Entropy model of dissipative structure on corporate social responsibility

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Abstract. Enterprise is prompted to fulfill the social responsibility requirement by the internal and external environment. In this complex system, some studies suggest that firms have an orderly or chaotic entropy exchange behavior. Based on the theory of dissipative structure, this paper constructs the entropy index system of corporate social responsibility (CSR) and explores the dissipative structure of CSR through Brusselator model criterion. Picking up listed companies of the equipment manufacturing, the research shows that CSR has positive incentive to negative entropy and promotes the stability of dissipative structure. In short, the dissipative structure of CSR has a positive impact on the interests of stakeholders and corporate social images.

1 Introduction
With the development of economy and technology, the survival environment of enterprises is becoming more and more complicated, and public is more concerned about corporate social responsibility. Whether CSR adapts to the external environment is critical to the development of the enterprise.

Dissipative structure is proposed by physicist Prigogine. According to this theory, the change of external conditions reaches a certain threshold, will cause the qualitative change from quantitative. Through the exchange of material, energy and information with the outside world, the system may change from the original disordered state to an ordered state. Zhu [1] applies the dissipative structure theory to the safe economic management system, and puts forward the development ideas of the leading safety economic management system from disorder to order. Song [2] studies the structural change of Chinese stock market based on dissipative structure, and obtains the characteristics of it from 2001 to 2015. CSR is the internal demand of open system and typical dissipative structure, and it is the path choice for enterprise and environment to continuously exchange. This paper uses the theory of dissipative structure to help us understand the confusion in CSR and suggest for enterprises to fulfill their social responsibilities in an orderly way. The introduction of dissipative structure theory provides a new way for CSR research.

2 Entropy and dissipative structure theory

2.1 Index system of corporate social responsibility entropy
As a complex system, the survival of enterprises is closely related to the external environment, in addition to the internal conditions. To judge the social responsibility of an enterprise, we need to measure it from both inside and outside. Internal environment is divided into stakeholders, corporate governance structure. Stakeholders include stockholders, creditors, employees, consumers and suppliers, and companies fulfill their responsibilities to these stakeholders to better achieve their operational objectives. Corporate governance structure includes the nature of equity, whether the
chairman and general manager is one person, the proportion of independent directors and executive shareholding ratio. Corporate governance structure and CSR have certain relevance. Good structure can promote the company to better fulfill its responsibilities. The external environment contains social expenditure and technological innovation. Social expenses include taxes on government payments, external donations and disclosure of environmental data. Technology innovation can better communicate with the external environment, prevent from behind closed doors, which consists of inputs on human resources and investments. The index system of CSR entropy is shown in table 1.

**Table 1: Index System of Corporate Social Responsibility Entropy**

| Variable                  | Measurement                                                                 |
|---------------------------|-----------------------------------------------------------------------------|
| **Stakeholders**          |                                                                             |
| Stockholder               | Basic EPS                                                                  |
| Creditor                  | Asset-liability ratio                                                      |
| Employee                  | Payment to employees and cash paid for employees/main business income       |
| Consumer                  | Main business cost/main business income                                     |
| Supplier                  | Cash paid for the purchase or services/main business income                 |
| **Governance Structure**  |                                                                             |
| The nature of equity      | State-owned enterprises for the 2, non-state-owned enterprises for the 1     |
| Whether the chairman or   | Yes for 2, no for 1                                                         |
| general manager is        |                                                                             |
| individual                |                                                                             |
| The proportion of         | Number of independent directors/board scale                                |
| independent directors     |                                                                             |
| Executive shareholding    | Total number of executives Holdings/total number of shares of the company   |
| ratio                     |                                                                             |
| **Social expenditure**    |                                                                             |
| Government                | (Payment of taxes and fees- refunds received)/ main business income         |
| Community                 | Donations/main business income                                             |
| Environment               | Whether the environment and sustainable development are disclosed, yes for 2, no for 1 |
| **Technological innovation** |                                                            |
| Personnel                 | Researchers/the total number of companies                                   |
| Funding                   | R&D expenses/total assets                                                  |

