systems

Article

Exploring the Path of Green Innovation and High-Quality Development of Influential Regional Enterprises Based on the Analysis of the Dynamic QCA Method and MATLAB Sustainability Prediction

Qijia Liu and Yeong-Gil Kim *

Department of Global Trade and Management, Shinhan University, Seoul 11644, Republic of Korea; liuqijia679@gmail.com
* Correspondence: ky3933@shinhan.ac.kr

Abstract: This study examines the multifactor linkage effects behind the differences in the sustainable development of green innovation of local enterprises in the spatio-temporal dimension so as to provide an important reference for the practice of sustainable development of green innovation of local enterprises. An analytical framework for the sustainable development of green innovation of local enterprises is established, and the dynamic QCA method is applied to analyse the provincial-level panel data of China from 2012 to 2021 to explore the linkage effect of each factor on the time axis, and to explore the differences of multifactors on the time axis. The study found that different factors may have different influence effects in different contexts. Firstly, while market demand is an important influencing factor, its role relative to economic drivers and social environment factors may be relatively limited in some contexts. Second, high levels of foreign investment and demand for innovation in the service sector have a significant impact on green innovation in local firms. At the same time, with the growing consumer preference for green products, green preferences in market demand have also begun to become an important factor influencing firms' green innovation. Meanwhile, in the spatial dimension, the provincial coverage has obvious regional differences. This requires local governments to fully consider the actual situation of the region when formulating relevant policies, and promote green innovation according to local conditions. This experiment is the first attempt to use the joint application of dynamic QCA and MATLAB for the study of green innovation in local enterprises, exploring the consistency in the longitudinal time dimension.

Keywords: factors; dynamic QCA; regional differences; time dimension; MATLAB

check for updates

Citation: Liu, Q.; Kim, Y.-G. Exploring the Path of Green Innovation and High-Quality Development of Influential Regional Enterprises Based on the Analysis of the Dynamic QCA Method and MATLAB Sustainability Prediction. *Systems* **2024**, *12*, 232. https://doi.org/10.3390/systems12070232

Academic Editor: Mitsuru Kodama

Received: 30 April 2024
Revised: 19 June 2024
Accepted: 23 June 2024
Published: 27 June 2024

1. Introduction

China is a vast country with a large population, and its economic and technological development shows obvious geographical differences [1,2]. Domestic and foreign scholars generally divide China into three major regions, namely, the eastern region, the central region and the western region, for the purpose of research, as shown in Figure 1. As an important engine of China's economic development, the eastern region has always led in terms of GDP per capita and government expenditure on social security [3]. Universities, research institutions and enterprises in the eastern region possess a large number of patents and scientific and technological achievements [4]. Scientific research institutions have also actively introduced advanced foreign technologies and, through digestion, absorption and re-innovation, have continued to promote the development of scientific and technological innovation [5]. The central region is at the middle level of China in terms of economic output and government expenditure on social security. The central region has a better industrial base, but agriculture is still its dominant industry. In recent years, the central region has been actively promoting the strategies of industrialisation, urbanisation and agricultural modernisation, and accelerating the pace of upgrading and transforming the industrial structure [6]. Although the western region is lagging behind economically, its government expenditure on social security is growing rapidly. This is mainly due to the fact that the western region is endowed with abundant resources and relatively low labour costs. The imperfect industrial system in the western region has led to its weak scientific and technological innovation capacity. As the government has increased its support for the western region, enterprises in the western region have begun to pay attention to scientific and technological innovation, constantly improving their technological level and beginning to transform [7].

Figure 1. Three major regional divisions in China: eastern, central and western regions.

In recent years, the synergistic relationship between corporate green innovation and per capita output has also been widely studied. Many scholars have gradually reached a consensus on the view that corporate green innovation improves resource use efficiency, reduces production costs and increases per capita output. Sustainable development depends to a certain extent on the ability to produce green technologies [8]. Castellani et al. argue that green technologies make a positive contribution to per capita income [9]. In terms of local government funding for technological innovation, local government environmental policies have a significant impact on green innovation in regional firms, and local government R&D investment positively moderates this association [10]. Lv et al. investigated the innovation efficiency of firms' green innovations in 30 provinces in China from 2003 to 2017, and statistically found that the environmental regime plays a positive moderating role between the financial structure and firms' green innovations [11]. By comparing the per capita output aspects of the regions, it was found that cities that overshoot their economic growth targets can have a significant dampening effect on green technological innovation in the regional service sector [12]. A study of social security expenditures by regional governments found that the introduction of FDI can have a positive impact on regional green technology specialisation and per capita income [13]. Regarding the new upgrading of green innovation in enterprises, some scholars have unfolded their research from the perspective of enterprises. Boajye et al. found that green innovation increases the cost of environmental governance, reduces investment in productive activities and negatively affects the performance of enterprises [14]. It is very interesting to note that the findings of Zhang et al. are completely opposite to those of Boajye et al. This may be due to the large development gap between the east and west of China [15]. Other scholars have taken a social perspective. Romer and Lucas, in their theory of endogenous economic growth, argue that technological progress restructures industries and contributes to social development [16,17].

The above studies have revealed the specific impact of per capita output value and government social security expenditure on enterprises' green technological innovation, respectively. However, they have not explored all three under the same theoretical framework. In addition, politics, business and social culture are all permeated with the influence of the social environment atmosphere, so the interaction between the three is inextricably linked to the influence of social environment factors [18–20]. The social and environmental climate for enterprises can improve the sense of social responsibility and credibility of enterprises. By publicising the green production, environmental protection measures and sustainable development business philosophy of enterprises, it will guide the transformation of pollution-intensive enterprises into cleaner ones and achieve a major transformation from the secondary to the tertiary sector [21]. For consumers, the promotion of green concepts in the social environment can enhance their environmental awareness and increase their knowledge of and demand for green consumption. By publicising environmental protection concepts and promoting green products and services, it guides consumers to change their consumer attitudes and behaviours and promotes green technological innovation by enterprises [22].

