, personal qualities, and social network resources, which enables executives to take into account the legitimate rights and interests of various stakeholders, generates a stronger willingness for green development, and enables manufacturing corporations to generate more green innovation activities. Executives with academic experience usually pay more attention to the long-term development of the corporation, formulate long-term plans and strategies to grasp future trends and opportunities (Cho et al., 2017), and then promote the green transformation and innovation of the corporation. Executive academic experience is important for green innovation in manufacturing corporations. Based on the above discussion, the following hypotheses are proposed:

H1: Executive academic experience positively promotes green innovation in manufacturing corporations.

#### *3.2. The relationship between executive academic experience and manufacturing corporate social responsibility*

There is a close relationship between the academic experience of executives and the social responsibility performance of manufacturing corporations. The academic experience of executives in colleges and universities or other scientific research institutions has cultivated their ethical concepts and professionalism, shaped their cognitive and ability imprints, and made them pay more attention to the sustainable development of the corporation, and take into account the environmental and social benefits of the corporate development instead of focusing on

maximizing short-term interests. Academic research work needs to comply with certain ethical norms and codes of conduct and is usually committed to solving social problems and promoting social progress, requiring a high level of social service and dedication, which inadvertently shapes the "moral cognitive imprint" of executives (Cao and Guo, 2020), making the executives more aware of their responsibilities and better able to grasp the relationship between corporate benefits and social benefits. This makes executives more aware of their responsibilities and better able to grasp the link between corporate effectiveness and social recognition. Executives with academic experience are more inclined to integrate ethical norms into the process of business operation and development and will be more proactive in pursuing the performance of social responsibility and the maintenance of public interests (Jiang et al., 2019). Based on this, this study proposed the H2 hypothesis. Next, green innovation in manufacturing corporations is distinguished from general technological innovation, emphasizing that corporations actively explore and utilize sustainable resources such as environmentally friendly technologies, environmentally friendly materials, and clean energy in all aspects of product or service research and development, production, operation, and sales, to achieve energy conservation and emission reduction of corporations through technological change, and to avoid all kinds of negative environmental problems generated by corporations in the process of production and operation (Li, 2017). Corporate development will prioritize economic benefits, but enterprises often harm the interests of other stakeholders in the process of profit-seeking, such as environmental pollution in the production and operation process. By fulfilling social responsibility, corporations can effectively resolve the antagonism between them and other interested parties, thus winning social support for corporate green innovation and building a good foundation of innovation resources (Xiao et al., 2021). Therefore, the social responsibility behavior of manufacturing corporations can, to a certain extent, guarantee the supply of resources for green innovation, alleviate the problem of resource constraints in the process of green innovation, and thus promote the development of corporate green innovation (Xiao et al., 2022). Combined with the above hypothesis H2 the relationship between executives' academic experience and corporate social responsibility performance, and then put forward the hypothesis:

H2: Executive academic experience positively contributes to manufacturing corporate social responsibility fulfillment.

H3: Executive academic experience can promote corporate green innovation by enhancing the social responsibility performance of manufacturing corporations, which means that social responsibility mediates the relationship between executive academic experience and corporate green innovation.

### *3.3. Moderating effects of environmental regulation*

As a kind of formal environmental regulation, market incentive-based regulation is based on government subsidies, which are supported by financial resources to reduce the costs and risks of corporate innovation, to incentivize corporations to carry out green innovation activities. The green development of corporations cannot be separated from the encouragement or supervision of regional government environmental policies, and among multiple environmental regulation tools, government subsidies are a direct and effective environmental regulation policy to incentivize corporate innovation (Wang et al., 2022), which can compensate for innovation inputs and alleviate the innovation risks and operational pressures (Liu et al., 2013). And this effect on corporate academic executives, in their higher moral pursuit, humanistic sentiment, and sense of responsibility, corporations are more willing to use subsidized resources for green activities, which in turn makes the resource pressure on corporate green innovation smaller and the opportunities better, and will further strengthen the willingness and ability of corporate green innovation.

