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Article

Unveiling Organizational Green Legitimacy: The Role of Green Logistics Practices in Chinese Manufacturing Firms

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Abstract

This research examines the impact of green logistics practices (GLPs) on the creation of organizational green legitimacy (OGL) and whether Industry 5.0 and supply chain uncertainties moderate this relationship. Unlike earlier studies, this research takes an in-depth look at GLPs as a second-order construct comprising six sub-dimensions, including green packaging, procurement, production, transportation, warehousing, and reverse logistics, and their significant role in building organizational green legitimacy. Based on cross-sectional data collected from 350 Chinese manufacturing companies in late 2024, this study uses partial least squares structural equation modelling (PLS-SEM) to examine the proposed relationships. The results of PLS-SEM reveal that GLPs positively influence organizational green legitimacy. Further results suggest that supply chain uncertainties, which is described as a second-order construct with three sub-constructs encompassing demand turbulence, negatively moderates this relationship. Moreover, this study finds that Industry 5.0 strengthens the positive relationship between GLPs and OGL. This study provides significant practical and theoretical implications for policymakers and extends the prevailing body of literature on organizational green legitimacy.

Keywords: green logistics practices; organizational green legitimacy; supply chain uncertainties; Industry 5.0; PLS-SEM; China
JEL: L6, L14, M11, M14, O31

1. Introduction

China's growing industrialization and economic development have positioned the country as a global manufacturing hub. Although the growth was tremendous, its environmental cost has also been very high because China is now one of the primary causes of the world's carbon footprint and industrial pollution (Zhao et al., 2025). With increasing global demands for greener business practices by consumers, stakeholders, and governments putting pressure on Chinese businesses to conform, Chinese enterprises are increasingly being pushed towards acquiring organizational green legitimacy (OGL). Green legitimacy becomes important in China since companies below the threshold of environmental regulation requirements may put themselves at risk of reputation loss, disciplinary actions from regulating agencies, as well as marketplace competitiveness. Furthermore, the Chinese government has also instigated stringent environmental regulations, such as the "Dual Carbon" policy that aims for carbon peaking by 2030 and carbon neutrality by 2060 (Wei et al., 2022; Zhu et al., 2024). Green legitimacy has an important role to play for companies competing in an increasingly competitive marketplace due to their impact on how the public perceives a company's commitment to the environment.

Green logistics practices (GLPs) are a key component of achieving green legitimacy by enhancing a company's reputation for responsible business practices. GLPs differ from other environmental practices like traditional waste minimization and use of renewable energy or sustainable production through the focus on reducing resource consumption and carbon intensity related to company's operational processes (Maji et al., 2023). Recent studies have shown GLPs impact green innovation, environmental sustainability, and economic performance (Agyabeng-Mensah and Tang, 2021; Maji et al., 2023). Since there has been increased focus on GLPs, their impact on green legitimacy has not yet been adequately analysed resulting in a need for future research. This study seeks to fill this notable gap by exploring how green logistics practices impact organizational green legitimacy, especially in the context of Chinese manufacturing companies. Based on legitimacy theory, a corporation could obtain social legitimacy through compliance with the contemporary environmental issues that are fixed by regulatory agencies (Rudko et al., 2025). Legitimacy theory, as a subset of institutional framework, specifically emphasizes how firms secure social legitimacy by signifying adherence to the prevailing environmental standards and regulations. Through the implementation of

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GLPs into their day-to-day operations, firms signal environmental accountability to regulators, investors, and customers, thereby enhancing their organizational green legitimacy (OGL). In addition to an institutional framework, the resource-based view (RBV) holds that a corporation's ability to maintain legitimacy with the potential for dramatic fluctuations in supply chain operations (due to uncertainty or other factors) is dependent on the corporation's internal resources, specifically those of operational resilience, adaptive capacity, and technological agility (Barney, 1991). Under high supply chain uncertainty, firms are less likely to maintain the implementation of GLPs; hence, they are less likely to establish the requisite link between implementing GLPs and their perception of legitimacy.

However, due to the uncertainty of the environment, many companies focus more on short-term costs than on raising their legitimacy through GLPs (Gomez-Trujillo et al., 2024). For example, uncertainties associated with the availability of green raw materials, changes in technology, and changing demand for green products all present significant challenges to applying green logistics. When effective risk management programs are in place, organizations can maintain their commitment to green logistics even when significant events or unrest occur, therefore highlighting the need for research into how these uncertainties impact GLPs–OGL relationship.

On the other side, Industry 5.0 holds the promise of creating significant improvements in green legitimacy. The focus of Industry 5.0 is on human-centric industrial processes and the application of robust and sustainable industrial processes. Advanced technologies such as artificial intelligence (AI), blockchain and IoT (Internet of Things) will allow organizations to automate their logistics process. They will also facilitate optimal resource utilization and deliver enhanced supply chain transparency. The application of Industry 5.0 technologies by manufacturing organizations in China will optimize the efficiency of the green legitimacy processes to improve their green legitimacy and address regulatory and stakeholder pressures.

To achieve these objectives, this study seeks to answer the following primary research questions:

How does green logistics management practices affect organizational green legitimacy?

How does supply chain uncertainties and Industry 5.0 moderate the relationship between GLPs and green legitimacy?

This research makes a substantial contribution to knowledge in many ways. First, it advances theoretical knowledge by combining legitimacy, institutional, and the RBV theories to provide explanations regarding the ways that GLPs and when they translate to OGL. Legitimacy theory explains the need for firms to implement GLPs in order to meet social expectations placed on them; institutional theory places this behaviour in the context of broader normative and regulatory pressure on firms; and finally, RBV theory explains how a firm's internal resource base determines the firm's continued ability to maintain legitimacy during periods of external disruption. This tri-theoretical lens creates a deeper and richer way to explain green legitimacy than previous studies that only utilized one theory. Second, the study provides new empirical research regarding the effects of supply chain uncertainties and Industry 5.0 on GLPs as it relates to their effectiveness in enhancing a firm's legitimacy. Third, the study utilizes Second-Order constructs to represent GLPs and supply chain uncertainties, creating a more complete representation of their multidimensional nature, thus allowing for a fuller understanding of the impact these two constructs have on OGL. Finally, The research is based in China and thus highlights the need for discussion around the lack of research in this area, even though, at the same time, China is one of the largest industrial nations in the world, and as such is at the forefront of the dual carbon policy agenda, thus giving firm leaders, policy makers and other stakeholders in these volatile environments valuable insight on how to align their operational sustainability goals with their strategic authority on legitimacy.

2. Theory and Hypotheses

2.1 Legitimacy Theory

The study is based on the theories of legitimacy and how organizations seek to meet their stakeholders' expectations, values and norms. The legitimacy theory states that companies must align their practices with those of the wider society in order to gain stakeholder's approval (Gulluscio, 2023; Suchman, 1995). Under the green legitimacy dimension, firms feel under increasing pressure to demonstrate good business practices (including environmentally positive) as a means to achieve success. This legitimacy relies on lawfulness and conformity with regulation and congruence with broad stakeholder expectations, such as consumers, regulators, and investors (Baah et al., 2021; DiMaggio and Powell, 1983; Suchman, 1995). Securing legitimacy compel firms to adopt practices that signal their commitment to sustainability in a bid to balance risks of reputation loss, regulatory sanctions, and competitive disadvantages. Within such an umbrella, green logistics activities are a strategic mechanism for constructing legitimacy as they answer directly to the environmental concerns involved with transportation, warehousing, and distribution.

From the legitimacy theory perspective, organizations are able to attain legitimacy in three broad forms: pragmatic, moral, and cognitive legitimacy. Pragmatic legitimacy is based on stakeholders' self-interest, and therefore, companies must convince stakeholders that the adoption of GLPs is in the interest of economic as well as operational benefits, such as cost minimization and efficiency improvements. Moral legitimacy, on the other hand, draws from normative acceptance such that firms gain legitimacy through engagement in environmentally sound and ethi-

cal business practices, e.g., green production, green warehousing, and green transportation, firms endeavour to appear green due to legitimacy pressure within their business (Jazairy and von Haartman, 2020). These practices, in turn, are responsible for guaranteeing a good reputation, conformity with evolving rules, and satisfaction of consumers and investors who are more concerned with sustainability.

2.2 Institutional Theory

Legitimacy theory and institutional theory should be combined with regard to how they help explain the influence of external forces (institutional) on the behaviours of organizations (DiMaggio and Powell, 1983). In terms of environmental sustainability, the institutional environment has many pressures for environmental behavioural compliance, especially in highly regulated portions of the global economy such as the Chinese Manufacturing sector. The institutional pressure to adhere to environmental standards, through the adoption of certain practices like green logistics, is not always based on achieving an efficiency gain, but instead, to achieve social acceptance and avoid possible sanctions. The institutional theory distinguishes between three types of force that organizations experience when adopting green logistics practices: coercive forces (Government Policy), normative forces (Industry Standards) and mimetic forces. The institutional theory supports that an organization that demonstrates green legitimacy has achieved a form of institutional conformity.

2.3 Resource-Based View (RBV)

The resource-based view claims that sustained competitive advantage (and therefore, sustained legitimacy) is a function of the internal bundle of resources owned by a firm (Barney, 1991). In highly volatile external environments, a firm's ability to adjust GLPs will differ within its supply chain; this has important implications for how firms will maintain green logistics practices (Juráček et al., 2025). By virtue of their superior resources (e.g., digital infrastructures, managerial expertise, financial slack, and agile supply chain capabilities), some firms are better equipped to withstand supply chain disruptions; therefore, they are more likely to have developed green logistics practices (Vyas et al., 2024). In contrast, resource-constrained firms may deprioritize sustainability, (Ooi and Memon, 2025) can weaken the GLPs–OGL link. Thus, RBV provides the theoretical rationale for why supply chain uncertainties moderates the relationship between GLPs and OGL: it acts as a "stress test" that reveals heterogeneity in firms' resource-based resilience. Additionally, this theory aligns with the moderating role of Industry 5.0, as AI and IoT could be considered strategic resources (Waheed et al., 2022) that enable a firm to generate GLPs into OGLs.