The qualitative comparative analysis (QCA) method can effectively qualitatively analyse the impact and influence of different factors on experiments. Therefore, this study incorporates economic factors such as per capita output, social environment factors such as government social security and market demand into the same framework. Drawing on the theory of synergy and complex systems, a composite-factor single-output analysis model is constructed. Panel data of 30 provinces (cities) provided by the National Bureau of Statistics (NBS) for the period 2012–2021 are utilised. The dynamic qualitative comparative analysis (QCA) method is adopted. Taking time as the vertical axis, the causal mechanism affecting the differences in green innovation and high-quality development of regional enterprises is revealed to explore in depth the differences in group preferences among different regions and to overcome the shortcomings of linear regression and fuzzy set qualitative comparative analysis in dealing with local practice contexts and factor linkage effects on the time vertical axis. This study aims to answer the following questions: Is there a single factor that is necessary for the sustainability of square businesses in the time dimension? Do these factors change over time and exhibit temporal effects? In addition, in the spatial dimension, does the coverage of the regional enterprise grouping model show regional differences?

2. Research Methodology and Data Construction, Framework and Data Construction

2.1. Theoretical Framework Construction

The influence of enterprises on green technology innovation is reflected in three core dimensions: the economic, social and market demand dimensions, as shown in Figure 2. At the level of economic drivers, these cover the high per capita gross regional product, the growing demand for green technology innovation in the regional service sector and the increase in the number of enterprises with foreign investment, which, together, drive the transition to green innovation [23]. An experiment carried out by Peng et al. found that higher per capita output has a positive impact on green technology innovation upgrading. With the increase in residents' income, the individual's requirements for quality of life will be increased accordingly, especially for the quality of the environment. Residents will pay more attention to environmental issues and participate more actively in environmental protection activities, thus promoting green innovation upgrading [24]. The increase in the disposable income of the population has driven the growth of social demand for green products, and enterprises need to respond to this change through green innovation. The service industry, as an important engine of economic growth, also needs to optimise and upgrade its industrial structure through green innovation, and enterprises with foreign investment, seeing the huge potential and business opportunities in the green market, will increase their investment efforts to jointly promote the process of sustainable development [25].

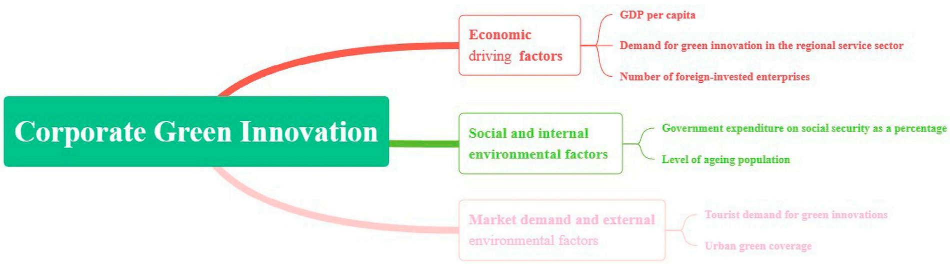

Figure 2. Theoretical framework.

The social environment and market demand have a profound impact on enterprises' green technology innovation. Economic development has led to increased government spending on social protection, highlighting the importance of the environment and sustainability. This policy direction has given strong impetus to green technological innovation by enterprises. At the same time, the ageing trend has increased the demand for quality of life, stimulating the market's desire for green and innovative products. Enterprises have responded positively by promoting green technological innovation to achieve sustainable development [26]. With the continuous promotion of urban greening construction, the living environment of residents has been significantly improved, and, at the same time, it also provides a broad application space for green technological innovation. With the growing demand for green innovation from tourists, the tourism industry is ushering in an opportunity for green transformation and upgrading. These positive factors together inspire enterprises to increase investment in green technology innovation, enhance the green quality of products and services and further promote the realisation of sustainable development [27].

2.2. Dynamic Qualitative Comparative Analysis Data Construction

Economic drivers mainly include three secondary conditions: gross regional product per capita, regional enterprises' demand for green innovation and the number of enterprises with foreign investment. The three factors of GDP per capita, regional service industry's demand for green innovation and the number of enterprises with foreign investment are particularly important when exploring in depth the impact of economic drivers on enterprises' green innovation [28]. As a key indicator to quantify the level of regional economic development, the increase in GDP per capita not only reflects the enhancement of the overall economic strength, but also provides the necessary material guarantee and market demand for green innovation activities [29]. A higher GDP per capita in a region often means that the residents of the region more strongly pursue a high quality of life, which drives the growth of demand for green innovative technologies and products [30]. The per capita gross regional product in this paper adopts the public data of the National Bureau of Statistics 2012–2021 [31]. At the same time, the prosperity and development of the service sector and the number of enterprises with foreign investment play an important role in driving the demand for green innovation [32,33]. The growth level of its indicators not only brings in the input of capital and technology, but also injects new vitality into the regional economy. Regarding the regional service industry's demand for green innovation, this paper refers to the research of statisticians. The scholar believes that, in the process of green innovation development of regional enterprises, the regional tertiary industry growth indicator is an important support for the sustainable development of local enterprises [34]. Data on the number of enterprises with foreign investment come from the provincial panel data published in the China Statistical Yearbook 2013–2022 [31].

When analysing the social and market environments in depth, factors such as the percentage of government social security expenditure, the level of ageing population, the demand for green innovations from tourists and the greening rate of the city are of particular importance [35]. The proportion of government social security expenditure not only reflects the government's emphasis on people's well-being, but also the cornerstone of social equity and stability [36]. An increase in this indicator will help build a more harmonious social environment and provide a stable social foundation for economic development. The level of the ageing population, on the other hand, reveals the trend of change in the social structure, with far-reaching impacts on the labour market, consumption patterns and many other aspects [37]. Actively responding to ageing is both a social challenge and a development opportunity. Demand for green innovation from the ageing population is based on the number of people aged 65 and above (Population Sampling Survey) (persons)/Population (Population Sampling Survey) as a reference indicator (source of data: Statistical Yearbook and National Bureau of Statistics) [31].