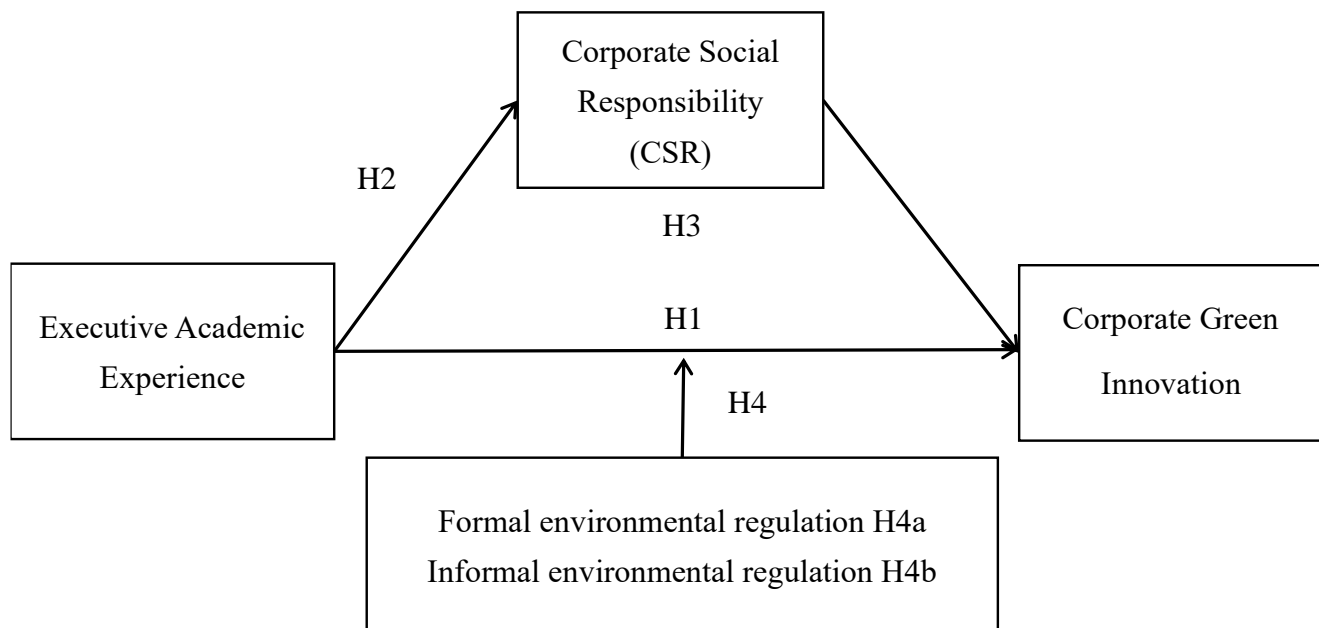
Informal environmental regulation, i.e., media attention can increase the public opinion pressure on executives

of manufacturing corporations, which in turn stimulates the green development of corporations. As an important medium of information transmission between corporations and the public, the externality pressure represented by media opinion dissemination can positively influence corporate green practices (Chen et al., 2018). Inadequate disclosure of corporate environmental information leads to information asymmetry, which can allow corporations the opportunity to engage in environmental speculation, thus exacerbating pollution problems (Su et al., 2021). However, in the age of informatization, media reports are rich in channels and greatly enhanced in influence, which guarantees stakeholders' right to environmental information and enhances the role of the media's reputational mechanism (Tian et al., 2016). Especially for executives who have a high sense of responsibility and morality after being shaped by their academic experiences, this external regulation can strengthen their environmental claims, which in turn acts on corporate green innovation. Therefore the hypothesis is proposed:

H4: Environmental regulation positively moderates the relationship between executive academic experience and green innovation in manufacturing corporations.

H4a: Formal environmental regulation, i.e., government subsidies positively moderates the effect of executive academic experience on green innovation in manufacturing corporations.

H4b: Informal environmental regulation, i.e., media attention positively moderates the effect of executive academic experience on green innovation in manufacturing corporations.



**Figure 1.** Model Assumption Relationship Diagram.

## 4. Data sources and methodology

### 4.1. Data sources

Considering that manufacturing corporations are the key target of pollution prevention and control, and also the important main body of green innovation, this paper selects China's A-share listed manufacturing corporations in Shanghai and Shenzhen from 2011-2021 as the research sample and carries out the following screening process: excluding ST, \*ST and PT company samples, and excluding samples with missing data of key variables. To eliminate the effect of extreme values, all continuous variables are Winsorize shrinkage of 1% above and below. The media attention data on green patents and informal environmental regulations in the paper are obtained from the Chinese

Research Data Service Platform (CNRDS). The CSR data are the data of the social responsibility measurement system of China A-share listed corporation released by Hexun.com. The data on the academic experience of executives, government subsidies of formal environmental regulations, and other corporate data are downloaded from the CSMAR database. The total preprocessed study sample was 14192.

