sustainability

MDPI

Article

Energy Sustainability Evaluation Model Based on the Matter-Element Extension Method: A Case Study of Shandong Province, China

Siqi Li [1] **and Rongrong Li** [1,2,*]

[1] School of Economic and Management, China University of Petroleum (East China), Qingdao 266580, China; lsq1836416@163.com
[2] School of Management and Economics, Beijing Institute of Technology, Beijing 10081, China
* Correspondence: lirr@upc.edu.cn; Tel.: +86-0532-8698-1324

Received: 23 October 2017; Accepted: 16 November 2017; Published: 18 November 2017

Abstract: Energy sustainability is of vital importance to regional sustainability, because energy sustainability is closely related to both regional economic growth and social stability. The existing energy sustainability evaluation methods lack a unified system to determine the relevant influencing factors, are relatively weak in quantitative analysis, and do not fully describe the 'paradoxical' characteristics of energy sustainability. To solve those problems and to reasonably and objectively evaluate energy sustainability, we propose an energy sustainability evaluation model based on the matter-element extension method. We first select energy sustainability evaluation indexes based on previous research and experience. Then, a variation coefficient method is used to determine the weights of these indexes. Finally, the study establishes the classical domain, joint domain, and the matter-element relationship to evaluate energy sustainability through matter-element extension. Data from Shandong Province is used as a case study to evaluate the region's energy sustainability. The case study shows that the proposed energy sustainability evaluation model, based on the matter-element extension method, can effectively evaluate regional energy sustainability.

Keywords: matter-element extension; energy sustainability; variation coefficient; model

1. Introduction

Energy is the lifeblood of economic development and the pillar of social development for a region. It is indispensable for people's daily life. In this sense, energy sustainability is of vital significance in shaping a region's destiny. Energy sustainability can be described on different scales, and different regions have specific particularities based on energy use over time and different energy sources [1–11]. Based on previous studies, Lynne Chester developed the concept of "energy sustainability" [1]. Christian Winzer defined energy sustainability as the continuity of energy supply relative to energy demand [2]. Kruyt et al. proposed four major elements of energy sustainability: energy usability of an economic entity, energy availability, economic cost of supply sustainability, and environmental sustainability [3]. Maull defined energy sustainability as embodying the eco-environmental sustainability of energy and the economic sustainability of energy. Eco-environmental sustainability involves sustainable development and represents the higher goal of energy sustainability [4]. Douglas R. Bohi et al. proposed that energy sustainability can be improved by introducing energy consumption reduction policies [5]. Benjamin K. Sovacool et al. conducted an analysis that concluded that energy sustainability consists of usability, affordability, efficiency, and environmental management [6]. Energy sustainability mainly centers on the threat posed by a sudden interruption in supply, so efficient investment portfolios can lower power generation cost, bring in more renewable energy sources, and improve energy sustainability [7]. Anil Markandya et al.

proposed that tax policies can be used when there is a threat to energy sustainability, which highlights the importance of the energy tax [8]. Larry Hughes proposed the concept of "4Rs"including review, reduce, replace, and restrict. All have a bearing on energy sustainability [9]. Purchasing energy from abroad does not translate to a guaranteed energy supply to China. Furthermore, the effect of guaranteeing cross-border pipeline transport is not very clearly defined [10,11].

Shandong Province is a major energy consumer in China; in 2015, the energy consumption of Shandong Province accounted for 8.55% of the total energy consumption of the country (data derived from Shandong Statistical Yearbook [12]). Shandong also faces problems with energy sustainability. Currently, its total energy consumption, dominated by coal consumption, continues to rise and its clean coal technologies need further improvement. There are also problems with the energy system, including a natural monopoly and imperfect market competition. The energy industry needs to be further transformed and upgraded.

These factors all influence regional energy sustainability. As such, scientifically evaluating the status of energy sustainability directs attention to that topic, and promotes regional sustainable development. At its heart, the sustainability of any activity refers to the balancing of social, environmental, and economic aspects and impacts. Therefore, these three aspects can inform energy sustainability. To support this work, this paper applies the matter-element extension method to establish an energy sustainability evaluation model; the corresponding indicators are selected from three domains: social, environmental, and economic. The study calculates the appropriate balance of the three aspects (that is, a multi-index correlation), and then evaluates the status of energy sustainability in Shandong Province. In addition, this model provides reference value for other regions and countries facing the same energy-related challenges.