In addition, tourists' demand for green innovations and the greening rate of cities are directly related to the market environment [38]. With the popularisation of the concept of green consumption, tourists' demand for green and innovative products and services is growing, which provides a broad space for the development of green industry [39]. And the urban greening rate, as an important indicator of urban ecological environment, not only affects the quality of life of residents, but also directly relates to the sustainable development of the city [40]. The above refers to the measurement method of Ma Liang, and the data are from the China Statistical Yearbook.

2.3. Construct Green Technology Innovation Index Prediction Model

Construct the loop cell structure in the green technology innovation index (LSTM memory network), which consists of three "gates" and one "cell state".

Forgetting gate: decides whether the cell state of the previous moment needs to be "forgotten".

Input gate*: determines whether the current input information is added to the cell state.

Output gate: decides what the output of the current moment is.

Inside the recurrent cell of the LSTM network that builds the green technology innovation index, the interior consists of four layers of interconnected hierarchies. Among them, forgetting gates (ft), input gates (it) and output gates (ot) are dedicated to controlling the information flow [41].

Establish a time prediction model for green technology innovation in China using panel data of 30 provinces (cities) from 2012 to 2021 on the platform of the National Bureau of Statistics of China. Take the green technology innovation data as a sample and establish an LSTM neural network. By making the input X the year serial number, it can output the predicted green technology innovation value of China Y. Firstly, establish the database X, Y:

$$X = [2012, 2013, 2014, 2015, 2016, \ldots\ldots 2021]$$

$$Y = [0.943, 0.906, 0.866, 0.870, 0.840, \ldots\ldots 0.993]$$

3. Data Analysis and Empirical Results

3.1. Measurement Method of Green Innovation of Regional Enterprises

The entropy method measures the weight of each indicator layer in the composite system. If there are p provinces (cities), m indicators and y years, $\mathbf{X}_{\alpha\beta\theta}$ is the value of the βth indicator of the αth province in the θth year ($\boldsymbol{\alpha}$ = 1, 2, 3 ... p; $\boldsymbol{\beta}$ = 1, 2, 3 ... m, $\boldsymbol{\theta}$ = 1, 2, 3 ... y). The formulae are as follows:

1. Indicator standardisation: Different indicators have different scales and units and therefore need to be standardised. If the indicator is positive,

$$\mathbf{Y}_{\alpha\beta\theta} = {(\mathbf{X}_{\alpha\beta\theta} - \mathbf{min}(\mathbf{X}_{\alpha\beta\theta}))} \Big/ {(\mathbf{max}(\mathbf{X}_{\alpha\beta\theta}) - \mathbf{min}(\mathbf{X}_{\alpha\beta\theta}))} \tag{1}$$

If the indicator is negative,

$$\mathbf{Y}_{\alpha\beta\theta} = \left(\mathbf{max}\left(\mathbf{X}_{\alpha\beta\theta}\right) - \mathbf{X}_{\alpha\beta\theta}\right) \Big/ \left(\mathbf{max}\left(\mathbf{X}_{\alpha\beta\theta}\right) - \mathbf{min}\left(\mathbf{X}_{\alpha\beta\theta}\right)\right) \tag{2}$$

where min represents the minimum value and max represents the maximum value.

2. Calculation of characteristic proportions or contributions $\mathbf{Z}_{\alpha\beta\theta}$:

$$\mathbf{Z}_{\alpha\beta\theta} = \frac{\mathbf{Y}_{\alpha\beta\theta}}{\sum_1^{\mathbf{p}} \sum_1^{\mathbf{y}} \mathbf{Y}_{\alpha\beta\theta}},\ \boldsymbol{\alpha} = 1,\ 2,\ 3\ \ldots\ldots\ \mathbf{p},\ \boldsymbol{\theta} = 1,\ 2,\ 3\ \ldots\ldots\ \mathbf{y} \tag{3}$$

3. Calculation of entropy $\mathbf{E}_{\beta}$:

$$\mathbf{E}_{\beta} = \mathbf{K} \sum_{\boldsymbol{\alpha}=1}^{\mathbf{p}} \sum_{\boldsymbol{\theta}=1}^{\mathbf{y}} \mathbf{Z}_{\alpha\beta\theta} \mathbf{ln}\left(\mathbf{Z}_{\alpha\beta\theta}\right),\ \mathbf{K} = -\frac{1}{\mathbf{ln}(\mathbf{yp})},\ 0 \leq \mathbf{E}_{\beta} \leq 1 \tag{4}$$

4. Calculate the information utility value of the βth indicator:

$$\mathbf{G}_{\beta} = 1 - \mathbf{E}_{\beta} \tag{5}$$

Determine the weights of evaluation indicators $\mathbf{W}_{\beta}$:

$$\mathbf{W}_{\beta} = \frac{\mathbf{G}_{\beta}}{\sum_1^{\mathbf{m}} \mathbf{G}_{\beta}},\ \boldsymbol{\beta} = 1,\ 2,\ 3\ \ldots\ldots\ \mathbf{m} \tag{6}$$

3.2. Constructing a Comprehensive Green Innovation Indicator System for Regional Enterprises

This paper is based on the panel data of Chinese provinces. Comprehensive green technology indicators are constructed from five dimensions: patent authorisation, technology market share, government green technology innovation investment, urban unemployment rate and energy utilisation rate, with reference to the study of Kuang Yunming et al. [21]. The data come from the National Bureau of Statistics [31], as shown in Table 1.

Table 1. Comprehensive evaluation index system of green innovation index for regional enterprises.

