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# Factors influencing marine ecological environment governance toward sustainability: a case study of Zhejiang Province

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At present, the marine ecological environment is facing enormous pressure from human activities, and there is an urgent need for coordinated governance by multiple entities to ensure that the marine ecological environment can continuously meet the needs of sustainable development. Marine ecological environmental governance plays multiple roles in the sustainable development of the ocean characteristics. Most existing studies have explored this field from the perspective of the government and public, while failing to adequately account for the factors influencing enterprises' participation in marine ecological environmental governance. This paper is an effort to provide some empirical research on the influencing factors of enterprises' participation in marine ecological environmental governance. Based on existing literature, empirical research (213 middle managers were surveyed from 68 coastal enterprises in Zhejiang, China), this study extracts eight core factors that influence corporate participation in marine ecosystems and uses the Fuzzy Decision-making Trial and Evaluation Laboratory approach (Fuzzy DEMATEL). Furthermore, experts from Chinese backgrounds elucidated the complex interdependencies among the factors, based on which key influencing factors were identified. The empirical results indicate that government attention and support, legal and regulatory requirements, and cost-benefit accounting have a positive net effect on corporate participation in marine ecosystem management; when these factors are improved, they drive improvements in other factors(Corporate Capital Capability, Corporate Social Responsibility, Government Enforcement and Appraisal, The Attention of Corporate Leaders, Corporate Internal Management System). Additionally, interviews with Chinese business people support the robustness of the findings and suggest that policymakers cannot ignore government enforcement and assessment efforts. Overall, the study findings can help advance corporate participation in marine environmental governance.

KEYWORDS

**sustainable development, corporate involvement, marine ecosystem, influencing factors, decision-making**

# 1 Introduction

According to the United Nations Food and Agriculture Organization, 40% of the world's population lives within 100 km of a coast. As a "second living space" for human beings, the ocean is significant to human life. It is not only a place for fishing, transportation, dumping waste, and extracting resources, but also plays an important role in regulating the atmosphere and weather and maintaining biodiversity (Boesch, 1999). According to the prediction made by the Organization for Economic Cooperation and Development, by 2030, marine industries with great development potential will outperform the overall performance of the global economy in terms of added value and job creation; meanwhile, the contribution of the marine economy to the global economic added value will double to $3 trillion, accounting for about 2.5% of the global economic added value. The ocean economy thus offers the potential for sustainable coastal development (Sea Technology group, 2011).

However, the exponential growth of human activities in the ocean (Marjo, 2017) has caused ecological stress and environmental pollution in coastal areas (Costanza, 1999; Martínez et al., 2007), which greatly threatens global marine biodiversity (Clausen and York, 2008). With the increasing use of the oceans and coastal areas, there is a need to pay greater attention to and reexamine the issue of ocean governance (Chang, 2012). If human activities are not controlled, the deterioration of the marine ecological environment will reach irreversible levels (Havice et al., 2021). Human economic activities have seriously undermined the sustainability of the marine ecological environment (Costanza et al., 1999), exceeded the capacity of marine resources, triggered marine ecological crises (McNelis and Schweitzer, 2001), and led to the unsustainable development of global fisheries (Clausen and York, 2008). Marine ecological environment issues are the most significant challenges facing the international community today, and coastal states are obliged to protect coastal ecosystems (Bolam et al., 2006).

Balancing environmental and economic goals was declared a great challenge for both developing and developed economies (Qian and Mandi, 2022). Maintaining the balance of marine ecosystems is one of the most important goals of marine environmental protection (Backer et al., 2010). The international community believes that marine ecological environment management should be given high priority and the direction of marine ecological environment development should be actively amended (Guterres, 2022). On September 25, 2015, the United Nations Summit on Sustainable Development was held at the UN's headquarters in New York. The 193 member countries of the UN formally adopted 17 sustainable development goals at the summit. Among them, the 14th development goal is as follows: Conserve and sustainably use the oceans, seas, and marine resources.

Sustainable development was used in *Our Common Future* (Report of the World Commission on Environment and Development), "*Chapter 2: Towards Sustainable Development*," which coined what has become the most often-quoted definition of sustainable development, that is, development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

And what is good ocean governance? Some scholars adopted eight elements of good governance as an analytical framework, namely, the rule of law, participatory, transparency, consensus-based decision making, accountability, equity and inclusiveness, responsiveness and coherence (Chang, 2010).

Academic researchers have studied the status and roles of multiple subjects in marine ecological environment governance based on sustainable development theory and governance theory. However, from the literature review in the second part of this article, we will find that there are many studies on the government, a moderate number of studies on social organizations and individual citizens, and few studies on enterprises. There are two reasons for this lack of research on enterprises: First, it is believed that enterprises are the main source of marine discharge, and it is logically flawed to allow them management over the discharge; second, it is believed that enterprises are profit-seeking subjects and naturally lack the sense of responsibility to participate in marine ecological environment management, which is a great obstacle to realizing the ocean's sustainable development (Virdin et al., 2021). Therefore, even if companies are asked to participate, they will not be "genuinely" willing to do so. That is why in the process of making laws and policies, legislators and decision-makers assume that in a world where money is more important than morality, enterprises are unwilling to participate in the governance of the marine ecological environment because of their own interests; thus, the government must make strict laws and policies to force enterprises to participate in this governance.

It is true that the targeted environmental, social and economic policies have crucial importance for steering such transition but institutional quality is needed to be combined for assurance and implementation of these policies effectively (Wu and Madni, 2021). What kind of policies and systems are quality? This study argues that systems that attach importance to and give play to the governance role of corporate entities are of quality. The enterprises, as primary users of the ocean, are key players in the ocean agenda (Singh, 2013). We must no longer follow the previous thinking of taking enterprises as the object of governance, but must regard enterprises as the main subject of governance. We should thoroughly explore the main factors affecting enterprises' participation, and give full play to the enthusiasm and initiative of enterprises in the marine ecological environment governance. This is the biggest difference between this study and previous studies. This study shifts the research perspective from government to enterprises, highlights and emphasizes the governance role of enterprise entities, fully explores the core factors affecting the participation of enterprise entities in marine ecological environment governance.

Thus, it is extremely important to explore the core factors that affect the participation of enterprises in marine ecological environment governance and to lay a solid foundation for designing a system that can fully realize the role of enterprises in future governance. This study explores three core questions: (1) What are the factors that influence corporate participation in marine governance? (2) What are the complex interdependencies between the factors, and how are the key factors decided? (3) What measures can be taken to promote corporate participation in marine ecological environment governance?

To answer the above propositions, this study identifies the relationships among factors and identifies core factors using the Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy DEMATEL), which was administered by Chinese experts. In addition, we conduct and analyze in-depth interviews with dozens of coastal enterprises in Zhejiang Province, China, to confirm the robustness of the results.

In order to achieve the above research purpose, this study takes dozens of coastal enterprises in Zhejiang Province as empirical research objects, and attempts to summarize the influencing factors from the survey. In this study, the representations of Zhejiang Province are mainly reflected in several key areas: Firstly, Zhejiang Province ranks first in China in terms of total coastline length and number of islands; Secondly, Zhejiang has the largest marine fishery in the country-Zhoushan Fishery and the scale of marine economic ranks among the top five in China. Thirdly, Zhejiang's total economic output has ranked among the top four in the country for many years, and the number of enterprises, especially the number of private enterprises, ranks first in the country. Finally, and most importantly, Zhejiang's marine economy has encountered a very typical conflict between marine economy and marine ecological environmental protection. Although Zhejiang has taken many measures in recent years, such as the plan of "Restoration and Revitalization of Zhejiang Fisheries", the establishment of marine nature reserves, the rectification action of the "Blue Bay", and the completion of the first provincial comprehensive marine ecological evaluation index system, these actions are carried out from the government, and the main position of enterprises is rarely reflected in policy documents and system design, and the participation role of enterprises is not considered in an important position.

