Research on Manufacturing Green Innovation Capability Based on Big Data Mining——Taking the New Energy Vehicle Companies as an Example

Feiran Guo¹, Qin Liu²*
Wuhan University of Technology, Wuhan, 430070, China
*Corresponding author: Qin Liu
¹444149282@qq.com, ²isunnygirl@qq.com

Abstract. In the early stages of China's economic development, the development mode characterized by "high pollution, high cost, and low efficiency" caused serious environmental pollution and resource shortages. The mode gradually restricted the healthy development of the industry. Accelerating economic system reform and promoting an update of green transformation about the industry are imminent. This research is based on text mining and sorting out of existing literature and news comments to construct an evaluation index for the green innovation capability of manufacturing companies. Through empirical research of new energy vehicle companies, this paper further analyzes the green innovation levels of typical domestic new energy vehicle companies. Empirical evidence shows that the level of green innovation of an enterprise is mainly determined by its ability to innovate green technology, and at the same time it is affected by the multiple effects of government policies, market environment, and consumer behavior. Finally, this article puts forward relevant suggestions for the development of the new energy vehicle industry from the government and enterprise levels.

1. Introduction
Innovation is the backbone of enterprise development, and green is the inevitable requirement for enterprises to adapt to the trend of the times. The development of green innovation is not only strategically oriented, but also means that the company implements green ideas and green behaviors into the entire process of product production, organization construction, and management marketing. Through the improvement of production technology and the innovation of management methods, the organizational production efficiency is improved, so the negative externalities to the environment is reduced. While saving production resources, companies achieve a balanced development of economic and ecological benefits.

As the basis of China's real economy, manufacturing industry is an important pusher to promote the transformation and upgrading of China's industry and realize the transformation of China's economy from large scale to strong technology. Under the multiple pressures of continuous strengthening of international and domestic environmental regulations, continuous improvement of the concept of green consumption, and more urgent improvements in the internal benefits of manufacturing companies, how to get out of the development cycle of "polluting first and then treating" and "environmental benefits for economic benefits" is the concern of every manufacturing enterprise with social responsibility and strategic vision. Being the first to achieve transformation means more market opportunities, larger market shares, and richer social resources. The company will have a stronger voice and competitiveness.
in future market competition [1]. Therefore, through the exploration of the important influencing factors of green innovation and the principle of action mechanism, it is worthwhile to build a scientific enterprise green innovation capability evaluation system.

Based on a review of previous literature on green innovation, we found that the number of high-level related researches has grown rapidly in recent years. As a multi-disciplinary and emerging field, scholars conduct detailed and in-depth researches through multiple perspectives such as environmental economics, innovation economics, and strategic management. In environmental economics, based on the "Porter Hypothesis", scholars have discussed the effects and mechanisms of different types of environmental regulations on corporate competitiveness, but have ignored factors such as internal factors of enterprises, pressures from social stakeholders, and environmental regulations[2]. In innovation economics, scholars pay more attention to the search for important influential factors in green innovation and identification of their trajectories. They often conduct empirical researches on one important factor, but lack comprehensive consideration of other factors[3]. As a complex concept with multiple dimensions and multiple connotations, green innovation needs comprehensive consideration about internal and external factors. In conclusion, this paper uses a combination of systematic thinking and multiple perspectives to explore a set of scientific evaluation indicators, and uses data from new energy automobile companies in the Chinese context to conduct an empirical research, making up for most of the empirical research in developed countries. The study has improved the existing research system of green innovation and has important theoretical and practical value.

2. Connotation and Measurement of Manufacturing Green Innovation

2.1. The connotation of manufacturing green innovation

So far, there are several ways in which academia defines green innovation. From the perspective of the object of action, green innovation is considered to be “hardware and software innovation related to green products or green processes, including technological innovation related to energy conservation, pollution prevention, pollution recovery, green product design, and corporate environmental management[4]. From the perspective of the target effect, green innovation includes the technical or non-technical content involved in the process of promoting resource conservation and ecological improvement, providing green consumer products while taking into account economic benefits, and achieving sustainable development of the enterprise.[5] From a broad definition, OCED believes that the content of green innovation is more extensive. "They are improvements in goods, services, processes, marketing methods, organizational structures, and institutional arrangements, whether intentionally or unintentionally, which leads to better Environmental improvement. " This research synthesizes the above-mentioned viewpoints, and believes that enterprises with green innovation will carry out technological transformation, management innovation and other activities driven by environmental regulations, pressure on stakeholder interests, technology and market factors, to improve their green performance.

