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Critical success factors of green innovation: Technology, organization and environment readiness

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ABSTRACT

Many organizations carry out green innovation for sustainable development, but not all are successful. Based on the technology-organization-environment framework, this study examines how prepared enterprises are for green innovation in terms of technology readiness, organization readiness, and environment readiness. It hypothesizes that the necessary and sufficient conditions along each dimension enable and facilitate green innovation, leading to competitive advantage through the mediation of environmental performance and firm performance. To test the research model, survey observations were collected from 340 companies in China. Supporting the hypothesized relationships, the results show that the necessary and sufficient conditions of all dimensions make significant but somewhat different contributions to the success of green innovation. The measurement instrument and research framework provide a self-assessment tool for organizations to strategize the preparation and implementation of green innovation for optimal sustainability outcomes.

1. Introduction

Enterprises around the world are facing the urgent issue of balancing productive consumption and ecological conservation. As a solution to the problem, sustainable development aims at low emission, energy saving, and material recycling. The fulfillment of this corporate social responsibility requires green innovation at the organizational level. On one hand, such an innovative endeavor allows companies to comply with the increasingly stringent environmental legislation and regulation; on the other, it helps them increase operational efficiency and create new business opportunities (e.g., by meeting the needs of environment-friendly customers).

Green innovation is driven by the legal requirement from the outside as well as a company's internal conditions, such as organizational culture and available resources. The endeavor requires continuous investment and persistent effort to bring business benefits to an enterprise along with the fulfillment of social responsibility. In this way, green innovation leads to corporate sustainability through an upward spiral of benign circles from ecological effort and performance improvement.

Numerous studies confirm the positive impacts of green innovation on corporate competitiveness, economic performance, and environment protection (Bonifant et al., 1995; Hart et al., 2003). Rennings (2004) showed that in addition to such typical spillover effects, green innovation produces additional external effects such as reducing the environmental cost of products, leading to "double external effects." As a systematic endeavor, corporate green innovation requires a creative integration of various internal and external resources through capability development and capital investment (Lampikoski et al., 2014). Due to the risk and uncertainty involved in green innovation, not all enterprises will get desired results, especially those ill-prepared (Roper and Tapinos, 2016). To achieve corporate sustainability, companies must get ready for green innovation by acquiring needed capabilities and resources.

Researchers examined different types of corporate innovation readiness, such as service innovation readiness (Yen et al., 2012), open innovation readiness (Waiyawuththanapoom et al., 2013), and

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enterprise systems innovation readiness (Lokuge and Sedera, 2014). Nevertheless, few have investigated it from the aspect of corporate green innovation. In the turbulent business environment, green innovation is not straightforward but error-prone, and it is hard for an organization to establish a clear roadmap that aligns innovative activities with sustainable goals (Lampikoski et al., 2014).

This study attempts to fill in the research gap by investigating green innovation readiness in terms of critical success factors. It addresses the research question “how can an organization get prepared for green innovation to achieve corporate sustainability?” Based on the technology-organization-environment (TOE) framework, it develops a research model that depicts how technological readiness, organizational readiness and environmental readiness affect green innovation that leads to short-term and long-term consequences. The hypothesized relationships are to be tested with empirical observations.

The results are likely to yield theoretical and practical implications for green innovation planning and implementation. In particular, the measurement and framework validated may help organizations assess their strengths, weaknesses, opportunities and threats in the innovative endeavor so as to maximize potential benefits and minimize possible risks. This allows enterprises to develop a more proactive strategy to prepare for the challenges rather than passively wait for problems to emerge. Many enterprises are yet to enter the green innovation arena worldwide, and a quantifiable assessment tool can be helpful. This is largely under-investigated as evidenced by the lack of empirical research, and this study fits in the “neglect spotting” niche in the literature (Sandberg and Alvesson, 2011).

2. Research background

According to the Organization for Economic Co-operation and Development (OECD), green innovation aims to reduce the negative impacts of economic activities on the environment, whether the impacts are intentional or unintentional (Clark and Martin, 2007). Compared to other largely interchangeable labels, such as “environmental innovation” and “ecological innovation”, “green innovation” is more specific to organizational efforts like green product innovation and green process innovation (Schiederig et al., 2012). Corporate green innovation involves the establishment of green management, the development of environment-friendly products, and the optimization of production, operational and service processes (Tseng et al., 2012). The comprehensive approach not only reduces environmental pollution but also improves corporate competitiveness (Lovins et al., 1999; Testa et al., 2011). The success of green innovation depends on the use of various technologies, making it a technology-enabled organizational endeavor (Kemp and Foxon, 2007).

Based on Rogers (1995) innovation diffusion theory (IDT), the TOE framework examines the factors affecting corporate adoption of innovations from technological, organizational and environmental aspects (Tornatzky et al., 1990). Technological factors refer to the attributes of an innovation (e.g., relative advantage, compatibility, and complexity as identified in IDT) important to potential users, organizational factors pertain to the characteristics of an enterprise (e.g., resources and capabilities) relevant to innovation adoption, and environmental factors concern the settings (e.g., consumer market and government policy) in which an enterprise implements an innovation (Tornatzky et al., 1990). Together, technological, organizational and environmental factors influence corporate decision-making regarding innovation adoption (Hwang et al., 2016).