2. Literature Review

When evaluating and studying the status of energy sustainability, some scholars have applied the perspectives of energy use efficiency, energy consumption, energy demand forecast, and others [11,13–19]. Blyth and Lefevre adopted the Herfindahl-Hirschman Index (HHI) to investigate the energy sustainability of energy suppliers [13]. Cail Cohen proposed an energy sustainability strategy, that is, energy diversification [14]. Mamdouh posited that the energy sustainability guarantee of America in the 21st century cannot be realized by focusing on energy alone, and that four measures should be introduced: development of blended fuels, improvement of energy efficiency, supervision and management of petroleum import dependence, and diversification of energy import sources [15]. Jansen et al. applied the property stack method to design a long-term energy sustainability index based on the Shannon-Wiener Index (SWI) [16]. Willrich proposed that the exporting country seeks investment and market sustainability, while the importing country seeks adequate energy supply to maintain the steady growth of the national economy. Energy sustainability results from direct interactions between the exporting country and the importing country [17]. Jonathan E. Sinton et al. analyzed the relationship between total energy consumption and energy use efficiency, and the relationship between economic development and industrial structure and other factors in China. As a result, they argued that energy consumption can be reduced by improving energy use efficiency and optimizing industrial structure [19].

The energy index system for sustainable development established by the International Atomic Energy Agency (IAEA) selected 41 evaluation indexes from energy-related fields, including gross domestic product (GDP), population, land, waste, and environment. These indexes provide references for member states in evaluating their environmental, economic, energy, and social policies [20]. Domestically, scholars establish related evaluation index systems mainly by analyzing different grades of factors influencing energy sustainability. These researchers then introduce different analytical methods to evaluate the status of energy sustainability. For example, Liu et al. adopted factor analysis, scenario analysis, and an ArcGIS spatial analysis technique to construct an energy sustainability evaluation model for China. They probed the spatial–temporal evolution characteristics of energy sustainability in China from two aspects: energy supply stability and energy use sustainability [11,21]. Hu et al. constructed three aspects and nine indexes to evaluate China's status of energy sustainability based on the pressure-state-response (PSR) model. They suggested that the country's energy sustainability can be enhanced in the future in four ways: strengthening energy exploitation and development, improving energy use efficiency, optimizing energy structure, and constructing diversified energy supply channels [22]. Many other scholars have completed related studies [23,24].

As mentioned above, there are many unresolved issues in evaluating energy sustainability. Those unsolved questions include the following. First, many scholars start from their own perspectives to determine relevant influencing factors, resulting in the absence of a unified system to evaluate the status of energy sustainability. Second, quantitative studies are relatively weak, and need improvements in spatial scale, evaluation, and other aspects. Third, a subjective weighting approach is used to assign weights to influencing factors, resulting in a lack of objectivity. Fourth, there is no clear understanding of the 'paradoxical' characteristics of energy sustainability, making it impossible to reflect the essence of dynamic change and development. Finally, studies have not reached a consensus on the criteria used for quantitative studies on energy sustainability.

Based on this literature review, this paper constructs and defines related evaluation indexes based on experience and previous studies. The study then uses the variation coefficient method to assign weights, and uses the matter-element extension model to analyze data about Shandong Province and evaluate its energy sustainability status. This method can correctly evaluate the status of energy sustainability, and achieve more objective results by eliminating the influence of human factors as much as possible. The approach also provides a new way to evaluate energy sustainability.

3. Materials and Methods

3.1. Energy Sustainability Evaluation Index System

This paper uses the energy sustainability evaluation index system established by Chen et al. with the Driving Force, Pressure, State, Impact, Response (DPSIR) model, which comprehensively analyzes and describes environmental problems and their relationships with social development. As a general framework derived from sociological studies and used to organize environmental status information, the DPSIR provides a system-level structure for index organization to support studies on environmental and sustainable development. The model applies the perspective of systematic analysis to assess interactions between mankind and environmental systems [11,25].