Objective Level	Criteria Level	Indicator Layer	Weights	Properties
Comprehensive Green Technology Indicators for Regional Enterprises	Patent Grants	Patent Applications and Authorisations(item)/ Year-End Resident Population (10,000)	0.3331	Forward
	Percentage of Technology Market Transactions	Technology Market Turnover (CNY billion)/ GDP (CNY billion)	0.3205	Forward
	Government Investment in Science and Technology Innovation	Share of Science and Technology Expenditure in Fiscal Expenditure	0.2303	Forward
	Urban Unemployment Rate	Urban Registered Unemployment Rate	0.0716	Forward
	Energy Utilisation Rate	Electricity Consumption Per Unit of GDP	0.0443	Negative

The green technology innovation development level of each region in China from 2012 to 2021, measured by this paper based on the entropy value method and the comprehensive green technology innovation index, is shown in Figure 3. The green technology innovation index in eastern China is leading; the central and western regions are gradually developing, but the gap between these and the green technology innovation index in the east is showing a widening trend. Overall, the green technology innovation index is steadily increasing. However, the western region needs more attention and investment to narrow the gap between them and the east and centre and promote the balanced development of green technology innovation in the country.

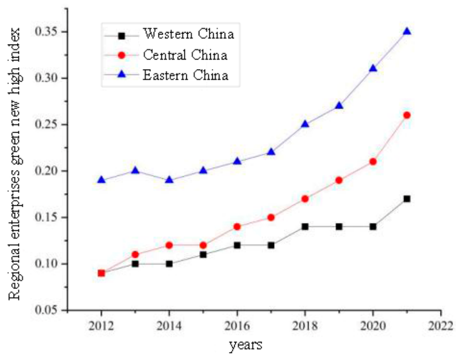

Figure 3. Green innovation index for regional enterprises.

3.3. Calibration

In this paper, based on Boolean algebra theory and previous studies, the data are calibrated precisely to ensure the consistency and coverage of the analysis [42–44]. The direct calibration method is used, and the 95% quartile, 50% quartile and 5% quartile are set as calibration anchor points [45–47], and the specific results are shown in Table 2.

Table 2. Calibration of variables.

	Variable Name	Fully Affiliated	Intersections	Completely Unaffiliated
Result variables	Green innovation of local enterprises (Y)	0.469	0.139	0.068
Conditional variables	Per capita gross regional product (A)	116,664	50,242	28,622
	Percentage of government expenditure on social security (B)	45.215	40.4	33.88
	Urban Green Coverage Rate (C)	0.194	0.134	0.084
	Level of ageing population (D)	0.159	0.108	0.072
	Tourist demand for green innovation (E)	5.511	0.995	0.01
	Number of enterprises with foreign investment (F)	79,639.850	6698	737.8
	Demand for innovation by regional service industries (G)	37,660.94	9850.3	1542.95

3.4. Necessity Analysis of Individual Conditions

According to the set theory of Boolean algebra and QCA design principles and applications, it is known that the smaller the adjustment distance of QCA panel data, the higher the consistency and accuracy [48]. However, the adjustment distance is not clearly defined in statistics. QCA experimental analysis needs to consider the data size and data inclusion; therefore, the median value of the adjustment distance used in this experiment is 0.3. As shown in Table 3, the seven indicators of per capita GDP (A), the proportion of government social security expenditures (B), the percentage of urban green coverage (C), the level of the ageing population (D), the demand of tourists for green innovations (E), the number of enterprises with foreign investment (F) and regional enterprises' demand for innovation (G) have an adjusted distance to green innovation that is greater than 0.3, and the coverage of less than 0.5 requires researchers to further explore the necessity [49].

By analysing the inter-group consistency and coverage of the corresponding variables (as shown in Tables 3 and 4), the following findings are obtained: Firstly, in the process of analysing the necessary conditions, we do not find that any single factor can constitute the necessary conditions for green innovation of local enterprises alone. This means that green innovation of local enterprises is a complex process that requires multiple factors to work together to achieve it. Secondly, in the inter-group data with an adjusted distance greater than 0.3, we observe that, in cases a, b and c, the level of consistency across years does not reach 0.9 [50]. Therefore, the necessary relationship is not satisfied. Meanwhile, by plotting the scatterplot of coverage and consistency, we find that the coverage is mainly concentrated on the right y-axis, which passes the test of the non-essential condition. However, the consistency does not pass the test of the non-essential condition. This further suggests that these factors may play a role in the green innovation process. However, they are not decisive and have their own research value.

Table 3. Analysis of the necessary conditions.

Variant	High Level of Local Business Green Innovation (Y)				Low Level of Local Business Green Innovation (~Y)			
	Aggregate Consistency	Aggregate Coverage	Inter-Group Consistency	Intra-Group Consistency	Aggregate Consistency	Aggregate Coverage	Inter-Group Consistency	Intra-Group Consistency
A	0.85	0.84	0.10	0.24	0.47	0.56	0.52	0.52
~A	0.56	0.46	0.18	0.45	0.87	0.88	0.11	0.21
B	0.75	0.69	0.06	0.38	0.58	0.65	0.28	0.47
~B	0.62	0.55	0.18	0.40	0.73	0.78	0.09	0.40
C	0.65	0.61	0.20	0.42	0.63	0.72	0.29	0.39
~C	0.71	0.61	0.25	0.35	0.86	0.70	0.15	0.39
D	0.77	0.71	0.20	0.30	0.54	0.61	0.36	0.49
~D	0.85	0.51	0.37	0.41	0.75	0.80	0.19	0.32
E	0.61	0.66	0.50	0.41	0.51	0.67	0.45	0.56
~E	0.69	0.54	0.29	0.32	0.74	0.70	0.19	0.34
F	0.77	0.79	0.06	0.37	0.88	0.61	0.15	0.60
~F	0.62	0.49	0.04	0.43	0.83	0.81	0.08	0.30
G	0.78	0.75	0.07	0.40	0.50	0.60	0.27	0.55
~G	0.85	0.49	0.20	0.47	0.79	0.81	0.07	0.35
average	0.7	0.6	0.2	0.4	0.7	0.7	0.2	0.4

Table 4. Data between groups with adjusted distances greater than 0.3.