The TOE framework provides an analytical lens to examine the adoption of innovative technologies at the organizational level. Researchers adapted the general framework with specific technological, organizational, and environmental factors to study corporate adoption of green technologies in different contexts (Aboelmaged, 2018; Chege and Wang, 2020; Ferreira et al., 2020; Hue, 2019). Compared with the adoption of a technology, however, green innovation is a long-term endeavor that requires an enterprise to make significant changes, which inevitably invoke risks. The better organizations are prepared for the implementation of such innovations in terms of technological capability as well as internal and external environments, the more likely they are to put potential dangers under control (Jones et al., 2005).

From a resource-based view, an enterprise must have the asset, capability, and motivation needed to successfully carry out innovations and corresponding changes (Cyert & March 1963; Grant, 1991). The success of organizational innovation largely depends on the availability of different resources critical to its execution. How smooth organizations implement innovations depends on technological benefits, organizational capabilities and environmental pressures (Ghobakhloo et al., 2011; Rowe et al., 2012; Xu et al., 2017). Therefore, technological, organizational, and environmental factors are also the resources needed for the success of green innovation.

3. Theory development

In the current business environment, green innovation is both a challenge and an opportunity for an enterprise that needs to pursue business goals and fulfill social responsibilities. To minimize risks and maximize benefits, organizations need to self-assess how well they are prepared for green innovation. Based on the TOE framework, this study develops the measurement instrument and research framework to investigate green innovation readiness. As shown in Fig. 1, the model identifies its different aspects and their components, and hypothesizes that each aspect makes differences in green innovation and subsequent outcomes.

In general, green innovation readiness describes how prepared an organization is to implement green innovation. It signifies the necessary and sufficient conditions for an enterprise to successfully carry out the endeavor in attaining sustainability goals. As per the TOE framework, there are three aspects of green innovation readiness: technology readiness, organization readiness, and environment readiness. They concern how ready an organization is for green innovation in terms of technical, internal and external conditions, respectively. Only when an enterprise is prepared for all aspects can it successfully implement green innovation and take full advantage. Based on the self-assessment of green innovation readiness before and during the implementation process, a firm may make timely adjustments, allocate important resources, and acquire essential capabilities.

Like each aspect of green innovation readiness, green innovation itself is a multi-dimensional construct. Researchers found that green innovation comprises three activities: green process innovation, green product innovation, and green managerial innovation (Abu Seman, Govindan, Mardani et al., 2019; Y. S. Chen, Lai and Wen, 2006; Chiou et al., 2011; Utterback and Abernathy, 1975). Oriented toward the internal operation, external market and overall administration, respectively, they are the major components of green innovation.

H1a. Green process innovation contributes to green innovation.

H1b. Green product innovation contributes to green innovation.

H1c. Green managerial innovation contributes to green innovation.