2.2. Evaluation index of manufacturing green innovation capability

This paper draws on the DEA model in the regional green innovation efficiency measurement which divides the green innovation capability into two dimensions: input and output[6].

In terms of investment, this article adopts the highly recognized "R & D investment funds", "R & D personnel ratio" and "equipment transformation and upgrade costs" to represent financial, human and material resources. In terms of output, the paper uses the "number of invention patents authorized" to measure the results of the company's scientific research stage. The success rate of technological transformation is more reflected in the market sales of new products, so the "new product market share" is taken as the specific indicator of the stage of achievement transformation. At the stage of expected waste recovery and treatment, the paper takes the "total environmental protection investment" to evaluate the company's end-of-line treatment.
3. Empirical Evaluation of Green Innovation in Manufacturing Industry Based on Principal Component Analysis

3.1. Evaluation data description
This article evaluates the green innovation capabilities of large auto companies that are developing new energy vehicle businesses. There are three sources of data: (1) Company annual reports (2) Corporate Social Responsibility Reports (3) New Energy Automotive Industry Websites (4) China and Multinational Patent Examination Information Search System

3.2. Evaluation data calculation
After simple processing of the data, the paper uses SPSS 25.0 for PCA. The KMO in Table 2 is 0.626, and the p-value of the Bartlett test is 0. It is basically considered that the sample data meets the analysis requirements.

Table 2. KMO and Bartlett's Test.

| KMO and Bartlett's Test |       |
|-------------------------|-------|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy | 0.626 |
| Approx. Chi-Square       | 29.517|
| Bartlett's Test of Sphericity |      |
| Df                      | 15    |
| Sig.                    | 0.000 |

The common factor variances for each indicator are: R & D personnel ratio(0.53), R & D investment funds(0.935), Number of invention patents authorized(0.763), New product market share(0.914), Total environmental investment(0.845).

Table 3. Total Variance Explained.

| Component | Total Eigenvalue | % of Variance | Cumulative % | Extraction Sums of Squared Loadings | Total Eigenvalue | % of Variance | Cumulative % |
|-----------|------------------|---------------|--------------|-------------------------------------|------------------|---------------|--------------|
| 1         | 2.786            | 46.437        | 46.437       | 2.786                               | 46.437           | 46.437        |
| 2         | 2.146            | 35.771        | 82.208       | 2.146                               | 35.771           | 82.208        |
| 3         | 0.078            | 12.471        | 94.679       | 0.078                               | 12.471           | 94.679        |
| 4         | 0.081            | 3.024         | 97.704       | 0.081                               | 3.024            | 97.704        |
| 5         | 0.095            | 1.582         | 99.286       | 0.095                               | 1.582            | 99.286        |
| 6         | 0.043            | 0.714         | 100.000      | 0.043                               | 0.714            | 100.000       |

Extraction Method: Principal Component Analysis
According to Table 3, the cumulative contribution rate of the first two principal components reached 82.2%, reflecting most of the information of the original variables, so two principal components can be extracted: Z1, Z2.
Table 4 Component Matrix

| Component                                  | 1     | 2     |
|--------------------------------------------|-------|-------|
| R & D personnel ratio                      | -.106 | .310  |
| R & D investment funds                     | .337  | -.117 |
| Equipment transformation and upgrade costs | .269  | -.285 |
| Number of invention patents authorized    | .308  | .078  |
| New product market share                   | .228  | .333  |
| Total environmental investment             | .123  | .398  |

Extraction Method: Principal Component Analysis
a. 2 components extracted

According to Table 4, the calculation formula of the principal component score is:

\[ Z1 = -0.16X1 + 0.337X2 + 0.269X3 + 0.308X4 + 0.228X5 + 0.123X6 \]
\[ Z2 = 0.31X1 - 0.117X2 - 0.285X3 + 0.333X4 + 0.398X6 \]

So, the sample's green innovation capability scores in 2018 are shown in Table 5.

