

## A Crossover Study Review of “Sustainability and Innovation”

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### Abstract

In order to discuss about main research issues and results in the field of sustainability and innovation, and by retrieving 2,663 journal articles with the theme of sustainability and innovation in Web of Science (WOS) database as the research object, the authors illustrate the growing importance and influence of this field through the analysis of several factors like paper's growth situation and academic field. Besides, it also established an exploratory clustering through multidimensional scaling analysis and cluster analysis of high frequency keywords which appear in these articles, and finally established three major research topics. The authors expect these research results can promote the more in-depth research for both the scholars and companies in the field of sustainability and innovation, and can also provide some enlightenment for the related policy making.

**Key words:** Document analysis; Subject analysis; Cluster analysis; Sustainability; Innovation

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### INTRODUCTION

With the quickening pace of world economic development, the enterprise continuously invest more

non-renewable resources in order to keep competitive advantage (Weng, Chen, & Chen, 2015). At the same time, a large number of sewage which caused environmental pollution problems are rising in the process of product production. In order to alleviate environmental degradation brought by the industrial development, sustainable development and green innovation has become the focus of discussion, which cause more and more concern about the government, enterprises and academia. Many scholars point out that enterprise acts as the main forms of social organization which worsening or improve the natural environment, hence the sustainability can be achieved only through green innovation of the enterprise (Nigel & Melville, 2010). As a consequence, when making business strategy, enterprises not only have to consider their economic goals, but also should take the sustainable development of the environment as an important factor into consideration. Therefore, we need to figure out the internal relation and interaction between the sustainability and innovation.

At present, through literature review, we found that most of scholars do a lot of research from different angles respectively in the field of sustainability and innovation. For example, figures like Hilke discussed that innovation could improve the environment and social performance; Ram et al pointed out the significance of enterprise sustainable strategy in their study; and Johanna clarified the sustainability-oriented innovation of SMEs (Hilke & Jacke, 2010; Ram, Prahalad, & Rangaswami, 2009) But few studies analyze the internal relation and interaction between sustainability and innovation from the global perspective, consequently what we lack were clear research outline and holistic cognition of the function mechanism between sustainable development and enterprise innovation.

Therefore, this article expects to establish a relatively clear research outline of the sustainability and

innovation through the document analysis and clustering, thus help us analysis problems like the impact of sustainable development on enterprise innovation and the significance of green innovation values et al more effectively. We also expect to help enterprises cognitive and seize the sustainable strategic opportunities to break the barrier of the green innovation, and hope to provide some enlightenment for the related policy making about sustainable development and enterprise innovation as well.

## 1. DATA AND DOCUMENT ANALYSIS

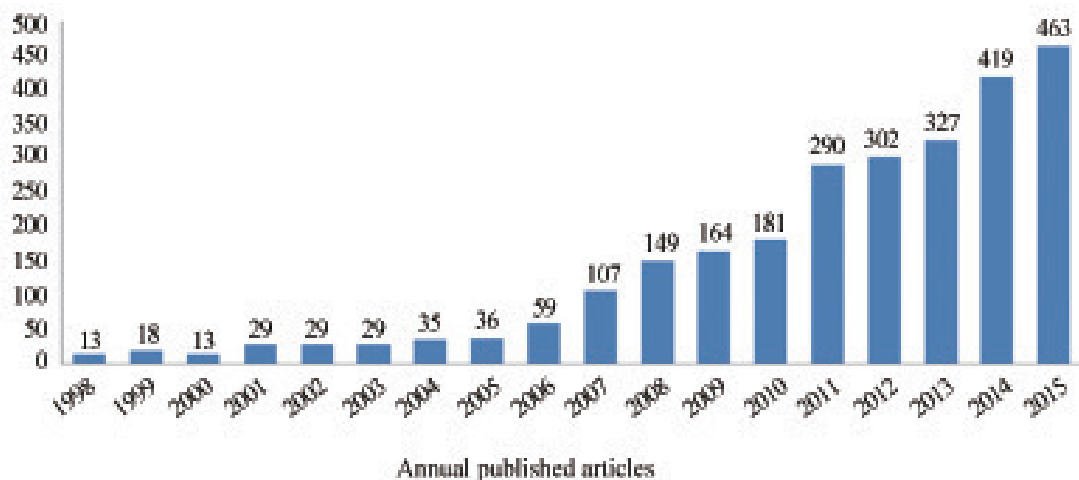
### 1.1 Data Sources

This research contains data regarding publication and citations from research papers on sustainability and innovation. The data sources consist of papers from 1998 to 2015 as indexed by the ISI Web of Science (WoS). The ISI WoS is one of the most reliable and widely accepted scientific databases offering citation data. Firstly, we collected papers that included both “sustain\*” and innovat\*” in their topic reference and either “sustain\*” or innovat\*” in their titles. The initial search produced 3,248

papers, but it also contained papers with little relevance to enterprise innovation. We reviewed the 3,248 papers by subject category and eliminated 585 papers which belong to the field of medicine or health et al. Then we got 2,663 papers which were suitable for our research. And all of the 2,663 papers included titles, keywords, abstracts, publication years, source journals, subject categories, and citation information.