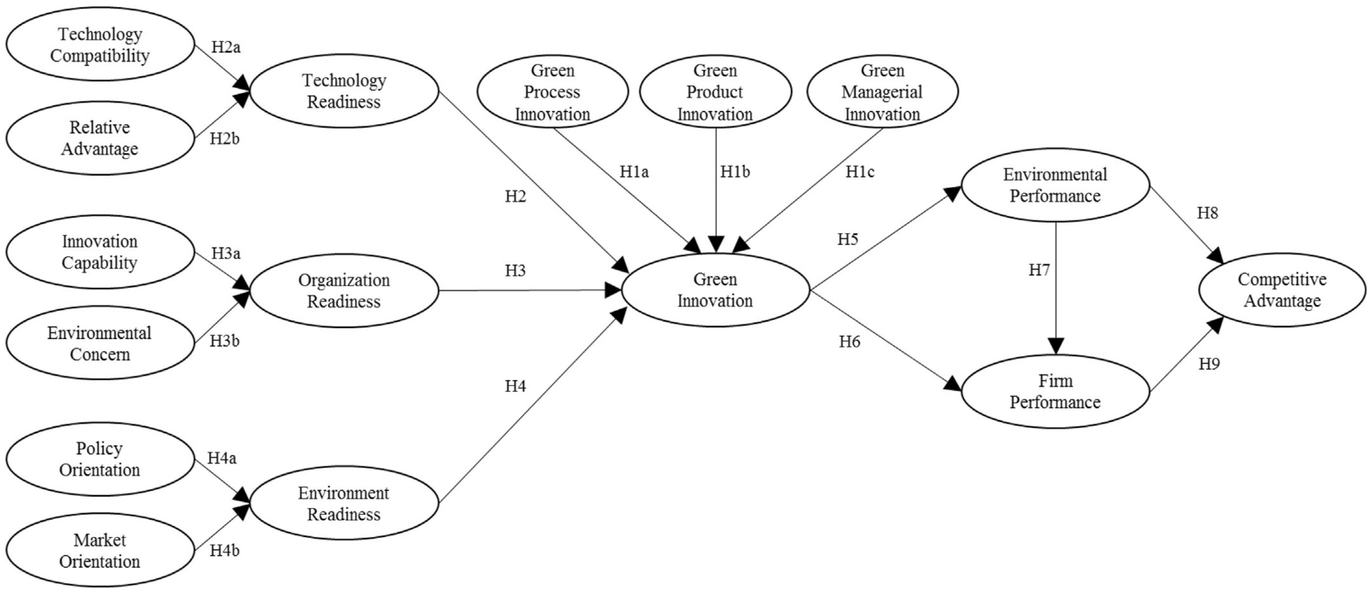

Fig. 1. Research model.

Technology readiness pertains to the likelihood that an enterprise adopts green innovation technologies smoothly as important organizational assets. The value of such a technological resource is largely determined by how well it works together with other technologies in use and facilitates green innovation activities. Denoted as compatibility and relative advantage respectively as per the IDT (Rogers, 1995), these properties are the necessary and sufficient conditions of technology adoption. The extent to which a new technology is used largely depends on its relative advantage and technology compatibility (Chatzoglou and Michailidou, 2019; Mohammed et al., 2017; Z. Yang, Sun, Zhang et al., 2015).

Similarly, the implementation of green innovation relies on two aspects of technology readiness. Technology compatibility is the necessary condition: if green innovation requires the resources unavailable in an organization or brings about changes inconsistent with its strategies, the implementation will be extremely difficult. Meanwhile, relative advantage in terms of the utility of green innovation technologies to corporate sustainability is the sufficient condition that facilitates the implementation effort. As the factors that push and pull green innovation forward, technology compatibility and relative advantage form the technology readiness for green innovation.

H2a. Technology compatibility contributes to technology readiness.

H2b. Relative Advantage contributes to technology readiness.

H2. Technology readiness positively affects green innovation.

Organization readiness refers to the characteristics of an enterprise essential for its implementation of green innovation. First, the company needs essential knowledge and expertise to manage organizational changes in green innovation (Dangelico et al., 2017; Lopes et al., 2017). Thus, absorptive capacity is conducive to green innovation implementation, along with sustainable capabilities (Aboelmaged and Hashem, 2019). In this sense, innovation capability is the necessary condition of green innovation at the organizational level.

From the contingency perspective, innovation capacity is more helpful to green innovation when an organization is motivated (K.-H. Tsai and Liao, 2017). As green innovation is time- and effort-consuming, employees are resistant to the changes unless they share a pro-environment mentality (Gürlek and Tuna, 2018; Muduli et al., 2013). A meta-analytic study on the driving factors of green innovation found that enterprises of a higher level of environmental concern are more likely to be innovative (Zubeltzu-Jaka et al., 2018). Therefore, environmental concern is a sufficient condition for employees to fully engage in green innovation activities (Hojnik and Ruzzier, 2016). In this sense, innovation capability and environmental concern comprise the organization readiness essential for green innovation.

H3a. Innovation capability contributes to organization readiness.

H3b. Environmental concern contributes to organization readiness.

H3. Organization readiness positively affects green innovation.

Environment readiness concerns the external pressures that push an enterprise to pursue green innovation. The institutional theory suggests that such forces motivate organizations to enhance measurable performances for sustainability benchmarking (Dubey et al., 2017). In particular, business and operation activities must comply with the legal and governmental requirements on environment protection (X. Chen, Yi, Zhang et al., 2018; X.-x. Huang, Hu, Liu et al., 2016; Kagan et al., 2003). Laying out the baseline for corporate sustainability, such a policy environment serves as a necessary condition of green innovation. Rather than passively meeting the requirement, an organization may actively cater to emerging consumer demands for green products/services (X.-x. Huang, Hu, Liu et al., 2016; Lin et al., 2013). Companies sensitive to such customer pressure are likely to be proactive in environmental management (Dai et al., 2018). Thus, market orientation can be regarded as the sufficient condition aspect of environment readiness. Both policy orientation and market orientation form the environment readiness for green innovation.

H4a. Policy orientation contributes to environment readiness.

H4b. Market orientation contributes to environment readiness.

H4. Environment readiness positively affects green innovation.