2.4 Industry 5.0 vs. Industry 4.0 in Green Logistics

While Industry 4.0 has focused on automating, connecting, and improving the efficiency of logistics through technology such as IoT and AI to improve speed, reduce costs and increase accuracy (Zong and Guan, 2025), Industry 5.0 represents a shift in the focus of logistics toward a human-centric, resilient and sustainable perspective (Guo et al., 2023; Maddikunta et al., 2022). The technologies used in Industry 4.0 are primarily developed to make logistics operations more efficient with technology enabling the operation of smarter logistics solutions, whereas the technologies in Industry 5.0 have moved away from merely improving the efficiency of operations to use these technologies for outcomes that are also of societal importance perusing (Jefroy et al., 2022). The distinction between these two philosophies of Industry 4.0 as only a technical enabler of sustainable logistics versus Industry 5.0 being a socio-technical legitimisation of sustainable logistics is key, because Societal Industry 5.0 legitimises sustainability as part of a larger commitment to preserving humanity and stakeholders, and fostering ethical innovation. Therefore, while Industry 4.0 is a technical enabler, Industry 5.0 serves as a socio-technical legitimisation of developments in sustainable logistics and therefore represents the appropriate theoretical framework for this study.

2.5 Hypotheses Development

2.5.1 Green Logistics Practices (GLPs) and Green Legitimacy

The rise of GLP has led to an increased focus on GLPs throughout the supply chain because they can help to mitigate the negative impacts on the environment and create a more sustainable system for manufacturers (Roy and Mohanty, 2024). While these practices can help manufacturing operations reduce their environmental impact, they also help to build a positive image among multiple stakeholders (customers, investors, regulatory agencies, etc.). Green legitimacy is the perception of how committed a manufacturing organization is to becoming sustainable. Companies are increasingly focusing on building green legitimacy because green legitimacy is a key contributor to achieving long-term competitive advantage and sustained success (Truong and Nagy, 2021). GLPs are a response to institutional pressures that advocate for environmental compliance (Daddi et al., 2020) specifically as related to the current tightening of sustainability governance in China. GLPs also serve to provide a company with tools for demonstrating its commitment to being environmentally sustainable through various activities, including the reduction of waste, increased energy efficiency, and improved materials use. By adopting GLPs, manufacturers can create operational efficiencies while simultaneously enhancing their market perception of legitimacy and responsibility.

In conclusion, adopting green practices provides organizations the opportunity to signal to their stakeholders that

they are environmentally conscious and establish a positive green image. These actions also affirm to stakeholders that these organizations will continue to implement sustainable business practices, without requiring tampering of their current systems.

Based on this discussion, we propose the following hypothesis:

H1: Green logistics practices positively influence firm organizational green legitimacy.

2.5.2 Moderating Role of Supply Chain Uncertainties

supply chain uncertainties involves unpredictability and variation in demand, supply, or technological innovation within supply chain activities (Tao et al., 2025). Supply chain uncertainties can lead to poor operation flow, as well as hinder strategic goals, such as sustainability and green logistics. Green logistics practices are attempts to reduce environmental impact and demonstrate an organization's commitment to sustainability. Green logistics practices include green manufacturing, green warehousing, and green transportation (Vienažindienė et al., 2021). The level of supply chain uncertainties will greatly affect how an organization adopts and implements green logistics practices. Green logistics practice consistency is virtually impossible for organizations to maintain, when raw material and component availability change significantly within the supply chain (Lisi et al., 2020). For example, if there are disruptions in raw material supplies, it can be difficult for organizations to source green materials, and to use energy-efficient transportation; and if there are changes in customer demand, organizations may be unable to utilize routing optimization and reduce their inventory and waste over a long-term plan for green logistics implementation (Tetteh et al., 2024).

Technological turbulence refers to the rapid rate at which technology is changing, which will also affect industrial firms' ability to create and sustain green logistics systems. Energy efficient means of transportation in warehouses and environmentally friendly means of packaging that have been invented recently represent technological breakthroughs that provide the opportunity for industrial firms to improve their sustainability strategies (Perotti and Colicchia, 2023). The fact that technologically driven advancements are changing very quickly also creates uncertainty around future advances (Dang et al., 2025). Firms experiencing a high level of technological turbulence may struggle to keep abreast of sustainable technology, making it difficult for them to maintain long-term commitment to the implementation of green logistics (Amankwah-Amoah and Syllias, 2020).

From a RBV perspective, the uncertainty inherent in supply chains can serve as an unexpected external event that creates heterogeneity in firms' internal capabilities (Nguyen et al., 2025). Firms that have limited financial slack, a high degree of digital flexibility, or an adaptive logistic infrastructure are typically unable to acquire the strategic resources necessary to continue to pursue green logistics practices during periods of unstable operating conditions (Vasiulis Ferreira Rodrigues et al., 2025). Therefore, although firms may initially use GLPs as a market signal to demonstrate their commitment to the environment, inconsistent implementation of GLPs during periods of uncertainty will likely lead to a loss of legitimacy (Bálint et al., 2025; Barney, 1991). In a nutshell, RBV provides an understanding of why supply chain uncertainties act to negatively moderate the relationship between GLPs and the OGL of firms due to the way that it tests whether or not a firm's green efforts rest upon a resilient, resource-based infrastructure or strictly upon compliance with regulations.

Thus, the hypothesis can be put as:

H2: Supply chain uncertainties negatively moderates the relationship between green logistics practices and firm green legitimacy.

2.5.3 Moderating Role of Industry 5.0

Industry 5.0 represents a new direction from the automation focus of Industry 4.0 and places equal value on collaborating with humans, being sustainable and supporting society (Martini et al., 2024). With the integration of Industry 5.0, businesses will use technology to enhance human capabilities, protect worker safety, and integrate social values into their product and logistics systems (Klingenberg et al., 2021; Nicoletti and Appolloni, 2024). The goal of Industry 5.0 is to create systems that allow for human interaction and create more sustainable processes. It is in line with global and Chinese trends to integrate sustainability into many aspects of business. Under the framework of Industry 5.0, GLPs are legitimized, since GLPs may allow a firm to demonstrate its commitment to being an environmentally responsible company as well as being a morally and socially responsible organization. From a legitimacy theory perspective (Suchman, 1995), GLPs implemented under the framework of Industry 5.0 will likely be perceived by stakeholders to not only decrease emissions, but also serve as ethical and social responsiveness.

From an institutional theory perspective, employing human-centric and eco-digital systems is an example of creating products and services that comply with the increasing trend toward responsible innovation and people-centred development in China, which has been encouraged as a policy priority. Companies that reflect these values will likely receive wider stakeholder support, in addition to aligning themselves with a global sustainability agenda and the priorities of the Chinese government. The resource-based view (RBV) is another reason why Industry 5.0 allows for companies to leverage GLPs. In particular, integrating advanced technologies with human-centric organizational values results in obtaining unique, rare, and socialised capabilities that are difficult to replicate (Shankar and Gupta, 2024). Examples of such capabilities include

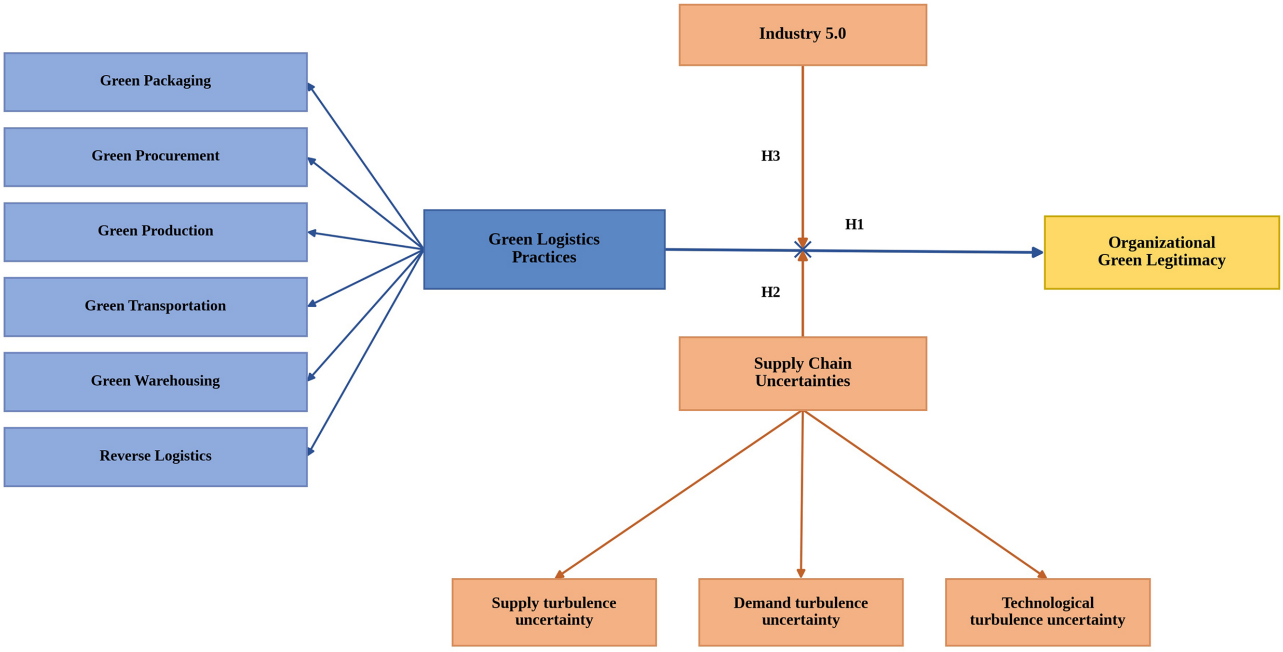


Fig. 1. Conceptual framework.

transparent, ethical, and adaptive green logistics systems, which allow an organization to move GLPs from the realm of being merely symbolic to a real, verifiable act with legitimate social importance. Many GLPs provide companies with clearer and more credible proof of adherence to environmental and social principles than if they were only reliant on one of these types of technologies (Malakar et al., 2025). In addition, Industry 5.0's driving concept of building resilient and flexible companies based on human and technology coexistence allows companies to adapt to changing environmental regulations and stakeholder needs while remaining committed to being ethical (Javaid et al., 2022). So, Industry 5.0 allows companies to more consistently and credibly apply sustainable practices to their products and operations through the use of a blend of technically agile and human-judged responses (Jefroy et al., 2022). Thus, the legitimacy-enhancing attributes of GLPs are much stronger when placed within an Industry 5.0 environment due to the moral/social authenticity conveyed through human-centric innovations, not merely due to technological efficiencies that lead us to the following hypothesis.

H3: Industry 5.0 positively moderates the relationship between green logistics practices and firm green legitimacy.

The study indicates the proposed relationships among the constructs as illustrated in Fig. 1.

