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# Green innovation dynamics in Chinese manufacturing enterprises: a new institutional and stakeholder theory inquiry

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**Abstract**
While green practices are widely recognized to promote environmental health, the context of 'manufacturing enterprises' green innovation' (MEGI) and the interplay of factors influencing such practices have received limited attention in the literature. This study explored the dominant factors and mechanisms of manufacturing enterprises' green innovation practices in China from the lens of the new institutional and the stakeholder theories. The study utilized hierarchical regression and correlation techniques to analyze dataset obtained from 214 Chinese manufacturing companies. The results of the study show that: (1) green innovation normative and green innovation imitation correlate positively with enterprises' green practices; (2) both innovative resources and capabilities have a strong positive correlation with enterprises' green innovation; (3) pressure from major stakeholders and secondary stakeholders have a moderate positive effect on green innovation; (4) the executives' environmental awareness positively regulates the relationship between green innovation normative and green imitation pressure, innovative resources, stakeholder pressure, secondary stakeholder pressure, and enterprise green innovation; and (5) the interaction between enterprise innovation capabilities and executive environmental awareness has a significant negative effect on manufacturing enterprises green innovation initiatives. Theoretically, the findings of this study deepen the strand of empirical studies on green innovation and build a rigorous foundation for the application of the new institutional and stakeholder theories. The study also proffers practical insights for managerial decision-making on green innovation.

**Keywords** Manufacturing enterprise green innovation · System pressure · Stakeholder pressure · Executive green awareness · China

**JEL Classification** D22 · D23

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## 1 Introduction

Green innovation continues to dominate academic and policy discussions as an effective strategy to reduce carbon emissions, resources consumption, and ultimately achieve environmental sustainability (Jiang et al., 2022; Wang et al., 2022). As a result, green innovation has become a benchmark for enterprises' environmental performance and fast becoming the driving force for inter-enterprise cooperation (Wang et al., 2022). Chinese manufacturers are, therefore, obliged to improve their environmental performance through green systems to remain relevant to keep their market share (Hao et al., 2022). Just what intricate interplay of factors that can guide firms' decision to achieve the optimum benefit of green strategies is not clearly understood in the literature.

The concept of green innovation, otherwise known as sustainable innovation or eco-innovation within the manufacturing industry has been operationalized as strategies and/or practices including adoption of advanced technologies, energy efficient production practices, and environmental sensitive manufacturing policy interventions (e.g., waste recycling) that enterprises integrate in their production lines or processes (Guan, 2017). Simply put, the systematic development and sequential application of new ideas, practices, services, or production policies that significantly improve ecological health (Huai & Lin, 2023; Sun & Chen, 2023; Uyarra et al., 2016).

It has been suggested that green innovation is the most potent way to actualize the 17 Sustainable Development Goals (SDGs), scheduled for 2030 (Ampaw et al., 2023, 2024; Santosh et al., 2023; Xu et al., 2017). With the advent of green production, manufacturing patterns have undergone significant changes. Currently, the survival of manufacturing enterprises is almost tied to their level of green production capabilities (Fan et al., 2022). For instance, the manufacturing industry is facing profound pressures from governments, local and international advocacy groups, as wel as supranational organizations to device innovative mechanisms to reduce their carbon emissions. These regulatory agencies and pressure groups have over the years adopted measures such as imposition of environmental taxes, naming and shaming, export restrictions, and green performance rating schemes to whip firms in conformity to appropriate green production systems (Yuan & Xiang, 2018). As a result, some Chinese firms are gradually losing their market competitiveness to Western competitors with superior green innovative strategies (Zhou et al., 2012; Zhu et al., 2023).

Since, green innovation practices are crucial for companies competitiveness. It is necessary to understand the factors associated with green behaviors of manufacturing companies and how these factors interact to engender economic benefits (Huang et al., 2022). Specifically, understanding the complex dynamics of green innovation pathways is crucial to guide manufacturing enterprises' green innovation activities. Currently, there is not enough studies that explores factors and mechanisms of MEGI. Available studies on green innovation did not systematically analyze the dynamics of corporate green innovation (Jiang et al., 2020; Tian et al., 2022; Xu et al., 2017). Further, the existing literature rarely discusses the association between green innovation and its antecedents. This development has led to a recommendation for comprehensive models for analysis of green innovative practices and mechanisms within firms (Jiang et al., 2020). The current study adopts a two-stage approach of data gathering and analyses to investigate pathways and mechanisms of MEGI in China.

Stage one of the study used qualitative interviews to establish key factors of MEGI among Chinese firms. Subsequently, factors derived from the interview data informed selection of two complementary theories; stakeholder and new institutional models to develop a conceptual framework to test hypothesized associations through a quantitative survey. Thus, based on the new institutional and stakeholders' theories, the current study explores the core influencing factors of green innovation of production firms, using Chinese companies as case analysis. Accordingly, a conceptual model was constructed based on some identified factors such as green target system pressure, organizational factors, stakeholders' pressure, and individual environmental awareness. Later, the interrelationships among these factors were explored.

The contributions of the current study can be seen from the following angles. First, from the institutional level, this is the novel study to explore the associations between green innovation regulatory pressure, social carbon emission standard pressure, and competitor imitation pressure. Second, from stakeholders' pressure level, this is the first attempt to explore the overarching impact of key stakeholder pressure and secondary stakeholder pressure on the MEGI. Third, to the best of our knowledge, this happens to be the initial study to empirically verify the role of senior executives' green awareness in the green innovation schemes of manufacturing enterprises. Therefore, this study deepens the new institutional and stakeholder theories, and expands their application empirically. More specifically, the study throws light on the mechanism of green innovation in the manufacturing industry from both internal and external perspectives. In practice, the study proffers novel mechanisms to design and implement green strategies in manufacturing enterprises in line with the promotion of triple bottom line agenda and green transformation of manufacturing enterprises.

The remainder of the current study is structured as follows. We identified the key influencing factors of MEGI, then review relevant literature and summarize hypotheses in Sect. 2. In Sect. 3, we presented a description of the data and methods of the study. Section 4 provided the data analysis and results of the study. In Sect. 5, we provided a detailed discussion of the results and study implications. The last section highlights the conclusion, limitations, and recommendations for further studies.

## 2 Theoretical framework

This study is underpinned by two popular organization behavioral theories: the new institutional and the stakeholder models. The key assumptions of each theory and how these frameworks together help to achieve the research objectives are discussed below.

### 2.1 New institutional and stakeholder theories

New Institutional Theory (NIT), also known as neo-institutionalism, emerged as a prominent concept in the field of institutional economics and organizational sociology in the late twentieth century. This was in response to the obvious limitations of traditional economic theories that focused entirely on market mechanisms and rational choice theories to explain organizational behavior (Guarnieri et al., 2023; Hussain et al., 2023; Santosh et al., 2023). Structurally, the NIT examines how institutions (i.e., formal and informal rules), norms, and structures, collectively, shape organizational outcomes and behaviour. It emphasizes on how organizations strategically respond to institutional constraints and pressures.

The Key features of the NIT include emphasis on institutional environments, the concept of isomorphism (i.e., convergence of organizational practices), the role of both formal and informal rules, and the distinction between institutional pillars—i.e., normative, regulative, and cognitive (Guarnieri et al., 2023; Santosh et al., 2023; Quynh et al., 2022). The NIT is premised on the following assumptions: (1) Organizations strive to attain normative, regulative and cognitive legitimacy within their institutional milieus. (2) Organizations are characteristically influenced by coercive, normative, and mimetic pressures, and (3) institutions are relatively stable but are likely to change over time (Guarnieri et al., 2023; Hussain et al., 2023; Zhang & Tu, 2022).

The stakeholder theory, on the other hand, is a framework that delineates organizational management and decision-making by emphasizing on the need to consider the interests of all stakeholders who are affected by the actions of an organization (Baah et al., 2023; Sena et al., 2023; Zhang et al., 2021). In particular, the stakeholder theory suggests that organizations should not focus entirely on maximizing shareholders' wealth but also should take into account the interests and expectations of other concern groups including, customers, communities, employees, suppliers and the environment.

The key features of the stakeholder theory are: (1) the identification of various stakeholders, (2) recognition of the diverse interests and power of stakeholders, (3) the focus on the symbiotic relationships between organizations and stakeholders, and (4) the notion of stakeholder salience (i.e., the hierarchical importance of stakeholders to an organization) (Griffith, 2009; Sena et al., 2023; Zhang et al., 2021). Moreover, the stakeholder theory is rooted in the assumptions that organizations exist in a structured network of relationships with stakeholders, stakeholders have legitimate claims on the organization, and organizations balance stakeholders' interests to achieve long-term success (Baah et al., 2023; Jiang et al., 2022; Kum et al., 2023).