Organizational innovation is conducive to the attainment of business goals as well as strategic competitiveness (Y. S. Chen, Lai and Wen, 2006). Similarly, green innovation is likely to have positive impacts on firm performance and completive advantage from the development of environment-friendly products, the improvement of operational efficiency, and the enhancement of managerial effectiveness (Bonifant et al., 1995; Guziana, 2011; Yalabik and Fairchild, 2011). In addition, green innovation helps an organization comply with sustainability regulations and reduce ecological impacts, leading to better environmental performance (Abu Seman, Govindan, Mardani et al., 2019; Chiou et al., 2011; J.-W. Huang and Li, 2017). The saving from recycling/remanufacturing and the improvement in organizational reputation/image also translate into better firm performance (Hart et al., 2003; Machiba, 2009; Porter and Linde, 1995; C.-S. Yang, Lu, Haider et al., 2013). In the long run, enhanced environmental performance and firm performance help an organization attain competitive advantage (C.-S. Yang, Lu, Haider et al., 2013).

H5. Green innovation positively affects environmental performance.

H6. Green innovation positively affects firm performance.

H7. Environmental performance positively affects firm performance.

H8. Environmental performance positively affects competitive advantage.

H9. Firm performance positively affects competitive advantage.

Together, the hypothesized relationships depict that different readiness components affect sustainability outcomes through the mediation of green innovation. The next section describes a research design to collect empirical observations for model testing. The results may help organizations formulate strategies, motivate employees and allocate resources for successful implementation of green innovation.

4. Methodology

This study collected survey data with a questionnaire containing the items to capture the constructs in the research model, as listed in the Appendix. The measures of technology readiness dimensions, technology compatibility, and relative advantage, are adapted from Kendall et al. (2001). The scales of organization readiness dimensions, environmental concern, and innovation capability, are based on M.-C. Tsai, Lee, and Wu (2010). Regarding environment readiness, policy orientation and market orientation are captured with items adapted from Kumar et al. (1998) and Narver and Slater (1990), respectively. The items of green process innovation, green product innovation, and green managerial innovation are adapted from Chiou et al. (2011) and Y. S. Chen, Lai, and Wen (2006). The measures of environmental performance and firm performance are based on Rao (2002). The scale of competitive advantage is based on Barney (2000), Coyne (1986), and Porter and Linde (1995).

As the world's factory, China faces the challenge of sustainable development, and encourages all businesses to implement green innovation. Green innovation is not just a public-relationship term but a lifeline for many firms to survive from stringent regulations and tough competitions. Based on the contact information compiled from several executive MBA and manager training programs, the questionnaire was distributed to participants from 450 organizations in China. Those part-time students and trainees are front-line managers at different levels: 5.0% held CEO/general manager positions, 37.1% were department managers (R & D, marketing, production), and 57.9% oversaw all kinds of operations. Before the survey, participants were asked to check all the typical green innovation activities that their companies had implemented. This filter question ensured that responses were based on actual experiences.

Within a one-month period, 347 valid responses were returned. Among them, 340 were complete, resulting in a valid response rate of 75.56%. To assess the non-response bias, early responses received during the first week were compared with late responses received during the last week, and *t*-test results indicate insignificant differences in mean scores. Table 1 reports the profiles of participating organizations, which were in line with the corporate compositions in China. As for the individuals who answered the questionnaire, the average age was 32 and there were more males (59.1%) than females (40.9%). The organization and participant profiles support sample representativeness.

5. Results

To examine the common method bias, Harman's single-factor test was conducted with both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) (Podsakoff et al., 2003). The EFA result revealed that the first factor extracted accounted for less than 50% (45.58%) of the total variance. The CFA result indicated that model fit deteriorated dramatically (χ^2 from 1693.28 to 4082.33, and χ^2/df from 1.75 to 3.95) when all measurement items were loaded onto a single factor rather than their own constructs. The results dismissed a single source of variance, and common method bias was not a big concern.

Table 2 reports the measurement validation results for first-order reflective constructs. The average responses were in the expected range (between 3.60 and 4.02 in the 5-level Likert scale used in the questionnaire) with reasonable variability (between 0.58 and 0.74). It is worth noting that environmental concern (EC) had the highest mean but lowest standard deviation, whereas policy orientation (PO) had the lowest mean but highest standard deviation. This shows that ecological mentality within organizations has become a consensus while environmental policy varies from one industry to another (e.g., more stringent for power plants than for

Table 1
Participating organization profiles (n = 340).

Dimension	Characteristic	Frequency (%)
Ownership	State owned	89(26.18%)
	Collectively owned	11(3.24%)
	Private	127(37.35%)
	Joint Venture	17(5.00%)
	Foreign	45(13.24%)
	Other	51(15.00%)
Industry	Manufacturing	116(34.12%)
	Energy	18(5.29%)
	Construction	36(10.59%)
	Logistics	12(3.53%)
	IT	47(13.82%)
	Service	51(15.00%)
	Other	60(17.65%)
Age (years in business)	Less than 3 year	40(11.76%)
	3–5 years	54(15.88%)
	6–10years	60(17.65%)
	11–15years	51(15.00%)
	Over 15years	135(39.71%)
Size (number of employees)	Less than 100 employees	79(23.24%)
	101-500 employees	70(20.59%)
	501-1000 employees	34(10.00%)
	1001-1500 employees	18(5.29%)
	1501-2000 employees	15(4.41%)
	Over 2000 employees	124(36.47%)

Table 2
Measurement validation of 1st-order reflective constructs.