2.2 The principle of entropy method and Brusselator model

Entropy has been widely used in various fields such as natural science, social science and anthropology [3]. Entropy in physics is the measurement of molecular movement disorder degree, in the social sciences on behalf of a certain degree of human society. Zhao [4] uses the entropy to determine the optimal combination weight of the network. Positive entropy is the reason for the instability of enterprise development. Negative entropy can effectively suppress the negative influence of positive entropy. In the production practice of the enterprise, the positive entropy is generated spontaneously, but the negative entropy can only be generated by the contact with the outside world. With the continuous input of negative entropy, once the threshold is exceeded, it becomes a dissipative structure. Dissipative Structure enterprises can maintain a high degree of adaptability and achieve sustainable development. Prigogine divides the macro system into: isolated systems, closed systems and open systems. Only exchange material, energy and information with the outside world, can open systems have the opportunity to form the dissipative structure. The Brusselator model proposed by Prigogine provides important quantitative analysis methods and determinants of dissipative structures.
2.3 Entropy calculation of CSR
First of all, the statistical values of each index were eliminated to eliminate the influence of different units. Normalized matrix is

\[ R_{ij} = \frac{r_{ij} - \min_{i} r_{ij}}{\max_{i} r_{ij} - \min_{i} r_{ij}} \]

The proportion of each index in the positive entropy flow is:

\[ p_{Ai} = \frac{R_{Ai}}{\sum_{i=1}^{m} R_{Ai}} \quad (j = 1, 2, \ldots, 9) \]

The entropy of each evaluation index of positive entropy flow is:

\[ e_{Aj} = -\frac{1}{\ln(m)} \sum_{i=1}^{m} p_{Ai} \ln p_{Ai} \quad (j = 1, 2, \ldots, 9) \]

\( e_{Aj} \) meet \( 0 \leq e_{Aj} \leq 1 \), and the difference coefficient of each index is:

\[ g_{Aj} = 1 - e_{Aj} \]

The weight of item \( i \)is:

\[ \lambda_{Aj} = \frac{g_{Aj}}{\sum_{j=1}^{9} g_{Aj}} \]

CSR positive entropy is:

\[ A = \sum_{j=1}^{9} \lambda_{Aj} e_{Aj} \]

Similarly, calculate the negative entropy.

2.4 Applying Brusselator model based on dissipative structure
According to Brusselator model [5], research on CSR entropy.
A, B -- represents the positive entropy and negative entropy in CSR;
D, E --two possible states of enterprise under positive and negative entropy interaction, D is non-dissipative structure, E for the dissipative structure;
X, Y --quantification factor of X in positive entropy flow index system and quantification factor of Y in negative entropy flow index system
CSR Entropy Brusselator model, as follows:

\[ \begin{align*}
A & \xrightarrow{k_1} X \\
B+X & \xrightarrow{k_2} Y+D \\
Y+2X & \xrightarrow{k_3} 3X \text{(the non-linear effect of quantifiable factors is exacerbated)} \\
X & \xrightarrow{k_4} E 
\end{align*} \]

According to the model above, it can be seen that the positive and negative entropy changes with the non-linear effect of quantifiable factors. We need to determine whether the CSR is a dissipative structure under the action of X and Y.

2.5 Judging basis of dissipative structure
According to the Brusselator model, only \( B > 1 + A^2 \), the system will have self-organization behavior. Therefore, we can get the following judgment basis:

\[ |B| - (1 + A^2) \begin{cases} > 0 & \text{dissipative structure} \\ = 0 & \text{in critical state} \\ < 0 & \text{nondissipative structure} \end{cases} \]

We only need to calculate the quantifiable factors. The A and B value can be judged whether the CSR for the dissipative structure.
3 Methodology
In this paper, the listed companies of equipment manufacturing industry are selected as research samples and classified according to the performance level of social responsibility. Among them, the CSR level is divided into three categories, namely CSR scores in the 0.3-0.4, 0.4-0.5 and greater than 0.5, each grade includes 27 samples, a total of 81 samples. The entropy of CSR in different levels of calculation results are shown in table 2.