## 2 Literature review

### 2.1 Research status of multiple subjects participating in marine ecological environment governance

To protect the marine ecological environment, some scholars believe that a universal communication strategy for protecting the environment should be developed (Jacobs et al., 2015). Ocean governance is seen as an effective management tool (Li, 2022). Many researchers have argued for the establishment of marine ecological and environmental accountability mechanisms from a governmental perspective (McNelis and Schweitzer, 2001), stronger integrated governmental management (Young et al., 2007), and an emphasis on the value of marine management (Ottersen et al., 2011) to resolve marine ecological crises. The performance of marine ecological environment management should be assessed, the results of which should guide government departments and public officials (Day et al., 2008). Furthermore, the assessment mechanism should guide the behavior of departments related to marine ecological environment protection (Kark et al., 2015). Such guidance would control the management of waste pollutants to achieve the sustainable development of the marine ecological environment (Al-Muzaini, 2013). Other scholars point to the need to promote collaborative conservation via communication and cooperation among various levels of government (Chang, 2012). Marine ecological environment governance institutions should actively carry out multi-level coordination and cooperation based on information sharing, to avoid over-bureaucracy (Gerhardinger et al., 2011). Some scholars have also studied China's marine governance mechanism, pointing out China could start with the establishing of a coordinating body to improve the communication and cooperation of the marine law enforcement bodies and gradually build up an integrated body, enforcing laws at sea (Qian et al., 2013).

Some researchers point out that governments are under great pressure and have limited capacity and argue that it can share social and environmental responsibility by improving the social responsibility of all relevant subjects (Eckerberg and Joas, 2004). This perspective emphasizes multi-subject collaborative governance of marine ecological environments, in which cooperation is essentially a grafting and transfer of responsibility. Collaborative governance is a spontaneous interactive behavior of multiple subjects, including governments, social organizations, enterprises, and individuals, emphasizing collaborative governance rather than management by individual entities (Tanaka, 2004). Some researchers believe that marine environmental governance refers to the process of mutual consultation, good cooperation, power sharing and joint improvement of marine environmental affairs by governments, enterprises and the public to achieve the natural balance and sustainable development of the marine environment (Ning and Mao, 2017). This participatory governance (Betsill and Corell, 2007) and community management (Kearney et al., 2007), which involves more stakeholders in the decision-making process for environmental protection (Gerhardinger et al., 2011), is more environmentally friendly than regulation by a single government body (Maarten, 2008) and helps to reduce the red tape of government management (Newig and Fritsch, 2009).

The main body of governance includes not only the government, but also social organizations (Hastings, 2013). Based on the theory of pluralistic co-governance, relevant methods of cooperation between the state and the state, between the state and the market, and between societies are provided (Brandes and Brook, 2007). Exploring the establishment of a collaborative governance system of multiple subjects and giving full play to the role of social subjects other than the government in marine ecological environmental protection and governance is an important research direction for marine ecological environmental protection and governance (Abe et al., 2016). Maritime governance has blossomed, covering various institutions and the public outside the government. Such diversified cooperation and interaction, like rivers flowing into the sea, has become a new force. In the governance process, various actors have demonstrated the unique charm of democratic consultation through laws and non-state mandatory contracts. This has enabled maritime governance to flourish like a fish in water, which can be promoted from top to bottom, or from bottom to top or in parallel, forming a multi-dimensional and all-round governance pattern (Quan et al., 2017).

In the above studies, the public and social organizations have received the most attention. Public participation in environmental policy and technology selection can improve policy acceptance

(Kildow and Mcilgorm, 2010). Public participation plays an important role in marine ecological and environmental governance (Forsyth, 2006), and public awareness of marine conservation is important for the implementation of relevant laws, regulations, and policies (Busenberg, 2007). The public actively participates in marine environmental management and cooperates with government departments to do so (Mee et al., 2008), which is a cheap and effective method to reduce environmental management costs and enhance people's environmental awareness (Hind et al., 2009). To enable effective public participation, it is necessary to establish a system of environmental governance with clear authority and responsibility and to open up smooth and diverse paths of participation (Driessen et al., 2012).

Social organizations have also received research attention. The role of these organizations in disseminating information and mobilizing the public to participate in decision-making is relatively strong (Peschard, 2007). Their participation of social organizations in ecological governance issues plays a major role in providing public related goods and services, promoting democratic decision-making, and effectively monitoring government (Jordan and Tuijl, 2008). The social and organizational innovations are very necessary to overcome the social issues, so government should encourage the establishment and sustainability of social organizations (Tao et al., 2023). The collaboration between governments and social organizations in ocean governance can also lead to more coherent policies and strategies through the communication and coordination of social organizations (Grip, 2017).

## 2.2 Current research on enterprise entities' participation in marine ecosystem management

It is evident that enterprises have not received sufficient attention in the research. Three aspects deserve attention.

First, the environmental awareness and social responsibility of enterprises is an obligation to reduce pollution emissions, use resources more efficiently, and avoid seriously affecting the rights of future generations (Mazurkiewicz, 2004). A positive outcome of this awareness and responsibility is that companies adopt marine ecological restoration measures (Kildow and Mcilgorm, 2010).

The ecological environment is a public product, and companies have no incentive to manage it. Businesses actively participate in environmental assessment processes because they believe that Environmental Impact Assessment (EIA) provides competing interest groups with the opportunity to reflect the results of their particular interests (Craik, 2008). Marine ecological and environmental problems are closely related to the production and operation activities of enterprises, and enterprises are both responsible parties and victims. Thus, enterprises' environmental awareness and social responsibility play an important role in marine ecological and environmental management.

Second, small and medium-sized enterprises (SMEs) in ecological and environmental governance form an important part of the world economy, but they are responsible for approximately 60% of total global carbon dioxide emissions for the sector, and 70% of pollution. These SMEs are faced with limited resources, knowledge, and technological capabilities to cope with their negative environmental impacts. Therefore, there is a need to classify these SMEs (e.g., into four types: environment-driven, dominance-driven, compliance-driven, and profit-driven) and to adopt comprehensive interventions, such as mandatory regulations, financial penalties, financial support, autonomy and promotion of education, environmental audits and reviews, business advice, and helplines, in order to ensure that SMEs meet their environmental obligations (Parker et al., 2009).

Environmental Management Systems (EMS) are effective tools helping SMEs manage, control, and monitor environmental legal compliance and are an effective means of preventing ecological damage. However, several SMEs point out that the first major obstacle to EMS implementation is the cost (Parker et al., 2009), which includes costs related to the necessary technical measures to ensure improved environmental performance, costs associated with EMS implementation, and costs to obtain third-party certification. The most effective way for SMEs to implement EMS is to collaborate with other businesses, public institutions, and local communities (Parker et al., 2009).

By operating through networks, SMEs can exchange information, experiences, and resources (Biondi et al., 2000). In addition, SMEs have insufficient awareness of whether their environmental behavior complies with legal requirements, and they do not have sufficient awareness of their environmental responsibilities or domestic environmental legislation. SMEs do not believe that "more legislation would better protect the environment," while policymakers prefer to strengthen enforcement and regulation (Wilson et al., 2012). This policy approach can help prevent more serious environmental violations by adopting mild environmental enforcement mechanisms such as Notice of Violation, which informs companies that they are violating the law and sets a deadline by which they must correct the error (Mintz et al., 2012).

Third, some researchers have analyzed the possible factors influencing enterprises' participation in the governance of marine ecosystems.

First is the government's influence on corporate participation in governance. Companies may adopt different coping strategies under different environmental laws and policies (Moledina et al., 2003), and government environmental control measures may drive companies to invest in environmental protection (Leiter et al., 2011). The government should strictly limit the harm caused by land-based sources of pollution, ship pollution, and the dumping of pollutants (Simeonova et al., 2017).