Construct	Mean(SD)	α	CR	AVE	1	2	3	4	5	6	7	8	9	10	11	12
1. TC	3.83(.59)	.79	.87	.62	**.79**											
2. RA	3.84(.65)	.85	.90	.69	.74	**.83**										
3. IC	3.79(.63)	.89	.92	.70	.68	.69	**.84**									
4. EC	4.02(.58)	.78	.87	.69	.65	.67	.60	**.83**								
5. PO	3.60(.74)	.90	.93	.72	.64	.57	.69	.49	**.85**							
6. MO	3.70(.69)	.87	.91	.71	.62	.61	.79	.55	.79	**.85**						
7. GPOI	3.96(.63)	.85	.90	.69	.55	.60	.70	.47	.54	.61	**.83**					
8. GPDI	3.84(.67)	.87	.91	.71	.58	.61	.71	.52	.59	.65	.78	**.85**				
9. GMGI	3.89(.70)	.87	.92	.80	.60	.58	.67	.51	.57	.63	.73	.73	**.89**			
10. EP	3.83(.67)	.84	.90	.75	.56	.54	.64	.47	.50	.53	.64	.59	.65	**.87**		
11. FP	3.69(.69)	.85	.91	.77	.51	.52	.56	.43	.45	.49	.45	.46	.55	.65	**.88**	
12. CA	3.74(.67)	.89	.92	.70	.62	.58	.63	.50	.55	.58	.57	.58	.63	.69	.75	**.84**

Note:1.TC-Technology Compatibility; 2.RA-Relative Advantage; 3.IC-Innovation Capability; 4.EC-Environmental Concern; 5.PO-Policy Orientation; 6.MO-Market Orientation; 7.GPOI-Green Process Innovation; 8.GPDI-Green Product Innovation; 9.GMGI-Green managerial Innovation; 10.EP-Environmental Performance; 11.FP-Firm Performance; 12.CA-Competitive Advantage. The bolded values on the diagonal of the correlation matrix are the square roots of the average variance extracted (AVE). All correlation coefficients were significant at the 0.001 level (two-tailed test).

service companies). The expected response patterns support the content validity of measurement scales. Cronbach's alpha (α) and composite reliability (CR) values were all larger than 0.7, indicating an acceptable level of internal consistency in the responses. In addition, all average variance extracted (AVE) values were well above 0.5, supporting convergent validity. Meanwhile, the square root of AVE was larger than relevant correlation coefficients for each construct. As the within-construct variance exceeded between-construct variance, discriminant validity was supported.

The measurement validity of first-order reflective constructs lays the foundation for assessing second-order formative constructs, including three aspects of green innovation readiness and green innovation itself. Unlike reflective constructs, formative constructs comprise different dimensions that are not supposed to covary. Table 3 reports the variance inflation factor (VIF) values for the components of each formative construct, and none of them were close to the threshold of five. The relatively weak multicollinearity indicated that the formative constructs have distinct components, qualifying them as multi-dimension constructs. In addition, all the regression weights and outer loadings were significant, suggesting that every component was important.

Once the measurement is validated, the hypothesized relationships in the research model can be tested. Because three dimensions of green innovation readiness and green innovation are first-order-reflective-and-second-order -formative constructs, the model was estimated using the two-stage method of partial least square (PLS) with SmartPLS 3.0 (Hair et al., 2016). As shown in Fig. 2, every structural path was significant, supporting all the research hypotheses.

Together, Technology Readiness, Organization Readiness, and Environment Readiness explained 62.0% of the variance in Green Innovation. Among them, Organization Readiness made the most contribution as its regression weight almost doubled those of Technology Readiness and Environment Readiness. Whereas the two components of Technology Readiness (i.e., Technology Compatibility as the necessary condition and Relative Advantage as the sufficient condition) made similar contributions, those of Organization Readiness and Environment Readiness were more distinct. For Organization Readiness, the necessary condition (i.e., Innovation Capability) exhibited more weight than the sufficient condition (i.e., Environmental Concern). However, it was the opposite for Environment Readiness: the sufficient condition (i.e., Market Orientation) surpassed the necessary condition (i.e., Policy Orientation). Among the Green Innovation components, the most salient was Green Managerial Innovation, followed by Green Process Innovation and Green Product Innovation. The results concerning the corresponding relationship between readiness dimensions and innovation activities are explainable: Green Managerial Innovation pertains to the Innovation Capability component of Organization Readiness, Green Process Innovation concerns the Relative Advantage component of Technology Readiness (e.g., green supply chain management depends on IT), and Green Product Innovation is relevant to the Market Orientation component of Environment Readiness.