Situation	Causal Combination Situations		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
a	~A and Y	Inter-group consistency	0.68	0.68	0.66	0.63	0.59	0.58	0.54	0.50	0.47	0.41
		Inter-group coverage	0.26	0.32	0.34	0.37	0.39	0.49	0.63	0.70	0.75	0.91
b	~F and Y	Inter-group consistency	0.62	0.61	0.64	0.64	0.63	0.63	0.65	0.61	0.59	0.57
		Inter-group coverage	0.31	0.37	0.38	0.41	0.44	0.50	0.59	0.62	0.67	0.74
c	~G and Y	Inter-group consistency	0.72	0.73	0.71	0.68	0.61	0.54	0.50	0.50	0.48	0.44
		Inter-group coverage	0.31	0.38	0.40	0.43	0.46	0.53	0.62	0.64	0.66	0.74

3.5. Configuration Analysis Results

In this paper, the truth table is constructed. The consistency threshold is set to 0.8, and the frequency threshold is set to 1. Also, the PRI threshold is determined to be 0.60. Table 5 shows that the consistency of grouping 1, grouping 2 and grouping 3 is 0.828, 0.827 and 0.845, respectively. The overall consistency is greater than 0.75, and the adjustment distance between intra-group and inter-group values for individual grouping is less than 0.3. It shows that the aggregated consistency has a better explanatory strength. These three groupings can be regarded as sufficient conditions affecting the generation of sustainable green innovation in local enterprises. From the study of group state 1, we observe the influence of different factors on the green innovation of enterprises. Cohort 1 shows that economic drivers such as the number of firms with foreign investment and the demand for innovation in the regional service sector, as well as socio-environmental factors such as a high level of government social security expenditure and the level of ageing, are the main drivers of green innovation in firms, while market demand has a limited impact. Configuration 2 further emphasises the importance of high levels of foreign investment and service sector innovation demand. At the same time, market demand stemming from tourists' preference for green begins to emerge. In configuration 3, economic, social and market demand factors show a more balanced state. The economic drivers are GDP per capita, a high level of foreign investment and a high level of regional demand for innovation in the service sector. The social environment factor is dominated by the high level of the government social security expenditure share. Market demand is dominated by the urban greening coverage rate.

These findings suggest that, in the context of China's geographical resource differences, localities should combine their own characteristics to achieve factor linkages in order to promote local firms' green innovation. It is worth noting that the multidimensional linkage model is demonstrated in grouping 3, although the study shows that the green innovation of local enterprises is influenced by multiple factors such as economic drive, social environment and market demand. However, this multidimensional linkage model still needs further in-depth exploration. The key lies in how enterprises balance supply and demand to achieve multidimensional power. Only by comprehensively considering economic, social and market demands can enterprises formulate a more reasonable and effective green innovation strategy. This is not only the key to enhancing the competitiveness of enterprises, but also the way to realise the sustainable development of green innovation. Therefore, future research should pay more attention to the balance and synergy of enterprises under the effect of multidimensional factors so as to promote the in-depth development of green innovation.

Table 5. Configuration truth table.

Conditional Variables	Parameterisation 1	Parameterisation 2	Parameterisation 3
Gross regional product per capita (A)	⊗	⊗	•
Percentage of government expenditure on social security (B)	•	•	•
Urban Green Coverage Rate (C)	⊗	⊗	•
Level of ageing population (D)	•		•
Tourist demand for green innovation (E)		•	⊗
Number of enterprises with foreign investment (F)	•	•	•
Demand for innovation by regional service industries (G)	•	•	•
Consistency	0.838	0.827	0.845
Original coverage	0.402	0.411	0.366
Unique coverage	0.019	0.08	0.095
Inter-group consistency adjusted distance	0.011	0.012	0.012
Intra-group consistency-adjusted distance	0.026	0.029	0.024
Overall PRI	0.611		
Overall consistency	0.827		
Overall coverage	0.402		

Note: • and ⊗ indicate presence and absence of core; blank indicates that presence and absence are also possible.

Finally, a stability check is carried out, and, after setting a consistency threshold of 0.8 and a PRI threshold of 0.60, the consistency of the experimental thresholds is increased by 0.05, respectively. The consistency of the experimental grouping of states with the results of the original study is found to be consistent in the robustness check so the experiment confirms that the analyses used demonstrate stability and reliability.

3.6. Between- and Within-Group Results

It is found that the adjusted distance of inter-group consistency for all three groupings is not greater than 0.3, indicating that there is no significant time effect. Further examination of its temporal changes reveals that the consistency levels of the three groupings show a decline from 2012 to2016. However, they collectively show a period of rapid growth in 2016–2021. As shown in Figure 4, among them, group state 3 has the fastest growth rate for inter-group consistency, growing from 0.84 to 1.00. The reason for this is that our government intervention plays a crucial role. Checking government websites and local service platforms finds that 60% more documents were released in 2016 to promote green development compared to in 2015. Meanwhile, the government sends out strong intervention signals. In terms of policy intervention, the Chinese government has introduced a series of policies to encourage green innovation and sustainable development, such as providing financial subsidies, tax incentives and loan facilitation, in order to incentivise enterprises to increase their research and development in green technologies. Regulatory constraints: the government has strengthened the formulation and enforcement of environmental protection regulations, imposing strict limits on pollution emissions and energy consumption. Government in green procurement: as one of the largest consumers, the government has given priority to green products and services to encourage enterprises to actively develop green products and enhance their green innovation capability [51].

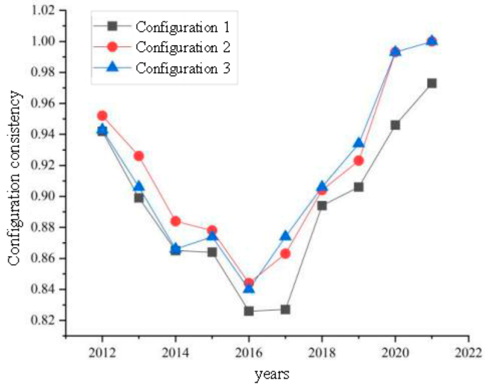

Figure 4. Configuration consistency analysis.