The second is the impact of enterprises' cost–benefit analysis on their participation in governance. Some researchers point out that waste disposal costs and raw material costs are increasing and that by developing a circular economy, the state can reduce the cost of waste resource recovery, which can motivate enterprises to choose appropriate methods for waste disposal (Pacheco et al., 2018). Some researchers believe that having a certain scale is an important prerequisite for enterprises to reduce resource consumption and minimize emissions. However, it is difficult to consume less resources without economies of scale; only when a critical scale is

reached can enterprises gain the economic feasibility to independently recycle resources and waste (Semenov, 2008). Corporate participation in governance can provide opportunities to reduce costs and increase revenues (Ambec and Lanoie, 2008) and can lead to a higher reputation, increased social acceptance, and higher returns (Miles and Covin, 2000). This is because consumers are more inclined toward environmentally friendly companies or goods (Glen and Hertwich, 2009).

Third, companies that use EMS, such as ISO14001, internally reduce the negative environmental impacts of companies along their supply chains (Wiengarten et al., 2013; Robinson, 2013; Leigh et al., 2021).

Fourth, motivation and awareness of the founder or management are important (Bocken et al., 2014; Klewitz and Hansen, 2014), and managers' judgments about the internal and external environment can significantly impact corporate environmental strategy (Aragón-Correa and Sharma, 2003).

Fifth, emphasis should be placed on the development of environmentally motivated social enterprises (EMSEs), which are social enterprises that pursue an organic balance between environmental and economic goals. EMSEs protect resources, ecosystems, biodiversity, and the economic functions of the environment (Vickers and Lyon, 2012), and have the potential to transform social needs and problems into business opportunities (Drucker, 1984), thereby providing innovative concepts of business development in marine industries.

However, problems also exist in the current academic research.

First, compared with the emphasis on the role of the government, there is little research on the governance roles of other subjects.

Second, enterprises have been treated as an object of governance, and their status as a subject of governance has not received due attention, nor has their governance role been given full play (Lee, 2009).

Third, in recent years, researchers have placed attention on the system of collaborative governance of the marine ecological environment by multiple subjects, but mainly from the perspective of government and social organizations, failing to grasp the motivation of enterprises as subjects to participate in marine ecological environmental governance.

Fourth, a few researchers have begun paying attention to the governance role of enterprises, but the method used does not gather direct survey data on enterprises, which renders it unable to enhance enterprises' active awareness of marine ecological environmental protection and thus ineffective.

In order to solve the above problems, this paper made different efforts from the existing research in the following aspects: Firstly, the research object of this paper focuses on the enterprises rather than the government. Secondly, this paper made empirical research on 213 middle managers of 68 coastal enterprises, deeply analyzed and explored the factors affecting the participation of enterprise entities in marine ecological environmental governance. Finally this paper used hybrid methods to judge the accuracy and interrelationship of these influencing factors from a more comprehensive perspective.

# 3 Research methodology

## 3.1 Influencing factors

In order to formulate the preliminary influencing factors, this study employed two aspects of work. One is to take enterprises in Zhejiang as the research samples. Secondly, this study analyzed a lot of literature, and extracted some corresponding influencing factors from the literature.

In this study, 68 enterprises in Zhejiang Province were selected as empirical research objects. The selection of these enterprise samples follows two principles: Firstly, the coverage should be wide, there must be both state-owned enterprises (35.3%) and private enterprises(64.7%), and there must be both joint stock limited companies(30.9%) and limited liability companies(69.1%). Secondly, these enterprises must have a certain impact on the marine ecological environment, both direct impact(55.6%) and indirect impact(44.4%). Among the 68 companies, 213 middle-level managers were interviewed in this study. The middle-level managers were selected because their concepts, attitudes and views directly affect the decision-making and management activities of enterprises participating in marine ecological environment governance.

This study did extensive literature analysis. Researchers have pointed out that enterprises are an important carrier of human economic behavior and a "major producer" of ecological pollution (Simeonova et al., 2017). Enterprises discharge pollutants (both legal and illegal) during production and operation, hindering the ecological environment's ability to repair itself and making such repair slower than the accumulation of pollutants. Conversely, enterprises occasionally cause environmental emergencies due to irregular operations during production and operation, such as production accidents and leakage of raw materials, as shown in the cases of marine oil and gas extraction (Kark et al., 2015) and marine fisheries (Cuellar-Pinzon, 2016).

Compared to environmental pollution and ecological damage caused by individuals, damage caused by enterprises is characterized by long duration, wide scope, and intensity. In the absence of external impetus, enterprises as private subjects do not actively consider individual interests alongside public interests.

The benefit paradigm of enterprise development concerns the accumulation of benefits but ignores environmental costs and the public interest concerning the ecological environment, focusing on the private interests of enterprises. The close connection between public and private interests requires a certain consensus and institutional design. Whether enterprises can find a balance between profit and ecological protection, the logical space for theoretical construction lies in whether governments can restrain enterprises from pursuing economic interests and instead aim to achieve harmonious coexistence between enterprises and nature.

Therefore, based on empirical research and literature analysis, this study compiled eight main factors that influence the participation of enterprises in marine ecological environment governance, shown in Table 1.

## 3.2 Research design of fuzzy DEMATEL

This study used Fuzzy DEMATEL to explore the complex relationships among the influencing factors. Since this is an expert-based methodology, convincing results can be obtained without a large sample (Lin et al., 2021). The views of 15 experts and scholars in China were collected in February 2022 (Table 2), covering multiple types of universities, government departments, and private enterprises, and their areas of expertise included environment, business operations, and ocean-related areas. Each expert had at least five years of experience, and this sample size is consistent with the relevant literature (Lin et al., 2021, Lin et al., 2022).

Questionnaire research was conducted in Chinese. The questionnaire design was based on the questionnaire format for the assessment of effects of influential factors, as shown in Table 3. Here, experts were asked to compare the effects of eight factors and on a five-point scale (1. no influence; 2. low influence; 3. medium influence; 4. high influence; 5. very high influence). For example, if the expert considered the influence of "Corporate Capital Capability ($C_1$)" on "Government Enforcement and Appraisal ($C_6$)" to be moderate, the expert filled in "3" in the corresponding box.

## 3.3 Fuzzy DEMATEL calculation process

This section describes the calculation process for each step of Fuzzy DEMATEL and the results of each calculation, respectively.

### 3.3.1 Step 1: set semantic parameters

First, the recovered questionnaire values are converted into fuzzy scale values, as shown in Appendix 1.

### 3.3.2 Step 2: generate the fuzzy direct relationship matrix

To determine the relationship model between n criteria, an n × n matrix is first generated. The influence of the elements in each row on the elements in each column of this

matrix can be expressed as a fuzzy number. All survey expert responses are converted according to the triangular fuzzy number (TFN) in Appendix 1, and then averaged to obtain the matrix relationship, as shown in Appendix 2 (Direct relation matrix).

$$z = \begin{bmatrix} 0 & \cdots & \tilde{z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1n} & \cdots & 0 \end{bmatrix}.$$

### 3.3.3 Step 3: normalize the fuzzy direct relationship matrix

Following Step 2, the normalization of the direct relationship matrix was obtained by the following equation.

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right),$$

where

$$r = \max_{i,j}\left\{\max_i \sum_{j=1}^{n} u_{ij}, \max_j \sum_{i=1}^{n} u_{ij}\right\},$$

$$i, j \in \{1, 2, 3, \ldots, n\}.$$

The normalized fuzzy direct relation matrix results are shown in Appendix 3.