Through the mediation of Environmental Performance and Firm Performance, Green Innovation led to Competitive Advantage. As expected, Green Innovation was a better predictor of Environmental Performance (standardized regression weight almost 0.7) than Firm Performance (standardized regression weight below 0.2). Green Innovation explained 48.0% of the variance in Environmental Performance by itself, and 44.2% of the variance in Firm Performance together with Environmental Performance that had a larger standardized regression weight. Influenced by many factors, such as organizational innovation in general, Firm Performance is a

Table 3
Measurement validation of 2nd-order formative constructs.

Construct	Component	VIF	Outer loading	Weight
Technology Readiness	Technology Compatibility	2.178	0.923***	0.504***
	Relative Advantage	2.178	0.940***	0.570***
Organization Readiness	Innovation Capability	1.564	0.987***	0.868***
	Environmental Concern	1.564	0.720***	0.199**
Environment Readiness	Policy Orientation	2.656	0.886***	0.290**
	Market Orientation	2.656	0.984***	0.755***
Green Innovation	Green Process Innovation	2.974	0.893***	0.308**
	Green Product Innovation	3.049	0.887***	0.260*
	Green Managerial Innovation	2.474	0.940***	0.526***

Note: *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

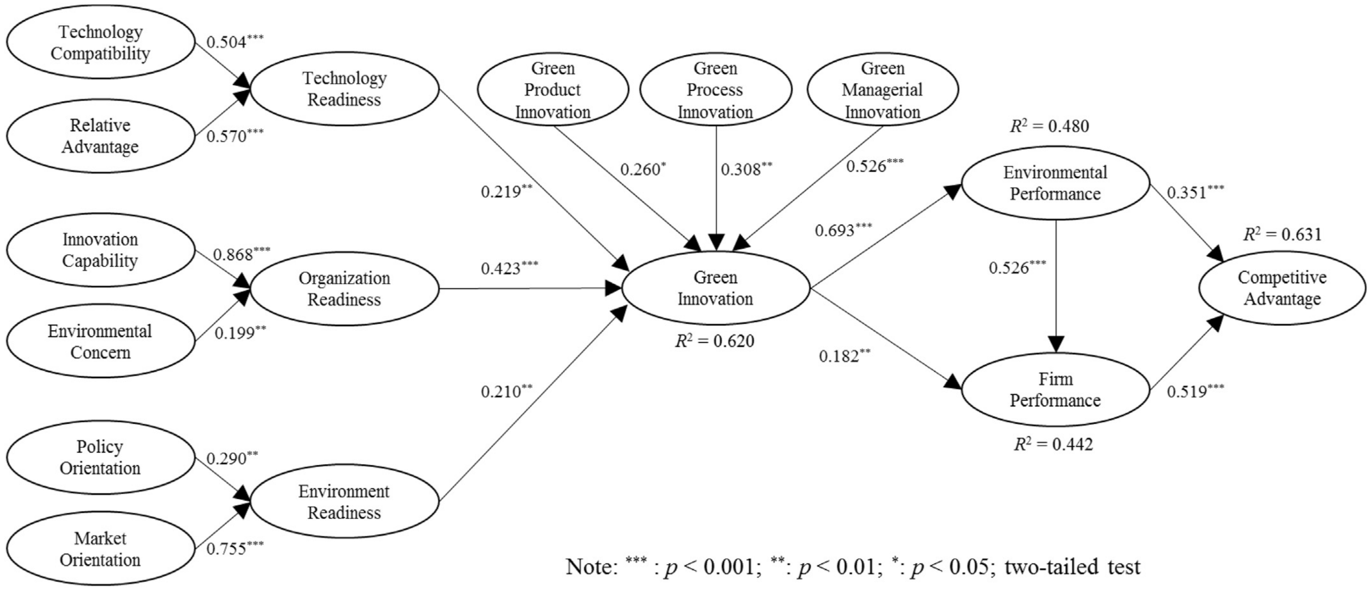

Fig. 2. Structural model estimates.

powerful predictor of Competitive Advantage (standardized regression weight above 1/2) compared with Environment Performance (standardized regression weight around 1/3). The results suggest that the main route of influence from Green Innovation to Competitive Advantage is via Environment Performance first and then Firm Performance. Together, 63.1% of the variance in Competitive Advantage was explained.

As the research model involves mediating relationships, their total indirect effects were evaluated with the non-parametric bootstrapping procedure (Hair et al., 2016). As per the results reported in Table 4, all indirect effects were positive and significant. In terms of the contributions of three aspects of green innovation readiness to green innovation outcomes, Organization Readiness was the most salient, followed by Environment Readiness and Technology Readiness. For an enterprise to benefit from green innovation, therefore, it is the most important to get prepared internally. This helps the organization respond to the external environment and utilize innovative technology. As for the three outcome variables, Environment Performance was most susceptible to the influence of different readiness dimensions, followed by Firm Performance and Competitive Advantage. Nevertheless, Green Innovation yielded a bigger total impact on Competitive Advantage than Firm Performance. This supports the hypothesized mediating relationships as the total effects are correlated with the number of mediators in between, through which the effects accumulate (e.g., the total effect from Green Innovation to Competitive Advantage is close to the sum of those from Green Innovation to Firm Performance and from Environmental Performance to Competitive Advantage).