To establish an evaluation system, this paper selects some indexes from the indexes of DPSIR, including natural population growth rate, economic growth rate, energy consumption per capita, and others, listed in Table 1. The natural population growth rate is defined as the ratio of the natural population increase (results from deducting the number of deaths from the number of births) in a set period (usually a year) to the average population (or mid-term population) of this period, expressed in the form of permillage. The GDP growth rate represents the economic growth rate. Energy consumption per capita is expressed by each person's average annual energy consumption. The energy consumption elasticity coefficient reflects the proportional relationship between the growth rate of energy consumption and that of the national economy. Both energy consumption per unit of GDP and energy consumption per 10,000 RMB industrial growth value can be used to reflect the relationship between economic growth and energy consumption.

3.2. Weight Determination by the Variation Coefficient Method

The objective weighting method is an effective way to reduce the intervention of human factors. It extracts valuable information by analyzing original data. Usually, the weights of each index in this method are determined using mathematical calculations [26,27]. Therefore, it can reflect the importance of indexes' authenticity better in the comprehensive evaluation [28]. As an objective weighting approach, the variation coefficient method calculates index weights based on index data, and reflects objective information about changes in that index data [29]. This paper uses the index data on Shandong Province during 2011–2014, derived from the Shandong Statistical Yearbook [12]. Table 1 provides the detailed data.

Process of weight determination:

Normalize original data to eliminate dimensional influence;

For "the smaller, the more optimal"-type indexes

$$x'_{ij} = \frac{\max_i [x_{ij}] - x_{ij}}{\max_i [x_{ij}] - \min_i [x_{ij}]} \quad (1)$$

For "the greater, the more optimal"-type indexes

$$x'_{ij} = \frac{x_{ij} - \min_i [x_{ij}]}{\max_i [x_{ij}] - \min_i [x_{ij}]} \quad (2)$$

In these expressions, x'_{ij} represents the data on the *j*th index in the *i*th year after processing; x_{ij} represents the measured data before processing. Table 2 presents the processed data.

Solve the mean $\overline{c_j}$ and standard deviation s_j of each index

$$\overline{c_j} = \frac{1}{n} \sum_{i=1}^{n} c_{ij} \quad (3)$$

$$s_j = \sqrt{\frac{\sum_{i=1}^{n} \left(c_{ij} - \overline{c_j}\right)^2}{n-1}} \quad (4)$$

Calculate the variation coefficient v_j of each index

$$v_j = \frac{s_j}{\overline{c_j}} \quad (5)$$

Determine the weight w_j of each index

$$w_j = \frac{v_j}{\sum_{i=1}^{n} v_j} \quad (6)$$

3.3. *Matter-Element Extension Model*

In the 1980s, the Chinese scholar Cai proposed the matter-element extension method, and used a formalized model to study and analyze the possibility and law of matter extension. This approach mainly solves incompatible complex issues, and is also suitable for the evaluation of multi-factor issues [18,30]. Since it was proposed, the matter-element extension model has been applied in many ways. Zhou et al. used the matter-element extension model to evaluate pension services for urban communities [31]. Zhao B et al. analyzed a multi-grade evaluation system and rock slope stability based on extension methods and system engineering theories [32]. Based on the extension-based theoretical analysis on matter-element models, Jia et al. proposed an extension portioning method for the vulnerable ground depression areas of Dezhou on the North China Plain [33]. Energy sustainability evaluations are a complex process; therefore, we use the matter element extension method to analyze it. This allows the full use of the matter element extension method and results in more scientific and reasonable evaluation results.

3.3.1. Determination of Classical Domain, Joint Domain, and the Matter-Element to Be Evaluated

(i) Determination of classical domain

$$R_j = (N_j, C_i, V_j{}') = \begin{bmatrix} N_j & C_1 & V_{1j} \\ & \vdots & \vdots \\ & C_n & V_{nj} \end{bmatrix} = \begin{bmatrix} N_j & C_1 & (a_{1j}, b_{1j}) \\ & \vdots & \vdots \\ & C_n & (a_{nj}, b_{nj}) \end{bmatrix} \tag{7}$$

In this expression, N_j represents the j energy sustainability grades (For example, N_1 represents the level I); C_i represents the characteristic of each sustainability grade (For example, C_1 represents the Natural population growth rate); $V_j{}'$ represents the quantitative range determined by N_j regarding C_i; and (a_{ij}, b_{ij}) represents the classical domain.