TABLE 1 Factors influencing enterprise participation in marine ecosystem management.

| Factor | Description | References |
|---|---|---|
| Corporate Capital Capability ($C_1$) | Corporate financial capacity is an important internal condition that affects corporate participation | (Wilson et al., 2012) |
| Corporate Social Responsibility ($C_2$) | Laws and regulations stipulate that protecting the environment is one of the social responsibilities of enterprises | (Kearney et al., 2007; Hind et al., 2009; Peschard, 2007) |
| Cost-Effectiveness Accounting ($C_3$) | Economic and social benefits &the cost of environmental prevention and protection | (Biondi et al., 2000; Ambec and Lanoie, 2008; Leiter et al., 2011; Mintz et al., 2012; Wilson et al., 2012; Simeonova et al., 2017) |
| Legal and Regulatory Provisions ($C_4$) | The degree of perfection of administrative legal responsibility and criminal legal responsibility | (Mazurkiewicz, 2004; Craik, 2008) |
| Government Attention and Support ($C_5$) | The more government attention and support, the more companies will turn to the direction of government attention and support | (Mazurkiewicz, 2004; Peschard, 2007; Craik, 2008) |
| Government Enforcement and Appraisal ($C_6$) | The stricter the law enforcement and assessment, the more corporate environmental legal responsibility can be realized | (Peschard, 2007; Parker et al., 2009; Grip, 2017; Tao et al., 2023) |
| The Attention of Corporate Leaders ($C_7$) | The more corporate leaders pay attention, the more they can achieve corporate environmental legal responsibility | (Glen and Hertwich, 2009; Wiengarten et al., 2013; Robinson, 2013) |
| Corporate Internal Management System ($C_8$) | The better the internal management system, the better the corporate environmental legal responsibility can be realized | (Miles and Covin, 2000; Ambec and Lanoie, 2008; Semenov, 2008; Vickers and Lyon, 2012) |

TABLE 2 Information on the Fuzzy DEMATEL questionnaire expert respondents.

| No. | Work Unit | Specialized Field | Working Years | Position/Professional title |
|---|---|---|---|---|
| 1 | Colleges and Universities | Law-related | 10 | Professor |
| 2 | Government Departments | Environment-related | 6 | Section Chief |
| 3 | Private Enterprises | Business Management | 9 | Manager |
| 4 | Scientific Research Institutes | Business Management | 8 | Associate Researcher |
| 5 | Private Enterprises | Marine-related | 5 | Deputy Manager |
| 6 | Government Departments | Business Management | 10 | Deputy Director |
| 7 | Private Enterprises | Environment-related | 12 | Vice President |
| 8 | State-owned enterprises | Law-related | 5 | Department Manager |
| 9 | Government Departments | Marine-related | 10 | Deputy Director |
| 10 | Private Companies | Environment-related | 6 | Department Director |
| 11 | State-owned companies | Environment-related | 6 | Department Minister |
| 12 | Private Companies | Business Management | 15 | Manager |
| 13 | State-owned enterprises | Law-related | 5 | Deputy Manager |
| 14 | Colleges and Universities | Marine-related | 10 | Professor |
| 15 | Private enterprises | Marine-related | 8 | Manager |

### 3.3.4 Step 4: Calculate the fuzzy full relationship matrix

Next, the fuzzy full relationship matrix is calculated with the following formula.

$$\tilde{T} = \lim_{k\to+\infty}(\tilde{x}^1 \oplus \tilde{x}^2 \oplus \ldots \oplus \tilde{x}^k).$$

If each element of the fuzzy full relational matrix is expressed, it can be calculated as follows.

$$\tilde{t}_{ij} = (l_{ij}^{"}, m_{ij}^{"}, u_{ij}^{"},).$$

$$[l_{ij}^{"}] = x_l \times (I - x_l)^{-1},$$

$$[m_{ij}^{"}] = x_m \times (I - x_m)^{-1},$$

$$[u_{ij}^{"}] = x_u \times (I - x_u)^{-1}.$$

Expressly, the inverse of the normalized matrix is calculated first; then, it is subtracted from matrix I. Finally, the normalized matrix is multiplied by the obtained matrix. Appendix 4 shows the fuzzy direct relationship matrix.

TABLE 3 Example of filling in the interaction relationship.

| | Corporate Capital Capability | Government Enforcement and Assessment |
|---|---|---|
| What is the degree of influence of "Corporate Capital Capability" on "Government Enforcement and Appraisal"? | | 3 |

### 3.3.5 Step 5: deblur to obtain clear values

Using the Converting Fuzzy Data into Crisp Scores (CFCS) method proposed by Opricovic and Tzeng (2003), the clear values of the total relationship matrix were obtained. The steps are as follows.

$$l_{ij}^n = \frac{(l_{ij}^t - \min l_{ij}^t)}{\Delta_{min}^{max}},$$

$$m_{ij}^n = \frac{(m_{ij}^t - min\ \ l_{ij}^t)}{\Delta_{min}^{max}},$$

$$u_{ij}^n = \frac{(u_{ij}^t - min\ \ l_{ij}^t)}{\Delta_{min}^{max}}.$$

$$So\Delta_{min}^{max} = \max u_{ij}^t - \min l_{ij}^t$$

Calculate the upper and lower bounds of the normalized values.

$$l_{ij}^s = {}^{m_{ij}^n}\Big/{}_{(1+m_{ij}^n - l_{ij}^n)}$$

$$u_{ij}^s = {}^{u_{ij}^n}\Big/{}_{(1+u_{ij}^n - l_{ij}^n)}.$$

The output of the CFCS algorithm is the clear value.

Calculate the total normalized crisp values; Appendix 5 shows the result of clear total relationship matrix:

$$x_{ij} = \frac{[l_{ij}^s(1 - l_{ij}^s) + u_{ij}^s \times u_{ij}^s]}{[1 - l_{ij}^s + u_{ij}^s]}.$$

### 3.3.6 Step 6: calculate the causal attributes of the factors

The last step is to find the sum of each row and each column of T. The sum of rows (D) and columns (R) can be calculated as follows:

$$D = \sum_{j=1}^{n} T_{ij} ,$$

$$R = \sum_{i=1}^{n} T_{ij} .$$

# 4 Empirical results and discussion

## 4.1 Fuzzy DEMATEL empirical analysis

The causal attribute positioning of each influencing factor obtained in this study is revealed in Table 4. The values of D+R are placed on the horizontal axis, while the values of D-R are placed on the vertical axis to plot the influence network relationship and reveal the influence relationship among the factors. D+R indicates the degree of importance of factor i in the whole system, and D-R indicates the net effect of factor i's contribution to the system. If D-R is positive, it shows that it has the attribute of cause (i.e., has the ability to influence other factors);if the opposite is true, it has the attribute of effect (i.e., the ability to be influenced by other factors).

According to the given vector R, the following order is given: Corporate Social Responsibility ($C_2$) > Corporate Capital Capability ($C_1$) > Government Enforcement and Appraisal ($C_6$) > Corporate Internal Management System($C_8$) > The Attention of Corporate Leaders ($C_7$) > Legal and Regulatory Provisions ($C_4$) > Government Attention and Support ($C_5$) > Cost-Effectiveness Accounting ($C_3$). Based on the received vector D, the following order is given: Government Attention and Support ($C_5$) > Legal and Regulatory Provisions ($C_4$) > Cost-Effectiveness Accounting ($C_3$) > Corporate Financial Capability ($C_1$) > Government Enforcement and Appraisal ($C_6$) > Corporate Social Responsibility ($C_2$) > The Attention of Corporate Leaders ($C_7$) > Corporate Internal Management System ($C_8$).

By degree of importance (D+R), Corporate Capital Capability ($C_1$) at 3.079 is the largest of the eight factors and the most important. This is followed by Corporate Social Responsibility ($C_2$) at 2.992, Government Enforcement and Appraisal ($C_6$) at 2.985, Government Attention and Support ($C_5$) at 2.788, Legal and Regulatory Provisions ($C_4$) at 2.622, and The Attention of Corporate Leaders ($C_7$) at 2.554. The two least important factors are Corporate Internal Management System ($C_8$) at 2.506 and Cost-Effectiveness Accounting ($C_3$) at 2.445.

As regards the net effect of the factors, only three factors have a positive net effect (i.e., the ability to influence other factors): Government Attention and Support ($C_5$) at 1.246, Legal and Regulatory Provisions ($C_4$) at 1.037, and Cost-Effectiveness Accounting ($C_3$) at 0.966. The remaining five factors are all influenced factors, among which Corporate Social Responsibility ($C_2$) at -0.701, The Attention of Corporate Leaders ($C_7$) at -0.754, and Corporate Internal Management System($C_8$) at -0.812 had the largest negative effect value.

Combined with the above analysis, this study mapped the influence network relationship of the eight influencing factors, as shown in Figure 1.