Table 4
Mediation relationship tests.

Total Indirect Effect	Estimate	*P*-value
Technology Readiness - > Competitive Advantage	0.1156	0.0097
Technology Readiness - > Environmental Performance	0.1519	0.0063
Technology Readiness - > Firm Performance	0.1198	0.0096
Organization Readiness - > Competitive Advantage	0.2229	0.0000
Organization Readiness - > Environmental Performance	0.2930	0.0000
Organization Readiness - > Firm Performance	0.2310	0.0000
Environment Readiness - > Competitive Advantage	0.1106	0.0057
Environment Readiness - > Environmental Performance	0.1453	0.0056
Environment Readiness - > Firm Performance	0.1146	0.0053
Green Innovation - > Competitive Advantage	0.5271	0.0000
Green Innovation - > Firm Performance	0.3643	0.0000
Environmental Performance - > Competitive Advantage	0.2731	0.0000

Note: Bootstrapping based on 5,000 subsamples; Two-tailed test.

6. Conclusion and implications

For a better understanding of critical success factors of green innovation, this study investigates its antecedents and consequences. Based on the TOE framework, it hypothesizes that technology readiness, organization readiness, and environment readiness shape green innovation, which leads to competitive advantage through the mediation of environmental performance and firm performance. The survey observations collected from 340 organizations in China provide supporting evidence to all the hypothesized relationships as summarized in Table 5.

The findings make several contributions to the green innovation literature. First of all, it conceptualizes the technology, organization and environment dimensions of green innovation readiness and operationalizes each with necessary and sufficient conditions. The findings suggest for different aspects of green innovation readiness, necessary and sufficient conditions play distinct roles. Whereas necessary conditions are critical to green innovation that would be impossible without them, its eventual success depends on sufficient conditions. Correspondingly, the results suggest a match of importance between green innovation activities (i.e., Green Managerial Innovation > Green Process Innovation > Green Product Innovation) and the more salient components of green innovation readiness dimensions (i.e., Innovation Capability of Organization Readiness > Relative Advantage of Technology Readiness > Market Orientation of Environment Readiness).

The latent construct of green innovation can be regarded as the first canonical correlation function between green innovation dimensions and green innovation activities, as canonical correlation analysis is a special case of structural equation modeling when two sets of variables are connected through a latent construct (Bagozzi et al., 1981). The regression weights on both sides are equivalent to canonical coefficients, which indicates the strengths of dependency between them. Previous research provides some hints on the

Table 5
Summary of hypothesis testing.

Hypotheses	Description	Results
H1a	Green Process Innovation - > Green Innovation	Supported
H1b	Green Product Innovation - > Green Innovation	Supported
H1c	Green Managerial Innovation - > Green Innovation	Supported
H2a	Technology Compatibility - > Technology Readiness	Supported
H2b	Relative Advantage - > Technology Readiness	Supported
H2	Technology Readiness - > Green Innovation	Supported
H3a	Innovation Capability - > Organization Readiness	Supported
H3b	Environmental Concern - > Organization Readiness	Supported
H3	Organization Readiness Positively Affects Green Innovation	Supported
H4a	Policy Orientation - > Environment Readiness	Supported
H4b	Market Orientation - > Environment Readiness	Supported
H4	Environment Readiness - > Green Innovation	Supported
H5	Green Innovation - > Environmental Performance	Supported
H6	Green Innovation - > Firm Performance	Supported
H7	Environmental Performance - > Firm Performance	Supported
H8	Environmental Performance - > Competitive Advantage	Supported
H9	Firm Performance - > Competitive Advantage	Supported

corresponding relationships, but it is the first time they are supported by empirical evidence in the context of green innovation. For instance, it is believed that managerial innovation requires an enterprise to have the capability to initiate and manage organizational changes (Mousavi et al., 2018; Tidd and Bessant, 2018). The results of this study confirm that the Innovation Capability component of Organization Readiness is indeed essential for Green Managerial Innovation. For another example, process innovation requires the use of information technology to streamline operations such as supply chain management (Lee et al., 2014; Z. Yang, Sun, Li et al., 2019). In this study, the Relative Advantage component of Technology Readiness and Green Process Innovation are the next salient pair. Finally, product innovation is indispensable from market demand (Lin et al., 2014; Lin et al., 2013), as supported by the correspondence between the Market Orientation component of Environment Readiness and Green Product Innovation.

In terms of the consequences of green innovation, this study includes both Environmental Performance and Firm Performance as the mediators of its effect on eventual Competitive Advantage. This helps answer the bottom-line question of whether green innovation is worth the effort for long-term corporate sustainability, and reveal the mechanisms underneath. Among all possible routes, the results suggest that the primary influence is through Environmental Performance as the first mediator and Firm Performance as the second. It is the first time that such a serial mediation is identified in the green innovation literature.

