Original Research Article

Development and validation of a corporate green innovation scale from the consumer perception perspective

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Abstract: From the perspective of consumer perception,this paper constructs a four-dimensional framework of Green Innovation.Sample data were collected through questionnaire surveys,and factor analysis,reliability, and validity tests were used to systematically verify the structural rationality and measurement quality of the scale.The results show that the Green Innovation scale has a clear and stable four-dimensional structure,with each dimension demonstrating good reliability and validity.This study not only provides a reliable tool for the empirical measurement of consumer-perceived Green Innovation but also lays a measurement foundation for subsequent exploration of the market mechanisms and policy effects of Green Innovation.

Keywords: green innovation; consumer perception; scale development; reliability and validity; factor analysis

1. Introduction

Against the backdrop of increasing global climate change pressure and tightening resource and environmental constraints,promoting the transformation of economic development mode towards green and low-carbon has become a universal consensus of the international community.As important practitioners of green tr ansformation,enterprises'Green Innovation implemented in product design,production processes,and related management activities is generally regarded as a key path to improve environmental performance and build competitive advantages.The market effect of corporate green innovation is not directly determined by objective innovation behaviors but is achieved through the intermediary process of consumer perception.Therefore,it is necessary to systematically develop and validate a corporate green innovation scale from the perspective of consumer perception.

2. Review

As an important concept connecting green development goals and corporate innovation activities,Green Innovation has become a core issue in sustainable development research.Chen et al.(2007)divided green innovation into Green Product Innovation and Green Process Innovation from the corporate strategic levelExisting studies generally regard green innovation as a multi-dimensional,systematic,and strategically oriented innovation form.Based on the above theoretical context,this paper defines corporate green innovation as a multi-dimensional green-oriented innovation behavior implemented by enterprises in product design,production processes,and related management activities,aiming at reducing resource consumption and environmental load and improving resource utilization efficiency.On this basis,the conceptual foundation of green innovation from the consumer perception perspective is constructed.

3. Research methods

Following the norms of scale development,this paper adopts a multi-stage empirical research method to develop and validate the corporate green innovation scale from the consumer perception perspective.In the item generation stage,based on the existing research results on green innovation,measurement items are designed from the perspective of consumer perceptibility,and the initial scale is formed through expert consultation and repeated

revisions.In the questionnaire design and data collection stage,a five-point Likert scale is used to measure each item,and a pre-survey is conducted before the formal investigation.The formal survey targets consumers who have used or are willing to purchase products from Chinese smart home appliance enterprises.To ensure the validity of perception-based measurements,samples that selected"completely unfamiliar"with the target enterprises were statistically filtered,and finally,980 valid samples meeting the requirements of statistical analysis were obtained.In the data analysis stage,SPSS 27.0 and AMOS 26.0 were used for factor analysis and reliability and validity tests.

4. Research results

4.1. Exploratory factor analysis

First,exploratory factor analysis was conducted on the 17 items of the Green Innovation scale to test its potential structural characteristics and the rationality of item attribution.Principal component analysis was used for factor extraction,and varimax orthogonal rotation was applied to optimize the factor structure.

As shown in Table 1,according to the criterion of eigenvalue greater than 1,a total of 4 common factors were extracted,with the cumulative explained variance reaching 85.205%.The overall explanatory power is high,indicating that the scale can fully reflect the potential structure of green innovation.Among them,the first factor has an eigenvalue of 4.198,explaining 24.484%of the total variance,mainly reflecting the behavioral characteristics of enterprises in promoting green practices at the institutional construction,management process,and organizational levels,and is named Green Management Innovation;the second factor has an eigenvalue of 3.620,explaining 20.977%of the total variance,focusing on green product design and functional optimization,and is named Green Product Innovation;the third factor has an eigenvalue of 3.395,explaining 19.951%of the total variance,mainly reflecting production process improvement,energy conservation and emission reduction,and resource efficiency improvement,and is named Green Process Innovation;the fourth factor has an eigenvalue of 3.272,explaining 19.793%of the total variance,reflecting enterprises'innovative practices in environmental governance and ecological improvement,and is named Green Environmental Innovation.

Table 1. Results of exploratory factor analysis(N=980).

Items	Factor 1	Factor 2	Factor 3	Factor 4	Communality
GPrI1	.032	.940	-.014	-.026	.885
GPrI2	.006	.949	.000	.001	.900
GPrI3	.019	.942	-.024	-.007	.889
GPrI4	.013	.944	.001	-.004	.892
GPI1	.003	.002	.922	.019	.851
GPI2	.022	-.012	.919	.012	.845
GPI3	-.007	.000	.925	-.006	.856
GPI4	-.009	-.026	.914	.030	.837
GMI1	.914	.018	.011	.015	.836
GMI2	.924	-.012	.009	.014	.854
GMI3	.903	.020	-.012	.040	.818
GMI4	.911	.023	-.008	-.003	.830
GMI5	.908	.025	.011	-.012	.826
GEI1	.009	-.004	.013	.917	.841
GEI2	.024	-.025	.054	.907	.827
GEI3	.022	-.005	.013	.927	.860
GEI4	-.005	.000	-.025	.915	.838
Eigenvalue	4.198	3.620	3.395	3.272	——
Explained Variance(%)	24.484	20.977	19.951	19.793	——
Cumulative Explained Variance(%)	24.484	45.460	65.412	85.205	——