(ii) Determination of joint domain

$$R_p = (P, C, V_p) = \begin{bmatrix} P & C_1 & V_{p1} \\ & \vdots & \vdots \\ & C_n & V_{pn} \end{bmatrix} = \begin{bmatrix} P & C_1 & (a_{p1}, b_{p1}) \\ & \vdots & \vdots \\ & C_n & (a_{pn}, b_{pn}) \end{bmatrix} \tag{8}$$

In this expression, P represents the entirety of energy sustainability grades; V_p represents the extended quantitative range of characteristic C_i; (The range is from the minimum value to the maximum value); and (a_{pi}, b_{pi}) represents the joint domain.

(iii) Determination of the matter-element to be evaluated

$$R_0 = (N_0, C, V) = \begin{bmatrix} N_0 & C_1 & V_1 \\ & \vdots & \vdots \\ & C_n & V_n \end{bmatrix} \tag{9}$$

In this expression, R_0 represents the matter-element to be evaluated; C_i represents the characteristics of the matter-element to be evaluated; and V_i represents the measured data on C_i.

3.3.2. Determination of the Critical Values of Joint Domain Matter-Element and Classical Domain Matter-Element

Based on the literature [34] and indexes selected for this paper, the method of determining the classical domain in literature [35] was used to determine the critical value in combination with actual conditions, as shown in Table 3. In Table 3, N_i represents the grading of energy sustainability degree; N_1 represents grade I (extremely secure); N_2 represents grade II (secure); N_3 represents grade III (critical sustainability); N_4 represents grade IV (insecure); N_5 represents grade V (extremely insecure); and N_p represents the range of the joint domain.

3.3.3. Data Correlation Calculation and Grade Judgment

$$\rho(v_i, V_j{}') = \left| v_i - \frac{1}{2}(a_{ij} + b_{ij}) \right| - \frac{1}{2}(b_{ij} - a_{ij}) \tag{10}$$

$$\rho(v_i, V_{pi}) = \left| v_i - \tfrac{1}{2}(a_{pi} + b_{pi}) \right| - \tfrac{1}{2}(b_{pi} - a_{pi}) \\ i \in \{1,2,3,4,5,6\},\ j \in \{1,2,3,4,5\}; \tag{11}$$

Formulas (10) and (11) represent the distance between point v_i and interval V_j, and the distance between point v_i and interval V_{pi}, respectively.

Based on the given distance formulas, the single index correlation function $K_j(v_i)$ is used to calculate the matter-element to be evaluated, N_0, and to evaluate the single index correlation of grade N_j

$$K_j(V_i) = \begin{cases} -\frac{\rho(v_i, V_j')}{|V_j'|}, & v_i \in V_j' \\ \frac{\rho(v_i, V_j')}{\rho(v_i, V_{pi}) - \rho(v_i, V_j')}, & v_i \notin V_j' \end{cases} \quad (12)$$

When $K_m(v_i) = \max K_j(v_i)$, the index v_i in the matter-element to be evaluated, N_0, belongs to the evaluation grade of N_m.

After obtaining the matter-element to be evaluated and the single index correlation of each evaluation grade, Formula (13) is used to calculate the matter-element to be evaluated: $K_j(V)$, i.e., using a multi-index correlation.

$$K_j(V) = \sum_i W_i K_j(v_i) \quad (13)$$

After obtaining a multi-index correlation of the matter-element to be evaluated, we arranged the specific values by size. The level of the maximum value represents the evaluation results for Shandong province energy sustainability.

4. Results

4.1. Application Example

Based on the selected evaluation indexes, this paper collects relevant data, and establishes the index system shown in Table 1.

Table 1. Index system and data.

Index	C_1	C_2	C_3	C_4	C_5	C_6
2011	5.40	10.9	0.1994	0.62	0.86	1.26
2012	4.95	9.8	0.2106	0.48	0.82	1.16
2013	5.01	9.6	0.2255	0.50	0.78	1.07
2014	7.39	8.7	0.2342	0.38	0.74	0.99
2015 (evaluating year)	5.88	8.0	0.2424	0.50	0.71	0.91

Notes: C_1-Population growth rate (‰); C_2-Economic growth rate (%); C_3-Per capita energy consumption (ton coal equivalent/people); C_4-Energy consumption elasticity; C_5-Energy intensity (tone coal equivalent/ten-thousand yuan); C_6-Energy consumption per unit of added value (tone coal equivalent/ten-thousand yuan); Data sources: Shandong Statistical Yearbook [12].