## 4.2 Identification of key factors

Based on the importance and net effect analysis, key factors affecting private enterprises' participation in marine ecosystem management were found: Cost-Effectiveness Accounting ($C_3$), Legal and Regulatory Provisions ($C_4$), and Government Attention and Support ($C_5$). To further confirm the robustness of the key factors, this study selected a total of 213 middle managers (all with experience exceeding five years) from 68 enterprises in Zhejiang to be interviewed on the importance of the influencing factors. From the 68 enterprises, 213 decision-makers and senior managers were interviewed using the questionnaire. This study only selected middle managers because the authors believe that in the operation of enterprises, these individuals make the important decisions and perform actual managerial activities. Their ideas, attitudes, and views directly determine the participation of enterprises in the marine ecological environment. Table 5 shows the distribution of enterprises and managers and Table 6 presents the interviewees' basic information.

TABLE 4 Cause-effect localization relationship of influencing factors.

| | D | R | D+R | D-R |
|---|---|---|---|---|
| Corporate Capital Capability ($C_1$) | 1.316 | 1.762 | 3.079 | -0.446 |
| Corporate Social Responsibility ($C_2$) | 1.146 | 1.847 | 2.992 | -0.701 |
| Cost-Effectiveness Accounting ($C_3$) | 1.705 | 0.739 | 2.445 | 0.966 |
| Legal and Regulatory Provisions ($C_4$) | 1.83 | 0.792 | 2.622 | 1.037 |
| Government Attention and Support ($C_5$) | 2.017 | 0.771 | 2.788 | 1.246 |
| Government Enforcement and Appraisal($C_6$) | 1.224 | 1.761 | 2.985 | -0.538 |
| The Attention of Corporate Leaders ($C_7$) | 0.9 | 1.654 | 2.554 | -0.754 |
| Corporate Internal Management System($C_8$) | 0.847 | 1.659 | 2.506 | -0.812 |

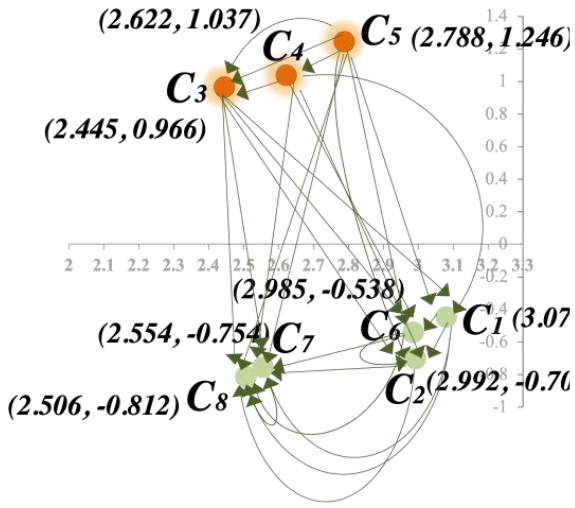


FIGURE 1
Influence network relationship map for factors.

According to the interviews, Government Enforcement and Appraisal($C_6$), Government Attention and Support ($C_5$), The Attention of Corporate Leaders ($C_7$), and Cost-Effectiveness Accounting ($C_3$) are the top four key factors, which are consistent with the key results obtained from Fuzzy DEMATEL. Cost-Effectiveness Accounting ($C_3$) and Government Attention and Support ($C_5$) are factors with a positive net effect that can influence other factors. Government Enforcement and Appraisal ($C_6$) and the Attention of Corporate Leaders($C_7$) are factors that are influenced factors; government attention and support will require increased government enforcement and assessment, and cost–benefit accounting will gain the attention of key business leaders. However, the interview results also show some differences from the results gained using Fuzzy DEMATEL. The main reason for this is that the experts, in their evaluations, provide solutions for the participation of enterprises in marine ecological management from a more ideal state, while, in contrast, the managers were encouraged to talk about their firms' actual state of participation in marine ecological management and their relevant daily management practices and experience. The difference between these two positions and perspectives generated both compatible and contrasting results.

TABLE 5 Types of enterprises surveyed and distribution of managers.

| Enterprise type | Number of enterprises | Number of management personnel |
|---|---|---|
| Metal smelting and processing enterprises | 8 | 22 |
| Real estate enterprises | 8 | 27 |
| Small household appliance manufacturing enterprises | 8 | 26 |
| Shipbuilding enterprises | 8 | 19 |
| Offshore oil enterprises | 4 | 19 |
| Marine tourism enterprises | 8 | 28 |
| Marine transport enterprises | 8 | 21 |
| Marine food processing enterprises | 8 | 24 |
| Marine fishing enterprises | 8 | 27 |
| Total | 68 | 213 |

TABLE 6 Basic information of the interviewees.

| Program | High School: Quantity and Percentage | Undergraduate: Quantity and Percentage | Masters: Quantity and Percentage |
|---|---|---|---|
| Academic qualifications | 52/24.4% | 123/57.7% | 38/17.9% |
| Age | 30-40 years old: Number and Percentage | 41-50 years old: Number and Percentage | Over 51 years old: Number and Percentage |
| Number/ ratio | 102/47.8% | 68/31.9% | 43/20.3% |
| Years of experience | 5-10 years: Number and Percentage | 11-15 years: Number and Percentage | Over 16 years: Number and Percentage |
| Number/ ratio | 112/52.6% | 69/32.4% | 32/15% |

The implication behind the interview results is that the relationship with the government is the most important external relationship of the companies and that dealing with the government is a core issue for the companies' survival and development (Leiter et al., 2011). Both the strength of government enforcement and assessment and the importance of government support and rewards or punishments directly affect the cultivation of local resources and related economic activity. When the government pays enough attention and provides enough support, it places enterprises in a certain government-created enforcement environment or institutional environment, and their natural tendency to avoid harm prompts them to actively adapt to the environment as expected by the government. Therefore, enterprises pay close attention to government trends. Government enforcement and assessment may result in the most direct losses for firms, such as environmental fines and suspensions, while government attention and support will guide resource allocation and flow, thus influencing firms' environmental investment decisions (Moledina et al., 2003).

The more attention the government allocates to the marine ecological environment, the better the performance of local marine environment management. The government can use the "visible hand," that is, tools such as financial subsidies, tax incentives, and corporate honors, to guide enterprises to transform and upgrade their production and operation toward cleanliness and sustainability and to invest in environmental protection activities. The strength of these two factors directly affects the strength of corporate action.

Conversely, the interview results also reveal The Attention of Corporate Leaders ($C_7$) as the top-ranking factor, although it was not highlighted in the Fuzzy DEMATEL results. However, this is in line with the current state of most companies' involvement in environmental governance in China. Although many companies have established a modern corporate system, effective corporate governance has not changed or reduced the authority of the "paternalistic leadership." If the chairperson or general manager, as the main leader of the company, is concerned about environmental issues, then it is more likely that the company's motivation and initiative to participate in marine ecological management will yield practical action. Thus, the likelihood of the company's involvement in marine ecosystem management's translating into action greatly increases.

In the survey, there is a very striking and impressive example confirming the importance of the main leaders of enterprises for their participation in the governance of the marine ecological environment. From the founder, legal representative, and general manager of Zhejiang Lanjing Technology Co., Ltd., we learned that these personnel have a good concept of marine ecology, attach great importance to marine ecological governance, actively participate in government-led marine ecological governance, and have developed an innovative "Blue Cycle" project for marine plastic pollution control. Through the construction of the "Blue Cycle" closed-loop governance platform and the establishment of 15 "small blue home" garbage recycling sites in 6 coastal counties and cities in the city of Taizhou, Zhejiang, marine plastic waste within one kilometer of the coastline has been well managed.

By opening up the whole industrial chain of plastic recycling, the "Blue Cycle" project has built a closed-loop management system for the whole process of "collection, transportation, disposal and regeneration" of marine plastic waste, reprocessing the recycled waste into high-value plastic raw materials, and obtaining authoritative international certification for these products. Plastic export enterprises have enhanced their environmental competitiveness, can increase the plastic's overall industrial value by 30%, and can realize the transformation of marine plastic waste into recycled treasure.