## 4.2. Methodology

### 4.2.1. Variable descriptions

The explained variable in this paper is corporate green innovation (GI). The measurement of corporate green innovation mainly focuses on the number of green patent applications and licenses, considering that the cycle of corporate green innovation is longer, more costly, and more beneficial in the long term, and the number of green patent applications can more effectively reflect the level of corporate green innovation, so this paper chooses the number of green patent applications to measure corporate green innovation, the corresponding number of green patent applications from the database of the Chinese Research Data Service Platform (CNRDS) was obtained to measure corporate green innovation.

The explanatory variable in this paper is executive academic experience (Academic). In this paper, the experience of corporate executive team members who have engaged or are engaged in research and teaching in universities, research institutions, or associations is used as the basis for judging the academic experience of executives. The study uses two metrics: first, the ratio of executives with academic experience (Academic). This metric is set as the percentage of executives with academic experience in the executive team of the corporation. Second, the presence of executives with academic experience (Academic2). It refers to whether at least one member of the corporate executive team has been or is engaged in research and teaching in universities, research institutions, or associations, and if so, Academic takes the value of 1, otherwise, it is 0. Also, the second measure was used as a measure of executive academic experience in the robustness test.

The mediating variable in this paper is corporate social responsibility (LnCSR). Regarding the measurement of CSR performance is mainly CSR ratings from third-party organizations. The CSR performance is measured based on the third-party CSR rating data, Hexun.com CSR scores of listed companies, and their CSR scores are processed by taking the natural logarithm.

The moderating variable in this paper is environmental regulation (ER), which includes formal environmental regulation (FORER) and informal environmental regulation (INFER). Formal environmental regulation (FORER) refers to government subjects, mainly including government subsidies, income tax incentives and other policies, and the government subsidies received by corporations are selected as a measure of this policy in this paper. Informal environmental regulation (INFER) is presented by the media attention of enterprises, and the number of news reports from financial newspapers in the CNRDS database is obtained as the source of media attention. The following variables affecting corporate green innovation are selected to control for in this paper, including Corporate size, gearing ratio, growth capacity, profitability, cash flow ratio, Tobin Q Value, equity concentration, board size, board independence, Age of the corporation, industry dummy variables, and annual dummy variables. The detailed definition of each variable is shown in Table 1.

**Table 1.** Variable definition and description.

Variable Type	Variable Name	Variable Symbols	Variable Description
Explained variable	Green Innovation	GI	Number of Green Patent Applications
Explanatory variable	Executive Academic Experience	Academic Academic2	The proportion of executives with academic experience in the executive team of a corporate Whether there are executives with academic experience in the executive team, set to 1 if there are, set to 0 if not
	Social Responsibility	LnCSR	Natural logarithm of Hexun CSR composite index
Moderating variable	Environmental Regulation	FORER INFER	Natural logarithm of total government subsidies received by the corporation during the year Media Attention
Control variables	Corporate size	Size	Natural logarithm of the total number of employees in the corporation
	Gearing ratio	Lev	Total debt/total assets at the end of the periods
	Growth capacity	Growth	Annual growth rate of total corporate assets
	Profitability	ROA	Net profit / Average total assets
	Cash Flow Ratio	Cash	Net cash flow from operating activities/total assets
	Tobin Q Value	TobinQ	Corporate Tobin Q Value
	Equity Concentration	First	Percentage of shareholding of the largest shareholder
	Board Size	Board	Natural logarithm of the number of board members
	Board Independence	Indep	Ratio of the number of independent directors to the number of board of directors
	Age of the corporation	Age	Natural logarithm of the number of years the corporation has been listed
Industry	Indu	Industry dummy variables	
Annual	Year	Annual dummy variables	

#### 4.2.2. Model Design

Based on the previous discussion and related assumptions, the following model is constructed:

(1) Model of the influence of executives' academic experience on green innovation in manufacturing corporations. To explore the relationship between executive academic experience and green innovation in manufacturing corporations, hypothesis 1 was tested and the model was constructed:

$$GI_{i,t} = a_0 + a_1 Academic_{i,t} + a_2 \sum Controls_{i,t} + a_3 \sum Indu_{i,t} + a_4 \sum Year_{i,t} + \varepsilon_{i,t} \quad (1)$$