3. Method

The aim of this research is to quantitatively measure how GLPs affect green legitimacy among manufacturing firms in China. A survey was completed by many manufacturing firms located in mainland China but not; Hong Kong, Macao, and Taiwan. The main purpose and goals for this research were communicated clearly to key stakeholders, such as department managers/directors, operations directors, production heads, technical Supervisors, etc. Invitation links to the survey were sent out through a secure third-party platform to make it easy to execute the survey and guarantee confidentiality of the data collected.

3.1 Data Collection

The data was collected using an online questionnaire distributed to managers of Chinese manufacturing firms. This method was chosen so that the results would accurately reflect how these managers believe they use GLP (Green Logistics Practice) and the effect that they think it has on their firm's 'green legitimacy' (regarding the environmental benefits of GLP). 700 invitations were sent via email, as well as through professional networks and other means, to managers of companies within multiple industries. The questionnaire was made available for 45 days, allowing the respondents ample opportunity to complete it when it was convenient for them. To enhance data quality and authenticity, several procedural safeguards were implemented. The questionnaire is reported in Appendix Table 7.

An attention check item was built into the online survey. Responses with large numbers of missing responses, repeated responses or a completion time of under 5 minutes were eliminated during the data cleaning procedure. The invitations were predominantly distributed using known professional contacts and association rosters, thus increasing the probability of having fewer non-eligible respondents in the data set. Following this quality control procedure, 450 responses were left for analysis, resulting in an ex-

cellent response rate (64.3%), which is usually considered exceptional for web-based surveys of organizational work. The sample was comprised of organizations engaged in a wide variety of manufacturing sub-sectors in China, with the majority of respondents coming from the electronics and information technology manufacturing industries (31.1%) and the machinery and equipment manufacturing industries (21.1%) sectors, which are the most prominent sub-sectors associated with the Chinese green manufacturing initiatives (Daniel et al., 2024). G*Power 3.1 (Heinrich Heine University Düsseldorf, Düsseldorf, Germany) analysis was employed to analyse whether the data collected was statistically sufficient to perform the model estimation and hypothesis testing.

3.2 Measures

The survey tool had two parts: the first part collected basic details about the respondents and their firms (type of business, size of company, level of management and employment information) to provide an adequate description of the sample and evaluate how representative it was. The second part included measurement items for all core constructs (adopted from reliable scales in existing research as a way to establish both reliability and construct validity) with all items measured on a seven-point Likert scale (1 = definitely disagree to 7 = definitely agree). This scale format has been strongly suggested by the literature for improving variances in responses and the precision of measurements (Podsakoff et al., 2003). Green logistics practices (GLPs) were examined using a multidimensional construct that included six dimensions of GLPs: Green production, green procurement, green packaging, reverse logistics, green transportation and green warehousing. Items used to measure GLPs were adapted from established scales in previous studies (Acquah et al., 2023; Afum et al., 2022; Chan et al., 2018; Roy and Mohanty, 2024) demonstrating a high level of reliability in their ability to measure observable, action-based environmental practices. The dependent variable in this study was organizational green legitimacy (OGL), which provides a measure of the degree to which an organization is perceived by its stakeholders to be in normative alignment with the social expectations placed on it concerning its level of environmental responsibility (Suchman, 1995). To study this, we employed items from previous research (Del-Castillo-Feito et al., 2021; Li et al., 2018) that identify stakeholder perceptions regarding the credibility of a company, compliance with regulations, and an organization's dedication to sustainability as three important components for both pragmatic and moral legitimacy. We used a second-order latent construct of supply chain uncertainties represents three variables: supply turbulence, demand turbulence and technological turbulence. The tripartite structure is well documented in supply chain literature (Zhang et al., 2020; Zhou et al., 2019) since each type of supply chain turbulence presents unique sources of environmental disruption from a supply chain perspective that create challenges for consistent application of 'green' practices. The second moderator, Industry 5.0, was assessed using an adapted scale developed by previous studies (Benghouala and Benamirouche, 2025; Wang et al., 2025). which focused on the incorporation of human-centric digital technologies into the supply chain. This scale was chosen because of its ability to showcase the human-machine synergy and sustainability differentiation that separates Industry 5.0 from Industry 4.0.

3.3 Data Analysis

Evidence collected was examined using partial least squares structural equation modelling (PLS-SEM) to develop a better understanding of how the research variables are related to one another. Following a two-stage process, analyses of both the measurement model & structural models were done using SmartPLS 4.0 (SmartPLS GmbH, Bönningstedt, Germany). The measurement model assessed the internal consistency (reliability) of the factor(s) as well as the validity of the factor(s) through convergent and discriminant validity (Henseler et al., 2015). In the structural model analysis, path coefficients, R^2, effect sizes (f^2) predictive relevance (Q^2), and bootstrapping were used to determine the significance of the path coefficients. Multi-collinearity was assessed by using variance inflation factor (VIF) values to show that there was no correlation among predictor variables.

3.4 Descriptive Statistics

The descriptives are presented in Table 1. There were 450 professionals surveyed from 350 Chinese manufacturing companies. In Table 1, there was a substantial number of males in the sample (77.8%) and about 22.2% females participating in the survey. The majority of respondents worked at large organizations (60.0%), followed by medium-sized companies (22.9%), while only 17.1% worked in small businesses. The respondents differed in their total work experience, since 30% had between 5–10 years. 20% of the respondents had less than 2 years' experience; 16.7% had more than 10 years' experience. Regarding designation, 40.0% held managerial roles, 36.7% were supervisors, and 23.3% were directors.

4. Results and Discussion

4.1 Data Screening

The data set was assessed for reliability, accuracy, and readiness for the PLS-SEM analysis before starting the analysis. Skewness and kurtosis were checked for normality of the distribution; the acceptable limits for normality were determined to be ±1.5. The small deviations were acceptable since PLS-SEM does not require strict assumptions of normality. The presence of multicollinearity among the independent variables was assessed by examining VIF; in this case, all variables' VIF values fell below the crit-

Table 1. Demographics.

Demographic variable	Categories	Frequency	Percentage (%)
Gender	Male	350	77.8%
	Female	100	22.2%
Company size	Small	60	17.1%
	Medium	80	22.9%
	Large Scale	210	60.0%
Experience	1–2 yrs	90	20.0%
	2–5 yrs	150	33.3%
	5–10 yrs	135	30.0%
	More than 10 yrs	75	16.7%
Current designation	Supervisors level	165	36.7%
	Managers level	180	40.0%
	Directors level	105	23.3%
Industry type	Electronics & IT Manufacturing	140	31.10%
	Machinery & Equipment	95	21.10%
	Chemicals & Plastics	75	16.70%
	Textiles & Apparel	60	13.30%
	Automotive & Parts	50	11.10%
	Others	30	6.70%

Note: The study surveyed 450 respondents from 350 firms. Multiple respondents from the same firm were used to reduce single-respondent bias.

ical cut-off of 5 suggested by Hair et al. (2019). Hence, multicollinearity among independent variables was not a significant issue. Harman's single-factor test was used to assess for Common Method Bias (CMB), while an unrotated exploratory factor analysis indicated that no factor accounted for more than 50% of the variance, meaning that CMB would not be a major concern (Podsakoff et al., 2003). Additionally, the full collinearity approach was used by examining VIF values for all constructs. The VIF values for all predictors were all below 3.3, confirming that method bias was not present (Kock, 2015).

4.2 PLS Analysis

The repeated indicators and two-stage approaches are two common ways researchers define and estimate higher-order constructs (Ringle et al., 2012). Previous research used simulations to compare the accuracy of the repeated indicators and two-stage approaches for estimating the relationships between first-order constructs and second-order constructs of reflective-formative higher-order constructs (Becker et al., 2012). This method was implemented by categorizing the exogenous variable GLPs into six dimensions including green production, green warehousing, green procurement, green packaging, reverse logistics, and green transportation. These dimensions have achieved high R^2 values of 62%, 41.1%, 59.6%, 63.3%, 67.7%, and 40.6% respectively. Furthermore, a strong correlation was found between GLPs and its sub-dimensions, with green production at 0.787, green warehousing 0.641, green procurement 0.772, green packaging 0.795, reverse logistics 0.823, and green transportation stood at 0.637 (Fig. 2). The extended repeated indicators approach for the supply chain uncertainties indicates three dimensions with a high R-squared value of 63.8% in supply turbulence uncertainty, 81.7%, in technological turbulence uncertainty and 93.9% in demand turbulence uncertainty respectively. Second-order supply chain uncertainties and its sub-dimensions were highly correlated: supply turbulence uncertainty stood at 0.799, technological turbulence uncertainty 0.904 and demand turbulence uncertainty at 0.969 (Fig. 3). In the second-order approach, two measurement models are assessed: the first for the first-order constructs and the second for the higher-order (second-order) construct (Sarstedt et al., 2019).

4.2.1 Measurement Model (First-Ordered Constructs)

Before testing the hypotheses, convergent and discriminant validity must be guaranteed to establish the measurement model accurately measures and discriminates the constructs of interest (Hair and Alamer, 2022). Convergent validity validates whether the operationalization of a construct is comparable to other theoretically related measures. In this study, it was investigated by examining to what degree the variables GLPs, green legitimacy, supply chain uncertainties and Industry 5.0 were in accordance with their hypothetical relations. It was carried out by conducting confirmatory factor analysis (CFA), factor loading test, average variance extracted (AVE), Cronbach's alpha (CA) and composite reliability (CR). All indicators showed strong factor loadings exceeding the 0.6 threshold (see Fig. 4), CR and CA confirming a robust connection between observed variables and their respective constructs (Hair and Alamer, 2022). Additionally, AVE values for all constructs surpassed the 0.5 benchmark, indicating that the measured variables explained more than 50% of the variance in their respective constructs (Hair and Alamer, 2022). As presented in Table 2, these findings confirm that the measurement model demonstrates sufficient convergent validity, ensuring that the constructs effectively capture their intended theoretical concepts and contribute to the study's overall validity.