The selection of these theories to guide this study was based on their overall common assumptions and perspectives (To be discussed next). Despite the commonalities between the two theories, there are notable differences between them. These are: (1) Unit of analysis—the NIT primarily focuses on organizations' interactions with their institutional environments, while the stakeholder theory emphasizes on the relationships between organizations and specific stakeholders. (2) Normative orientation: Empirically, both theories demonstrate distinct normative implications for organizational behavior. In detail, the NIT tends to be more descriptive in analyzing how organizations conform to institutional pressures, whereas stakeholder theory underscores a normative approach to address stakeholder engagements and balancing their interests. (3) Scope of analysis: The NIT typically observes a wide-ranging societal and institutional context affecting organizations. The stakeholder theory, on the other hand, focuses on specific organizational decisions, and how they affect stakeholders. (4) Treatment of power: The NIT invariably addresses power dynamics issues indirectly by focusing on institutional constraints and pressures. On the other hand, the stakeholder theory directly addresses power dynamics between organizations and stakeholders (Aisjah et al., 2023; Baah et al., 2023; Hussain et al., 2023; Quynh et al., 2022).

### 2.2 Commonalities between the NIT and stakeholder theory

The two theories share several commonalities including: (1) Organizational environment: Both theories acknowledge the importance of external forces—such as institutional factors and stakeholder pressure in shaping the conduct of organizations. (2) Focus on relationships: The two theories stress on the importance of relationships (i.e., either with institutions or stakeholders) in guiding organizational decision-making. (3) Legitimacy and accountability: Both theories highlight the significance of organizational legitimacy and accountability, albeit from diverse frameworks. More specifically, the NIT underscores the essence of achieving legitimacy within institutional framework. On the other hand, the stakeholder theory focuses on accountability to diverse stakeholder groups (Aisjah et al., 2023; Baah et al., 2023; Hussain et al., 2023; Quynh et al., 2022; Zhang & Tu, 2022).

As indicated earlier, these broader perspectives and complimentary arguments served as a comprehensive theoretical basis for this analysis. Integration of the new institutional and stakeholder theories in the present study highlights the interplay between institutional pressures and stakeholder dynamics in shaping manufacturing enterprises green innovation practices as demonstrated in the following. First, institutional pressures and stakeholder expectations: Institutional pressures, including industry standards, and government regulations can mirror the expectations of various stakeholders regarding environmental sustainability and triple bottom line initiatives. For example, stringent environmental regulations may be experienced in response to pressure from pro-environmental activists, advocacy groups and concerned citizens. In the light of this, organizations may adopt green innovation practices not only as a mechanism to comply with government regulations but also to meet the expectations of stakeholders. Second, organizational responses to institutional and stakeholder pressures: Manufacturing enterprises navigate stakeholder and institutional pressures by strategically responding to the calls for green innovation practices. They may institute internal policies, invest in R&D, and team up with stakeholders to develop sustainable products and processes.

Again, legitimization and social license: Integrating the new institutional and stakeholder theories can enhance the understanding of how manufacturing enterprises seek to gain legitimacy and a social license to operate within the framework green innovation. By balancing institutional norms and stakeholder concerns, organizations can demonstrate their environmental commitment, and accordingly seek the needed support from customers, regulators, investors, and other stakeholders. Four, long-term sustainability and competitive edge: Green innovation practices inspired by institutional pressures and stakeholder expectations are likely to translate into long-term sustainability and enhanced competitive edge of manufacturing enterprises. Specifically, by addressing environmental issues, while taking remedial measures to meeting the diverse needs of stakeholders, organizations can enhance their, innovation capacity, resilience, and market positioning in an ever increasingly sustainability-conscious business environment. Five, dynamic interactions: Arguably, organizational behaviors are motivated by the dynamic interactions between institutions and stakeholders. In principle, the new institutional theory acknowledges the role of institutions in shaping organizational behavior, while stakeholder theory recognizes the importance of stakeholders' expectations and actions. The integration of the two perspectives, proffers an empirical opportunity to examine how institutional pressures and stakeholder dynamics interact to drive green innovation practices in Chinese manufacturing enterprises. Six, strategic decision-making and practical implication: Manufacturing enterprises navigate complex institutional frameworks and manage diverse relationships with stakeholders when pursuing green innovation initiatives.

In essence the integration of the new institutional and stakeholder theories offers a robust framework for a nuanced understanding of the complex dynamics behind green innovation practices within Chinese manufacturing enterprises. By considering the interplay between the two theories, a deeper insight is gained on how organizations navigate environmental sustainability challenges and drive positive change in their operations. This integrated approach can inform decision-making, and managerial strategies, aimed at promoting triple bottom line and environmental stewardship in manufacturing enterprises.

### 2.3 Identification of the key influencing factors of MEGI

Grounded theory is described as an inductive qualitative research approach which is characterized by constant appraisal and theoretic sampling. Structurally, it aims to derive direct theories from systematic data analysis. This suggests that Grounded theory entails the designing of iterative abstract concepts from adaptive and a flexible research protocol, with a great deal of emphasize on theoretical saturation as an endpoint. Moreover, Grounded theory is believed by many as an indispensable mechanism to exploring the ever intricate social phenomena. It thus, proffers scholars a nuanced understanding "grounded in the lived experiences of individuals or groups." In the framework of Grounded theory, researchers generally do not make theoretic assumptions prior to the start of their work (Louvier & Innocenti, 2023). The norm is that they start with actual observations, summary of experiences from raw data, and then elevate to systematic theory. Thus, this method proffers a scientific mechanism to establishing substantive theories from a bottom-up approach. This method has a wide range of applications in exploring the influencing factors of a certain phenomenon (Chametzky, 2020; Chun et al., 2019; Thompson et al., 2021). Against this backdrop, we investigated the factors influencing MEGI from the lens of Grounded theory. In particular, we selected 35 participants from 22 enterprises in some Chinese Provinces namely, Chengdu, Chongqing and Xi'an for the study. These participants mainly came from manufacturing companies such as metallurgy, plastic production, automobile manufacturing, and cement production.

We repeatedly performed open coding, axial coding, selective coding and theoretical saturation tests on the original data to obtain the factors influencing MEGI. In detail, 15 important categories were identified using open coding. These 15 categories were green innovation regulation, supportive green innovation policy, green innovation incentive regulation, industry carbon emission standard, customer green demand, social green innovation culture environment, green innovation pressure of benchmarking enterprises, green innovation pressure from competitors in the industry, non-sedimentary redundant resources, green innovation input capacity, sedimentary redundant resources, green innovation R&D capability, green innovation technology absorption capability, green innovation risk awareness of executives, and green innovation revenue awareness of executives.

By coding the main axes, we grouped all factors into seven main categories namely, green innovation regulatory pressure, social carbon emission standard pressure, competitor imitation pressure, key stakeholder pressure, secondary stakeholder pressure, green innovation capability, green innovation risk awareness of executives, and green innovation benefit awareness of executives. Based on institutional theory, the current study classifies green innovation regulatory pressure, social carbon emission standard pressure and competitor imitation pressure into one category. This was collectively named green innovation system pressure (GISP). The innovation resources and capabilities by firm were categorized as organizational factors. Key and secondary stakeholders' green innovation pressures were accordingly grouped as stakeholder green innovation pressures. Furthermore, we grouped executive green innovation risk and benefit awareness as executive environmental awareness.

These variables were obtained through a large number of interviews and then classified. Each variable has an important influence on the MEGI. However, the influence mechanism of these variables on MEGI still needs to be further studied.

## 2.4 Development of hypotheses

### 2.4.1 New institutional theory (NIT) and the influence of GISP on MEGI

The NIT posits that organizations not only operate in a certain technological environment, but also survive in a certain institutional environment. At the heart of NIT is the idea that institutions, including organizational structures, norms, and formal rules form the cornerstone upon which organizations and individual functions, wielding substantial influence on their behaviors by instituting constraints, expectations and incentive schemes (Guarnieri et al., 2023; Quynh et al., 2022; Surajit et al., 2023). A key and well-known concept within NIT is Isomorphism. Isomorphism refers to the propensity of organizations or individuals to adopt analogous practices, structures, norms and cultures over time, toward a successful end (Surajit et al., 2023; Santosh et al., 2023). More specifically, Isomorphism can emerge from different propositions. These include coercive forces, mimetic forces and normative forces. Under coercive forces, external pressures often times dictate conformity to a set of principles or societal standards. Mimetic forces, on the other hand, encompass the duplication or imitation of successful brands or institutions. Normative forces are strictly based on legitimacy. This suggests that individuals or organizations may be compelled to adopt certain practices on the grounds of legitimacy (Surajit et al., 2023; Santosh et al., 2023; Quynh et al., 2022).