### 1.2 Document Analysis

We began by showing trends based on the annual number of published papers in Figure 1. During the period of 1998-2015, it is clear that the annual number of publications kept ascending. The publications increased from 13 in 1998 to 463 in 2015. About 36 times by 17 years indicated that scholars pay more and more attention to the “sustainability and innovation”. We also found that the 2,662 papers were dominated mainly by two regions, namely, Europe and North America, and mostly distributed in developed countries such as USA (660 papers, 1<sup>st</sup>), England (313 papers, 2<sup>nd</sup>). This may show that the developed countries pay more attention to environmental protection and sustainable development than underdeveloped countries.



**Figure 1**  
**Annual Published Articles in 1998-2015**

As pointed out by Garfield (1979) there is no commonly available, fully satisfactory “measure of quality” of research, but citation rates do represent the impact of published research on the international community—an indication of the influence of individuals and groups. The citation rate of a paper may be measured as a partial gauge of its impact (rather than its quality or degree of importance) where impact is defined as “actual influence on surrounding research activity at a given time” (King, 1987). Therefore, we also examine the impact of the research of “sustainability and innovation” by doing

a citation count over a specified time period as shown in Table 1.

It can be seen from Table 1 that 2,663 papers were totally cited 27,414 times, each article was cited 10.29 times a year on average. In addition, both of the published and cited number of articles increased year by year, which proved that the research in the field of “sustainability and innovation” increasing its importance and influence in the international academic society. And all of these also revealed the necessity and value of our study.

**Table 1**  
Citation Number of the Articles About Sustainability and Innovation

Year blocks	Total number of publications	Total number of citations
1998-2000	13+18+13=44	0+11+49=60
2001-2003	29+29+29=87	84+111+139=334
2004-2006	35+36+59=130	229+242+302=773
2007-2009	107+149+164=420	496+771+1104=2371
2010-2012	181+290+302=773	1619+2258+3322=7199
2013-2015	327+429+463=1209	4377+5581+6719=16677
Total	2663	27414
Average	147.94	1523

**Table 2**  
The High Frequency Keywords of Abstract and 44 Research Variables

Frequently observed keywords	Research variables
Sustainability, innovation, sustainable development, environment, knowledge management, eco-innovation, climate change, renewable energy, governance, sustainable agriculture, technology, entrepreneurship, competitiveness,...	Sustain-, innov-, develop-, environ-, knowledg-, eco-, climat-, chang-, gover-, agricultur-, chin-, technolog-, entrepr-, competi-, high-, educat-, effici-, renew-, energ-, polic-, corpor-, soci-, responsi-, SMEs, manag-, advan-, parti-, implement-, learn-, assess-, collabor-, product-, econom-, inform-, life-, cycl-, green-, transi-, bio-, case-, stud-, perform-, countri-, system-

**2.2 Co-Occurrence Matrix of Keywords**

Through the study of the statistical analysis of word frequency of high frequency keywords, we can find the current research hot spot in a special area. But we can not find out the internal relation between them just through arranging their frequency, thus we adopt the method of co-occurrence analysis to further our analysis. The theoretical basis of keywords co-occurrence analysis generally believed that if two keywords frequently appear in the same paper at the same time, it often

**2. KEYWORDS ANALYSIS**

**2.1 Frequency of Keywords**

Based on the statistics of retrieved 2,663 articles, we got total 6,454 keywords. However, too many variables will cause randomized results of our clustering and multidimensional scaling analysis, which may lead to the unclear classification of the keywords. So we selected the high frequency keywords and eliminated the ones which were not subject keywords (paper, research, etc.) and finally screen out 44 keywords as our research variables. Part of the frequently observed keywords and the 44 research variables were shown in Table 2.

indicated that the connection between the two keywords is much close. Therefore, we establish the co-occurrence matrix of the variable keywords as our research base, and we chose to generate the dissimilarity matrix (Table 3) due to that the similarity matrix contains too much zero value, which will cause the increase of statistical error. As shown in Table 3, the higher numerical values indicate the worse similarity of the two keywords; Instead the smaller numerical means the better similarity of the two keywords.