(2) Model of mediating effect of social responsibility. To explore the role of social responsibility in the influence of executives' academic experience on green innovation in manufacturing corporations, hypotheses 2 and 3 were

tested and the following model was constructed:

$$LnCSR_{i,t} = \beta_0 + \beta_1 Academic_{i,t} + \beta_2 \sum Controls_{i,t} + \beta_3 \sum Indu_{i,t} + \beta_4 \sum Year_{i,t} + \varepsilon_{i,t} \quad (2)$$



$$GI_{i,t} = \chi_0 + \chi_1 Academic_{i,t} + \chi_2 LnCSR_{i,t} + \chi_3 \sum Controls_{i,t} + \chi_4 \sum Indu_{i,t} + \chi_5 \sum Year_{i,t} + \varepsilon_{i,t} \quad (3)$$

(3) Model of the moderating effect of environmental regulation. To explore the role of environmental regulation in the influence of executives' academic experience on green innovation in manufacturing corporations, hypothesis 4 is tested and the following model is constructed:

$$GI_{i,t} = \varphi_0 + \varphi_1 Academic_{i,t} + \varphi_2 FORER_{i,t} + \varphi_3 Academic * FORER_{i,t} + \varphi_4 \sum Controls_{i,t} + \varphi_5 \sum Indu_{i,t} + \varphi_6 \sum Year_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$GI_{i,t} = \varphi_0 + \varphi_1 Academic_{i,t} + \varphi_2 INFORER_{i,t} + \varphi_3 Academic * INFORER_{i,t} + \varphi_4 \sum Controls_{i,t} + \varphi_5 \sum Indu_{i,t} + \varphi_6 \sum Year_{i,t} + \varepsilon_{i,t} \quad (5)$$

## 5. Empirical results and analysis

### 5.1. Descriptive statistical analysis

In this paper, A-share-listed manufacturing corporations in Shanghai and Shenzhen from 2011 to 2021 are selected as the research sample, and the unbalanced panel data are formed after the screening, elimination, and other related treatments. Table 2 shows the descriptive statistics of the variables.

**Table 2.** Descriptive statistics of variables.

Variable	N	Mean	P50	SD	Min	Max
GI	14192	6.043	1	16.05	0	113
Academic	14192	0.094	0	0.141	0	0.600
Academic2	14192	0.392	0	0.488	0	1
LnCSR	14192	2.993	3.063	0.718	-4.605	4.299
FORER	14192	14.11	15.57	4.953	0	19.95
INFER	14192	3.438	3.332	1.277	0.693	7.587
Size	14192	7.697	7.614	1.126	5.204	10.81
Lev	14192	0.382	0.370	0.194	0.050	0.878
Growth	14192	0.169	0.114	0.345	-0.478	2.075
Cash	14192	0.048	0.046	0.066	-0.144	0.236
TobinQ	14192	2.085	1.671	1.269	0.886	8.744
ROA	14192	0.052	0.045	0.055	-0.221	0.228
Board	14192	2.121	2.197	0.186	1.609	2.565
Indep	14192	0.375	0.333	0.053	0.333	0.571
First	14192	0.343	0.327	0.140	0.091	0.716
Age	14192	1.878	1.946	0.930	0	3.296

As shown in Table 2, the minimum value of the number of green patent applications in the sample of listed manufacturing corporations in China from 2011 to 2021 is 0, the maximum value is 113, the mean value is 6.043, and the standard deviation is 16.05, which means that there are large differences in the number of green patent applications in different corporations and that there is a large gap in the level of green innovation (GI). Meanwhile, the median of 1 shows that the overall green innovation level of China's listed manufacturing corporations is low. The academic experience of executives is processed to form corporate-level data, with a minimum value of 0, a maximum value of 0.6, a mean value of 0.094, and a median value of 0. There are still some differences in the status of the academic experience of executives in different corporations. For Corporate Social Responsibility (LnCSR), the minimum value is -4.605, the maximum value is 4.299, and the average value is 2.993, which indicates that corporations as a whole are more socially responsible, but there are some differences in the performance of social