Based on the recognition of institutional dynamism, NIT is able to examine the courses of institutional growth or change, which may result from exogenous shocks, or internal changes within the organizational structure. Institutional transformation may also arise from deliberate course of actions by institutional managers desiring to champion novel practices. This suggests that NIT calls attention to the complex association between institutions and power dynamics. In the light of this, NIT recognizes the overarching effect of organizations' influential actors to define the institutional landscape by manipulating institutions to serve their utmost interests (Hussain et al., 2023; Surajit et al., 2023).

NIT decomposes the institution-organizational-dyad into micro and macro-levels at the operational stage. The former entails exchanges among organizations and individuals, while the later refers to the structural dynamic forces within the society at large. This multi-layered viewpoint permits a holistic appreciation of how institutions evolve over time. Moreover, in the spirit of institutional logics, NIT espouses that different collection of practices and values shape the behaviors of specific institutions. Eventually, this translates into varied array of organizational structure (Kerlin et al., 2021; Surajit et al., 2023; Santosh et al., 2023). Based on NIT, the current study explores the mechanisms of green innovation regulatory pressure, social carbon emission standard pressure and competitor imitation pressure on MEGI.

Green innovation regulatory pressure refers "to the pressure on enterprises with significant environmental pollution". This is because governmental and nongovernmental pro-environmental institutions attach a great deal of importance to green development goals, and accordingly regard the enactment of green innovation targets as a benchmark for enterprises legal backing for operation (Deng et al., 2022). Regulatory pressure mainly comes from various formal and informal regulatory bodies and are motivated by green innovation targets such as emission reduction targets set by the government for specific industries, and routine on-site inspection. Others are monitoring and penalties for non-compliant enterprises. Violation of green innovation regulations can result in severe penalties for firms (Guo et al., 2023; Zhang & Tu, 2022). It must be highlighted that green innovation standard issued by the government is the most important external pressure affecting green innovation initiatives of enterprises. Because enterprises adopt various innovative measures to avoid various penalties, mandatory green innovation regulation is the main motivation for enterprises to adopt green innovative standards (Deng et al., 2022). In addition, coercive regulation forces firms to enhance their green innovation performance through dedicated efforts. In contrast to large firms, some incentive regulations such as financial assistance and special policies are the main factors that engender green innovation advocacy in most SMEs. For instance, "Environmental tax policies" can significantly promote green innovation production technologies of enterprises. Various green innovation technology information, special support funds, and cooperation platforms can also provide green innovation support to the industry chain. By providing firms with green innovation resources and reducing the costs and risks of green innovation, incentives and support regulations can guide manufacturing firms to implement green innovation strategies (Ma & Zhao, 2022). Based on the above discussion, we propose that:

**H1a** Green innovation regulatory pressure has a positive effect on MEGI behaviours.

Social carbon emission standard pressure refers to the norms and expectations imposed by the society on enterprises towards environmental protection, sustainable development, and green practice (Zhou et al., 2013). This pressure comes from many sources, including consumers, investors, governments, non-governmental organizations (NGOs) and public opinion. For example, in recent times, consumers are awakening to environmental protection practices of firms, and this is beginning to show in their purchasing decisions. On the other hand, investors now require strict green strategies from enterprises as part of pre-investment checklists. This pressure can be used to motivate firms to implement green innovation activities and eventually gain green innovation recognition from society. Faced with green innovation values and codes of conduct from industry associations, scholars posit that, firms will not only compare themselves with other firms within the industry but also try to maintain the same standards and norms with them as spelt out in the new institutional theory (Hussain et al., 2023; Quynh et al., 2022; Surajit et al., 2023). In addition, the green innovation demands of customers are not only an important normative pressure for companies but also an important motivation for green innovation (Surajit et al., 2023; Tang et al., 2017). With the implementation of the green innovation policy, consumers' preference for green innovation products is gradually formed. Moreover, the implementation of green innovation helps to reinforce the synergy between enterprises, consumers, and supply chain partners (Deng et al., 2022; Liu et al., 2021). Based on this background, we propose that:

**H1b** Social carbon emission standard pressure has a positive effect on MEGI behaviours.

Competitor imitation pressure refers to the pressure that arises from the competition for resources between competitors and benchmarking firms (Jiang et al., 2020). Thus, green innovation imitation pressure arises from enterprises' perceptions on competitors' green innovation behaviour. Firms in social network settings oftentimes mimic the behaviours of other firms which are exceling within the ecosystem (Santosh et al., 2023; Surajit et al., 2023). In the context of green innovation, enterprises attribute competitors' achievements to their green innovation strategic choices, and subsequently, imitate their actions. Because of their focus on green innovation issues, competitors will learn from or imitate the green innovation practices of benchmarked firms to sustain their existence in business (Guan, 2017). In addition, competitors' green innovation development may also receive resource support from the government. Benchmarking firms, will further implement green innovation policies to obtain corresponding resources and development opportunities (Jiang et al., 2020). In view of the foregoing, we propose that:

**H1c** Competitor imitation pressure has a positive effect on MEGI.

#### 2.4.2 The influence of organizational factors on MEGI

Ndlela et al. (2001), argue that a firm's core competitive advantage is its possession of resources that are scarce, unique, irreplaceable, and difficult to imitate. Wagner and Schroeder (2010), also, suggest that a firm's core advantage is derived from the firm's unique capabilities. Therefore, the ability of a manufacturing enterprise to maintain a sustainable competitive advantage on the market depends largely on whether it possesses some key resources and capabilities.

Manufacturing enterprise green innovation has an important relationship with the resources that it possesses (Uyarra et al., 2016). The resources possessed by a firm are difficult to change in a short period. Therefore, if a firm is constrained by resources, its green innovation will be greatly hindered. Enterprises with good operating conditions tend to accumulate a large number of resources, which are conducive to supporting new projects (Yuan & Xiang, 2018). This suggests that enterprises will implement green innovation policies only if they have sufficient resources. Accordingly, we propose that:

**H2a** Innovation resources have a positive effect on MEGI behaviours.

Enterprise green innovation capability refers to the input, R&D, and production capabilities of enterprises in green innovation (Qi et al., 2021). In particular, green input capability refers to the various human, financial and material resources related to green innovation. This capability is mainly reflected in MEGI behaviours in two dimensions. That is, to guarantee the potential of green innovation and to guarantee the source of technology and creativity for green innovation. Green R&D capability also plays an important role in supporting green innovation activities of enterprises. Enterprises can achieve innovation and substantial improvements in processes, products, and management by integrating internal and external resources (Adenle et al., 2017; Gyamerah et al., 2022; Jiang et al., 2021). In addition, manufacturing firms will enhance their green innovation production capacity because of increasing green innovation preferences of consumers. Green innovation production capacity helps to promote the process of MEGI behaviours and provides a strong guarantee for MEGI (Zhao et al., 2019). Therefore, we propose that:

**H2b** Innovation capability has a positive effect on MEGI behaviours.

#### 2.4.3 Impact of stakeholder pressure on MEGI

The stakeholder theory avers the significance of recognizing the interests of a varied group of stakeholders, including internal persons such as shareholders and employees; and regulatory bodies, customers, and communities, as external entities (Aisjah et al., 2023; Baah et al., 2023; Jiang et al., 2022; Zhang et al., 2021). Central to the stakeholder theory is the "concept of stakeholder salience". Fundamentally, it is a concept that assesses the importance of stakeholders on three pillars. These are: (1) on the basis of the power stakeholders wield, (2) the earnestness with which stakeholders' interests must be addressed, and (3) the legitimacy of stakeholders' claims. This particular assessment framework guide enterprises to manage and prioritize their arrangements with stakeholders (Aisjah et al., 2023; Demartini et al., 2023; Griffith, 2009).

The engagement with stakeholder is pivotal and instrumental tenet of the stakeholder theory. In detail, the theory urges organizations to dynamically integrate stakeholders' concerns in the decision-making processes. It also makes a strong advocacy on how to nurture transparent communication channels in order to have a better understanding of stakeholder concerns and respond swiftly. The overarching goal of the stakeholder theory is to set in motion a tactical stakeholder management milieu, "wherein organizations circumnavigate the complexities of competing stakeholder interests to create value for all parties involved" (Baah et al., 2023; Griffith, 2009; Jiang et al., 2022; Sena et al., 2023).

It is instructive to stress that there is a harmony between the stakeholder theory and the triple bottom line concept. This is because the stakeholder theory also underscores a comprehensive evaluation of the performance of organizations by taking into account socioeconomic, and ecological dimensions (Baah et al., 2023; Kum et al., 2023; Shihong and Chen et al., 2023). The foregoing development suggests that ethical considerations, including low-carbon emission and minimal greenhouse footprint are highly upheld in the stakeholder theory. In essence, the theory makes a passionate appeal to organizations to be particular about their sustainable practices and ethical implications of their operations (Aisjah et al., 2023; Demartini et al., 2023; Kum et al., 2023).