The variation coefficient method is used to determine the weights of indexes, shown in Table 2.

Table 2. Non-dimensionalized data and weights.

Index	C_1	C_2	C_3	C_4	C_5	C_6
2011	0.8156	1	1	0	0	0
2012	1	0.5	0.6782	0.5833	0.3333	0.3704
2013	0.9754	0.4091	0.25	0.50	0.6667	0.7037
2014	0	0	0	1	1	1
weights	$W_1 = 0.1370$	$W_2 = 0.1742$	$W_3 = 0.1867$	$W_4 = 0.1595$	$W_5 = 0.1742$	$W_6 = 0.1682$

Based on the method of determining the classical domain described above, the critical value is determined based on actual conditions, shown in Table 3.

For Step 4, based on data for 2015 in Shandong Province, the matter-element model established above was used to calculate the correl[ation between sample data and different evaluation grades. This allowed the determination of evaluation results.

Table 3. Critical values of joint domain matter-element and classical domain matter-element.

	N_1	N_2	N_3	N_4	N_5	N_p
C_1	(0, 5.064)	(5.064, 5.79)	(5.79, 6.516)	(6.516, 7.242)	(7.242, 7.968)	(0, 7.968)
C_2	(10.9, 10.239)	(10.239, 9.4095)	(9.4095, 8.58)	(8.58, 7.7505)	(7.7505, 6.921)	(6.921, 10.9)
C_3	(0, 0.2091)	(0.2091, 0.2224)	(0.2224, 0.2357)	(0.2357, 0.2491)	(0.2491, 0.2624)	(0, 0.2624)
C_4	(0, 0.424)	(0.424, 0.496)	(0.496, 0.568)	(0.568, 0.64)	(0.64, 0.712)	(0, 0.712)
C_5	(0, 0.738)	(0.738, 0.783)	(0.783, 0.828)	(0.828, 0.873)	(0.873, 0.918)	(0, 0.918)
C_6	(0, 0.974)	(0.974, 1.08)	(1.08, 1.186)	(1.186, 1.292)	(1.292, 1.398)	(0, 1.398)

Notes: N_1, N_2 … N_p indicates the grade; C_1, C_2 … C_6 indicate the index.

4.2. Evaluation Process

Step 1 Establish classical domain

$$R_1 = (N_1, C_i, V_1{}') = \begin{bmatrix} N_1 & C_1 & (0, 5.064) \\ & C_2 & (10.9, 10.239) \\ & C_3 & (0, 0.2091) \\ & C_4 & (0, 0.424) \\ & C_5 & (0, 0.738) \\ & C_6 & (0, 0.974) \end{bmatrix}$$

R_2, R_3, R_4, and R_5 can be obtained using the same approach.

Step 2 Establish joint domain

$$R_p = (P, C, V_p) = \begin{bmatrix} N_p & C_1 & (0, 7.968) \\ & C_2 & (6.921, 10.9) \\ & C_3 & (0, 0.2624) \\ & C_4 & (0, 0.712) \\ & C_5 & (0, 0.918) \\ & C_6 & (0, 1.398) \end{bmatrix}$$

Step 3 Establish the matter-element to be evaluated

$$R_0 = (N_0, C, V) = \begin{bmatrix} N_0 & C_1 & 5.88 \\ & C_2 & 8.0 \\ & C_3 & 0.2424 \\ & C_4 & 0.5 \\ & C_5 & 0.71 \\ & C_6 & 0.91 \end{bmatrix}$$

Step 4 Calculate the correlation and evaluation results

Table 4 provides the results of the correlation analysis and evaluation.

Table 4. Correlation and evaluation results.

Index	$K_1(V_i)$	$K_2(V_i)$	$K_3(V_i)$	$K_4(V_i)$	$K_5(V_i)$	Evaluation Results
C_1	−0.2810	−0.0413	0.1240	−0.2335	−0.3948	III
C_2	−0.7288	−0.6748	−0.5664	−0.6992	−0.5000	V
C_3	−0.6251	−0.5001	−0.2501	0.4997	−0.2499	IV
C_4	−0.2639	−0.0185	0.0556	−0.2429	−0.3977	III
C_5	0.2818	−0.1186	−0.2598	−0.3620	−0.4394	I
C_6	0.0657	−0.1159	−0.2584	−0.3613	−0.4391	I
$K_j(V)$	−0.2641	−0.2597	−0.2082	−0.2231	−0.4017	III