Although Fuzzy DEMATEL revealed the critical influence of Legal and Regulatory Provisions ($C_4$), it seems to be less valued in the interviews, which may be related to the current laws and regulations concerning marine ecological environmental protection being unsound and the legal liability system imperfect. Although many studies and experts in Fuzzy DEMATEL do pay attention to ecological environmental protection laws and regulations, it is obvious that a somewhat idealized state of requirements.

Per the interviews, the actual managers of enterprises do not think that laws and regulations promote enterprises' participation in marine ecological management. Some companies are not aware of the stipulations of environmental laws and regulations and do not fully understand their environmental legal obligations, whereas others understand environmental laws and regulations but do not perceive them as being regularly enforced. Thus, the key is government enforcement and assessment. Due to the impact of marine ecological management on the future, China's related governance efforts should be concerned with these problems.

## 5 Discussion

Combined with the literature mentioned above, some literature analyzed the factors affecting enterprises' participation in environmental governance, but there are two obvious problems in these analyses: Firstly, the analysis of influencing factors in existing studies is relatively fragmented and each article may analyze influencing factors from a certain angle or several angles. These analyses do provide useful references for this research, but unfortunately, the existing studies have not sorted out the influencing factors comprehensively and systematically, so this study extracts some of the influencing factors from the existing studies and systematically sorts them out to form 8 influencing factors Furthermore, we sought the basic views of experts and enterprise management on these 8 factors. Secondly, from the existing literature, it can be determined that researchers rarely go to enterprises to conduct more detailed research. Rather, they prefer to conduct research from the perspective of government subjects, and pay more attention to what kind of laws, policies, and institutional documents should be formulated.

This study employs a mixed-method approach, utilizing both literature analysis to extract relevant influencing factors from a multitude of sources and the Fuzzy DEMATEL method to invite experts with extensive theoretical knowledge and practical experience to analyze the relevant influencing factors. Simultaneously, it emphasizes the governance role of the enterprise and conducts on-site visits to 68 enterprises, interviewing 213 middle-level managers to understand their genuine perspectives on marine ecological environment governance. These perspectives are then compared and analyzed against the conclusions obtained through literature analysis and the Fuzzy DEMATEL method, thereby accurately revealing the content and interrelationships of relevant influencing factors.

This study expands upon the scope of existing research and employs a mixed-method approach that is less commonly utilized in existing studies while conducting effective comparative analyses. The comparative analysis reveals that the 8 influencing factors summarized in this study are generally acknowledged by experts and enterprises. According to the results of Fuzzy DEMATEL method, this study identifies 3 factors with "cause" attributes: cost-benefit accounting (C3), legal regulations (C4), and government attention and support (C5) as being the most critical factors affecting enterprise participation in marine ecological environment governance. Improvements in these factors will promote the improvement of the remaining 5 factors. The empirical survey results are highly consistent with these findings. Additionally, during the empirical survey, the importance of enterprise leadership attention (C7) was also revealed.

# 6 Conclusions and recommendations

The purpose of this study was to obtain the key factors that affect the participation of Chinese enterprises in marine ecological environment governance and to put forward targeted policy recommendations by analyzing the interrelationship of these factors.

Based on the literature and empirical research, this study identifies eight factors influencing the participation of enterprises in marine ecological and environmental governance, namely, Corporate Capital Capability (C1), Corporate Social Responsibility (C2), Cost-Effectiveness Accounting ($C_3$), Legal and Regulatory Provisions ($C_4$), Government Attention and Support ($C_5$), Government Enforcement and Appraisal($C_6$), The Attention of Corporate Leaders($C_7$), and Corporate Internal Management System($C_8$). Among these 8 factors, Cost-Effectiveness Accounting (C3), Legal and Regulatory Provisions (C4), Government Attention and Support (C5), and The Attention of Corporate Leaders(C7) are most deserving of attention. These factors exhibit a direct positive correlation with whether enterprises take participation actions and possess the ability to promote other factors. Therefore, it is necessary to reinforce the status and role of these "cause"-capable factors.

According to the results of Fuzzy DEMATEL, Cost-Effectiveness Accounting ($C_3$), Legal and Regulatory Provisions ($C_4$), and Government Attention and Support ($C_5$) are the most critical factors with the attribute of "cause," which is supported by the interviews and reveals the importance of The Attention of Corporate Leaders($C_7$).

Per the results, this study proposes policy recommendations at the government and enterprise levels:

(1) At the government level, there are three areas for targeted work: the first is to fully demonstrate the government's support for marine ecological environment governance and view that it is important, and to fully express the government's governance intention and attract enterprises to actively participate in the government-led marine ecological environment governance activities with the attitude of "no matter how much attention and support" through various policy tools and means. This will help enterprises feel that participating in governance is profitable for enterprises themselves and is in line with the long-term development plan of enterprises, so as to gradually foster a situation of "government leading–enterprise leading" in the main system of marine ecological environment governance.

(2) Second, the government can actively promote the revision, improvement, and effective implementation of laws and regulations for marine ecological environment governance. Governance in this area is in a process of development. The laws and regulations are not perfect or fully implemented and need to be made more effective. However, the legal and regulatory environment is an important part of enterprises' own survival. Therefore, the government can continue to promote the improvement and implementation of laws and regulations and ameliorate the daily situation of law enforcement and assessment work, so that enterprise actions in marine ecological protection can meet the government's expectations and form a long-term mechanism.

(3) Third, the government can strengthen education and training at the leadership level within enterprises. The government should let entrepreneurs know that, for the sustainable development of the industrial economy, human beings began to reflect on traditional development thinking and strive to find a development strategy that harmonizes industrial economic development and resource protection (Du et al., 2023).This kind of education is not a unilateral notification that damage to the marine ecological environment will be punished but is rather aimed to help enterprises understand that participating in government-led marine ecological environment governance action is profitable for enterprises and that cooperation with the government can achieve win–win results.

(4) At the enterprise level, cost–benefit accounting is important, but it cannot only focus on the short-term calculation of costs and benefits. Enterprises should adhere to the concepts of sustainable development and green business (Liu and Cao, 2024), actively help the development concept of the main leaders of the enterprise evolve, formulate an enterprise development plan that meets the requirements of green environmental protection, actively integrate into government actions to control the marine ecological environment, transform the governance action into "business opportunities," and achieve innovative green development. If encountering dilemmas in green transformation, enterprises can actively seek help from relevant government departments such as economic, information, and environmental protection departments.

(5) In the process of planning enterprises' own innovative green development, a focus on process management and environmental reengineering for marine pollution prevention and control will internalize the externalities of marine pollution generated by the enterprise. The early stage should include enterprises' production activities for environmental assessment, environmental protection design for production processes, environmental protection materials audit, and effective prevention and control at the source. The intermediate stage should include stronger monitoring and rectification of each production link, mainly production monitoring,pollution investigation,production process innovation, green technology management capabilities (Lou et al., 2023), and so on,to ensure that the production link will not produce external pollution. The long term should include effective emergency disposal of marine pollutants,avoiding pollution-generated external problems,and preventing endangerment of the marine ecological environment and the living environment of the surrounding residents.