Drawing on the stakeholder theory, the current study, advances that in a green development environment, the green innovation behavior of manufacturing enterprises is partly influenced by stakeholders (Baah et al., 2023; Kum et al., 2023; Zhang et al., 2021). Pressure from consumers, shareholders, unions, just to mention a few, has an incredible influence on the green development strategies of companies. These individuals or groups are referred to as stakeholders (Jiang et al., 2022). Clarkson (1995), argues that stakeholders can be divided into key and secondary stakeholders. Key stakeholders are organizations or individuals who play a decisive role in the survival and development of the firm, such as the firm's employees, consumers, shareholders, etc. Secondary stakeholders, on the other hand, are individuals or organizations that interact with the enterprise but are not directly involved in decision-making, such as the government and the media. Managers of organizations make informed decisions based on the demands of stakeholders. Moreover, the production decisions of companies must strategically consider the interests of their stakeholders. Under the requirement of green innovation target, stakeholder pressure largely restrains the behaviours of enterprises, and this can prompt them to transform to green innovation production mode. Although, the association between the secondary stakeholders and the enterprises is not as close as that of the key stakeholders, their green innovation pressure will also drive the enterprises to take green innovation decisions. This will in turn play an important role in improving the green innovation competitiveness of enterprises (Guan, 2017). Based on the above analysis, we propose the following:

**H3a** Key stakeholder pressure positively influences MEGI behaviours.

**H3b** Secondary stakeholder pressure positively influences MEGI behaviours.

### 2.4.4 Impact of executive environmental awareness on MEGI

Under green innovation system pressure (GISP), there is empirical evidence which suggests that, the greater the executive environmental awareness, the higher the propensity to perceive the gains from green innovation development. Under this condition, the executives are more likely to adopt responsive green innovation strategies (Jiang et al., 2022). Green innovation system can only be effectively implemented if the executives have a strong sense of environmental awareness. Strong environmental awareness guides manufacturing companies to adopt green innovation measures, and ultimately achieve green innovation targets (Uyarra et al., 2016). In addition, whenever the executives' awareness of green innovation benefits increases, it becomes easier for them to identify significant market opportunities and resources. Companies are more likely to implement green innovation policies under this condition (Xu et al., 2017).

When environmental awareness increases, the executives' responsibility for green innovation becomes stronger. Therefore, the more likely they are to invest in innovative resources (Jiang et al., 2020). This, also suggests that managers will consider more about the return-on-investment projects when selecting projects because of resource limitation. Structurally, corporate green innovation requires more resources as inputs, but future returns are difficult to guarantee. In this case, only top managers who regard green innovation as their responsibility will invest sufficient resources into it (Xu et al., 2017). Furthermore, the greater the executives' environmental awareness, the greater the likelihood to engage in green innovation. This is because it is only through this medium that they can absorb various environmental consciousness from within and without the organization to enhance their innovative capabilities (Hao et al., 2022).

Executive environmental awareness helps companies to meet the challenges brought by external stakeholder pressure and motivates them to fully consider stakeholders' demands (Jiang et al., 2022). In the context of green innovation, stakeholders such as government, community, NGOs, academia, media and the public, recognize the importance of green innovation development, and accordingly, put pressure on enterprises from various directions to act responsibly (Aisjah, et al., 2023; Baah et al., 2023; Jiang et al., 2020; Kum et al., 2023). This suggests that, through persistent pressure, strong executive environmental awareness will compel enterprises to adopt green innovation measures by acting responsibly. Therefore, in the face of stakeholder pressure, strong executive environmental awareness motivates firms to implement innovative behaviours (Guan, 2017). Against this backdrop, we put forward the following hypotheses. The theoretical model for the current study is presented in Fig. 1.

**H4a** Executive environmental awareness moderates positively the association between green innovation system pressure (GISP) and MEGI.

**H4b** Executive environmental awareness moderates positively the association between social carbon emission standard pressure and MEGI.

**H4c** Executives' environmental awareness moderates positively the association between competitor imitation pressure and MEGI.

**H4d** Executive environmental awareness moderates positively the association between innovation resources and MEGI.

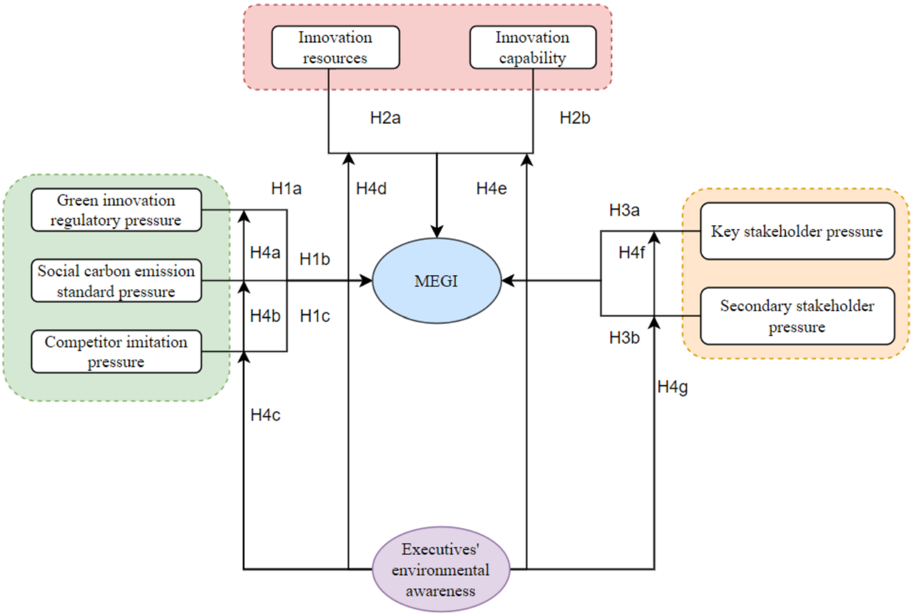


**Fig. 1** The research model

**H4e** Executive environmental awareness moderates positively the association between innovation capability and MEGI.

**H4f** Executive environmental awareness moderates positively the association between key stakeholder pressure and MEGI.

**H4g** Executive environmental awareness moderates positively the association between secondary stakeholder pressure and MEGI.

## 3 Methodology

### 3.1 Research approach

This study adopted a rigorous and in-depth approach to develop a comprehensive framework to contribute data to guide enterprises' green innovation pathways. A two-phase research approach was adopted. First, qualitative data was gathered through grounded theory framework to establish key factors of MEGI. Afterwards, the new institutional and the stakeholder theories were integrated based on the factors identified from the qualitative data to develop a conceptual framework to guide the analysis.

#### 3.1.1 Phase one—grounded theory approach

Grounded theory is an inductive qualitative research approach which is characterized by constant appraisal and theoretic sampling. Structurally, it aims to derive direct theories from systematic data analysis. Grounded theory entails the designing of iterative abstract concepts from adaptive and flexible research protocols, with a great deal of emphasize on theoretical saturation as an endpoint. Moreover, Grounded theory is believed by many as an indispensable mechanism to exploring the ever intricate social phenomena. It thus, proffers scholars a nuanced understanding "grounded in the lived experiences of individuals or groups." In the framework of Grounded theory, researchers generally do not make theoretic assumptions prior to the start of their work (Louvier & Innocenti, 2023). The norm is that they start with actual observations, summary of experiences from raw data, and then elevate to systematic theory. Thus, this method proffers a scientific mechanism to establishing substantive theories from a bottom-up approach. This method has a wide range of applications in exploring the influencing factors of a certain phenomenon (Chametzky, 2020; Chun et al., 2019; Thompson et al., 2021).

In this phase, we recruited 35 interview participants working in 22 different manufacturing enterprises across Chinese Provinces namely, Chengdu, Chongqing, and Xi'an for the study data. These participants mainly came from manufacturing companies such as metallurgy, plastic production, automobile manufacturing, and cement production. We repeatedly performed open coding, axial coding, selective coding, and theoretical saturation tests on the original data to obtain the factors influencing MEGI. In detail, 15 proximate categories were identified using open coding. These 15 proximate categories were green innovation regulation, supportive green innovation policy, green innovation incentive regulation, industry carbon emission standard, customer green demand, social green innovation culture environment, green innovation pressure of benchmarking enterprises, green innovation pressure from competitors in the industry, non-sedimentary redundant resources, green innovation input capacity, sedimentary redundant resources, green innovation R&D capability, green innovation technology absorption capability, green innovation risk awareness of executives, and green innovation revenue awareness of executives.