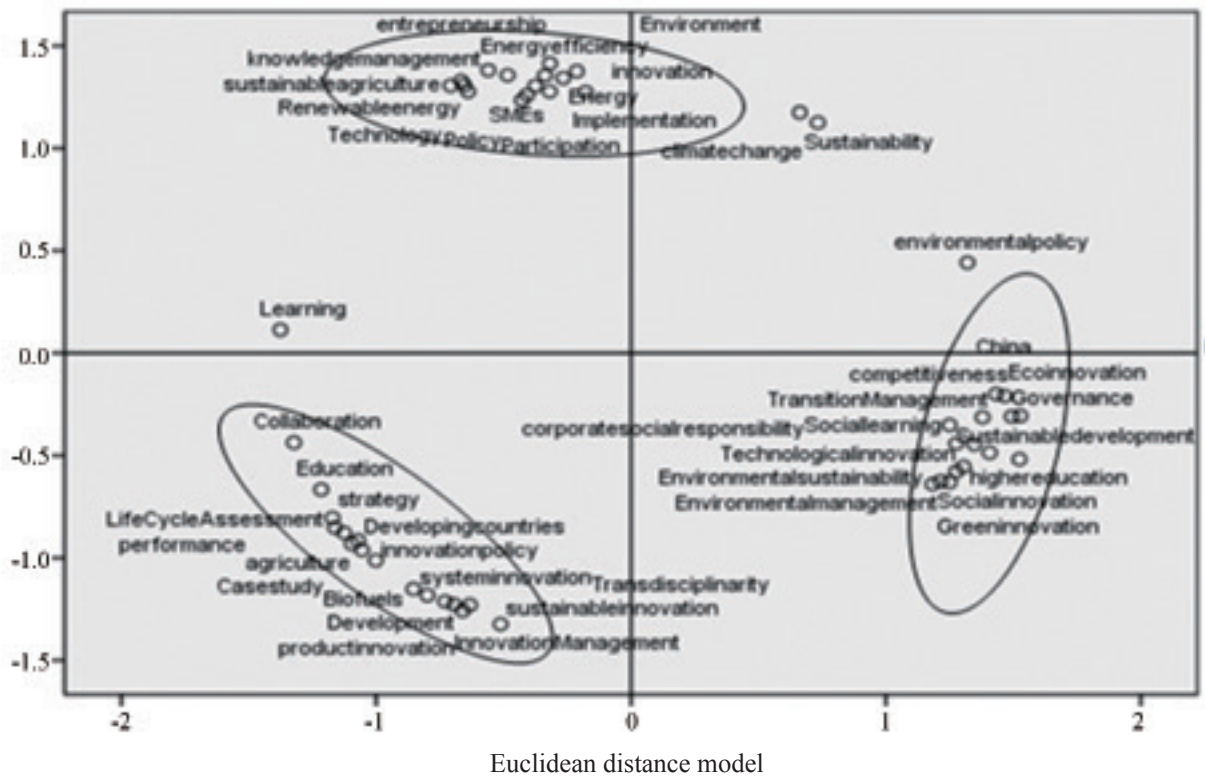
**Table 3**  
Co-Occurrence Matrix of the Variable Keywords (Dissimilarity Matrix)

	Sustainability	Innovation	Sustainable development	Environment	Knowledge management	...
Sustainability	0	0.9745	0.9989	0.9947	0.9992	...
Innovation	0.9745	0	0.9787	0.9946	0.9798	...
Sustainable development	0.9989	0.9787	0	0.9959	0.9986	...
Environment	0.9947	0.9946	0.9959	0	1	...
Knowledge management	0.9992	0.9798	0.9986	1	0	...
...	...	...	...	...	...	...

### 2.3 Clustering and Multidimensional Scaling Analysis

Clustering analysis is a kind of analysis method which based on some of characteristics of the target, and classified the research object according to the principle that birds of a feather flock together. It aims at achieving the goal that the similarity between the research objects in the same group is high, at the same time, the differences between objects in different groups is big. Due to the focus of this study was the semantic relationship between extracted keywords, so we choose the hierarchical clustering (system clustering) method which was relatively intuitive. We use SPSS 20.0 statistical analysis software, input the complete variable dissimilarity matrix, to cluster and form the corresponding dendrogram. Finally, with the screening of the representative clusters and subsequent multidimensional scaling analysis to correct our result, we established several research topics in the field of sustainability and innovation.