The range of intra- and inter-group consistency adjustment distances is almost the same, and the intra-group consistency adjustment distance is not greater than 0.3. The variability in the distribution of the geographic coverage of the grouping models is revealed in Table 6. The explained cases of group states 2 and 3 are mainly concentrated in the central region, and may stem from the unique resource conditions and policy environment in these regions. However, histogram 1 shows stronger explanatory power in East, Central and West China, with a coverage of more than 0.5, indicating its universality. This shows that firms in different regions may be affected by different factors when facing green innovation and sustainability challenges. Such geographical differences may stem from the diversity of regional levels of economic development, market demand, resource distribution and policy orientations. For policymakers and entrepreneurs, an in-depth understanding of the geographical characteristics of the model can help develop more targeted strategies and measures to promote the green transformation and sustainable development of enterprises.

Table 6. Geographical coverage.

	Eastern China	**Central China**	**Western China**
Configuration 1	0.56	0.62	0.55
Configuration 2	0.38	0.46	0.38
Configuration 3	0.39	0.46	0.38

3.7. Consistent Prediction of Sustainable Development of Green Innovation of Local Enterprises

Using MATLAB 9.12, the article constructs a consistency prediction model for the sustainable development of green innovation in local enterprises, as shown in Figure 5. The root-mean-square error (RMSE) of the model is 0.9, a value that indicates that the predictive accuracy of the model can be applied to consistency prediction. The RMSE is a commonly used metric for assessing the predictive ability of a model which measures the magnitude of the model's error by calculating the mean of the squared difference between the predicted value and the actual value. A lower RMSE value means that the model has a higher prediction accuracy. From the trend of the model's prediction graph, it can be observed that the overall trend of the consistency index of the sustainable development of green innovation of local enterprises shows a gradual decrease followed by a rapid growth trend. According to the prediction trend, China's progress in green technological innovation is gradually accelerating, and the consistency index of enterprises' sustainable development of green innovation will be maintained at around 0.90.

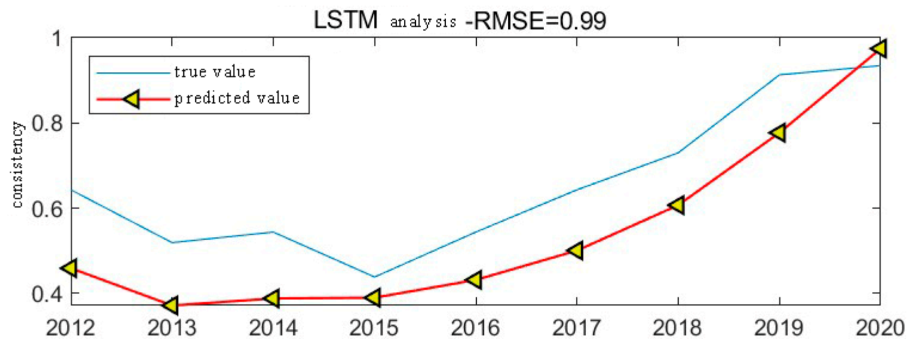

Figure 5. Coherent projections for the sustainable development of innovation.

4. Results

This paper applies the dynamic QCA research method. Using the data cases of 30 provincial governments in China, it explores the influence effects of both supply and demand influencing factors on the sustainable development of green innovation of local enterprises. The core influencing factors affecting the sustainable development of local enterprises' green innovation and the interaction between them during 2012–2021 are revealed.

These findings suggest that the influencing factors of local enterprises' sustainable development of green innovation are complex and diverse, and that different factors may have different influencing effects in different contexts. Firstly, although market demand is an important influencing factor, its role relative to economic drivers and social environment factors may be relatively limited in some cases. This suggests that, when promoting green innovation in local enterprises, we cannot rely solely on the pull of market demand, but also need to take into account various factors such as economic and social environment factors. Second, high levels of foreign investment and demand for innovation in the service sector have a significant impact on green innovation in local enterprises. This suggests that attracting foreign investment and promoting innovation in the service sector are important ways to enhance the green innovation capacity of local enterprises. At the same time, with the increasing preference of consumers for green products, green preferences in market demand have also begun to become an important factor influencing enterprises' green innovation. In addition, the resource differences and characteristics of different regions make it necessary for local enterprises to combine their own realities in the process of green innovation and realise the linkage and complementarity of factors. This requires local governments to take into full consideration the actual situation of the region when formulating relevant policies and promote green innovation according to local conditions. In the spatial dimension, the sustainable development of green innovation of local enterprises shows regional differences. This may be due to the differences in the level of economic development, industrial structure, policy environment and other factors in different regions. Therefore, when promoting green innovation, differentiated policy measures need to be formulated for the characteristics of different regions. Finally, by constructing a consistency prediction model, the study finds that China's progress in green technology innovation is gradually accelerating, and the consistency index of enterprises' sustainable development of green innovation will be maintained at a high level. This indicates that China's green innovation activities will become more active and stable in the future, providing strong support for sustainable development.

5. Discussion

In this study, the process of in-depth analysis of enterprises' green innovation is limited by the timeliness of and quality differences in the secondary public data, which leads to the absence of information on some key variables and details, as well as the uncertainty of data quality and reliability. At the same time, although macro-level analyses can reveal the overall trend, they ignore the individual differences among enterprises and the process of dynamic change. Therefore, future research needs to explore a wider range of data sources, combined with micro-level analyses, in order to gain a more comprehensive understanding of the actual situation and influencing factors of green innovation in enterprises so as to provide more accurate and specific guidance for enterprise practice and policy formulation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/systems12070232/s1, Supplementary File: Publicly available data from the China Statistical Bureau—(collected and collated).

Author Contributions: Conceptualisation, Q.L. and Y.-G.K.; methodology, Y.-G.K.; software, Q.L.; validation, Q.L. and Y.-G.K.; formal analysis, Q.L.; investigation, Q.L.; resources, Y.-G.K.; supervision, Y.-G.K.; project administration, Y.-G.K.; funding acquisition, Y.-G.K. All authors have read and agreed to the published version of the manuscript.