4.3. Analysis on Evaluation Results

Table 4 provides the single index correlations of different indexes: C_1 and C_4 have a sustainability grade of III; C_5, and C_6 have a sustainability grade of I; C_3 has a sustainability grade of IV; and C_2 has a sustainability grade of V. Of the six indexes, two have a critical sustainability grade; two have an extremely secure grade; one has an insecure grade; and one has a significantly insecure grade. By calculating the comprehensive correlation using Formula (13), we generate: max $K_j(V) = -0.2082$ and $K_4(V) = -0.2231$. This outcome indicates that Shandong Province had a critical sustainability grade in 2015; since then, it has shifted towards unsustainability. This is consistent with actual conditions, embodies the status of energy sustainability faced by Shandong Province, and provides a valuable reference for other regions.

5. Conclusions

The energy sustainability evaluation model established in this paper resulted from combining the variation coefficient method for weight assignment and the matter-element extension method. This approach provides a new perspective to quantitatively evaluate the status of energy sustainability, and has significant benefits. First, adopting the variation coefficient method for weight assignment achieves more scientific and reasonable index weights, and reduces the influence of subjective factors. Second, based on an established energy security index system [34], this paper satisfactorily embodies the relationship between energy sustainability and socio-economic development, and strengthens the comprehensive analysis and evaluation of the status of energy sustainability. Finally, applying the matter-element extension method reflects the characteristics associated with the dynamic development of energy sustainability, and shows the 'paradoxical' characteristics inherent in that sustainability.

Acknowledgments: Thanks for the reviewers' valuable advice and approval. The current work is supported by "the Fundamental Research Funds for the Central Universities" (27R1706019B) and the Recruitment Talent Fund of China University of Petroleum (East China) (05Y16060020). We have received the grants in support of our research work. We have received funds for covering the costs to publish in open access.

Author Contributions: Siqi Li performed the experiments, analyzed the data, and contributed reagents/materials/analysis tools, and selected the data, Rongrong Li conceived and designed the experiments and wrote the paper; All authors read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Chester, L. Conceptualising energy security and making explicit its polysemic nature. *Energy Policy* **2010**, *38*, 887–895. [CrossRef]
2. Winzer, C. Conceptualizing energy security. *Energy Policy* **2012**, *46*, 36–48. [CrossRef]
3. Kruyt, B.; Vuuren, D.P.V.; Vries, H.J.M.D.; Groenenberg, H. Indicators for energy security. *Energy Policy* **2009**, *37*, 2166–2181. [CrossRef]
4. Maull, H. *Raw Materials, Energy and Western Security*; Palgrave Macmillan: Basingstoke, UK, 1984.
5. Bohi, D.R.; Toman, M.A. *The Economics of Energy Security*; Springer: Amsterdam, The Netherlands, 1996; pp. 425–452.
6. Sovacool, B.K.; Brown, M.A. Competing Dimensions of Energy Security: An International Perspective. *Annu. Rev. Environ. Resour.* **2009**, *35*, 77–108. [CrossRef]
7. Awerbuch, S. Portfolio-Based Electricity Generation Planning: Policy Implications For Renewables And Energy Security. *Mitig. Adapt. Strateg. Glob. Chang.* **2006**, *11*, 693–710. [CrossRef]
8. Markandya, A.; Pemberton, M. Energy security, energy modelling and uncertainty. *Energy Policy* **2010**, *38*, 1609–1613. [CrossRef]
9. Hughes, L. The four 'R's of energy security. *Energy Policy* **2009**, *37*, 2459–2461. [CrossRef]
10. Leung, G.C.K. China's energy security: Perception and reality. *Energy Policy* **2011**, *39*, 1330–1337. [CrossRef]