There are limitations to this study. First, enterprises' responsibilities to the marine ecological environment includes pollution reduction, implementation of a cleaner production system, and marine ecological damage repair. This study mainly covers the first two aspects, and more in-depth research on damage repair remains necessary. Second, from this research, we can see that this study pays more attention to research at the decision-making and management level in enterprises; meanwhile, the research on general employees has been insufficient, a gap mainly determined by this study. Furthermore, regulating the negative impact of enterprise production and operation activities on the marine ecological environment with legal and regulatory remedies and promoting coordination between production activities and ecological protection requires in-depth consideration. In particular, future researchers can try to use econometric models to analyze this problem in more depth. Comparative studies through different methods will be more helpful for us to draw useful conclusions.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

## Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

## Author contributions

LC: Writing – original draft, Writing – review & editing. YJH: Writing – original draft, Writing – review & editing. YZH: Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## References

Abe, J., Brown, B., Ajao, E. A., and Donkor, S. (2016). Local to regional polycentric levels of governance of the Guinea Current Large Marine Ecosystem. *Environ. Dev.* 17, 287–295. doi: 10.1016/j.envdev.2015.06.006

Al-Muzaini, S. (2013). Management of land-based sources of marine pollution. *Aquat Ecosyst. Health Manag* 16, 347–356. doi: 10.1080/14634988.2013.825564

Ambec, S., and Lanoie, P. (2008). Does it pay to be green? a systematic overview. *Acad. Manage Rev.* 22, 45–62. doi: 10.5465/amp.2008.35590353

Aragón-Correa, J. A., and Sharma, S. A. (2003). Contingent resource-based view of proactive corporate environmental strategy. *Acad. Manage Rev.* 28, 71–88. doi: 10.5465/amr.2003.8925233

Backer, H., Leppänen, J. M., Brusendorff, A. C., Forsius, K., Stankiewicz, M., and Mehtonen, J. (2010). HELCOM Baltic Sea Action Plan–A regional program of measures for the marine environment based on the Ecosystem Approach. *Mar. pollut. Bull.* 60, 642–649. doi: 10.1016/j.marpolbul.2009.11.016

Betsill, M. M., and Corell, E. (2007). "NGO diplomacy: the influence of nongovernmental organization," in *International Environmental Negotiations* (The MIT Press, Cambridge, United States), 146–148. doi: 10.1162/glep.2008.8.4.146

Biondi, V., Frey, M., and Iraldo, F. (2000). Environmental management systems and SMEs: motivations, opportunities and barriers related to EMAS and ISO 14001 implementation. *JSTOR* 29, 55–69. doi: 10.9774/GLEAF.3062.2000.SP.00007

Bocken, N., Farracho, M., and Kemp, R. (2014). The front-end of eco-innovation for eco-innovative small and medium sized companies. *JET* 31, 43–57. doi: 10.1016/j.jengtecman.2013.10.004

Boesch, D. F. (1999). The role of science in ocean governance. *Ecol. Econ* 31, 189–198. doi: 10.1016/S0921-8009(99)00078-6

Bolam, S. G., Rees, H. L., Somerfield, P., Smith, R., Clarke, K. R., Warwick, R. M., et al. (2006). Ecological consequences of dredged material disposal in marine environment: A holistic assessment of activities around the England and wales coastline. *Mar. pollut. Bull.* 52, 415–426. doi: 10.1016/j.marpolbul.2005.09.028

Brandes, O. M., and Brook, D. B. (2007). "The soft path for water in a nutshell," in *A Joint Publication of Friends of the Earth CANADA, Ottawa, ON, and the POLIS Projecton Ecological Governance* (University of Victoria, Victoria, BC). doi: 10.1111/cobi.12562

Busenberg, G. J. (2007). Citizen participation and collaborative environmental management in the marine oil trade of coastal Alaska. *Coast. Manage.* 35, 239–253. doi: 10.1080/08920750601042310

Chang, Y. C. (2010). International legal obligations in relation to good ocean governance. *Chin. J. Int. Law* 9, 589–605. doi: 10.1093/chinesejil/jmq024

Chang, Y. C. A. (2012). Note on a comparison of the ocean governance system between mainland China and Taiwan. *OCEAN Dev. Int. Law* 43, 311–329. doi: 10.1080/00908320.2012.698930

Clausen, R., and York, R. (2008). Global biodiversity decline of marine and freshwater fish: A cross-national analysis of economic, demographic, and ecological influences. *Soc. Sci. Res.* 37, 1310–1320. doi: 10.1016/j.ssresearch.2007.10.002

Costanza, R. (1999). The ecological, economic, and social importance of the oceans. *Ecol. Econ* 31, 199–213. doi: 10.1016/S0921-8009(99)00079-8

Costanza, R., Andrade, F., Antunes, P., van den Belt, M., Boesch, D., Boersma, D., et al. (1999). Ecological economics and sustainable governance of the oceans. *Ecol. Econ* 31, 171–187. doi: 10.1016/S0921-8009(99)00077-4

Craik, N. (2008). *The International Law of Environmental Impact Assessment* Vol. 195 (Cambridge, England: Cambridge University Press). doi: 10.1017/CBO9780511494611

Cuellar-Pinzon, J. (2016). Genetic markers in marine fisheries: types, tasks and trends. *Fish ResMulti-level environmental governance:*. 173, 194–205. doi: 10.1016/j.fishres.2015.10.019

Day, V., Paxinos, R., Emmett, J., Wright, A., and Goecke, M. (2008). The Marine Planning Framework for South Australia: A new ecosystem-based zoning policy for marine management. *Mar. Policy* 32, 535–543. doi: 10.1016/j.marpol.2007.10.009

Driessen, P. P. J., Laerhoven, F., Runhaar, H. A. C., and Vermeulen, W. J. V. (2012). Towards a conceptual framework for the study of shifts in modes of environmental governance–experiences from the Netherlands. *Environ. Policy Gov* 22, 143–160. doi: 10.1002/eet.1580

Drucker, P. (1984). Converting social problems into business opportunities: the new meaning of corporate social responsibility. *Calif Manage Rev.* 26, 53–63. doi: 10.2307/41165066

Du, N., Fathollahi-Fard, A. M., and Wong, K. Y. (2023). Wildlife resource conservation and utilization for achieving sustainable development in China: main barriers and problem identification. *Environ. Sci. pollut. Res.* doi: 10.1007/s11356-023-26982-7

Eckerberg, K., and Joas, M. (2004). Multi-level environmental governance: a concept under stress? *Local Environ.* 9, 405–412. doi: 10.1080/1354983042000255315

Forsyth, T. (2006). Cooperative environmental governance and waste-to-energy technologies in Asia. *TMSD* 5, 209–220. doi: 10.1386/ijtm.5.3.209/1

Gerhardinger, L. C., Godoy, E. A. S., Jones, P. J. S., Sales, G., and Ferreira, B. P. (2011). Marine protected dramas: the flaws of the Brazilian national system of marine protected areas. *Environ. Manage* 47, 630–643. doi: 10.1007/s00267-010-9554-7

Glen, P., and Hertwich, E. G. (2009). Carbon footprint of nations: a global, trade-linked analysis. *Environ. Sci. Technol.* 43, 6414–6420. doi: 10.1021/es803496a

Grip, K. (2017). International marine environmental governance: A review. *Ambio* 46, 413–427. doi: 10.1007/s13280-016-0847-9

Guterres, A. (2022) *UN Oceans Conference*. Available online at: http://www.cbcgdf.org/English/NewsShow/5012/20304.html.

Hastings, D. (2013). National ocean policy creates more red tape, hurts economy. *Sea Technol.* 54 (1), 40–40.