Table 5 Comprehensive score of green innovation for sample companies.

| Complex | Ranking |
|---------|---------|
| BAIC    | 0.856   | 3      |
| BAC     | -0.867  | 7      |
| SAIC    | 1.005   | 2      |
| FAW     | -1.104  | 8      |
| DFAC    | 0.142   | 4      |
| CCAG    | -0.201  | 6      |
| JAC     | 0.017   | 5      |
| JMC     | -1.288  | 9      |
| BYD     | 1.445   | 1      |

3.3. Analysis of evaluation results
Specifically, BYD's strong performance in the new energy vehicle industry in recent years not only benefits from long-term experience accumulation in core technologies but also is closely related to the spirit of innovation within the company. BYD has been committed to the research and development of key technologies such as batteries, electric control, and electrics, and has now formed a mature electric supply chain. In 2018, BYD's total investment in environmental protection reached 6.47 billion yuan. With its unique advantages, it applied green products such as energy storage power stations and electric forklifts to the entire production process, which greatly improved energy efficiency. Therefore, BYD ranks first in green innovation ability and is a leader in the new energy automobile industry.

Stimulated by the "dual-slope policy", large state-owned enterprises such as SAIC, BAIC, Dongfeng Group have also increased their R & D investment, with "four modernizations" as the main development direction in the future. Among them, SAIC-Volkswagen New Energy Plant was completed and used in November 2019, with a total investment of 17 billion yuan. It is currently the most intelligent and largest pure electric vehicle plant in China. In addition, the improvement of SAIC's green innovation capabilities also benefits from its precise layout in overseas markets. BAIC Group owns the only A-share listed new energy vehicle production company- Baic Bluepark New Energy Technology Co., Ltd. The separation of the new energy vehicle segment from the traditional vehicle segment has solved the problem of leaning manpower and R & D resources. An independent assessment system has also injected momentum into the development of BAIC new energy vehicles.

In the context of industrial transformation and upgrading, FAW Group's resources are still inclined to the traditional automotive sector, and sales of joint venture brand car are still the main contributor to operating income, which are important reasons why FAW's overall level of green innovation is not high.
4. Conclusion and suggestion

This article uses the principal component analysis method to extract the two main factors that affect the green innovation capability of the manufacturing industry, and conducts an empirical study in the field of new energy vehicles in the automotive manufacturing industry. Research shows that the improvement of green innovation capacity is basically determined by the improvement of the company's green innovation technology level, which is directly proportional to the company's R & D investment and new product market share. In addition, combining the actions and measures of automobile manufacturers in the new energy sector in recent years, this article finds that the development of international markets, the improvement of product supporting service systems, and the improvement of internal resource integration capabilities are also important ways for enterprises to improve their green innovation capabilities.

Based on the above research, this article proposes the following suggestions for the development of new energy vehicles:

1. At the government level, in terms of environmental regulations, the government should lean more towards “incentive” policies, from focusing solely on governance results to guiding companies to develop green technologies, upgrade equipment and green transformation, and eventually reduce corporate emissions from the source. For green industries such as new energy vehicles, the government must introduce related policies to stimulate the development of market entities while raising the threshold for subsidies, such as relaxing the industry access standards for new energy vehicles and encouraging more high-quality companies to enter and refine the industry.

2. At the corporate level, on the one hand, new energy automobile companies must accelerate their own research and development, on the other hand, they must also build an industry green innovation cooperation network based on their own technological advantages to share innovation risks and promote the overall innovation capacity of the new energy automobile industry. In addition, the improvement of infrastructure such as charging piles and the recycling of batteries also require the joint efforts of enterprises and governments.

Acknowledgment This work is supported by the National Social Science Foundation of China(No. 19BSH105)

References

[1] Emrah Karakaya, Antonio Hidalgo et al. 014 Renewable and Sustainable Energy Reviews 33
[2] Hongjun Cao, Zewen Chen 2017 Nankai Business Review 20 (06): 95-103
[3] Jing Zhang, Wei Zhou 2015 Science and Technology Management Research 35 (08): 232-237
[4] Chen Y S, Lai S B, Wen C T 2006 Journal of Business Ethics 67(4): 331-339
[5] Driessen PH, Hillebrand B 2013 Transcations on Engineering Management 60(2):315-326
[6] Sarkis, Joseph 2012 Eurpean Journal of Operational Research 219(2):386-395