responsibility among different corporations. In terms of environmental regulation, after processing, the minimum value of formal environmental regulation (FORER) is 0, the maximum value is 19.95, the mean value is 14.11, and the standard deviation is 4.953, which can be seen that there is a big difference in the level of accepting government subsidies among the listed manufacturing corporations in A-shares in Shanghai and Shenzhen; the minimum value of informal environmental regulation (INFER) is 0.693, the maximum value is 7.587, and the mean value is 3.438, which can be seen that different listed corporations in the manufacturing industry receive different degrees of media attention, showing a certain degree of variability in the level of informal environmental regulation. The minimum value is 0.693, the maximum value is 7.587, and the average value is 3.438, which can be seen that different listed corporations in the manufacturing industry are subject to different degrees of media attention, and show certain differences in the level of informal environmental regulation.

### 5.2. Multicollinearity test

To test the problem of multicollinearity among the variables and to ensure the scientific rigor of the results of the next step of the analysis, the Variance Inflation Factor (VIF) test was carried out, and the results are shown in Table 3. As shown in Table 3, the VIF of each variable is less than 3, and the mean value of VIF is 1.48, which indicates that there is no serious multicollinearity problem among the variables, and the next step of analysis can be carried out.

**Table 3.** Multicollinearity test.

Variable	VIF	1/VIF
ROA	2.37	0.42258
Size	2.08	0.48062
Lev	1.79	0.55845
Board	1.61	0.62236
Age	1.6	0.62455
LnCSR	1.56	0.64233
Indep	1.49	0.67157
Cash	1.34	0.74378
INFER	1.32	0.75982
TobinQ	1.27	0.7852
Growth	1.12	0.89487
First	1.08	0.92394
FORER	1.07	0.93328
Academic	1.03	0.97272
Mean VIF	1.48	

### 5.3. Regression Analysis of Executive Academic Experience and Green Innovation in Manufacturing Corporations

As can be seen from the regression results in Table 4, the regression coefficient of executive academic experience on green innovation is 8.885, and it is significant at the 1% level, indicating that executive academic experience has a significant role in promoting green innovation in manufacturing corporations, and this result verifies that H1. The specificity of academic research work and environment shapes academic executives' noble moral concepts and a stronger sense of social responsibility, sense of mission, and humanistic sentiment, which is conducive to the cultivation of their long-term orientation and awareness so that corporations pay more attention to environmental benefits and pursue green innovation. In addition, the academic experience is conducive to the

cultivation of corporate social capital, bringing external heterogeneous information and resources to manufacturing corporations, meeting the needs of innovation and development of manufacturing corporations, providing certain support and guarantee for the formulation and implementation of corporate sustainable development decisions, and promoting the development of corporate green innovation.

**Table 4.** The impact of executive academic experience on corporate green innovation.

	(0)	(1)
	GI	GI
Academic		8.885***
		(0.866)
Size	4.895***	4.872***
	(0.149)	(0.149)
Lev	5.605***	5.971***
	(0.836)	(0.834)
Growth	0.009	-0.061
	(0.371)	(0.370)
TobinQ	-0.071	-0.126
	(0.116)	(0.115)
ROA	16.312***	17.005***
	(2.980)	(2.970)
Cash	-10.243***	-10.129***
	(2.153)	(2.145)
Indep	9.822***	9.003***
	(2.757)	(2.748)
Board	1.391*	0.991
	(0.825)	(0.823)
First	-2.788***	-2.470***
	(0.906)	(0.903)
Age	0.367**	0.521***
	(0.167)	(0.167)
Year_FE	Yes	Yes
Indu_FE	Yes	Yes
Constant coefficients	-40.354***	-40.310***
	(2.529)	(2.519)
N	14192	14192
R <sup>2</sup>	0.221	0.226

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

#### 5.4. Regression analysis of the mediating effect of social responsibility

We test the mediating effect based on the stepwise regression of Wen and Ye (2014), the results are shown in the following Table 5.