It can be seen from Table 2 that when the total value of CSR is between 0.3 and 0.4, the positive entropy is 0.7730 and the negative entropy is -0.7730, CSR is a non-dissipative structure. When it is between 0.4 and 0.5, the positive entropy is 0.8037 and the negative entropy is -1.6887, CSR is a dissipative structure. When it is greater than 0.5, the positive entropy is 0.7858 and the negative entropy is -1.7396, CSR is a dissipative structure.

With the increase of the social responsibility level, the positive entropy increases(0.8037 > 0.7730, 0.7858 > 0.6788), but the negative entropy increases to a greater extent(-0.7730 > -1.6887, -0.7730 > -1.7396), enough to offset the negative effects of positive entropy, enhance the adaptability of CSR.

| Variable | CSR0.3--0.4 | CSR0.4--0.5 | CSR greater than 0.5 |
|----------|-------------|-------------|---------------------|
| Entropy  | Weight      | Entropy     | Weight              |
| Stockholder | 0.0073 | 0.9950 | 0.0072 | 0.9952 | 0.0060 | 0.9965 |
| Creditor | 0.0342 | 0.9766 | 0.2506 | 0.8329 | 0.0547 | 0.9685 |
| Employee | 0.0830 | 0.9431 | 0.0418 | 0.9721 | 0.1218 | 0.9299 |
| Consumer | 0.0079 | 0.9946 | 0.0501 | 0.9666 | 0.0053 | 0.9970 |
| Supply | 0.0333 | 0.9772 | 0.0697 | 0.9535 | 0.0971 | 0.9441 |
| The nature of equity | 0.0264 | 0.9819 | 0.0268 | 0.9822 | 0.0314 | 0.9819 |
| Whether the chairman and general manager is one person | 0.0254 | 0.9826 | 0.0213 | 0.9858 | 0.0314 | 0.9819 |
| The proportion of independent directors | 0.1158 | 0.9206 | 0.0670 | 0.9553 | 0.0709 | 0.9592 |
| Executive shareholding ratio | 0.6668 | 0.5430 | 0.4656 | 0.6895 | 0.5813 | 0.6655 |
| Government | 0.0123 | -1.9774 | 0.0397 | -1.9735 | 0.0192 | -1.9878 |
| Community | 0.8104 | -0.5182 | 0.6496 | -1.5657 | 0.5661 | -1.6415 |
| Environmental | 0.0110 | -1.9798 | 0.0240 | -1.9840 | 0.0106 | -1.9933 |
| Personnel | 0.0929 | -1.8302 | 0.1291 | -1.9137 | 0.1367 | -1.9134 |
| Funding | 0.0733 | -1.8659 | 0.1576 | -1.8946 | 0.2674 | -1.8307 |
| Positive entropy | 0.6788 | 0.8037 | 0.7858 |
| Negative entropy | -0.7730 | -1.6887 | -1.7396 |

4 Conclusion
The dissipative structure theory points out that the enterprise is an open system, which exchanges material, energy and information with the outside world. With the change of environment, this kind of exchange can form an ordered structure, which provides a reasonable explanation for the fulfillment of CSR. In the study of CSR, the introduction of entropy and dissipative structure theory which enriches the research methods is a new attempt. This paper establishes the index system of CSR and quantifies it. Through establishing Brusselator model, it is concluded that the positive performance of social responsibility can reach the dissipative structure, which has certain guiding significance and promoting effect on the fulfillment of CSR.

CSR Entropy Model of Dissipative Structure assessment of social responsibility is a new way, as well as the index selection and quantification need further study.
References
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