By coding the main axes, we grouped all factors into seven main categories namely, green innovation regulatory pressure, social carbon emission standard pressure, competitor imitation pressure, key stakeholder pressure, secondary stakeholder pressure, green innovation capability, green innovation risk awareness of executives, and green innovation benefit awareness of executives. As indicated earlier, these factors informed the decision to select the two complementary models; NIT and stakeholder theories to develop a survey to test the hypothesized relationships in the second phase.

#### 3.1.2 Phase two—survey development

Firstly, we developed a preliminary questionnaire based on review of empirical applications of the selected theoretical models. Secondly, we invited experts to help revise the questionnaire. In addition, two senior managers each drawn from eight companies in Chengdu (Xi'an and Chongqing) were randomly chosen for detailed interviews after which the questionnaire was further modified. These eight manufacturing companies have over the years gained good reputation when it comes to strategic investments in green technology. Again, these firms have clear long-term and short-term policy directions towards green production (Hao et al., 2022). In particular, the dataset was collected through diverse mechanisms, including email, WeChat, and on-site distribution. The measurement scale contained 41 questions, based on the objective of the study. We used a five-point Likert scale (1 = highly disapproval, 5 = highly approval).

### 3.2 Variable source

All the constructs used in the analysis were derived from the extant literature and/or the two main theories applied in this study. This was to ensure that the study findings are reliability, robust, valid, and theoretically sound and interpretable. While some were adopted directly from relevant studies (e.g., Aragón-correa et al., 2008; Jiang et al., 2022; Xu et al., 2017; Zhang et al., 2015), others were modified to suite the study context and objectives. Constructs not originally in Chinese language were translated into simplified Chinese for simplicity and easy understanding by the respondents. The translated constructs and their measurement items were pre-tested to determine whether they are in synchronous or consistent with the original constructs. Contextualizing these existing variables/constructs helped in collecting accurate data with all the dynamism, richness, and unique attributes the original constructs and measured instrument could not have captured for the analysis. Specifically, the dependent variable—MEGI was adapted and measured based on Xu et al (2017) and Zhang et al (2015) studies. Six measurement items were derived from these studies to evaluate the dependent construct.

The executive environmental awareness construct was directly adopted from the studies of Jiang et al (2022), Xu et al (2017) and Aragón-correa et al (2008). Based on predicted associations between low-carbon innovation and executive environmental awareness reported in the referenced studies, this variable was used as the moderating variable in the study. In total, six questions were adapted from the studies cited to measure environmental awareness. Further, the selected independent constructs of the study were based on the NIT and stakeholder theories. This was done to offer a detailed understanding and conceptual relevance on green innovation practices in Chinese manufacturing enterprises. The constructs derived from each theory proffer unique insights into different aspects of organizational behaviors, emphasizing how the NIT and stakeholder theories were used complementary as discussed elsewhere in this study (see Sect. 2).

Precisely, based on the theoretical assumptions and subsequent applications of the NIT model, constructs including green innovation regulatory pressure, social carbon standard emission pressure and competitor imitation pressure were derived and their relationship with MEGI were investigated. The green innovation regulatory pressure was measured using items from DiMaggio et al. (1983) and Jiang et al. (2020). Likewise, the social carbon emission standard pressure was operationalized from Guan (2017) and Xu et al. (2017). Competitor imitation pressure was adopted and measured from Guan (2017). Moreover, items on organizational factors were designed following Chan (2010), Guan (2017) and Jiang et al (2020). Items on executive environmental awareness were adapted from Aragón-correa et al. (2008), Jiang et al. (2022) and Xu et al. (2017). Following Clarkson (1995) and Wang (2019), key stakeholder pressure and secondary stakeholder pressure were used as the constructs for stakeholder theory. In all, we designed 6 question items to measure key and secondary pressures. The above variables are shown in Table 1.

Control variables: Following Jiang et al. (2020) and Xu et al. (2017), the current study used enterprise type (ET), years established (YE), enterprise scale (ES) which was measured by the number of employees in a firm, and industry type (IT) as the control variables. We classified the types of enterprises into four namely, state-owned corporation, foreign-funded corporation, joint venture corporation, and private corporation. Years of establishment was measured based on the duration of enterprise's existence.

**Table 1** The researched variables

| Variable | Measurement index | Literature resources |
|---|---|---|
| Manufacturing enterprise green innovation (MEGI) | ELI1: Enterprise have set short-term green innovation goals | Xu et al. (2017) and Zhang et al. (2015) |
| | ELI2: The enterprise has set a long-term green innovation goal | |
| | ELI3: Enterprise have formulated clear plans for implementing green innovation activities | |
| | ELI4: Enterprises implement comprehensive green innovation quality management | |
| | ELI5: Enterprise have designed energy-saving products | |
| | ELI6: Enterprises have designed green innovation products | |
| | ELI7: Enterprise improve production processes to reduce carbon emissions | |
| Green innovation regulatory pressure (GIRP) | GIRP1: The production of the enterprise must comply with the relevant domestic green laws and regulations | DiMaggio et al. (1983) and Jiang et al. (2020) |
| | GIRP2: The production of the enterprise must comply with the relevant green innovation regulations of the exporting country | |
| | GIRP3: The government has formulated tax policies related to the green innovation targets | |
| | GIRP4: The government has provided subsidies related to low carbon for enterprises | |
| | GIRP5: The government actively publicized and promoted the implementation of the green innovation targets | |
| Social carbon emission standard pressure (SCESP) | SCESP1: Customers of enterprises require products to meet green innovation standards | Guan (2017), Xu et al. (2017) |
| | SCESP2: Customers value products with green innovation concept | |
| | SCESP3: The supplier requires the production of the enterprise to meet the green innovation regulations | |
| | SCESP4: The public (including communities, non-governmental pro-environmental organizations, etc.) pay a great deal of attention to green innovation issues | |

**Table 1** (continued)

| Variable | Measurement index | Literature resources |
|---|---|---|
| Competitor imitation pressure (CIP) | CIP1: Competitors of the enterprise have successfully adopted the industry-leading green innovation process | Guan (2017) |
| | CIP2: The alternative products of the product have successfully adopted the leading green innovation process | |
| | CIP3: Industry leaders have successfully adopted the industry's leading green innovation process | |
| Innovative resources (IR) | IR1: The current production and operation of the enterprise is better, but lower than the predetermined capacity | Jiang et al. (2020) and Chan (2010) |
| | IR2: The enterprise has more professional talents and has certain potential | |
| | IR3: Enterprises have sufficient financial resources for free disposal | |
| | IR4: The enterprise has sufficient relationship resources | |
| Innovation capability (IC) | IC1: Enterprises can obtain sufficient funds to carry out green innovation activities | Guan (2017) and Jiang et al.(2020) |
| | IC2: Enterprises can attract green innovative talents | |
| | IC3: Enterprises attach importance to and support scientific research and development | |
| | IC4: Enterprises have good R&D conditions and R&D atmosphere | |
| | IC5: Enterprises have the ability to flexibly configure production plans and production lines | |
| | IC6: The enterprise has adopted an advanced green innovation management system | |

**Table 1** (continued)

| Variable | Measurement index | Literature resources |
|---|---|---|
| Pressure from key stakeholders (PKS) | PKS1: Investors tend to invest in enterprises with fully disclosed green innovation information | Clarkson (1995) and Wang (2019) |
| | PKS2: The upstream and downstream enterprises and competitive enterprises of the company attach great importance to the green innovation development mode and tend to use green innovation products | |
| | PKS3: Employees have a strong environmental awareness and will take actions | |
| Pressure from secondary stakeholders (PSS) | PSS1: In recent 3 years, the impact of green innovation credit on this enterprise has become more and more obvious | |
| | PSS2: In recent 3 years, the public's awareness of green is very strong | |
| | PSS3: In the past 3 years, the media have reported more and more times on enterprises that violate the green innovation policies | |
| Executives' environmental awareness (EEA) | EEA1: Enterprise executives are well aware of the impact of the green innovation on enterprises | Xu et al. (2017), Aragón-correa et al.(2008) and Jiang et al.(2022) |
| | EEA2: Enterprise executives are very familiar with the carbon emission level of production in their industry | |
| | EEA3: Corporate executives are well aware of the green innovation regulations | |
| | EEA4: Enterprise executives believe that green innovation can improve the enterprise image | |
| | EEA5: Business executives believe that green innovation can improve the economic performance of enterprises | |
| | EEA6: Enterprise executives believe that green innovation can improve enterprise environmental performance | |

Enterprise scale was measured by the natural logarithm of the number of all employees in the enterprise. Moreover, we categorized industry type into six main manufacturing groups as depicted in Table 2.