Establishing discriminant validity is crucial in an attempt to confirm whether the study's constructs are empirically distinct and not redundant definitions of the same construct. Discriminant validity in this study was assessed using the Fornell and Larcker (1981) criterion and the Heterotrait-Monotrait (HTMT) ratio (Henseler et al., 2015). The Fornell and Larcker criterion was developed by cross-verifying the square root of the Average Variance Extracted (AVE) of each construct with inter-construct correlations. The results were in line with discriminant validity because the square root of the AVE of each construct was higher

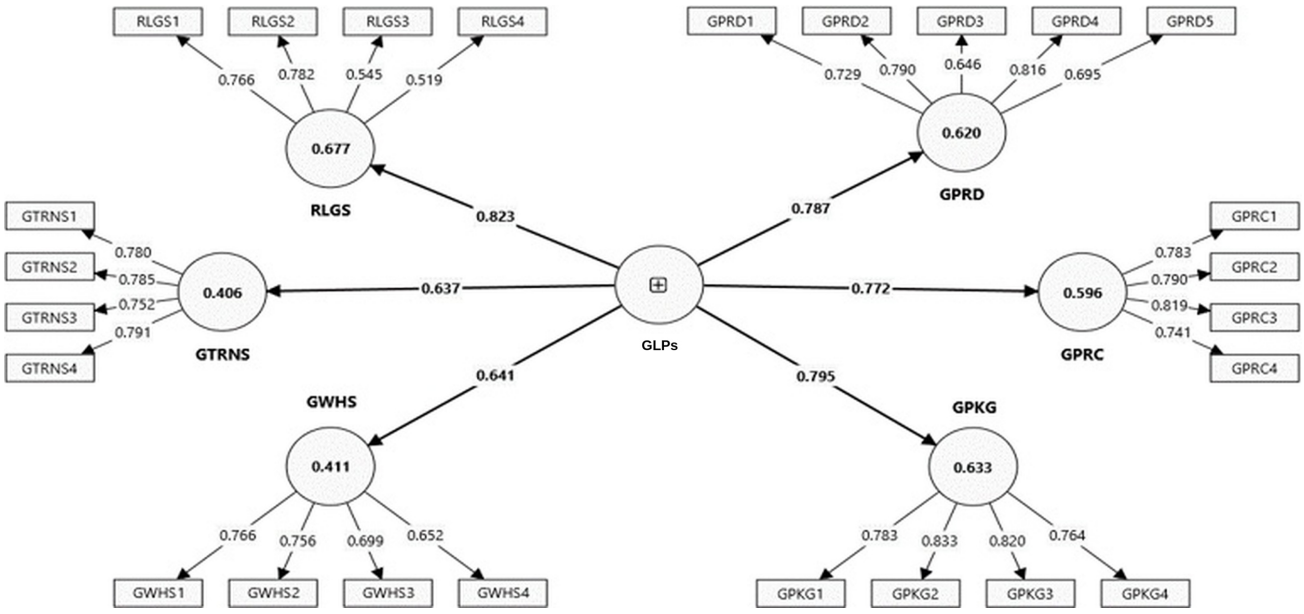


Fig. 2. Extended repeated indicators for GLPs. GLPs, green logistics practices; RLGS, reverse logistics; GPRD, green production; GTRNS, green transportation; GPRC, green procurement; GWHS, green warehousing; GPKG, green packaging.

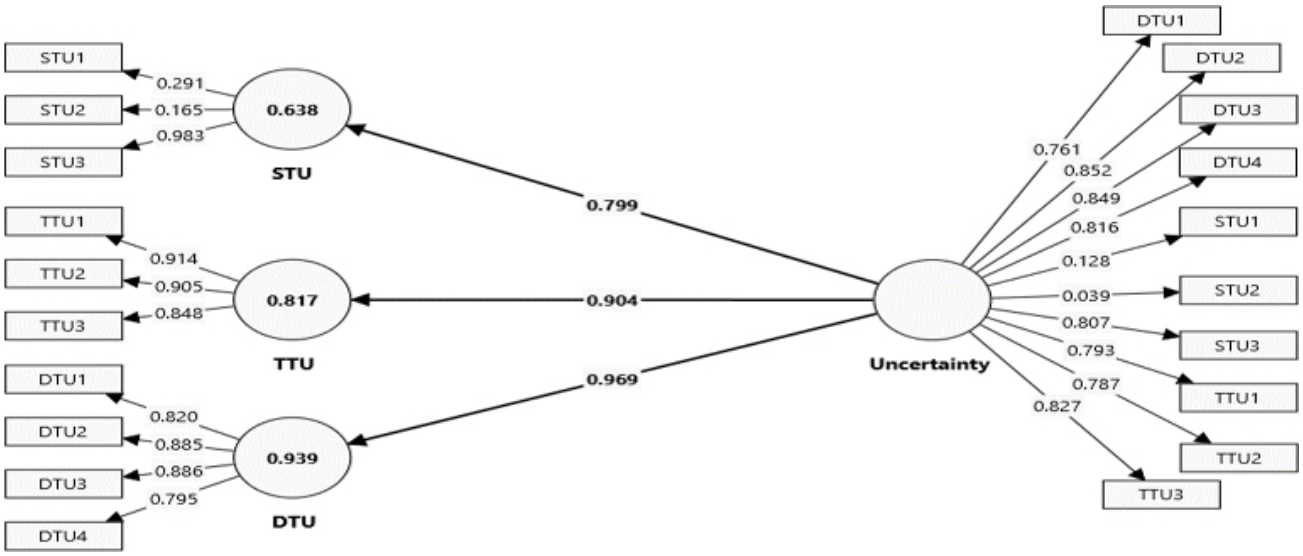


Fig. 3. Extended repeated indicators for supply chain uncertainties. STU, supply turbulence uncertainty; TTU, technological turbulence uncertainty; DTU, demand turbulence uncertainty.

than its inter-construct correlations, which validated that each construct was measuring distinct variance. In addition, HTMT method provided a more stringent test, whereby HTMT ratios for each construct pair were below the 0.90 threshold, except for GWHS, which was exactly at the cut-off, further validating construct separation (Henseler et al., 2015). These methods together provide great empirical support for discriminant validity in the measurement model as evident from the findings presented in Table 3.

4.2.2 Measurement Model (Second-Order Constructs)

GLPs and supply chain uncertainties were conceptualized as second-order constructs in the study. GLPs comprise six dimensions: green procurement, green packaging, green production, green transportation, green warehousing, and reverse logistics, whereas supply chain uncertainties comprise three dimensions: demand turbulence uncertainty, supply turbulence uncertainty, and technological turbulence uncertainty, as shown in Table 4. For confirming the second order construct (SOC) validity outer weights, outer loading and values of VIF are checked (Sarstedt et al., 2019). The outer weights proved to be significant. All

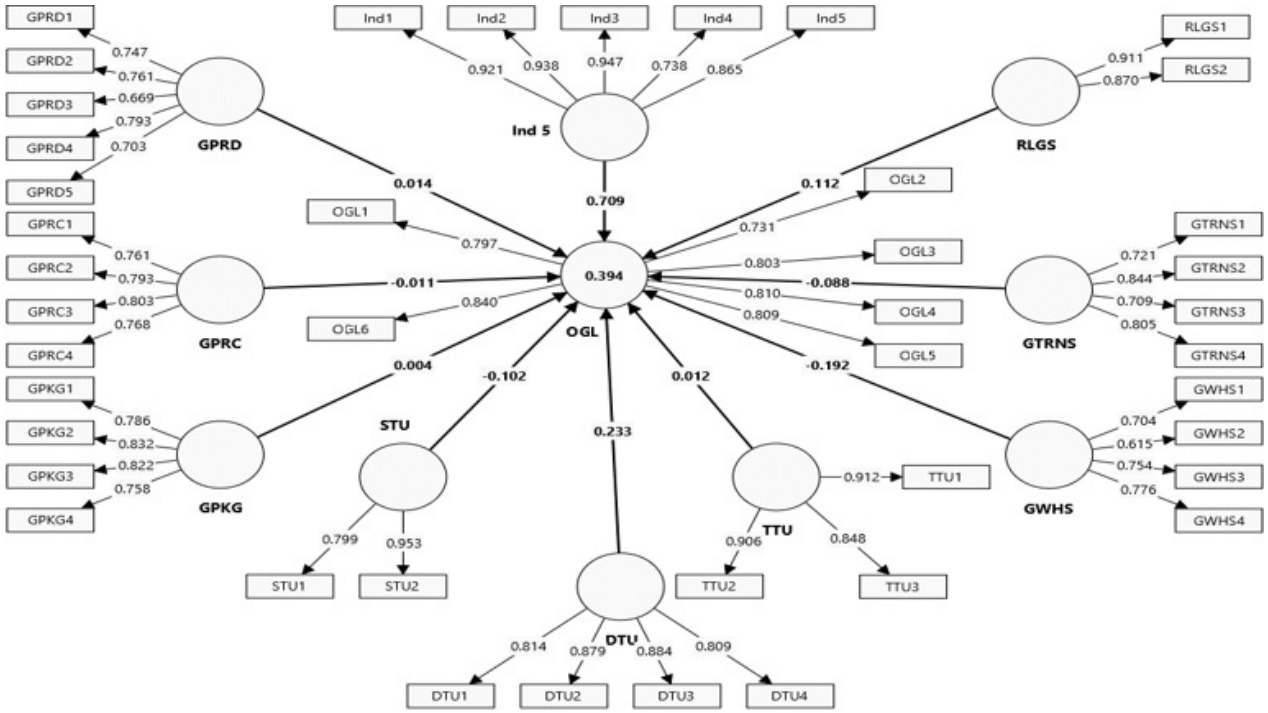


Fig. 4. Measurement Model first-ordered construct.

Table 2. Convergent validity.

Construct	Cronbach's alpha	CR (rho_a)	CR (rho_c)	AVE
Demand turbulence uncertainty	0.868	0.872	0.910	0.717
Green legitimacy	0.886	0.887	0.914	0.639
Green packaging	0.812	0.813	0.877	0.640
Green procurement	0.790	0.800	0.863	0.611
Green production	0.788	0.789	0.855	0.542
Green transportation	0.782	0.839	0.854	0.595
Green warehousing	0.701	0.710	0.806	0.511
Industry 5.0	0.930	0.956	0.947	0.783
Reverse logistics	0.742	0.759	0.885	0.793
Supply turbulence uncertainty	0.733	0.980	0.871	0.773
Technological turbulence uncertainty	0.867	0.867	0.919	0.791

Note: CR, composite reliability; AVE, average variance extracted.

outer loadings exceeded the 0.50 threshold, except for STU, which had a loading of 0.451. Last, VIF values proved less than 5. As all criterion are fulfilled as shown in Fig. 5 and Table 4, SOC validity was confirmed (Sarstedt et al., 2022).