Funding: This study was conducted without receiving any external funding.

Data Availability Statement: The original data presented in the study are openly available in the National Bureau of Statistics of China. The collected data are properly stored at Shinhan University. Please find some data of this article in Supplementary File.

Conflicts of Interest: It is hereby declared that there are no conflicts of interest in this study.

References

1. Geary, J.; Nyiawung, J. The impact of Chinese investments on western multinational enterprises' work and employment practices: A consideration of institutional, political and dominance effects. *Hum. Relat.* **2022**, *75*, 842–870. [CrossRef]
2. Tsui, K.Y. Decomposition of China' s regional inequalities. *J. Comp. Econ.* **1993**, *17*, 600–627. [CrossRef]
3. Wu, W.; He, F.; Zhuang, T.; Yi, Y. Stakeholder analysis and social network analysis in the decision-making of industrial land redevelopment in China: The case of Shanghai. *Int. J. Environ. Res. Public Health* **2020**, *17*, 9206. [CrossRef]
4. Shen, X.; Li, H.; Tolbert, P.S. Converging tides lift all boats: Consensus in evaluation criteria boosts investments in firms in nascent technology sectors. *Organ. Sci.* **2021**, *34*, 2415–2435. [CrossRef]
5. Kostka, G.; Zhang, X.; Shin, K. *Information, Technology, and Digitalization in China's Environmental Governance*; Taylor & Francis: Oxfordshire, UK, 2020; pp. 1–13.
6. Jiang, J.; Qian, J.; Wen, Z. Social protection for the informal sector in urban China: Institutional constraints and self-selection behaviour. *J. Soc. Policy* **2018**, *47*, 335–357. [CrossRef]
7. Child, J.; Tse, D.K. China's transition and its implications for international business. *J. Int. Bus. Stud.* **2001**, *32*, 5–21. [CrossRef]
8. Song, Y.; Zhang, Z.; Sahut, J.-M.; Rubin, O. Incentivizing green technology innovation to confront sustainable development. *Technovation* **2023**, *126*, 102788. [CrossRef]
9. Castellani, D.; Marin, G.; Montresor, S.; Zanfei, A. Greenfield foreign direct investments and regional environmental technologies. *Res. Policy* **2022**, *51*, 104405. [CrossRef]
10. Chen, Y.; Yao, Z.; Zhong, K. Do environmental regulations of carbon emissions and air pollution foster green technology innovation: Evidence from China's prefecture-level cities. *J. Clean. Prod.* **2022**, *350*, 131537. [CrossRef]
11. Lv, C.; Shao, C.; Lee, C.C. Green technology innovation and financial development: Do environmental regulation and innovation output matter? *Energy Econ.* **2021**, *98*, 105237. [CrossRef]
12. Shen, F.; Liu, B.; Luo, F.; Wu, C.; Chen, H.; Wei, W. The effect of economic growth target constraints on green technology innovation. *J. Environ. Manag.* **2021**, *292*, 112765. [CrossRef] [PubMed]
13. Paramati, S.R.; Mo, D.; Huang, R. The role of financial deepening and green technology on carbon emissions: Evidence from major OECD economies. *Financ. Res. Lett.* **2021**, *41*, 101794. [CrossRef]
14. Boakye, D.J.; Tingbani, I.; Ahinful, G.S.; Nsor-Ambala, R. The relationship between environmental management performance and financial performance of firms listed in the Alternative Investment Market (AIM) in the UK. *J. Clean. Prod.* **2021**, *278*, 124034. [CrossRef]
15. Zhang, Q.; Ma, Y. The impact of environmental management on firm economic performance: The mediating effect of green innovation and the moderating effect of environmental leadership. *J. Clean. Prod.* **2021**, *292*, 126057. [CrossRef]
16. Romer, P.M. Increasing returns and long-run growth. *J. Political Econ.* **1986**, *94*, 1002–1037. [CrossRef]
17. Lucas, R.E., Jr. On the mechanics of economic development. *J. Monet. Econ.* **1988**, *22*, 3–42. [CrossRef]