From the perspective of item loading distribution,the standardized loadings of each measurement item on its corresponding factor are significantly higher than 0.50,and the loadings on other factors are low,with no obvious cross-loading phenomenon,indicating that the item attribution is clear and the structure has good discrimination. At the same time,the communality of each item is at a high level,indicating that the extracted common factors

can well explain the information of the original variables.Overall,the results of exploratory factor analysis support the four-dimensional composition of the Green Innovation scale,and the scale structure has good initial rationality and construct validity,providing a reliable foundation for subsequent reliability tests and confirmatory factor analysis.

4.2. Reliability and validity tests

4.2.1. Reliability test

Cronbach'sαcoefficient was used to test the internal consistency reliability of the Green Innovation scale. As shown in **Table 2**, the Cronbach'sαcoefficient of the total Green Innovation scale is 0.779,indicating that the overall scale has an acceptable level of internal consistency.From the perspective of each dimension,the Cronbach'sαcoefficients of Green Product Innovation,Green Process Innovation,Green Management Innovation,and Green Environmental Innovationare 0.959,0.940,0.949,and 0.937 respectively,all significantly higher than the recommended threshold of 0.70.Both the Green Innovation scale and its dimensions have passed the internal consistency reliability test,demonstrating good measurement stability.

Table 2. Results of scale reliability analysis.

Dimensions	Items	Number of Items	Cronbach'sα
Green Product Innovation	GPrI1, GPrI2, GPrI3, GPrI4	4	.959
Green Process Innovation	GPI1, GPI2, GPI3, GPI4	4	.940
Green Management Innovation	GMI1, GMI2, GMI3, GMI4, GMI5	5	.949
Green Environmental Innovation	GEI1, GEI2, GEI3, GEI4	4	.937
Total Green Innovation Scale	1-17	17	.779

4.2.2. Validity test

KMO sampling adequacy test and Bartlett's sphericity test were used to test the scale validity.As shown in **Table 3**, the KMO value of the Green Innovation scale is 0.884,significantly higher than the recommended standard of 0.80,indicating that there is a strong correlation between items and the sample data is suitable for factor analysis.Meanwhile,the approximate chi-square value of Bartlett's sphericity test is 16010.624,with degrees of freedom of 136 and a significance level of $p<0.001$,further verifying the appropriateness of the data structure.The overall scale has good construct validity.

Table 3. Results of scale validity analysis (N=980).

KMO Sampling Adequacy Measure		.884
Bartlett's Sphericity Test	Approximate Chi-Square	16010.624
	Degrees of Freedom	136
	Significance	.000

4.3. Confirmatory factor analysis

AMOS 26.0 was used to conduct confirmatory factor analysis on the Green Innovation scale.As shown in **Table 4**, the overall model fit is good,and all core fit indices meet the recommended standards,indicating that the constructed four-dimensional measurement model has a good match with the sample data.The standardized factor loadings of each item on its corresponding latent dimension are all significant and relatively high,indicating that each item can effectively reflect the corresponding green innovation dimension.The results show that the Green Innovation scale has good construct validity and measurement stability.

Table 4. Confirmatory factor analysis model fit indices and test results.

Indices	Recommended Standards	Results of This Study	Meeting the Standard?
χ^2/df	<3(or<5)	0.899	Yes
CFI	>0.90	1.000	Yes
TLI	>0.90	1.001	Yes
GFI	>0.90(optional)	0.988	Yes
RMSEA	<0.08(<0.05 is better)	0.000	Yes
SRMR	<0.08	0.015	Yes

5. Discussion and conclusion

Based on the consumer perception perspective,this paper systematically develops and validates a corporate green innovation scale.The research results show that green innovation can be divided into four dimensions:Green Product Innovation,Green Process Innovation,Green Management Innovation,and Green Environmental Innovation.Both exploratory and confirmatory factor analyses support this multi-dimensional structure setting,providing a relatively systematic structural framework for the measurement of the green innovation concept.In terms of measurement characteristics,the scale shows good statistical performance in both reliability and validity tests,indicating that consumers can form stable and distinguishable perceptual judgments on different types of corporate green innovation behaviors.Compared with measurement methods mainly based on corporate self-assessment or objective indicators,this paper constructs the scale from the consumer perception perspective,helping to make up for the lack of attention to the demand-side perspective in existing research. Methodologically,this paper follows a standardized scale development process,conducts double tests on the scale structure through exploratory and confirmatory factor analysis,and verifies the robustness of the measurement model under the condition of a large sample.

In general,the green innovation scale developed in this paper can provide a reliable measurement tool for subsequent relevant empirical research,corporate green innovation evaluation,and policy effect analysis.Future research can further test this scale in different industries or contexts to expand its scope of application.

References

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