4.3 Confirmatory Factor Analysis

The measurement model was evaluated using confirmatory factor analysis (CFA) to assess overall model fit prior to structural path estimation. As shown in Table 5, multiple goodness-of-fit indices were examined. The Comparative Fit Index (CFI) = 0.913 and Tucker-Lewis Index (TLI) = 0.919 exceed the recommended threshold of 0.90 for good fit (Hu and Bentler, 1998). Hu and Bentler (1998) recommend a cut-off value of 0.08 for SRMR and 0.0 for RMSEA however, the value RMSEA should not exceed 0.08. The Root Mean Square Error of Approximation (RMSEA) = 0.074 falls below the 0.08 cut-off, indicating close fit. The χ^2/df ratio of 3.543 is well below the upper limit of 5.0, further supporting model adequacy (Lomax, 2004). Collectively, these fit indices indicate that the measurement model fits the data well, supporting the validity of the latent structure and justifying progression to structural model testing.

4.4 Hypotheses

After verifying the measurement models, we tested the structural model to check the hypothesized relationships in the research model using bootstrap procedure of 5000 subsamples. The findings in Table 6 and Fig. 5 underscored that GLPs positively effects green legitimacy ($\beta = 0.343$; $p < 0.01$), the moderating effects of supply chain uncertainties ($\beta = –0.667$; $p < 0.01$) is negative and significant, but the moderating effect of Industry 5.0 ($\beta = 0.558$; $p < 0.01$) is positively significant on the relationship between GLPs and green legitimacy. Hence, H1, H2 and H3 are supported. The R^2 value indicates the current study accounts for 55.4% of the variance in green legitimacy. The Q^2 values for the dependent construct green legitimacy is 0.488, illuminating acceptable extrapolative significance and indicates satisfactory predictive relevance of the model.

Table 3. Discriminant validity.

Construct	1	2	3	4	5	6	7	8	9	10	11
1. DTU	0.847										
2. OGL	0.354	0.799									
3. GPKG	0.706	0.317	0.800								
4. GPRC	0.735	0.293	0.602	0.782							
5. GPRD	0.774	0.329	0.567	0.671	0.736						
6. GTRNS	0.273	0.298	0.271	0.294	0.298	0.772					
7. GWHS	0.294	0.244	0.315	0.238	0.291	0.652	0.715				
8. Ind 5	0.178	0.530	0.215	0.182	0.225	0.638	0.607	0.885			
9. RLGS	0.567	0.290	0.704	0.507	0.490	0.242	0.303	0.175	0.891		
10. STU	0.036	0.301	0.078	0.020	0.022	0.360	0.451	0.708	0.091	0.879	
11. TTU	0.799	0.321	0.656	0.671	0.716	0.250	0.246	0.184	0.522	0.029	0.889
HTMT											
1. DTU											
2. OGL	0.401										
3. GPKG	0.830	0.372									
4. GPRC	0.860	0.342	0.727								
5. GPRD	0.823	0.384	0.701	0.839							
6. GTRNS	0.322	0.334	0.335	0.365	0.368						
7. GWHS	0.393	0.288	0.444	0.333	0.393	0.900					
8. Ind 5	0.187	0.569	0.228	0.198	0.241	0.748	0.726				
9. RLGS	0.707	0.355	0.862	0.653	0.647	0.323	0.445	0.199			
10. STU	0.074	0.341	0.134	0.086	0.106	0.509	0.602	0.834	0.155		
11. TTU	0.882	0.366	0.772	0.786	0.894	0.294	0.320	0.186	0.651	0.050	

Note: DTU, Demand turbulence uncertainty; OGL, organizational green legitimacy; GPKG, green packaging; GPRC, green procurement; GTRNS, green transportation; GWHS, green warehousing; Ind 5, Industry 5.0; RLGS, reverse logistics; STU, supply turbulence uncertainty; TTU, technological turbulence uncertainty.

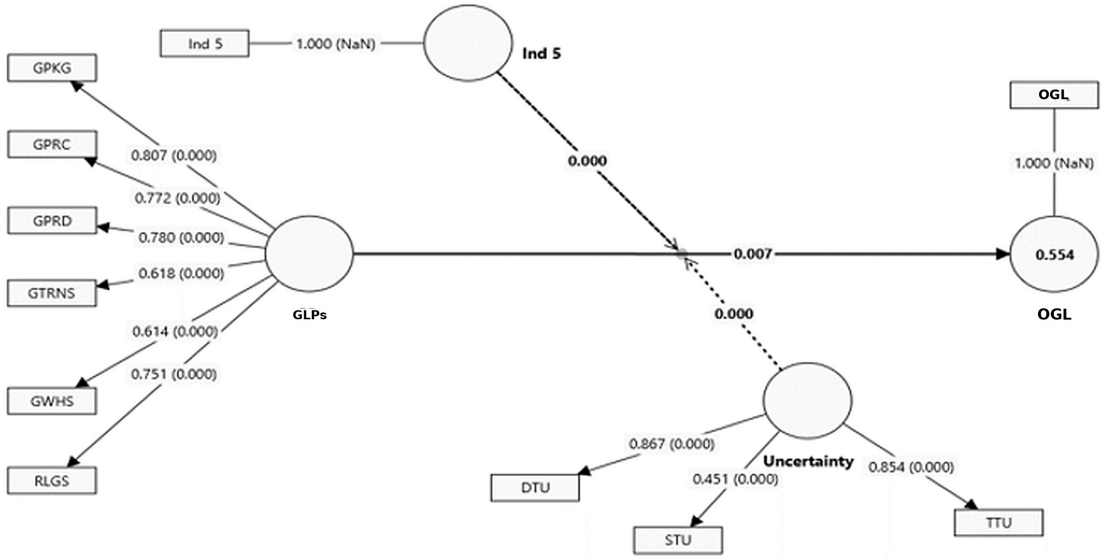


Fig. 5. Structural model.

Fig. 6 describes the moderating role of supply chain uncertainties on the relationship between GLPs and green legitimacy. As shown, when supply chain uncertainties is low (see the red line), GLPs are strongly and positively related to green legitimacy. However, as supply chain uncertainties increases (see the green line), this relationship weakens and turns negative, indicating that uncertainty undermines the legitimacy gains from GLPs.

Table 4. Second order constructs.

SOC	LOC	Outer weights	T value	*p* value	Outer loadings	VIF
GLPs	GPKG	0.246	10.674	0.000	0.807	2.458
	GPRC	0.227	9.759	0.000	0.772	2.141
	GPRD	0.255	9.919	0.000	0.780	2.018
	GTRNS	0.231	6.221	0.000	0.618	1.810
	GWHS	0.189	5.018	0.000	0.614	1.838
	RLGS	0.225	9.074	0.000	0.751	2.067
SCU	DTU	0.493	13.943	0.000	0.867	2.770
	STU	0.420	4.527	0.000	0.451	1.001
	TTU	0.448	13.469	0.000	0.854	2.769

Note: SOC (Second-order construct): A higher-level construct formed by multiple lower-order constructs. LOC (Lower-Order Construct): A first-level construct that represents a specific dimension of a broader construct, and SCU indicates supply chain uncertainties.

Table 5. Goodness-of-fit values.

Fit Indices	Recommended value	Source	Estimated model
Chi-square			892.633
p value	In-significant	(Hu and	0
χ^2/df	≤5	Bentler,	3.543
RMSEA	≤0.06	1998),	0.074
GFI	≥0.90	(Lomax,	0.917
SRMR	≤0.08	2004),	0.294
NFI	≥0.90	(Khan et	0.901
TLI	≥0.90	al., 2019)	0.919
CFI	≥0.90		0.913

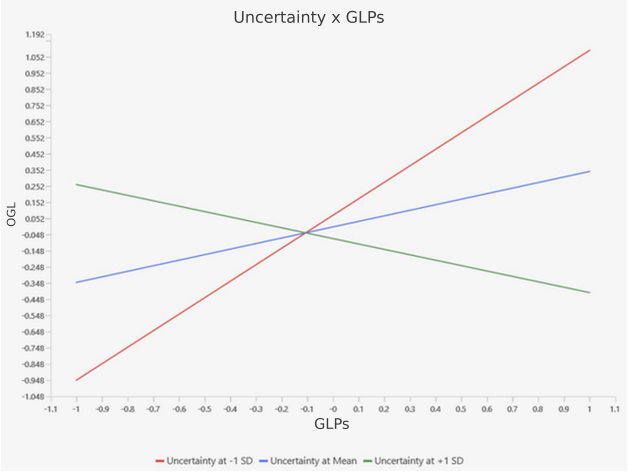


Fig. 6. Supply chain uncertainties moderation.

Fig. 7 describes the moderating role of Industry 5.0 on the relationship between GLPs and green legitimacy. As shown, when the concept and implementation of Industry 5.0 is low (see the red line), firms exhibit a low level of green legitimacy. However, as the concept and implementation of Industry 5.0 increases (see the green line), firms show more green legitimacy.

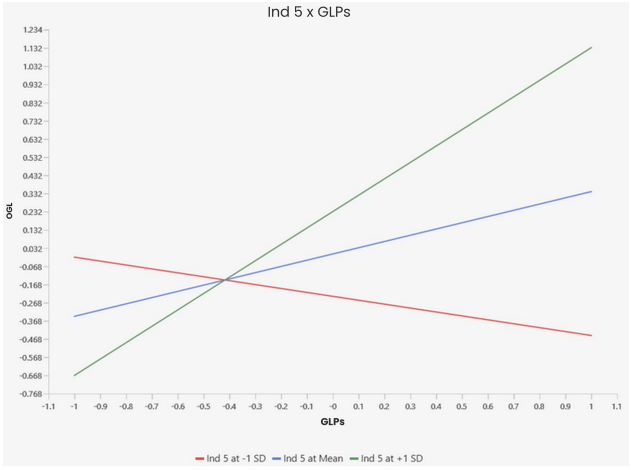


Fig. 7. Industry 5.0 moderation.

4.5 Discussion

This study introduces a novel theoretical framework that explores how green logistics and green legitimacy interact in an organization; additionally, it identifies how both are influenced by the elements of Industry 5.0 and supply chain uncertainties. The framework is unique because it provides a detailed understanding of GLPs as a second-order construct, which consists of six sub-levels (i.e., the areas of green packaging, green procurement, green production, green transportation, green warehousing, and reverse logistics), and how the combination of all these elements is essential for the development of an organization's green legitimacy. The framework's robustness is evidenced by its high level of explanatory power (R^2 = 55.4 percent), as well as its ability to predict (i.e., Q^2 value = 0.488), and therefore, its value as a tool for accurately portraying and predicting the complexities associated with the interdependence of these constructs.