As can be seen from Table 5, the test results of model (2) show that the regression coefficient of executive academic experience on the social responsibility of manufacturing corporations is positively significant at the 1% level, which is because academic experience helps cultivate individual noble humanistic sentiment and a strong sense of moral responsibility. Academic research work requires a strong spirit of social service and dedication, and following the corresponding ethical norms, which shape the "moral cognitive imprint" of executives, making them pay more attention to the performance of CSR, and be more aware of the importance of corporate social performance and social acceptance, which in turn promotes the manufacturing industry's CSR behaviors, and the H2 Validated. The addition of social responsibility to model (3) shows that it is positively significant with green

innovation at the 1% level. At the same time, the coefficient of executive academic experience decreases from 8.885 to 8.797, which proves that social responsibility plays a partly mediating role in the mechanism of executive academic experience influencing green innovation of manufacturing corporations, which verifies H3, i.e., academic experience cultivates executives' value cognition and ethical pursuits, strengthens their long-term orientation and sense of responsibility, influences their decision-making about the long-term development of corporations, and strengthens the performance of corporate social responsibility. responsibility performance.

**Table 5.** Regression analysis of the mediating effect of social responsibility.

	(2)	(3)
	LnCSR	GI
Academic	0.100*** (0.035)	8.797*** (0.866)
LnCSR		0.880*** (0.211)
Control variables	Yes	Yes
Year_FE	Yes	Yes
Indu_FE	Yes	Yes
N	14192	14192
R2	0.384	0.227

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

To ensure the test rationality and rigor, the Bootstrap method is used to test the mediating effect of social responsibility again. When the 95% confidence interval does not include 0, it is recognized that the indirect or direct effects significantly exist. Table 6 below shows that none of the confidence intervals include 0, which means that the above mediating effect of social responsibility is established.

**Table 6.** Bootstrap test.

	Observed Coef.	Bootstrap Std. Err.	z	P> z	Normal based [95% Conf. Interval]	
_bs_1	0.094947	0.036297	2.62	0.009	0.023805	0.166087
_bs_2	8.766952	0.983395	8.91	0.000	6.839534	10.69437

Notes: Referring to the test proposed by Wen and Ye (2014).

### 5.5. Regression analysis of the moderating effect of environmental regulation

The moderator variables heterogeneity environmental regulation and its interaction terms with executive academic experience Academic\*FORER and Academic\*INFER were added to the model, respectively. According to the regression results in Table 7, the regression coefficients of the interaction terms Academic\*FORER and Academic\*INFER with green innovation (GI), were significantly at the 1% level positively correlated. It indicates that the moderating effect of formal and informal environmental regulation is established, validating H4a and H4b. This also indicates that the positive moderating effect of environmental regulation on the relationship between executive academic experience and green innovation in manufacturing corporations holds, which in turn validates H4. That is, effective environmental regulation can positively enhance the role of executive academic experience in promoting corporate green innovation in terms of both "resources" and "willingness".

Under formal environmental regulation, corporations are supported by subsidies from the Government. On the one hand, this helps enterprises to overcome the problem of scarce financial resources for green innovation and avoids the situation that manufacturing corporations carry out green innovation but have the intention but not the ability to do so. On the other hand, executives with academic experience cherish the financial resource support from

the government more under the moral pursuit. Under the long-term orientation and sense of responsibility, they are more inclined to actively utilize such financial resources to serve the green development of a corporation and promote its green innovation. Under informal environmental regulation, manufacturing corporations are subject to environmental pressures exerted by media attention and scrutiny. Academic executives, guided by their perceived personal values and ethical pursuits, are more willing to strengthen their environmental claims, safeguard the interests of stakeholders, cooperate with regional policies, and spend more energy on pursuing environmental performance. At the same time, to take into account their reputation and maintain their corporate image, they will also respond to the public's expectations and increase their investment in environmental protection, which will in turn promote the development of corporate green innovation.

**Table 7.** A test of the moderating effect of environmental regulation.

	(1)	(2)	(3)
	GI	GI	GI
Academic	8.885*** (0.866)	8.825*** (0.864)	8.077*** (0.853)
FORER		0.149*** (0.029)	
Academic*FORER		0.940*** (0.169)	
INFER			2.407*** (0.119)
Academic*INFER			4.928*** (0.650)
Control variables	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes
Indu_FE	Yes	Yes	Yes
N	14192	14192	14192
R <sup>2</sup>	0.226	0.230	0.251

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

### 5.6. Robustness and endogeneity tests

To avoid the impact of variable selection bias on the estimation results, we conduct robustness tests on corporate green innovation using the number of green patents granted (GI2) instead of the number of green patent applications, and whether a corporation has executives with academic experience (Academic2) as a measure of executives' academic experience. To avoid the endogeneity problem that may be caused by green innovation in turn affecting executive selection and corporate operation and financial indicators, the explanatory variables and control variables in lag one and lag two are utilized to conduct the test again, respectively.