Multidimensional scaling analysis is the multivariate statistical analysis method which aims to analyze the similarities or differences between the research objects. It can reduce research individuals (samples or variables) which locate in multidimensional space to low dimensional space to locate, analysis, and classified, and also able to retain the original relationship between objects (Sandral, Rebecca, & Bennett, 1995). At the same time, because of all the position of the variables are made sure, the result is more image, more intuitive and easier understood than factor analysis and cluster analysis. Therefore, we still use SPSS 20.0 statistical software, Multidimensional Scale (ALSCAL) function, to finish the two dimensional scaling analysis. The multidimensional scaling analysis map we got was as shown in Figure 2, and the distance between the point which represents the 44 keywords reflected their similarity.



**Figure 2**  
**Multidimensional Scaling Analysis Map**

We returned the classified keywords to the literatures they frequently appeared, and then found out the two dimensions of the taxonomy: The abscissa was arranged by the government (macro) - enterprise (micro) dimension; and the y-coordinate was carried out from the antecedent (reason) - outcome (result) dimension. Therefore, according to the results of clustering and multidimensional scaling analysis,

combined with literature analysis, the research in the field of sustainability and innovation were likely to be summarized into three topics clusters: a) how could the requirements of sustainable development drive the green innovation of enterprises; b) the enterprises' innovation approach to achieve the goal of sustainable development; c) how could the government behaviors affect the green innovation behavior of the enterprises.

### 3. CLUSTERING RESULTS OF RESEARCH TOPICS

#### 3.1 Sustainability Drive the Green Innovation

Just as what we mentioned in the Introduction, enterprises have to implement the strategy of sustainability mostly because the government, society, market and even enterprise itself raise a claim about it. Therefore, through literature review, we summarized the internal and external factors of the requirements in green innovation.

The requirement of environmental sustainability. Most of traditional modes of economic growth are on the basis of huge resource consumption, which leads to resource shortage as well as environmental decay. And it would cause much obstacles to enterprise development in return. Thus, companies have to follow the ethic of the sustainable development, continually invest on environmental affairs and technology exploration. As Costantini said, enterprises should consciously involve in the construction of ecological environment, and capture new business opportunities in market prospect of green economy (Costantini & Mazzanti, 2012).

The requirement of the green market. Wong pointed out that many organizations, products and service innovation were restricted by market factors (Wong, 2013). On the one hand, consumers are gradually formed the green consumption view, which forced enterprises to integrate sustainable development into its production and operation activities. On the other hand, new trade barriers in international market (environmental standards) are increasingly replacing the original tariff barriers. For example, More than half of the foreign capital enterprise have obtained environmental certification. More and more foreign manufacturing enterprises such as Toyota, ford, etc. prefer to invest in Chinese manufacturers which have got the ISO14001 authentication (Zhu, Joseph, & Lai, 2007). Therefore, the establishment and development of green market forced China's enterprises to meet the environmental standards and processes so as to expand market share and assure their competitive advantage.

The requirement of enterprises development. According to the study of Hockerts, the ultimate goal of all enterprises was to obtain economic benefits, but environmental performance was also an integral component of the economic performance (Hockerts & Wustenhagen, 2010). So how to weigh the economic and environmental performance has become an important strategic choice for enterprises. Successful environmental protection measures help companies create new opportunities and be competitive, and also increase the value of its core businesses (Shultz & Holbrook, 1999; Chiarvesio, De, & Maria, 2015). In addition, companies are likely to establish a good image through fulfilling its social responsibility so that it may create new market

opportunities and realize the high integration of the supply chain.

#### 3.2 Innovation Approaches to Achieve Sustainability

Harper's research suggests that it will show that many sustainable innovations are directed at the improvement of technological processes and to lower costs of production (Harper & Becker, 2004). These innovations can be seen as incremental. So through literature review, we found that most scholars focus their research view of enterprise's innovation ability mainly on two aspects: management innovation and technology innovation.

Management innovation. The continuous development of science and technology makes the innovation activities of enterprise increasing its dependence on scientific management, traditional management means already can not effectively meet the development of high technology (Inoue, Arimura, & Nakano, 2013). For example, Amidon (1996) pointed out that if knowledge can't be used it will not be able to play value, scientists and engineers should cooperate interdisciplinary and cross-industry to speed up the application of new knowledge and new ideas. Armbruster pointed out that if an enterprise applied the goal of sustainable development to its organization management, established a flexible organization structure to real-time control its internal and external resources, it would realize the energy conservation and emissions reduction in the whole operating process so as to ensure the sustainable competitive advantage (Armbruster, Kimer, & Lay, 2006). Besides, Rinaldo suggested that the corporate culture is the source of enterprise innovation, the establishment of environmental sustainability concept and culture within the organization can not only help enterprises realize environmental benefits, but also can bring additional economic performance (Rinaldo & Vezzani, 2010).