Our analysis shows that GLPs significantly and positively impact an organization's green legitimacy in support of hypothesis 1 (H1). This reveals that GLPs are key to enhancing the image and reputation of the organization as a sustainable business. Companies that engage in sustainable transportation, sustainable warehousing, sustainable procurement, sustainable manufacturing, sustainable packaging, and sustainable reverse logistics will establish a credible basis through their sustainability initiatives, which will help build stakeholder trust in the organization and, ultimately, their green legitimacy. This finding supports prior literature regarding the importance of integrating sustainability into an organization's core processes to achieve both environmental and reputation benefits. From a legitimacy theory perspective, this illustrates how organizations can

Table 6. Hypotheses results.

Hypothesis	Path	β	T value	*p* value	f^2
H1	GLPs → Green legitimacy	0.343	2.697	0.007	0.078
H2	GLPs*supply chain uncertainties → Green legitimacy	–0.667	7.85	0.000	0.481
H3	GLPs*Industry 5.0 → Green legitimacy	0.558	6.744	0.000	0.324
		Green legitimacy			
R^2		55.4%			
Q^2		48.8%			

align their activities with those society expects concerning environmental responsibility and their actions will therefore be seen as legitimate and supported by their stakeholders.

Moreover, there are significant negative effects of supply chain uncertainties on the green legitimacy of organizations supported by GLPs, supporting H2. This means that the presence of uncertainties, particularly demand turbulence, undermines the ability of GLPs to drive green legitimacy. The rationale for this finding is predicated upon the destabilizing effects that supply chain uncertainties have on the provision of resources, the disruption of operations and the reduction of credibility associated with green initiatives. This issue is particularly pronounced in the manufacturing sector within China because the absence of both political and supplier stability leads to organizations taking a reactive rather than a strategic approach to sustainability decisions.

The relationship between Industry 5.0 and green logistics practice (GLP) has a positive influence on organizational green legitimacy, supporting hypothesis 3. The relationship highlights that the Industry 5.0 approach enhances the efficiency of the GLPs through the application of cutting-edge technologies, combined with the incorporation of human-centric methodologies. By doing so, organizations can achieve the maximum efficiency, transparency and scalability in their green logistics operations. This combined approach increases the degree of fit between operational performance and sustainability objectives, while also enhancing the organization's credibility as a leader in sustainable innovation. The legitimacy theory describes how the implementation of Industry 5.0 technologies allows organizations to exceed society's expectations regarding environmental responsibility, thereby further enhancing their legitimacy. In China's government-guided innovation ecosystem, by adopting Industry 5.0, organizations align themselves with the national goal of "smart green manufacturing" and, therefore, improve political and institutional legitimacy, as well as market-based credibility.

Taken together, our results conclude that green logistics practices do lead to green legitimacy, their success is very much influenced by the "stability" and "technological maturity" of the supply chain environment in which they exist. Such environmental characteristics are evident in the competitive environment of manufacturers within China, which are typically characterized by high levels of competitive pressure, a multiplicity of suppliers, and quickly changing legislation related to the environment. Consequently, it would appear that, for firms in China, the use of symbolic/standalone green initiatives alone will not produce green legitimacy from their stakeholders (Li et al., 2018). Therefore, in order for GLPs to build legitimacy, they must be supported by resilient, low-uncertainty operations and augmented by Industry 5.0 capabilities that provide the capability for both consistent execution and the ability to effectively communicate. Conversely, organizations that use digital tools (such as blockchain for traceability, IoT for real-time tracking, etc.) to validate and openly share sustainability-related performance with their supply chain partners and government regulators will have established a systemic commitment to sustainability, which aligns with the policy focus of China's "green supply chain collaboration" (Ozuem et al., 2024). Thus, what our research demonstrates is that organizational green legitimacy in the context of China's institutional framework is generated not by green action alone but through verifiable stable accountable and networked green activity.

5. Implications of the Study

5.1 Theoretical Implications

This paper contributes to the advancement of different theories concerning the interaction between modern green logistics practices and their capacity to convey a company's environmentally ethical reputation during periods of dynamic change within the supply chain. First, legitimacy theory is typically seen as the means to understand how firms adopt GLPs because they wish to conform to societal expectations of behaviour. However, this study builds upon and expands that view of legitimacy, by exploring how legitimacy is not only fluid and contextual, but also contingent on both external and internal factors. Thus, while the influence of GLPs on an organization's OGL is primarily dependent on both a firm's internal resources available to sustain such practice(s) and the environmental stability of an organization, it provides a bridge between the micro-strategic actions of firms today and the macro-institutional pressures faced by firms throughout time.

Second, from RBV perspective, we suggest that organizations will perceive supply chain uncertainties as a 'stress test' for their organizational resources. As a result, organizations that do not possess the strategic resources

necessary to respond to periods of heightened uncertainty and turbulence will be less likely to invest in green logistics practices, thus creating questions around their green commitment from stakeholders in the future. We will extend the definition of 'legitimacy' to include companies' demonstration of resilience in difficult times as well as meeting regulatory requirements. Furthermore, we demonstrate how through Industry 5.0 firms can communicate that sustainability is part of their social value systems rather than simply an operational metric. Thus, Industry 5.0 represents both a resource available to create competitive advantage (RBV) and an identifier of organizational conformance to normative standards (Institutional Theory) forming two different channels for enhancing legitimacy.

5.2 Practical Implications

This study emphasizes the strategic significance for all businesses to adopt green logistics practices into their daily business strategies. Creating environmentally-friendly practices throughout all areas of their supply chain will provide an organization with green legitimacy and build confidence among their stakeholders and in turn give them a competitive advantage in the marketplace. Organizations must also recognize supply chain uncertainties that can hinder their sustainability initiatives, particularly demand fluctuations, and put in place structure and procedures, such as effective risk management systems, flexible supply networks, and effective contingency planning processes, to ensure continued operation of their sustainability initiatives. Organizations should explore and utilize available Industry 5.0 technologies, such as artificial intelligence, block chain technology, and smart automation, to help them to operate their GLPs more efficiently while also increasing operational transparency and responsiveness and positioning themselves as leaders in sustainable innovation.

This study also guides the policymakers to develop a favourable environment for green logistics and establishing business models based on advanced technologies, and providing solutions to the uncertainties related to the supply chain as a result of demand fluctuations and material shortages. Governments need to create a framework of collaborative risk-sharing arrangements and provide institutions that will support the development of supply chain resilience through public-private partnerships. Policymakers can further promote the values of Industry 5.0 by financially supporting the retraining of workers, by subsidising the construction of green digital infrastructure and by creating opportunities for equal access to innovative solutions necessary for creating sustainable development.

Firms pursuing "green logistics" benefit both the environment and society. By holding businesses accountable to their sustainable commitments, consumers, civil society, and the media can support companies in their pursuit of environmentally responsible behaviour. With the growth of awareness around the potential for Industry 5.0 to provide communities with the tools needed to use technology in a way that maximizes ecological integrity while supporting the well-being of human beings through worker-safe automation and ethically sourced materials, it is expected that sustainability will continue to become a focus of businesses globally, including in industrial areas of Germany, manufacturing hubs in India, and logistics in the United States. Those organizations aligning themselves with these trends will provide themselves with the social legitimacy to operate successfully in society.

6. Conclusion

This study, grounded by legitimacy theory, examined how green logistics practices obviously have a major effect on the legitimacy of companies' environmentally friendly operations, and that this impact is moderated by both Industry 5.0 and uncertainty within the supply chain. In addition to surveying what previous studies had shown regarding green logistics and uncertainties within the supply chain, this is the first study to take a systematic and thorough look at how green logistics and uncertainty within the supply chain are both second-order constructs and how they affect organizational green legitimacy. The research was conducted using data from a survey of 450 managers of Chinese manufacturing companies. Hypotheses testing was completed using the partial least squares structural equation modelling (PLS-SEM) method. Results suggest that GLPs can help improve the credibility and image of companies as sustainable businesses and that, in addition, this relationship is negatively impacted by supply chain uncertainties, which are also a second-order construct with three sub-constructions. Finally, Industry 5.0 enhances the positive relationship between green logistics and Organizational Green Legitimacy (OGL). These findings highlight the importance of recognizing how external uncertainties and technological advancement shape the relationship between GLPs and OGL.

The study has a number of limitations. First, China's unique economic, regulatory and cultural characteristics may represent an influencing factor on how green logistics practices are implemented and how organizations perceive their own green legitimacy. Thus, while the findings are relevant to China, they may not be generalizable to organizations in other areas of the world with different institutional, market and social characteristics. Caution should therefore be taken when extrapolating these results to other cultures and geographic regions. The study employs cross-sectional data, which identifies associations at one point in time only. Despite the information being relevant, the strategy does not allow us to establish the dynamic and ever-evolving nature of GLPs, supply chain uncertainties, and Industry 5.0 technologies over time. The application of a longitudinal study would offer proof of what occurs in relations and changes over different phases of organizational sustainability programs. Additionally, the study relies ex-

Table 7. Constructs questionnaire.