According to the test results in Table 8, Table 9, and Table 10, the coefficients between the relevant variables in the multiple regression results tables remain significant in accordance with the previous analysis, i.e., the positive facilitating effect of executive academic experience on green innovation in manufacturing corporations, the mediating effect of social responsibility, and the positive moderating effect of heterogeneous environmental regulation have been verified again. Except for the slight difference in the significance level of the coefficients of the relevant variables, the two sets of tests are basically consistent with the previous results, indicating that the findings of this paper are robust and reliable.

**Table 8.** Robustness test.

	(1)	(2)	(3)	(4)	(5)
	GI2	LnCSR	GI2	GI2	GI2
Academic2	1.246*** (0.163)	0.022** (0.010)	1.230*** (0.163)	1.204*** (0.163)	1.116*** (0.160)
LnCSR			0.649** (0.136)		
FORER				0.022 (0.024)	
Academic2*FORER				0.163*** (0.033)	
INFER					1.242*** (0.092)
Academic2*INFER			4.928*** (0.650)		0.917** (0.126)
Control variables	Yes	Yes	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes	Yes	Yes
Indu_FE	Yes	Yes	Yes	Yes	Yes
N	13416	14192	13416	13416	13416
R <sup>2</sup>	0.220	0.384	0.221	0.222	0.247

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

**Table 9.** Endogeneity test-lag one period behind.

	(1)	(2)	(3)	(4)	(5)
	GI	L LnCSR	GI	GI	GI
L_Academic	10.672*** (1.018)	0.115*** (0.038)	10.551*** (1.018)	8.472*** (1.091)	9.565*** (1.003)
L_LnCSR			1.054** (0.247)		
L_FORER				0.427*** (0.055)	
L_Academic*FORER				1.503*** (0.318)	
L_INFER					2.621*** (0.142)
L_Academic*INFER					5.639*** (0.816)
Control variables	Yes	Yes	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes	Yes	Yes
Indu_FE	Yes	Yes	Yes	Yes	Yes
N	11610	11610	11610	11610	11610
R <sup>2</sup>	0.232	0.355	0.233	0.237	0.257

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

**Table 10.** Endogeneity test-lag two periods behind.

	(1)	(2)	(3)	(4)	(5)
	GI	L2 LnCSR	GI	GI	GI
L2_Academic	11.649*** (1.205)	0.104** (0.043)	11.507*** (1.204)	9.306*** (1.369)	10.166*** (1.196)
L2_LnCSR			1.360*** (0.292)		
L2_FORER				0.694*** (0.074)	
L2_Academic*FORER				1.187*** (0.415)	
L2_INFER					2.806*** (0.171)
L2_Academic*INFER					4.895*** (0.993)
Control variables	Yes	Yes	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes	Yes	Yes
Indu_FE	Yes	Yes	Yes	Yes	Yes
N	9375	9375	9375	9375	9375
R <sup>2</sup>	0.236	0.331	0.237	0.244	0.259

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

## 5.7. Heterogeneity analysis

### 5.7.1. Heterogeneity in the character of corporations

The character of the corporation may have an impact on the relationship between executive academic experience and green innovation. Through regression analysis on the sample of state-owned corporations and non-state-owned corporations, the results are shown in Table 11. The study found that the academic experience of executives has a significant positive impact on manufacturing corporations with different characteristics, which means that the academic experience of executives is conducive to the promotion of green innovation behaviors in manufacturing corporations, regardless of whether they are state-owned or non-state-owned corporations.

**Table 11.** Heterogeneity in the character of corporations.

	State-owned	Non-state-owned
	GI	GI
Academic	17.326*** (2.329)	6.689*** (0.842)
Control variables	Yes	Yes
Year_FE	Yes	Yes
Indu_FE	Yes	Yes
N	3902	10289
R <sup>2</sup>	0.313	0.191

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

### 5.7.2. Heterogeneity of dual roles

This paper focuses on the significance of executive academic experience for green innovation, which cannot be separated from the discussion of the tenure of important executives within the corporation. The dual roles are the same, that is, whether the chairman and general manager are the same person, when the relevant executives within the corporation have dual roles, their background concepts tend to have a more direct impact on the development of the corporation. The regression analyses in this paper for the dual roles sample versus the non-dual roles sample are shown in Table 12. It was found that the academic experience of executives is equally contributing to green innovation in manufacturing corporations, and it also confirms the economic importance of the academic experience of the executive team.