### 3.3 Sample and data collection

To ensure the randomness of the selected provinces and cities, we stratified the provinces of China by region. Then, a random sampling was used to select some enterprises from regions such as Chongqing, Beijing, Sichuan, Hubei, Shaanxi, and Shandong. The scope of investigation of the study was confined to manufacturing industry with higher-than-average environmental pollution levels. Following Jiang et al. (2020), company executives used in the present study are largely "chairpersons, general managers, deputy general managers, assistant general managers, environmental department managers or environmental project leaders" and other managers who play important roles in the selection and implementation of green innovation practices. A total of 345 questionnaires were distributed in this study. After discarding invalid questionnaires, a total of 214 valid questionnaires were retained for the study. Therefore, the effective recovery rate was 62.03%.

Descriptive statistics using frequencies and percentages were used to describe the baseline characteristics of the study sample. The measurement model was assessed by evaluating the reliability and validity of the study constructs (Pallant, 2020). The reliability check was determined using Cronbach's alpha, while validity was assessed through conducting convergent and discriminant test (Table 2). Prior to testing the hypothesized relationships between variables, a correlation analysis was conducted to determine the strength of relationships between variables using means, standard deviation, and correlation coefficients. Finally, hierarchical multiple regression models were used to investigate the hypothesized relationships between variables. All statistical analyses were performed using the Statistical Package for Social Science software version 24.0 (IBM Corp., Armonk, New York, NY, USA), and statistical significance was defined at a value of $p < 0.05$. The descriptive statistics of the sample are shown in Table 2.

### 3.4 Validity and reliability test

Traditionally, prior to hypotheses testing, a preliminary test is conducted to examine the validity and reliability of the study construct (Pallant, 2020). As shown in Table 3, it can be seen that Cronbach's α coefficient values for the nine latent variables and their various dimensions in the study are all greater than 0.7. These indicate that the scale has high reliability. The lowest value of CR for the nine variables is 0.732 (Table 3). This indicates that the scales have a good convergent validity. It is instructive to emphasize that the variables used in the current study are all from well-established scales in literature.

## 4 Results

### 4.1 Descriptive statistics and correlation analysis

The mean, standard deviation and correlation analysis of each variable are shown in Table 4. We found that manufacturing enterprise green innovation (MEGI), green innovation regulatory pressure (GIRP), social carbon emission standard pressure (SCESP), competitor imitation pressure (CIP), innovation resources (IR), Innovation capability (IC), pressure of key stakeholders (PKS), pressure of secondary stakeholder (PSS) and executives' environmental awareness (EEA) were all significantly positively correlated.

## 4.2 Hypothesis testing

The current study verified the relevant theoretical assumptions of MEGI through the maximum likelihood method. We tested the pertinent research hypotheses from green innovation system pressure (GISP), organizational variables, stakeholder green innovation pressures, and executive environmental awareness. Following, Akuffo and Ampaw (2013), the association between variables were directly estimated by bringing the normalized mean values of all second-order factors into the regression equation.

The regression results of green innovation system pressure (GISP) on MEGI are shown in Table 5. Model 1, is the regression outcome after the inclusion of 4 control variables in the model. Based on Model 1, we put the green innovation regulatory pressure (GIRP), social carbon emission standard pressure (SCESP), and competitor imitation pressure (CIP) into Model 2 to test the association between the above variables and green innovation of manufacturing enterprises. Model 3, incorporated the quadratic terms of the aforementioned three variables based on Model 2, to determine whether there is inverted U-shaped association between them and the dependent variable. Furthermore, based on Model 3, Model 4 was used to introduce the pairwise product term of the three variables above.

The regression results in Table 5, show that green innovation regulatory pressure has a positive effect on the MEGI ($\beta = 0.249$, $p < 0.01$). Social carbon emission standard

**Table 2** Characteristics of the samples

| Items | Categories | Frequency (N = 438) | Percent (%) |
|---|---|---|---|
| Enterprise scale (number of employees) | Under 100 | 12 | 5.61 |
| | 100–200 | 21 | 9.81 |
| | 201–500 | 18 | 8.41 |
| | 501–800 | 52 | 24.30 |
| | More than 800 | 111 | 51.87 |
| Years of operation | Less than 3 years | 13 | 6.07 |
| | 3–5 years | 8 | 3.74 |
| | More than 5 years | 193 | 90.19 |
| Type of enterprise | State—owned corporation | 97 | 45.33 |
| | Foreign-funded corporation | 62 | 28.97 |
| | Joint venture corporation | 35 | 16.36 |
| | Private corporation | 20 | 9.35 |
| Industry type | Metallurgical industry | 48 | 22.43 |
| | Transportation Equipment manufacturing industry | 15 | 7.01 |
| | Petrochemical, pharmaceutical and plastic industries | 32 | 14.95 |
| | Textile, garment and leather industry | 24 | 11.21 |
| | Mechanical equipment manufacturing industry | 45 | 21.03 |
| | Other manufacturing | 50 | 23.36 |

pressure has a positive effect on the MEGI (β = 0.346, $p < 0.001$). Competitor imitation pressure also has a positive effect on the MEGI (β = 0.286, $p < 0.001$). Moreover, the regression results in Model 3, show that the quadratic term of green innovation regulatory pressure has a negative correlation between MEGI (β = − 0.167, $p < 0.05$). The results, further show that there is an inverted U-shaped association between green innovation system pressure and MEGI. Therefore, H1b and H1c were accepted. H1a was, however.

Table 6, shows the regression results of organizational factors on MEGI. In particular, Model 6, introduced two variables—innovation resource and innovation capacity on the basis of Model 1. We found that innovation resources had a positive effect on MEGI (β = 0.243, $p < 0.05$), and innovation capacity also had a positive effect on MEGI (β = 0.353, $p < 0.001$). Additionally, Model 7, introduced the quadratic term of the above two variables based on Model 6, and Model 8, introduced the product term of the above two variables based on Model 7. We found that the quadratic terms of innovation resources and innovation capacity are not significantly related to MEGI. The above results indicate that there is no inverted U-shaped association between innovation resources and innovation capability and MEGI. Therefore, hypotheses H2a and H2b were accepted.

The influence of stakeholder pressure on businesses' green innovation strategies was examined in this study by substituting the control variables into the regression equation. The output is depicted in Table 7. Specifically, we found that the β value of key stakeholder pressure was 0.351, and significant at the level of 0.001, and the β value of secondary stakeholder pressure was 0.194, and significant at the level of 0.05. Furthermore, model 10, introduced the quadratic term of the above two variables based on model 9, and model 11, introduced the product term of the above two variables based on model 10. We found that the quadratic terms of key stakeholder pressure and secondary stakeholder pressure are not significantly related to MEGI. The above results show that there is no inverted U-shaped association between the above two variables and MEGI. Therefore, hypotheses H3a and H3b were verified.

Finally, we examined the moderating effect of executive environmental awareness through the following. First, we decentralized the relevant variables prior to the regression test in order to minimize the multicollinearity between interaction terms and explanatory factors. The regression outputs are depicted in Tables 8 and 9. As shown in Table 8, the regression results for Model 13, show that the interaction term between green innovation regulatory pressure (GIRP) and executives' environmental awareness (EEA) has no meaningful correlation with MEGI. Therefore, H4a was not accepted. In addition, executives' environmental awareness moderated positively the association between social carbon emission standard pressure and MEGI (β = 0.283, $p < 0.01$). Also, executives' environmental awareness moderated positively the association between competitor imitation pressure and MEGI (β = 0.181, $p < 0.05$). Therefore, both H4b and H4c were accepted.

The regression results of Model 19 are displayed in Table 9. It can be observed that the interaction term between innovation resources and executives' environmental awareness had a positive influence on MEGI (β = 0.365, $p < 0.001$). Therefore, H4d was verified. On the other hand, the interaction term between innovation capability and executives' environmental awareness, had a negative impact on enterprise green innovation (β = − 0.329, $p < 0.001$). This finding suggests that executives' environmental awareness negatively moderates the association between innovation capability and MEGI. H4e was therefore, not accepted. In addition, executives' environmental awareness positively moderated the association between key stakeholders' pressure, and manufacturing enterprise green innovation (β = 0.154, $p < 0.05$). Finally, executives' environmental awareness moderated