Technology innovation. Technology innovation often means seize potential opportunities of the market, in order to get economic benefit, to produce new product with adopting new production process (Smith, Stirling, & Berkhour, 2005). It usually includes product innovation and process innovation. Product innovation was the core elements of technology innovation, it refers to the to redistribute and combination of various resources so as to develop a new product or improve the traditional products, and realize its successful application and popularization. Deborah thinks that the product innovation should be a concept of whole process, it refers to the whole process of new product from its research and development to production and sales (Deborah & Cynthia, 1996). Medeiros pointed out that enterprises should comprehensively control the raw materials, product features, manufacturing process, sales and recycling, etc. (Medeiros, Janine, & Duarte, 2014). They should ensure the utility, health, environmental protection,

and many other qualities of the product so as to grab more market share and promote the establishment of green market and green consumption ideas. In addition, Johanna believed that clean production should be rooted in process, and applied the sustainable strategy to the whole manufacturing process to improve the overall efficiency and reduce ecological damage (Johanna & Erik, 2014). In a word, product innovation can help enterprises seize market opportunities and exploit new market, and technology innovation helps to provide the better product at a lower cost and higher efficiency. Therefore, the ability of technology innovation is likely to be the fundamental way to achieve sustainable development (Aguado, Alvarez, & Domingo, 2013).

### 3.3 The Effect of Government Behaviors

Government is the manager of the ecological environment, it may be passively affected by enterprises' production operation and become stakeholders of enterprises' green innovation activities (Hoen, Tan, & Fransoo, 2014). Therefore, the government is likely to take some measures, like regulation and laws, to affect the implementation of green innovation activities directly or indirectly.

**Education and propaganda.** The foundation of achieving sustainable development is cultivating the environmental protection conception of social public, and only the government has the ability to propaganda and education the public that under decentralized state (Bergek & Berggren, 2014). The government establishes green ecological view and green consumption idea in the whole society by the means of publicity and education, which can promote the formation of green market so as to prompt enterprises to implement energy conservation and emissions reduction. The enterprises will also take some measures like green products innovation in order to reduce cost and maintain their competitive advantage.

**Policy regulation.** On the one hand, the government provides marginal incentive for enterprises through levying environment tax, forcing polluting enterprises to update the green technologies and take more effective pollution control measures in order to reduce the cost of pollution. On the other hand, through subsidies and preferential policies, the government not only encouraged companies to pay more attention to the resource utilization and recovery in the process of production, but also can stimulate them to increase the investment in environmental protection, which will promote the development of green technology and environmental protection of the whole industry (Ghisetti & Pontoni, 2015).

**Economic means.** The government usually influence the green innovation behavior of enterprises by two kinds of means, namely market means and non-market means. On the one hand, the government takes control of contamination gross and distribute it to enterprises by sell, lease, gift, etc.. The emissions trading has advantages

of minimizing the cost of pollution control and simplify operation, so it will encourage enterprises to choose the implementation of green innovation behavior (Ford, Steen, & Verreynne, 2014). On the other hand, the government forces companies to take the external costs as part of their economic decisions through credit, subsidies and other non-market means, so many enterprises will be more willing to make transformation towards environment friendly and technology innovation enterprises in order to control the cost of pollution.

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## CONCLUSION

The worsening global environment problem causes the sustainable development and green innovation getting more and more attention by academic circles and the whole society. All the enterprises need to realize the status and influence of sustainable strategy, and actively promote the green innovation ability according to corresponding environmental policy to gain competitive advantage. Therefore, this article expects to establish a crossover research outline of the sustainability and innovation so as to provide reference for the green transformation of enterprises, and hopes to promote the more in-depth research and provide some enlightenment for the related policy making.

This study firstly chooses 2,663 papers on sustainability and innovation, from 1998 to 2015, which indexed by the ISI WOS as our data sources. Then with the use of document analysis, keywords analysis, clustering and multidimensional scaling analysis, we finally established three topics clusters: a) how could the requirements of sustainability drive the green innovation of enterprises; b) the enterprises' innovation approach to achieve sustainability; c) the influence of government behaviors on the enterprises' green innovation behaviors.

However, there are still some deficiencies in this article. Firstly, we only selected the WOS database as the research data sources, which may lead to the partiality and lack of applicability. Besides, although keywords can reflect the core idea of articles, the keywords analysis was still of great subjective judgment, which may affect the objectivity of our research. So we are looking forward to some more comprehensive and in-depth research to enrich this area.

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