18. Zhang, N.; Sun, J.; Tang, Y.; Zhang, J.; Boamah, V.; Tang, D.; Zhang, X. How Do Green Finance and Green Technology Innovation Impact the Yangtze River Economic Belt's Industrial Structure Upgrading in China? A Moderated Mediation Effect Model Based on Provincial Panel Data. *Sustainability* **2023**, *15*, 2289. [CrossRef]
19. Zhang, J.; Huang, R.; He, S. How does technological innovation affect carbon emission efficiency in the Yellow River Economic Belt: The moderating role of government support and marketization. *Environ. Sci. Pollut. Res.* **2023**, *30*, 63864–63881. [CrossRef] [PubMed]
20. Li, H.; Xu, R. Impact of fiscal policies and natural resources on ecological sustainability of BRICS region: Moderating role of green innovation and ecological governance. *Resour. Policy* **2023**, *85*, 103999. [CrossRef]
21. Kuang, Y.; Lin, B. Natural gas resource utilization, environmental policy and green economic development: Empirical evidence from China. *Resour. Policy* **2022**, *79*, 102992. [CrossRef]
22. Hu, N.; Zheng, B. Natural resources, education, and green economic development. *Resour. Policy* **2023**, *86*, 104053. [CrossRef]
23. Pengwei, W.; Ji, Y. Tourists' Willingness to Pay Conservation Fees: The Case of Hulunbuir Grassland, China. *J. Resour. Ecol.* **2023**, *14*, 656–666. [CrossRef]
24. Hou, P.; Liu, X.L.; Cheng, S. Who is More Willing to Pay for Green Electricity? A Case Study of Anyang City, China. *J. Resour. Ecol.* **2022**, *13*, 231–237.
25. Alvarado, R.; Ponce, P.; Criollo, A.; Córdova, K.; Khan, M.K. Environmental degradation and real per capita output: New evidence at the global level grouping countries by income levels. *J. Clean. Prod.* **2018**, *189*, 13–20. [CrossRef]
26. Alvarez, R.C.; Emery, M. From action research to system in environments: A method. *Syst. Pract. Action Res.* **2000**, *13*, 683–703. [CrossRef]
27. Keahey, J. Sustainable development and participatory action research: A systematic review. *Syst. Pract. Action Res.* **2021**, *34*, 291–306. [CrossRef]
28. Tudor, C.; Sova, R. On the impact of gdp per capita, carbon intensity and innovation for renewable energy consumption: Worldwide evidence. *Energies* **2021**, *14*, 6254. [CrossRef]
29. Stiglitz, J.E.; Sen, A.; Fitoussi, J.-P. *The Measurement of Economic Performance and Social Progress Revisited*; M. OFCE: Paris, France, 2009.
30. Romão, J.; Kourtit, K.; Neuts, B.; Nijkamp, P. The smart city as a common place for tourists and residents: A structural analysis of the determinants of urban attractiveness. *Cities* **2018**, *78*, 67–75. [CrossRef]
31. China's National Bureau of Statistics under 2010–2023. China NBS. Available online: www.stats.gov.cn (accessed on 15 March 2024).
32. Xue, D.; Ding, Y.; Yu, L.; Deng, X. The Impact of Green Institutional Pressure from Local Governments on Corporate Innovation: An Empirical Evidence from Foreign-Invested Enterprises in China. *Sustainability* **2023**, *15*, 11678. [CrossRef]
33. Zhou, J.; Li, H. Review and Prospects of Green Innovation Ecosystems from the Perspective of Value Emergence. *Systems* **2024**, *12*, 206. [CrossRef]
34. Su, Y.; Fan, Q.M. Renewable energy technology innovation, industrial structure upgrading and green development from the perspective of China's provinces. *Technol. Forecast. Soc. Change* **2022**, *180*, 121727. [CrossRef]
35. Rode, P. Cities and the green economy. In *The Economy of Green Cities: A World Compendium on the Green Urban Economy*; Springer: Berlin/Heidelberg, Germany, 2013; pp. 79–98.
36. Cannon, T.; Twigg, J.; Rowlee, J. Social Vulnerability, Sustainable Livelihoods and Disasters. *Rep. DFID Confl. Humanit. Assist. Dep. (CHAD) Sustain. Livelihoods Support Off.* **2003**, *93*, 1–63.
37. Börsch-supan, A. Aging population: Problems and policy options in the US and Germany. *J. Econ. Policy* **1991**, *6*, 103–140. [CrossRef]
38. Park, J.; Page, G.W. Innovative green economy, urban economic performance and urban environments: An empirical analysis of US cities. *Eur. Plan. Stud.* **2017**, *25*, 772–789. [CrossRef]
39. Tang, C.; Han, Y.; Ng, P. Green consumption intention and behavior of tourists in urban and rural destinations. *J. Environ. Plan. Manag.* **2023**, *66*, 2126–2150. [CrossRef]
40. Shi, Z.; Wu, Y.; Chiu, Y.; Pang, Q.; Zhang, L. Assessing city sustainable development—Residents' quality of life from the perspective of sustainable development goals and spatiotemporal evolution. *Sustain. Dev.* **2023**, *31*, 1456–1474. [CrossRef]
41. Mateus, B.P.C. Production Optimization Indexed to the Market Demand through Neural Networks. Master's Thesis, Universidade da Beira Interior, Covilhã, Portugal, 2023.
42. Befani, B. *Pathways to Change: Evaluating Development Interventions with Qualitative Comparative Analysis (QCA)*; Expertgruppen för biståndsanalys (the Expert Group for Developent Analysis) Pobrane: Stockholm, Sweden, 2016.
43. Jiao, J.L.; Zhang, X.L.; Tang, Y.-S. What factors determine the survival of green innovative enterprises in China?—A method based on fsQCA. *Technol. Soc.* **2020**, *62*, 101314. [CrossRef] [PubMed]
44. Zhang, M.; Li, B. How to improve regional innovation quality from the perspective of green development? Findings from entropy weight method and fuzzy-set qualitative comparative analysis. *IEEE Access* **2020**, *8*, 32575–32586. [CrossRef]
45. Leoni, F.; Bazzan, G. Using QCA as an approach to make sense of micro-level data-centric practices for policy innovation: A walk-through. In Proceedings of the International Conference on Public Policy (ICPP6), Toronto, ON, Canada, 27–29 June 2023; International Public Policy Association: Vaulx en Velin, France, 2023.
46. Cai, Y.; Du, L.; Jiang, X. Uncovering Configurations of Internal and External Factors for Creating Firm's High Green Innovation Performance Using csQCA. *Res. Sq.* **2021**. [CrossRef]

47. Zhao, Y.; Bai, J.; Liang, Y. What Kind of Green Innovation Mode Produces High Competitiveness in Cities? Configuration Analysis Based on fsQCA. *J. Syst. Manag.* **2024**, *33*, 420.
48. Zhao, Y.; Wu, X.; Zhang, J. Analysis of the paths affecting corporate green innovation in resource-based cities: A fuzzy-set QCA approach. *Sustainability* **2022**, *15*, 337. [CrossRef]
49. Fan, X.; Ren, S.; Liu, Y. The Driving Factors of Green Technology Innovation Efficiency—A Study Based on the Dynamic QCA Method. *Sustainability* **2023**, *15*, 9845. [CrossRef]
50. Fan, X.; Shan, X.; Day, S.; Shou, Y. Toward green innovation ecosystems: Past research on green innovation and future opportunities from an ecosystem perspective. *Ind. Manag. Data Syst.* **2022**, *122*, 2012–2044. [CrossRef]
51. Fassio, F.; Tecco, N. Circular economy for food: A systemic interpretation of 40 case histories in the food system in their relationships with SDGs. *Systems* **2019**, *7*, 43. [CrossRef]