**Table 3** Outcome of validity and reliability test

| Variable | Measuring item | Cronbach's Alpha | | KMO | | AVE | CR |
|---|---|---|---|---|---|---|---|
| Manufacturing enterprise green innovation (MEGI) | MELC1 | 0.764 | 0.848 | 0.735 | 0.836 | 0.786 | 0.857 |
| | MELC2 | 0.785 | | 0.778 | | | |
| | MELC3 | 0.679 | | 0.812 | | | |
| | MELC4 | 0.722 | | 0.765 | | | |
| | MELC5 | 0.734 | | 0.837 | | | |
| | MELC6 | 0.751 | | 0.786 | | | |
| | MELC7 | 0.679 | | 0.764 | | | |
| Executives' environmental awareness (EEA) | EEA1 | 0.734 | 0.735 | 0.747 | 0.787 | 0.775 | 0.732 |
| | EEA2 | 0.674 | | 0.775 | | | |
| | EEA3 | 0.725 | | 0.764 | | | |
| | EEA4 | 0.736 | | 0.837 | | | |
| | EEA5 | 0.758 | | 0.788 | | | |
| | EEA6 | 0.767 | | 0.849 | | | |
| Green innovation regulatory pressure (GIRP) | GIRP1 | 0.635 | 0.774 | 0.848 | 0.775 | 0.712 | 0.827 |
| | GIRP2 | 0.745 | | 0.718 | | | |
| | GIRP3 | 0.728 | | 0.839 | | | |
| | GIRP4 | 0.739 | | 0.634 | | | |
| | GIRP5 | 0.724 | | 0.782 | | | |
| Social carbon emission standard pressure (SCESP) | SCESP1 | 0.728 | 0.821 | 0.869 | 0.912 | 0.625 | 0.831 |
| | SCESP2 | 0.817 | | 0.772 | | | |
| | SCESP3 | 0.692 | | 0.768 | | | |
| | SCESP4 | 0.712 | | 0.725 | | | |
| Competitor imitation pressure (CIP) | CIP1 | 0.764 | 0.795 | 0.748 | 0.824 | 0.786 | 0.872 |
| | CIP2 | 0.728 | | 0.879 | | | |
| | CIP3 | 0.732 | | 0.769 | | | |
| Innovation resources (IR) | IR1 | 0.834 | 0.778 | 0.767 | 0.921 | 0.621 | 0.821 |
| | IR2 | 0.691 | | 0.775 | | | |
| | IR3 | 0.744 | | 0.736 | | | |
| | IR4 | 0.685 | | 0.878 | | | |
| Innovation capability (IC) | IC1 | 0.747 | 0.764 | 0.699 | 0.914 | 0.717 | 0.823 |
| | IC2 | 0.754 | | 0.757 | | | |
| | IC3 | 0.758 | | 0.769 | | | |
| | IC4 | 0.762 | | 0.887 | | | |
| | IC5 | 0.639 | | 0.759 | | | |
| | IC6 | 0.745 | | 0.779 | | | |
| Pressure from key stakeholders (PKS) | PKS1 | 0.674 | 0.759 | 0.778 | 0.951 | 0.721 | 0.821 |
| | PKS2 | 0.725 | | 0.785 | | | |
| | PKS3 | 0.736 | | 0.882 | | | |
| Pressure from secondary stakeholders (PSS) | PSS1 | 0.758 | 0.784 | 0.759 | 0.868 | 0.645 | 0.845 |
| | PSS2 | 0.767 | | 0.775 | | | |
| | PSS3 | 0.678 | | 0.765 | | | |

**Table 4** Descriptive statistics and correlation coefficients

| Variable | Means | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GIRP | 5.472 | 1.512 | **1** | | | | | | | | |
| SCESP | 4.357 | 0.874 | 0.518** | **1** | | | | | | | |
| CIP | 4.546 | 1.654 | 0.414** | 0.419** | **1** | | | | | | |
| IR | 5.834 | 1.974 | 0.306* | 0.508** | 0.421** | **1** | | | | | |
| IC | 4.912 | 1.857 | 0.415** | 0.417** | 0.534** | 0.435** | **1** | | | | |
| PKS | 5.196 | 1.843 | 0.507** | 0.515** | 0.408** | 0.404** | 0.414** | **1** | | | |
| PSS | 4.792 | 1.521 | 0.438** | 0.475** | 0.522* | 0.432** | 0.541** | 0.417** | **1** | | |
| EEA | 5.125 | 1.957 | 0.407** | 0.425** | 0.523** | 0.394** | 0.394* | 0.388** | 0.482** | 1 | |
| MEGI | 4.426 | 1.584 | 0.421** | 0.458** | 0.524* | 0.436** | 0.517** | 0.416** | 0.547** | 0.547* | 1 |

Means are measured based on average factor scores; SD means standard deviation; **shows significance at the level of 0.01; *shows significance at the level of 0.05

**Table 5** Regression analysis of green innovation system pressure (GISP) and MEGI

| Independent variables | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Enterprise scale | 0.214 | 0.082 | 0.161 | 0.092 |
| Years established | −0.176 | −0.175 | −0.124 | −0.474 |
| Enterprise type | 0.253* | 0.153 | 0.275* | −0.175 |
| Industry type | 0.061 | 0.246 | 0.042* | 0.221 |
| GIRP | | 0.249* | 0.376*** | 0.187* |
| SCESP | | 0.346*** | 0.385*** | 0.347*** |
| CIP | | 0.286*** | 0.279*** | 0.314*** |
| $GIRP^2$ | | | −0.167* | −0.167* |
| $SCESP^2$ | | | 0.078 | 0.074 |
| $CIP^2$ | | | 0.047 | 0.019 |
| GIRP*SCESP | | | | 0.079 |
| GIRP*SCESP | | | | 0.327 |
| GIRP*SCESP | | | | 0.015 |
| $R^2$ | 0.351 | 0.435 | 0.524 | 0.547 |
| Adjusted $R^2$ | 0.324 | 0.467 | 0.476 | 0.489 |
| F | 0.867 | 4.273 | 6.891 | 6.351 |

***shows significance at the level of 0.001; *shows significance at the level of 0.05

positively the association between secondary stakeholders' pressure and manufacturing enterprise green innovation ($\beta = 0.239$, $p < 0.001$). Therefore, H4f and H4g were accordingly accepted.

**Table 6** Regression analysis of Organizational factors and MEGI

| Independent variables | 1 | 6 | 7 | 8 |
|---|---|---|---|---|
| Enterprise scale | 0.214 | 0.082 | 0.161 | 0.092 |
| Years established | −0.176 | −0.175 | −0.124 | −0.474 |
| Enterprise type | 0.253* | 0.153 | 0.275* | −0.175 |
| Industry type | 0.061 | 0.246 | 0.042* | 0.221 |
| IR | | 0.243* | 0.376*** | 0.187* |
| IC | | 0.353*** | 0.385*** | 0.347*** |
| $IR^2$ | | | −0.167 | −0.167 |
| $IC^2$ | | | 0.078 | 0.074 |
| IR*IC | | | | 0.015 |
| $R^2$ | 0.351 | 0.467 | 0.567 | 0.582 |
| Adjusted $R^2$ | 0.324 | 0.453 | 0.484 | 0.424 |
| F | 0.867 | 4.679 | 6.876 | 7.367 |

***shows significance at the level of 0.001; *shows significance at the level of 0.05

## 5 Discussion and implications

The present study constructed a comprehensive framework to explore the mechanisms that influence green innovation of enterprises from four dimensions. These are green innovation system pressure (GISP), organizational factors, stakeholder pressure, and individual green innovation consciousness. Based on the new institutional and stakeholder theories, the present study explored the differential influence of the above factors on manufacturing enterprise green innovation and came through with the following.

First, the regression results in Table 5, show that green innovation regulatory pressure has a positive effect on MEGI. Social carbon emission standard pressure and competitor's imitation pressure also has a positive correlation with MEGI. Table 5, further shows that the quadratic term of green innovation regulatory pressure has a negative correlation with enterprise green innovation. This may be the case because the excessive pressure of green innovation system will reduce green innovation R&D initiatives among enterprises. Under this scenario, more enterprises will use limited resources due to obvious constraints. This suggests that, when a country sets various green innovation targets, they cannot be achieved overnight. It is, therefore, necessary to execute them step-by-step, and in a gradual fashion to empower enterprises to succeed after the implementation stage. This finding of the present study corroborates with earlier findings by Xu et al. (2017), who concluded that, not all system pressures have a positive role in promoting green innovation initiatives among enterprises.