Construct	Indicator	Items
Green production	GPRD1	Our company prioritize renewable resources in our production processes.
	GPRD2	Our company production processes are regularly audited for environmental compliance.
	GPRD3	Our company recycling activities carried out to ensure full usage of resources.
	GPRD4	Our company employees are trained on eco-friendly production techniques.
	GPRD5	Our manufacturing processes are examine to reduce the amount of waste, energy consumption and emissions.
		(Digalwar et al., 2013; Roy and Mohanty, 2024)
Green procurement	GPRC1	Our company obtain products or services that meet the green requirement or policy.
	GPRC2	We ensure the safe, incoming movement of product to our facilities.
	GPRC3	Our Company engage long term partnerships with green-certified suppliers.
	GPRC4	Our company document and disclose procurement policies as it relates to sustainable production practices.
		(Chan et al., 2018; Roy and Mohanty, 2024)
Green packaging	GPKG1	We continuously improve our packaging for environmental friendliness.
	GPKG2	We conduct periodic assessments of our packaging practices.
	GPKG3	We use recyclable or bio degradable packaging materials.
	GPKG4	Customers are encouraged to return packaging for reuse.
		(Acquah et al., 2023; Afum et al., 2022)
Reverse logistics	RLGS1	We track and report the volume of returned materials.
	RLGS2	Environmental benefits are integral to our reverse logistics.
		(Pushpamali et al., 2021)
Green transportation	GTRNS1	Transportation routes are optimized to reduce emissions.
	GTRNS2	We use software to plan environmentally friendly routes.
	GTRNS3	Green vehicle maintenance practices are enforced.
	GTRNS4	We actively measure and reduce transportation carbon footprint.
		(Colicchia et al., 2013)
Green warehousing	GWHS1	Our warehousing adheres to green building standards.
	GWHS2	Environmental impact of warehousing is regularly assessed.
	GWHS3	Automated systems improve warehousing energy efficiency.
	GWHS4	Waste from warehousing operations is minimized.
		(Wang, 2019)
Supply turbulence uncertain	STU1	Supply source of our main products frequently has considerable variation in volume.
	STU2	In general, there is significant uncertainty in supply source for our main products.
		(Sun et al., 2009)
Demand turbulence uncertain	DTU1	Demand fluctuations affect green logistics planning.
	DTU2	Logistics demand is unpredictable nationwide.
	DTU3	The demands and preferences of customers in the principal industry are constantly changing.
	DTU4	Demand uncertainties challenge green logistics efforts.
		(Chu et al., 2018; Zhu and Sarkis, 2007)
Technology turbulence uncertain	TTU1	Technologies behind the major products in the industry upgrade rapidly.
	TTU2	Innovation of new production processes in the principal industry occurs very fast.
	TTU3	The technology in our industry is changing rapidly.
		(Zhang et al., 2020; Zhou et al., 2019)
Organizational green legitimacy	OGL1	Our Most consumers in the general public approve of our company's sustainable manufacturing practices.
	OGL2	We Promotes respect to international treaties and standards.
	OGL3	Our company is committed to meeting the industry standards in its sustainable production practices.
	OGL4	Our company responds in an ethical and committed manner to the local organizations' demands.
	OGL5	Our company promotes respect to international treaties and standards.
	OGL6	Our company follows government regulations for green operating procedures in the industry.
		(Del-Castillo-Feito et al., 2021; Li et al., 2018)

Table 7. Continued.

Construct	Indicator	Items
Industry 5.0	Ind1	Our firm uses collaborative robots (cobots) to assist workers in repetitive tasks.
	Ind2	Human workers are involved in decision-making alongside AI systems.
	Ind3	Technology is designed to enhance worker safety and well-being.
	Ind4	Employees are trained to work effectively with intelligent machines.
	Ind5	The firm prioritizes human creativity and critical thinking over full automation.
		(Benghouala and Benamirouche, 2025; Wang et al., 2025)

clusively on self-reported data from a single source, managers within each firm, which introduces the potential for common method bias. Although we conducted Harman's single-factor test and variance inflation factor (VIF) analyses, and found no evidence of severe bias, the possibility remains that shared method variance may have inflated the observed relationships. Future research could mitigate this concern by triangulating survey responses with objective measures (e.g., third-party ESG ratings, environmental audit reports, or digital trace data on logistics performance) or by collecting data from multiple informants (e.g., procurement managers, sustainability officers, and external stakeholders). Finally, given the exclusive reliance on survey data, future studies could strengthen validity through methodological triangulation, such as combining managerial surveys with semi-structured interviews, sustainability disclosure reports, or third-party performance metrics.

Availability of Data and Materials

The data is available on reasonable request from the corresponding author.

Author Contributions

TJK and JW conceived the study and were responsible for the design and development of the data analysis. TJK and FUK were responsible for data collection and analysis. TJK, JW and D-GB were responsible for data interpretation. FUK and AB were responsible for analysis validation. TJK wrote the first draft of the article. TJK, JW, FUK, D-GB and AB reviewed and edited the final draft. All authors contributed to critical revision of the manuscript for important intellectual content. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

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Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

See Table 7.

References

Acquah ISK, Baah C, Agyabeng-Mensah Y, Afum E. Green procurement and green innovation for green organizational legitimacy and access to green finance: The mediating role of total quality management. Global Business and Organizational Excellence. 2023; 42: 24–41. https://doi.org/10.1002/joe.22183

Afum E, Agyabeng-Mensah Y, Baah C, Asamoah G, Kusi LY. Eco-market orientation in the logistics industry: a conveyor belt for achieving organizational outcomes via green logistics practices. The International Journal of Logistics Management. 2022; 33: 712–734. https://doi.org/10.1108/ijlm-07-2021-0383

Agyabeng-Mensah Y, Tang L. The relationship among green human capital, green logistics practices, green competitiveness, social performance and financial performance. Journal of Manufacturing Technology Management. 2021; 32: 1377–1398. https://doi.org/10.1108/jmtm-11-2020-0441

Amankwah-Amoah J, Syllias J. Can adopting ambitious environmental sustainability initiatives lead to business failures? An analytical framework. Business Strategy and the Environment. 2020; 29: 240–249. https://doi.org/10.1002/bse.2361

Baah C, Agyabeng-Mensah Y, Afum E, Mncwango MS. Do green legitimacy and regulatory stakeholder demands stimulate corporate social and environmental responsibilities, environmental and financial performance? Evidence from an emerging economy. Management of Environmental Quality: an International Journal. 2021; 32: 787–803. https://doi.org/10.1108/meq-10-2020-0225

Barney J. Firm resources and sustained competitive advantage. Journal of Management. 1991; 17: 99–120. https://doi.org/10.1177/014920639101700108

Becker JM, Klein K, Wetzels M. Hierarchical Latent Variable Models in PLS-SEM: Guidelines for Using Reflective-Formative Type Models. Long Range Planning. 2012; 45: 359–394. https://doi.org/10.1016/j.lrp.2012.10.001

Benghouala MA, Benamirouche H. Investigating the implementation of Industry 5.0: An empirical study on manufacturing companies in Algeria. Sustainable Futures. 2025; 10: 101111. https://doi.org/10.1016/j.sftr.2025.101111

Bálint M, Vilas-Boas da Silva JM, Möhring MM. Green innovations in third-party logistics: managerial reasons, external stakeholder influences and contingencies in the natural-business environment. Cogent Business & Management. 2025; 12: 2460613. https://doi.org/10.1080/23311975.2025.2460613

Chan SW, Tiwari SS, Ahmad MF, Zaman I, Sia WL. Green procurement practices and barriers in furniture manufacturing companies. International Journal of Supply Chain Management. 2018; 7: 431–438.

Chu Z, Xu J, Lai F, Collins BJ. Institutional Theory and Environmental Pressures: The Moderating Effect of Market Uncertainty on Innovation and Firm Performance. IEEE Transactions on Engineering Management. 2018; 65: 392–403. https://doi.org/10.1109/tem.2018.2794453

Colicchia C, Marchet G, Melacini M, Perotti S. Building environmental sustainability: empirical evidence from Logistics Service Providers. Journal of Cleaner Production. 2013; 59: 197–209. https://doi.org/10.1016/j.jclepro.2013.06.057

Daddi T, Bleischwitz R, Todaro NM, Gusmerotti NM, De Giacomo MR. The influence of institutional pressures on climate mitigation and adaptation strategies. Journal of Cleaner Production. 2020; 244: 118879. https://doi.org/10.1016/j.jclepro.2019.118879

Dang J, Sedikides C, Wildschut T, Liu L. Nostalgia encourages exploration and fosters uncertainty in response to AI technology. The British Journal of Social Psychology. 2025; 64: e12843. https://doi.org/10.1111/bjso.12843

Daniel NA, Sindhwani R, Kumar R, Mathiyazhagan K. Identifying the drivers and barriers for the implementation of sustainable manufacturing. International Journal of Logistics Systems and Management. 2024; 48: 532–559. https://doi.org/10.1504/ijlsm.2024.140402

Del-Castillo-Feito C, Blanco-González A, Díez-Martín F. The effect of implementing environmental policies and employees' environmental training in multinational companies' legitimacy level in emerging countries. Journal of Cleaner Production. 2021; 312: 127817. https://doi.org/10.1016/j.jclepro.2021.127817

Digalwar AK, Tagalpallewar AR, Sunnapwar VK. Green manufacturing performance measures: an empirical investigation from Indian manufacturing industries. Measuring Business Excellence. 2013; 17: 59–75. https://doi.org/10.1108/mbe-09-2012-0046

DiMaggio PJ, Powell WW. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. American Sociological Review. 1983; 48: 147–160. https://doi.org/10.2307/2095101

Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research. 1981; 18: 39–50. https://doi.org/10.2307/3151312

Gomez-Trujillo AM, Gonzalez-Perez MA, Baena-Rojas JJ. Sustainable strategy as a lever for corporate legitimacy and long-term competitive advantage: an examination of an emerging market multinational. European Business Review. 2024; 36: 112–139. https://doi.org/10.1108/ebr-01-2023-0003

Gulluscio C. Legitimacy Theory. In Encyclopedia of Sustainable Management (pp. 2209–2215). Springer: Cham. 2023.