The findings of this study provide guidance on how firms can be better prepared for green innovation and get the most out of it. To deal with the changes incurred, it is important for companies that implement green innovation to evaluate organization, technology and environment readiness, and formulate corresponding strategies. This proactive approach (e.g., to reduce employee resistance by enhancing environmental awareness) helps enterprises mitigate the risks in green innovation. Enterprises at different levels of green innovation readiness may customize how they implement green innovation. For companies at relatively low levels of readiness, incremental implementation is preferred, while those at relatively high levels of readiness can be more ambitious. A self-assessment of the green innovation readiness of an enterprise helps it establish a mechanism to keep track of technological evolution, internal resources and external conditions related to green innovation. Following the contingency management approach, this allows the organization to strategize innovation implementation. In this sense, the self-assessment of green innovation readiness is not a one-time deal but a continuous effort.

To carry out green managerial innovation, green process innovation, and green product innovation successfully, enterprises need to meet both necessary and sufficient conditions from technology, organization and environment aspects. First, they must make sure that they establish green cultures, adopt compatible technologies and comply with environmental policies to kick-start green innovation. For the optimization of outcomes, they need to further develop innovation capability, take advantage of state-of-art technologies and pay attention to market demands. The most essential is to develop the innovation capability that enables the organization to manage the changes involved in green innovation through the enhancement of expertise and learning. This lays the foundation for utilizing advantageous technologies for green process innovation and meeting market demands for green product innovation.

The inclusion of ecological, business and strategic consequences provides insights on how green innovation affects corporate sustainability. The findings suggest that enterprises can fulfill their social responsibilities and business goals simultaneously. Through the serial mediation of environmental performance and firm performance, green innovation leads to a competitive advantage in the long run. Such a mechanism assures enterprises of the worthiness of green innovation effort and the importance of green innovation readiness. Rather than viewing green innovation as merely a social responsibility to fulfill, enterprises should treat it as a business opportunity. In this way, they can go beyond meeting the necessary conditions but strive to excel in the sufficient conditions.

Despite the insights, this study has limitations. In particular, the sample was drawn from a single country, limiting the generalizability of the findings to other parts of the world. Future studies may collect observations from countries at different development stages (e.g., developed vs. developing) and of distinct cultures (e.g., Western vs. Eastern). With such multi-country analyses, researchers can compare the mean responses as well as relationship strengths. Leading to a more comprehensive understanding of green innovation readiness, it is expected that economic development and national culture make differences to various extents.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Yali Zhang: Supervision, Conceptualization. **Jun Sun:** Investigation, Writing - original draft. **Zhaojun Yang:** Methodology, Writing - review & editing. **Ying Wang:** Validation, Visualization.

Appendix. Measurement Items

Technology Readiness: Technology Compatibility (TC) and Relative Advantage (RA)

The technologies adopted for green innovation …

TC1: work well with what we currently use.
TC2: meet our operational needs.
TC3: match the requirement of suppliers/customers.
RA1: increase operational efficiency.
RA2: promote job effectiveness.
RA3: enhance product/service quality.

Organization Readiness: Environmental Concern (EC) and Innovation Capability (IC)

To facilitate green innovation, our organization …

EC1: cultivates a green culture among employees.
EC2: pays attention to environment protection in daily operations.
EC3: incorporates sustainable development in corporate strategy.
IC1: encourages employees to think creatively.
IC2: provides managerial support at all levels.
IC3: makes resources available as possible.

Environment Readiness: Policy Orientation (PO) and Market Orientation (MO)

Regarding the external factors of green innovation, our organization...

PO1: pays attention to environmental policies.
PO2: complies with environmental policies.
PO3: shares policy updates with employees.
MO1: keeps track of green product/service demands.
MO2: understands customers' environmental concerns.
MO3: regards customers as environmental partners.

Green Innovation: Green Product Innovation (GPDI), Green Process Innovation (GPCI), and Green Managerial Innovation (GMGI)

Our organization engages in green innovation by...

GPDI1: certifying green products with eco-labels.
GPDI2: using environment-friendly raw materials.
GPDI3: considering product degrading/remanufacturing.
GPCI1: reducing energy/resource consumption during production.
GPCI2: generating less pollution/waste during production.
GPCI3: recycling materials (e.g., remanufactured parts) during production.
GMGI1: adopting environmental management standards (e.g., ISO 14000).
GMGI2: establishing green supply chain management.
GMGI3: implementing environment audit/control systems.

Environmental Performance (EP)

Green innovation reduces our organization's …

EP1: energy/resource consumption.
EP2: waste/pollutant emission.
EP3: product-lifecycle environmental impact.

Firm Performance (FP)

Green innovation increases our organization's …

FP1: operational efficiency.
FP2: market share.
FP3: corporate profitability.

Competitive Advantage (CA)

Our organization outperforms competitors in …

CA1: operation/product cost.
CA2: product/service quality.
CA3: research and development (R&D).
CA4: management effectiveness.

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