Second, the study found that innovation resources and innovation capabilities have positive effects on MEGI behaviours. This conclusion confirms prior research by Zhu et al. (2023), who posited that innovative resources and innovative capabilities are indispensable elements for enterprises to carry out green innovation. In detail, sufficient innovation resources can guarantee the development of green innovation activities of enterprises. It can also provide abundant resources to green innovation enterprises. This also suggests that sufficient innovation resources can promote the development of MEGI behaviours. Innovation is a key resource needed for manufacturing enterprises to implement green innovation. Having good innovation capabilities is not only helpful to promote green innovation

**Table 7** Regression analysis of stakeholder pressure and MEGI

| Independent variables | 1 | 9 | 10 | 11 |
|---|---|---|---|---|
| Enterprise scale | 0.214 | 0.175 | 0.182 | 0.187 |
| Years established | −0.176 | 0.367 | 0.367 | −0.432 |
| Enterprise type | 0.253* | 0.182 | 0.275 | −0.187 |
| Industry type | 0.061 | 0.276 | 0.341 | 0.237 |
| SPS | | 0.351*** | 0.241 | 0.179* |
| SSS | | | 0.194* | 0.352*** |
| $SPS^2$ | | | | −0.175 |
| $SPS^2$ | | | | 0.067 |
| SPS*SPS | | | | 0.068 |
| $R^2$ | 0.351 | 0.287 | 0.427 | 0.539 |
| Adjusted $R^2$ | 0.324 | 0.195 | 0.414 | 0.457 |
| F | 0.867 | 4.785 | 7.876 | 4.358 |

***shows significance at the level of 0.001; *shows significance at the level of 0.05

**Table 8** Analysis of adjustment effect of executive green awareness (1)

| Independent variables | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|
| Enterprise scale | 0.253 | 0.285 | 0.217 | 0.278 | 0.267 | 0.273 |
| Years established | −0.184 | −0.179 | −0.191 | −0.193 | −0.195 | −0.951 |
| Enterprise type | 0.267 | 0.253 | 0.247 | 0.285 | 0.253 | 0.197 |
| Industry type | 0.075 | 0.094 | 0.089 | 0.081 | 0.079 | 0.157 |
| GIRP | 0.185* | 0.237* | | | | |
| SCESP | | | 0.219* | 0.244*** | | |
| CIP | | | | | 0.163** | 0.175** |
| EEA | 0.179*** | 0.211*** | 0.235*** | 0.216*** | 0.248*** | 0.325*** |
| GIRP * EEA | | 0.176 | | | | |
| SCESP* EEA | | | | 0.283** | | |
| CIP* EEA | | | | | | 0.181* |
| $R^2$ | 0.051 | 0.287 | 0.021 | 0.078 | 0.364 | 0.282 |
| Adjusted $R^2$ | 0.047 | 0.095 | 0.432 | 0.534 | 0.353 | 0.189 |
| F | 5.867 | 4.793 | 7.341 | 15.358 | 0.878 | 16.784 |

***shows significance at the level of 0.001; **shows significance at the level of 0.01; *shows significance at the level of 0.05

**Table 9** Analysis of adjustment effect of executive green awareness (2)

| Independent variables | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|
| Enterprise scale | 0.219 | 0.231 | 0.237 | 0.207 | 0.142 | 0.235 | 0.317 | 0.184 |
| Years established | −0.125 | −0.185 | −0.182 | −0.186 | −0.207 | −0.251 | −0.217 | 0.242 |
| Enterprise type | 0.278 | 0.247 | 0.267 | 0.255 | 0.286 | 0.217 | 0.225 | 0.217 |
| Industry type | 0.085 | 0.075 | 0.078 | 0.073 | 0.127 | 0.162 | 0.079 | 0.174 |
| IR | 0.367** | 0.337*** | | | | | | |
| IC | | | 0.173** | 0.164** | | | | |
| SPS | | | | | 0.312*** | 0.301*** | | |
| SSS | | | | | | | 0.161** | 0.231*** |
| ELA | 0.323*** | 0.232*** | 0.245** | 0.229*** | 0.231*** | 0.202*** | 0.224*** | 0.243*** |
| IR* EEA | | 0.365*** | | | | | | |
| IC* EEA | | | | −0.329*** | | | | |
| SPS* EEA | | | | | | 0.154* | | |
| SSS* EEA | | | | | | | | 0.239*** |
| $R^2$ | 0.239 | 0.225 | 0.314 | 0.434 | 0.412 | 0.327 | 0.321 | 0.417 |
| Adjusted $R^2$ | 0.172 | 0.123 | 0.207 | 0.312 | 0.431 | 0.323 | 0.327 | 0.425 |
| F | 4.817 | 6.121 | 7.317 | 7.816 | 8.514 | 8.324 | 8.619 | 9.327 |

***shows significance at the level of 0.001; **shows significance at the level of 0.01; *shows significance at the level of 0.05

in enterprises, but it is also, a sure guarantee for enterprises to implement green innovation policies. In addition, the study observed that key stakeholders' pressure and secondary stakeholders' pressure have positive effects on green innovation of enterprises, suggesting that stakeholder pressure is another important factor driving the green innovation of enterprises.

Green innovation in Chinese enterprises can be divided into two stages: low-level and high-level. At present, most manufacturing enterprises in China are in the early stage of green innovation, with relatively low goals and corresponding hardware levels. This suggests that strong executive environmental awareness will motivate companies to take proactive measures to improve environmental health, However, green innovation capability of enterprises is lagging. The green innovation of many enterprises in China are yet to reach an advanced stage. In view of this, both institutional pressure and stakeholders' pressure must be leveraged to push enterprises to deepen the culture of green innovation in their operations. Moreover, the current study established that executives' green innovation consciousness positively regulates the association between secondary stakeholders' pressure and enterprise green innovation. This conclusion is consistent with the findings of Peng and Wei (2015), who indicated that executives' environmental awareness positively regulates the pressure from key stakeholders and ecological innovation of enterprises. The possible reason is that, with the continuous improvement and implementation of the green innovation policies, the pressure on green development of enterprises is very pronounced, and both major and secondary stakeholders' pressures have impact on the green innovation of enterprises.

The results of this research highlight some opportunities for firm managers and policymakers to leverage to improve low-carbon production and supply chain activities. One of the interesting observations from this study is the relationship between executive environmental awareness and enterprise green innovation. As this finding indicates that higher executive environmental awareness is associated with improved environmental performance, will regular workshops to create environmental sustainability awareness among frontline managers in manufacturing firms automatically translates to improved green production systems? Is it time to expand environmental awareness creation through introduction of compulsory environmental course modules in tertiary managerial programs and executive MBAs? These and other research and policy considerations are open for further investigation.

It was also found that while emission standard regulations and pressure from various quarters may initially engender green production strategies among firms, setting the standards too high has the potential to push some firms out of business in the long run, particularly among young enterprises. This finding suggests a consideration of several factors and in setting the environmental standards to avoid wiping out the budding enterprises. Truly, a one-size-fits-all policy approach will be detrimental to entrepreneurial activities, and ultimately, economic development.

## 6 Conclusion and limitations

The attainment of the 17 Sustainable Development Goals (SDGs), as scheduled in 2030, is only feasible from the lens of dedicated and religious efforts by all stakeholders. More so, since sustainability is pivotal and a cornerstone for these strategic goals, policies toward the attainment of utmost greenhouse gases reduction, and low-carbon footprint have become a holy grail, and a significant subject for debate among academics and professionals. In view of the foregoing, the present study contributes to the debate by leveraging the new institutional and stakeholders' theories to explore the drivers of MEGI. In particular, Chinese manufacturing companies, focusing on green innovation were sampled for the study, and concluded on the following: First, social carbon emission standard pressure and competitor imitation pressure had a positive impact on manufacturing enterprises' green innovation. This shows that "moderate system pressure" as spelt out in the coercive forces framework of Isomorphism (i.e., new institutional theory) and stakeholders' pressure can promote MEGI. Second, innovation resources and capabilities had a positive impact on MEGI. This suggests that manufacturing enterprises should continuously accumulate their own green innovation resources and improve their green innovation capabilities. This offers a sure guarantee for enterprises to implement green innovation policies. Third, the study found that both key stakeholder pressure and secondary stakeholder pressure have a positive impact on MEGI, in conformity with the stakeholders' theory. Under this condition, the government, society, and the media can effectively promote enterprises' green innovation initiatives by constantly creating green innovation concepts, while pressurizing industry players to stick to green production mode.. Fourth, executives' environmental awareness positively regulated the association between green innovation normative pressure, green innovation imitation pressure, innovation resources, key stakeholder pressure, secondary stakeholder pressure and MEGI. This implies that the executives of manufacturing companies, environmental awareness has a great influence on triple bottom line footprints. This is more so when the executives are in constant position to exert the necessary pressure on stakeholders to act responsibly on the environment; and are ever ready to facilitate sustainable projects emanating from the employees or other quarters. The foregoing reiterates the need to create a functional communication system in manufacturing companies to enable all stakeholders to apprise the executives of sustainable initiatives for implementation.

The limitations of the present study are as follows: First, the data source of the study have limitations. The study used "cross-sectional data" from specific manufacturing enterprises in China. In future studies, dataset can be obtained from a wider range of enterprises to enhance the generalization of findings. Second, the present study only discusses the influencing mechanisms of four variables on enterprise green innovation behaviours. Thus, more variables can be included in future studies. Third, only four control variables were used in this study. Future research can explore other control variables.

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**Data availability** The data that support the findings of this study are available from the corresponding author, Yuguo Jiang, upon reasonable request.

## Declarations

**Conflict of interest** The author(s) declared no potential conflicts of interest with respect to the research, authorship,and/or publication of this article.

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