Guo L, Sun D, Warraich MA, Waheed A. Does industry 5.0 model optimize sustainable performance of Agri-enterprises? Real-time investigation from the realm of stakeholder theory and domain. Sustainable Development. 2023; 31: 2507–2516. https://doi.org/10.1002/sd.2527

Hair J, Alamer A. Partial Least Squares Structural Equation Modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. Research Methods in Applied Linguistics. 2022; 1: 100027. https://doi.org/10.1016/j.rmal.2022.100027

Hair JF, Risher JJ, Sarstedt M, Ringle CM. When to use and how to report the results of PLS-SEM. European Business Review. 2019; 31: 2–24. https://doi.org/10.1108/ebr-11-2018-0203

Henseler J, Ringle CM, Sarstedt M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science. 2015; 43: 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hu LT, Bentler PM. Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. Psychological Methods. 1998; 3: 424–453. https://doi.org/10.1037//1082-989x.3.4.424

Javaid M, Haleem A, Singh RP, Suman R. Artificial intelligence applications for industry 4.0: A literature-based study. Journal of Industrial Integration and Management. 2022; 7: 83–111. https://doi.org/10.1142/S2424862221300040

Jazairy A, von Haartman R. Analysing the institutional pressures on shippers and logistics service providers to implement green supply chain management practices. International Journal of Logistics Research and Applications. 2020; 23: 44–84. https://doi.org/10.1080/13675567.2019.1584163

Jefroy N, Azarian M, Yu H. Moving from Industry 4.0 to Industry 5.0: What Are the Implications for Smart Logistics? Logistics. 2022; 6: 26. https://doi.org/10.3390/logistics6020026

Juráček L, Jurík L, Makyšová H. Institutional, Resource-Based, Stakeholder and Legitimacy Drivers of Green Manufacturing Adoption in Industrial Enterprises. Administrative Sciences. 2025; 15: 311. https://doi.org/10.3390/admsci15080311

Khan SZ, Yang Q, Waheed A. Investment in intangible resources and capabilities spurs sustainable competitive advantage and firm performance. Corporate Social Responsibility and Environmental Management. 2019; 26: 285–295. https://doi.org/10.1002/csr.1678

Klingenberg CO, Borges MAV, Antunes Jr JAV. Industry 4.0 as a data-driven paradigm: a systematic literature review on technologies. Journal of Manufacturing Technology Management. 2021; 32: 570–592. https://doi.org/10.1108/jmtm-09-2018-0325

Kock N. Common Method Bias in PLS-SEM: A full collinearity assessment approach. International Journal of E-Collaboration. 2015; 11: 1–10.

https://doi.org/10.4018/ijec.2015100101

Li D, Huang M, Ren S, Chen X, Ning L. Environmental Legitimacy, Green Innovation, and Corporate Carbon Disclosure: Evidence from CDP China 100. Journal of Business Ethics. 2018; 150: 1089–1104. https://doi.org/10.1007/s10551-016-3187-6

Lisi W, Zhu R, Yuan C. Embracing green innovation via green supply chain learning: The moderating role of green technology turbulence. Sustainable Development. 2020; 28: 155–168. https://doi.org/10.1002/sd.1979

Lomax RG. A beginner's guide to structural equation modeling. Lawrence Erlbaum Associates: Mahwah, NJ. 2004.

Maddikunta PKR, Pham QV, B P, Deepa N, Dev K, Gadekallu TR, et al. Industry 5.0: A survey on enabling technologies and potential applications. Journal of Industrial Information Integration. 2022; 26: 100257. https://doi.org/10.1016/j.jii.2021.100257

Maji IK, Mohd Saudi NS, Yusuf M. An assessment of green logistics and environmental sustainability: Evidence from Bauchi. Cleaner Logistics and Supply Chain. 2023; 6: 100097. https://doi.org/10.1016/j.clscn.2023.100097

Malakar P, Khan SA, Gunasekaran A, Mubarik MS. Digital Technologies for Social Supply Chain Sustainability: An Empirical Analysis Through the Lens of Dynamic Capabilities and Complexity Theory. IEEE Transactions on Engineering Management. 2025; 72: 664–675. https://doi.org/10.1109/tem.2024.3524896

Martini B, Bellisario D, Coletti P. Human-Centered and Sustainable Artificial Intelligence in Industry 5.0: Challenges and Perspectives. Sustainability. 2024; 16: 5448. https://doi.org/10.3390/su16135448

Nguyen H, Nguyen MTT, Binh D, Nguyen LDX, Phung HM. Strategic responses to uncertainty shocks and consequences: a study of sustainability-oriented exporters in an emerging country. Benchmarking: an International Journal. 2025; 32: 2046–2069. https://doi.org/10.1108/bij-08-2023-0588

Nicoletti B, Appolloni A. Green Logistics 5.0: a review of sustainability-oriented innovation with foundation models in logistics. European Journal of Innovation Management. 2024; 27: 542–561. https://doi.org/10.1108/ejim-07-2024-0787

Ooi SK, Memon KR. Addressing Resource Scarcity: The Role of Responsible Innovation and Resilience in SMEs' Competitive Advantage and Sustainability Performance. Corporate Social Responsibility and Environmental Management. 2025; 32: 5734–5746. https://doi.org/10.1002/csr.70005

Ozuem W, Ranfagni S, Willis M. Digital transformation for fashion and luxury brands. Springer: Cham, Switzerland. 2024.

Perotti S, Colicchia C. Greening warehouses through energy efficiency and environmental impact reduction: a conceptual framework based on a systematic literature review. The International Journal of Logistics Management. 2023; 34: 199–234. https://doi.org/10.1108/ijlm-02-2022-0086

Podsakoff PM, MacKenzie SB, Lee JY, Podsakoff NP. Common method biases in behavioral research: a critical review of the literature and recommended remedies. The Journal of Applied Psychology. 2003; 88: 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Pushpamali N, Agdas D, Rose TM, Yigitcanlar T. Stakeholder perception of reverse logistics practices on supply chain performance. Business Strategy and the Environment. 2021; 30: 60–70. https://doi.org/10.1002/bse.2609

Ringle CM, Sarstedt M, Straub DW. Editor's comments: a critical look at the use of PLS-SEM in MIS Quarterly. MIS Quarterly. 2012; 36: iii–xiv.

Roy S, Mohanty RP. Green logistics operations and its impact on supply chain sustainability: An empirical study. Business Strategy and the Environment. 2024; 33: 1447–1476. https://doi.org/10.1002/bse.3531

Rudko I, Bashirpour Bonab A, Fedele M, Formisano AV. New institutional theory and AI: toward rethinking of artificial intelligence in organizations. Journal of Management History. 2025; 31: 261–284. https://doi.org/10.1108/jmh-09-2023-0097

Sarstedt M, Hair JF, Cheah JH, Becker JM, Ringle CM. How to Specify, Estimate, and Validate Higher-Order Constructs in PLS-SEM. Australasian Marketing Journal. 2019; 27: 197–211. https://doi.org/10.1016/j.ausmj.2019.05.003

Sarstedt M, Radomir L, Moisescu OI, Ringle CM. Latent class analysis in PLS-SEM: A review and recommendations for future applications. Journal of Business Research. 2022; 138: 398–407. https://doi.org/10.1016/j.jbusres.2021.08.051

Shankar R, Gupta L. Modelling risks in transition from Industry 4.0 to Industry 5.0. Annals of Operations Research. 2024; 342: 1275–1320. https://doi.org/10.1007/s10479-024-06055-9

Suchman MC. Managing legitimacy: Strategic and institutional approaches. Academy of Management Review. 1995; 20: 571–610. https://doi.org/10.5465/amr.1995.9508080331

Sun S, Hsu M, Hwang W. The impact of alignment between supply chain strategy and environmental uncertainty on SCM performance. Supply Chain Management: an International Journal. 2009; 14: 201–212. https://doi.org/10.1108/13598540910954548

Tao J, Aamir M, Shoaib M, Yasir N, Babar M. Bridging the Gap Between Supply Chain Risk and Organizational Performance Conditioning to Demand Uncertainty. Sustainability. 2025; 17: 2462. https://doi.org/10.3390/su17062462

Tetteh FK, Owusu Kwateng K, Mensah J. Green logistics practices: A bibliometric and systematic methodological review and future research opportunities. Journal of Cleaner Production. 2024; 476: 143735. https://doi.org/10.1016/j.jclepro.2024.143735

Truong Y, Nagy BG. Nascent ventures' green initiatives and angel investor judgments of legitimacy and funding. Small Business Economics. 2021; 57: 1801–1818. https://doi.org/10.1007/s11187-020-00373-5

Vasiulis Ferreira Rodrigues N, De Camargo Fiorini P, Piato ÉL, Lopes de Sousa Jabbour AB, Chiappetta Jabbour CJ. Resources and capabilities for logistics 4.0 and sustainable value creation: a study of logistics service providers in an

emerging market. The International Journal of Logistics Management. 2025; 36: 1385–1409. https://doi.org/10.1108/ijlm-11-2023-0471

Vienažindienė M, Tamulienė V, Zaleckienė J. Green Logistics Practices Seeking Development of Sustainability: Evidence from Lithuanian Transportation and Logistics Companies. Energies. 2021; 14: 7500. https://doi.org/10.3390/en14227500

Vyas N, Dasgupta D, Sošić G. Supply chain network design: How to create resilient, agile and sustainable supply chains. Kogan Page Publishers: London, United Kingdom. 2024.

Waheed A, Alharthi M, Khan SZ, Usman M. Role of Industry 5.0 in leveraging the Business Performance: Investigating Impact of Shared-Economy on Firms' Performance with Intervening Role of i5.0 Technologies. Sage Open. 2022; 12. https://doi.org/10.1177/21582440221094608

Wang J, Wu Z, Wang T. Data Quality Improvement Supports Digital Transformation in Industry 5.0. Sustainability. 2025; 17: 11183. https://doi.org/10.3390/su172411183

Wang X. Study on relationship between green logistics activity and logistics performance. Cluster Computing. 2019; 22: 6579–6588. https://doi.org/10.1007/s10586-018-2344-3

Wei YM, Chen K, Kang JN, Chen W, Wang XY, Zhang X. Policy and management of carbon peaking and carbon neutrality: A literature review. Engineering. 2022; 14: 52–63. https://doi.org/10.1016/j.eng.2021.12.018

Zhang Y, Wang L, Gao J, Li X. Servitization and business performance: the moderating effects of environmental uncertainty. Journal of Business Industrial Marketing. 2020; 35: 803–815. https://doi.org/10.1108/JBIM-03-2019-0123

Zhao R, Hu C, Du C, Wang C, Sun L. Synergistic effect assessment of pollution and carbon reduction and pathway of green transformation at regional level in China. Journal of Cleaner Production. 2025; 495: 145013. https://doi.org/10.1016/j.jclepro.2025.145013

Zhou Y, Shu C, Jiang W, Gao S. Green management, firm innovations, and environmental turbulence. Business Strategy the Environment. 2019; 28: 567–581. https://doi.org/10.1002/bse.2265

Zhu Q, Sarkis J. The moderating effects of institutional pressures on emergent green supply chain practices and performance. International Journal of Production Research. 2007; 45: 4333–4355. https://doi.org/10.1080/00207540701440345

Zhu Y, Hu Y, Zhu Y. Can China's energy policies achieve the "dual carbon" goal? A multi-dimensional analysis based on policy text tools. Environment, Development and Sustainability. 2024; 28: 5551–5590. https://doi.org/10.1007/s10668-024-05190-4

Zong Z, Guan Y. AI-Driven Intelligent Data Analytics and Predictive Analysis in Industry 4.0: Transforming Knowledge, Innovation, and Efficiency. Journal of the Knowledge Economy. 2025; 16: 864–903. https://doi.org/10.1007/s13132-024-02001-z