**Table 12.** Heterogeneity of dual roles.

	Dual roles	Non-dual roles
	GI	GI
Academic	11.982*** (1.355)	6.870*** (1.133)
Control variables	Yes	Yes
Year_FE	Yes	Yes
Indu_FE	Yes	Yes
N	4420	9772
R <sup>2</sup>	0.283	0.216

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

### 5.7.3. Heterogeneity in the degree of marketization

From the perspective of the institutional environment, executives with academic experience in different institutional environments may differ in their understanding and grasp of the market environment. Combined with

the different degrees of market-oriented green innovation of manufacturing corporations under the corresponding institutional environments, the role of executive academic experience on green innovation of manufacturing corporations needs to be further analyzed. Distinguishing the research sample of this paper into regions with high and low marketization intensity, the regression results are shown in Table 13. The study shows that executive academic experience positively contributes to green innovation in manufacturing corporations in both high and low marketization environments.

**Table 13.** Heterogeneity in the degree of marketization.

	High degree of marketization	Low degree of marketization
	GI	GI
Academic	7.357*** (1.070)	10.868*** (1.470)
Control variables	Yes	Yes
Year_FE	Yes	Yes
Indu_FE	Yes	Yes
N	8696	5496
R <sup>2</sup>	0.241	0.234

Notes: Standard errors are presented in parentheses; \*\*\*, \*\*, and \* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

## 6. Conclusions

Based on the perspective of executive academic experience, this paper selects China's A-share listed manufacturing corporations from 2011 to 2021 as the research sample, empirically investigates the impact of executive academic experience on the green innovation of manufacturing corporations, and tests the relationship between executive academic experience and green innovation of manufacturing corporations under the mediating role of social responsibility and the moderating role of environmental regulation.

(1) The academic experience of executives helps to promote green innovation in manufacturing corporations. After a long period of academic training, executives tend to have higher theoretical literacy, stronger independent thinking ability, and insight and are better able to anticipate and respond to the environment and market changes faced by corporations. As a result, corporate executives will pay more attention to the long-term planning of corporations and promote green transformation and innovation.

(2) The academic experience of executives is conducive to the fulfillment of social responsibility for manufacturing corporations. Long-term academic research experience fosters a high sense of responsibility and mission in individuals, strengthens the ethical norms that executives follow in corporate decision-making, and provides intrinsic motivation for corporations to actively undertake social responsibility, which in turn generates more socially responsible behaviors in corporations.

(3) Corporate social responsibility mediates the relationship between executive academic experience and green innovation in manufacturing corporations, which implies that executive academic experience can contribute to green innovation by strengthening the corporate social responsibility performance of manufacturing corporations. On the one hand, executives with academic experience have sufficient incentives to strengthen their corporate social responsibility behavior, which in turn helps firms clarify the relationship between business development and environmental protection. On the other hand, under the role of a team of executives with rich academic experience, corporations have a stronger social responsibility orientation, and therefore will be more active in social practices and devote more environmental attention and innovative resource allocation to green development.

(4) Both formal and informal environmental regulation positively moderated the role of executive academic



experience in promoting green innovation for manufacturing corporations. Under governmental environmental regulation, executives with academic experience are more inclined to cooperate with the government's environmental policies and cater to the government's theme of green development under the intrinsic drive of moral responsibility perception and the extrinsic pressure of social expectations. Under the informal environmental regulation of media attention, executives with high value perception care more about corporate image and personal reputation, and will avoid the negative impacts of environmental pollution and resource waste on themselves and their corporations, so they are more willing to actively cooperate with the regional environmental policy, increase environmental protection investment, and promote the development of corporate green innovation.

Direction for further research: The mediating mechanism of executive academic experience affecting green innovation in manufacturing corporations needs to be further explored. This paper only explores the mediating role of corporate social responsibility between executive academic experience and corporate green innovation, while there may be other paths for executive academic experience to promote green innovation in manufacturing corporations, and future research can be carried out in terms of financing constraints, and the level of regional Industry-University-Research (IUR).

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## Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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