11. Wang, Q.; Chen, X. China's electricity market-oriented reform: From an absolute to a relative monopoly. *Energy Policy* **2012**, *51*, 143–148. [CrossRef]
12. Shandong, S.B.O. *Statistical Yearbook of Shandong*; China Statistics Press: Beijing, China, 2016.
13. Lefevremarton, N.; Blyth, W. Energy Security and Climate Change Policy Interactions—An Assessment Framework. *Oil Gas Energy Law J.* **2005**, *3*, 17–46.
14. Cohen, G.; Joutz, F.; Loungani, P. Measuring energy security: Trends in the diversification of oil and natural gas supplies. *Energy Policy* **2011**, *39*, 4860–4869. [CrossRef]
15. Salameh, M.G. The new frontiers for the United States energy security in the 21st century. *Appl. Energy* **2003**, *76*, 135–144. [CrossRef]
16. Jansen, J.C. *Desinging Indicators of Long-Term Energy Supply Security*; Energy research Centre of The Netherlands: LE Petten, The Netherlands, 2004.
17. Willrich, M. *Energy and World Politics*; Simon and Schuster: New York, NY, USA, 1975.
18. Wang, Q.; Chen, X. Energy policies for managing China's carbon emission. *Renew. Sustain. Energy Rev.* **2015**, *50*, 470–479. [CrossRef]
19. Sinton, J.E.; Fridley, D.G. 'What Goes Up: Recent Trends in China's Energy Consumption'. *Energy Policy* **2000**, *28*, 671–687. [CrossRef]
20. Iaea, V.E.; Iea, P.E. Energy indicators for sustainable development: Guidelines and methodologies. *Science* **2005**, *195*, 968.
21. Liu, L.; Lei, S.; Gao, T.; Liu, X. Evaluation and Spatial-temporal Evolution of Energy Security in China. *Acta Geogr. Sin.* **2012**, *67*, 1634–1644.
22. Hu, J.; Wu, H.; Hu, X. Construction of energy security evaluation index system based on PSR model in China. *Stat. Decis.* **2016**, *8*, 62–64.
23. Wang, Q.; Li, R. Decline in China's coal consumption: An evidence of peak coal or a temporary blip? *Energy Policy* **2017**, *108*, 696–701. [CrossRef]
24. Wang, Q.; Jiang, X.-T.; Li, R. Comparative decoupling analysis of energy-related carbon emission from electric output of electricity sector in Shandong Province, China. *Energy* **2017**, *127*, 78–88. [CrossRef]
25. Kohsaka, R. Developing biodiversity indicators for cities: Applying the DPSIR model to Nagoya and integrating social and ecological aspects. *Ecol. Res.* **2010**, *25*, 925–936. [CrossRef]
26. Muriana, C.; Vizzini, G. Project risk management: A deterministic quantitative technique for assessment and mitigation. *Int. J. Proj. Manag.* **2017**, *35*, 320–340. [CrossRef]
27. Liu, D.; Liang, Z.; Zhao, W.; Liu, X.; Yi, Z. Application of TOPSIS objective weighting method in drought comprehensive evaluation. *Int. J. Hydroelectr. Energy* **2011**, *29*, 8–10.
28. Ma, H. Objective weighting method in comprehensive evaluation system. *CO-Operativecon. Sci.* **2009**, *17*, 50–51.
29. Zhao, H.; Ma, L.; Jia, Q. Grey relational analysis model based on coefficient of variation method and its application. *Heilongjiang Sci. Technol. Water Conserv.* **2007**, *35*, 26–27.
30. Ng, D.K.W.; Cai, W. Treating non-compatibility problem from matter element analysis to extenics. *ACM SIGICE Bull.* **1997**, *22*, 2–9. [CrossRef]
31. Zhou, Y.; Hao, L.; Liu, W. Extenics-based Study on Evaluation of Urban Community Home-care Service for the Elderly. *Proced. Comput. Sci.* **2016**, *91*, 576–580. [CrossRef]
32. Zhao, B.; Xu, W.Y.; Liang, G.L.; Meng, Y.D. Stability evaluation model for high rock slope based on element extension theory. *Bull. Eng. Geol. Environ.* **2015**, *74*, 301–314. [CrossRef]
33. Jia, C.; Xu, X.; Zhang, Y.; Han, J. Susceptibility area regionalization of land subsidence based on extenics theory. *Clust. Comput.* **2017**, *20*, 53–66. [CrossRef]
34. Chen, Z.; Lei, X. Energy security evaluation model based on entropy weight extension method in China. *Syst. Eng.* **2015**, *7*, 153–158.
35. Zhang, C.; Zhang, J.; Li, C.; Wang, S. Method for determining classical domain in extension pattern recognition algorithm. *J. Nav. Aeronaut. Eng. Inst.* **2015**, *1*, 87–90.