Havice, E., Campbell, L. M., Campling, L., and Smith, M. D. (2021). Making sense of firms for ocean governance. *One Earth* 4, 602–604. doi: 10.1016/j.oneear.2021.04.022

Hind, E. J., Hiponia, M. C., and Gray, T. S. (2009). From community-based to centralized national management—A wrong turning for the governance of the marine protected area in Apo Island, Philippines. *Mar. Policy* 34, 54–62. doi: 10.1016/j.marpol.2009.04.011

Jacobs, M. J., Schloeder, C. A., and Tanimoto, P. D. (2015). Dryland agriculture and rangeland restoration priorities in Afghanistan. *J. Arid Land* 7, 391–402. doi: 10.1007/s40333-015-0002-7

Jordan, L., and Tuijl, P. (2008). Political responsibility in transnational NGO advocacy. *World Dev.* 28, 2051–2065. doi: 10.1016/S0305-750X(00)00078-4

Kark, S., Brokovich, E., Mazor, T., and Levin, N. (2015). Emerging conservation challenges and prospects in an era of offshore hydrocarbon exploration and exploitation. *Conserv. Biol.* 29, 1573–1585. doi: 10.1111/cobi.12562

Kearney, J., Berkes, F., Charles, A., Pinkerton, E., and Wiber, M. (2007). The role of participatory governance and community based management in integrated coastal and ocean management in Canada. *Coast. Manage* 35, 79–104. doi: 10.1080/10.1080/08920750600970511

Kildow, J. T., and Mcilgorm, A. (2010). The importance of estimating the contribution of the oceans to national economies. *Mar. Policy* 34, 367–374. doi: 10.1016/j.marpol.2009.08.006

Klewitz, J., and Hansen, E. (2014). Sustainability-oriented innovation of SMEs: A systematic review. *J. Clean Prod* 65, 57–75. doi: 10.1016/j.jclepro.2013.07.017

Lee, K. H. (2009). Why and how to adopt green management into business organizations. *MD* 47, 1101–1121. doi: 10.1108/00251740910978322

Leigh, S. C., Papastamatiou, Y. P., and German, D. P. (2021). Gut microbial diversity and digestive function of an omnivorous shark. *Mar. Biol.* 168, 55–71. doi: 10.1007/s00227-021-03866-3

Leiter, M. A., Parolini, A., and Winner, H. (2011). Environmental regulation and investment: Evidence from European industry Data. *Ecol. Econ* 70, 759–770. doi: 10.1016/j.ecolecon.2010.11.013

Li, H., Wang, W., Fan, L., Li, Q., and Chen, X. (2020). A novel hybrid MCDM model for machine tool selection using fuzzy DEMATEL, entropy weighting and later defuzzification VIKOR. *Appl. Soft Comput.* 91, 106207. doi: 10.1016/j.asoc.2020.106207

Li, X. L. (2022). ""Global marine environmental crisis governance: Mechanism evolution"," in *Compound dilemma and optimization path(in chinese), academic forum*, vol. 45. , 1–15. doi: 10.3969/j.issn.1004-4434.2022.02.001

Lin, S. H., Zhang, H., Li, J. H., Ye, C. Z., and Hsieh, J. C. (2022). Evaluating smart office buildings from a sustainability perspective: A model of hybrid multi-attribute decision-making. *Technol. Soc.* 68, 101824. doi: 10.1016/j.techsoc.2021.101824

Lin, S. H., Zhao, X., Wu, J. H., Liang, F. C., Li, J. H., Lai, R. J., et al. (2021). An evaluation framework for developing green infrastructure by using a new hybrid multiple attribute decision making model for promoting environmental sustainability. *Socio-Econ. Plan. Sci.* 75, 100909. doi: 10.1016/j.seps.2020.100909

Liu, T., and Cao, X. (2024). Going green: how executive environmental awareness and green innovation drive corporate sustainable development. *J. Knowl. Econ*. doi: 10.1007/s13132-024-01788-1

Lou, S., Yao, C., and Zhang, D. (2023). How to promote green innovation of high-pollution firms? A fuzzy-set QCA approach based on the TOE framework. *Environ. Dev. Sustain*. doi: 10.1007/s10668-023-04107-x

Maarten, A. (2008). Environmental governance in a multilevel institutional setting. *Energy Environ.* 19, 779–786. doi: 10.1260/09583050878536357

Marjo, V. (2017). Global marine governance and oceans management for the achievement of SDG 14. *United Nations Chronicle* 54, 1, 66–1, 68. doi: 10.18356/ec606c8a-en

Martínez, M. L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P., and Landgrave, R. (2007). The coasts of our world: Ecological, economic and social importance. *Ecol. Econ* 63, 254–272. doi: 10.1016/j.ecolecon.2006.10.022

Mazurkiewicz, P. (2004). *Corporate environmental responsibility: Is a common CSR framework possible* (Washington, D. C.: World Bank working p-aper). Available at: http://documents.worldbank.org/curated/en/577051468339093024/Corporate-environmental-responsibility-Is-a-common-CSR-framework-possible.

McNelis, D. N., and Schweitzer, G. E. (2001). Environmental security: An evolving concept. *Environ. Sci. Technol.* 35, 108A–113A. doi: 10.1021/es0122849

Mee, L. D., Jefferson, R. L., Laffoley, D., and Elliott, M. (2008). How good is good? Human values and Europe's proposed Marine Strategy Directive. *Mar. pollut. Bull.* 56, 187–204. doi: 10.1016/j.marpolbul.2007.09.038

Miles, M., and Covin, J. (2000). Environmental marketing: A source of reputational, competitive, and financial advantage. *J. Bus Ethics* 23, 299–311. doi: 10.1023/A:1006214509281

Mintz, J. A., Rechtschaffen, C., and Kuehn, R. (2012). *Environmental Enforcement: Cases and Materials* (Durham, North Carolina, the United States: Carolina Academic Press).

Moledina, A. A., Coggins, J. S., Polasky, S., and Costello, C. (2003). Dynamic environmental policy with strategic firms: prices versus quantities. *JEEM* 45, 356–376. doi: 10.1016/S0095-0696(02)00055-4

Newig, N., and Fritsch, O. (2009). Environmental governance: participatory, multi-level-and effective? *Environ. Sci. Policy* 19, 197–214. doi: 10.1002/eet.509

Ning, L., and Mao, H. L. (2017). Analysis on the positioning of the government, enterprise and the public in marine environmental governance. *Ocean Dev. Manage.* 34, 13–20. doi: 10.20016/j.cnki.hykfygl.2017.04.002

Ottersen, G., Olsen, E., Meeren, G. I. V. D., Dommasnes, A., and Loeng, H. (2011). The Norwegian plan for integrated ecosystem-based management of the marine environment in the Norwegian Sea. *Mar. Policy* 35, 389–398. doi: 10.1016/j.marpol.2010.10.017

Pacheco, D. A. D. J., Caten, C. S. T., Jung, C. F., Navas, H. V. G., and Cruz-MaChado, V. A. (2018). Eco-innovation determinants in manufacturing SMEs from emerging markets: Systematic literature review and challenges. *JET-M* 48, 44–63. doi: 10.1016/j.jengtecman.2018.04.002

Parker, C. M., Redmond, J., and Simpson, M. A. (2009). review of interventions to encourage SMEs to make environmental improvements. *Environ. Plann* 27, 279–301. doi: 10.1068/c0859b

Peschard, I. (2007). Participation of the public in science: towards a new kind of scientific practice. *Hum. Affairs* 2, 138–153. doi: 10.2478/v10023-007-0013-x

Qian, C., and Madni, G. R. (2022). Encirclement of natural resources, green investment, and economic complexity for mitigation of ecological footprints in BRI countries. *Sustainability* 14, 15269. doi: 10.3390/su142215269

Qian, C., Wang, N., and Zhao, Y. (2013). The current development of the ocean governance mechanism in China. *Coast. Manage* 41, 120–133. doi: 10.1080/08920753.2013.768515

Quan, Y. B., Yin, L. M., and Wang, T. G. (2017). Interest logic and solution mechanism in the marine environmental governance(in chinese). *J. Zhejiang Ocean University (Humanities Sciences)* 34, 1–6. doi: 10.3969/j.issn.1008-8318.2017.01.001

Robinson, H. A. (2013). Stubberud Published Green innovation in germany: A comparison by business size. *JIBR* 12, 47.

Sea Technology group (2011). Ocean industry contributes £3.7 billio00 jobs to U.K. economy, council says. *Sea Technology: Worldwide Inf. Leader Mar. Business Sci. Eng.* 52 (3), 50.

Semenov, I. (2008). The multidimensional approach to marine industry development:Part I.Obstacles and willingness to the EU marine industry reengineering. *Polish Marit Res.* 15, 77–85. doi: 10.2478/v10012-007-0087-9

Simeonova, A., Chuturkova, R., and Yaneva, V. (2017). Seasonal dynamics of marine litter along the Bulgarian Black Sea coast. *Mar. pollut. Bull.* 119, 110–118. doi: 10.1016/j.marpolbul.2017.03.035

Singh, J. S. (2013). "Coastal ecology: development, directions and dimensions," in *Maritime Affairs: Journal of The National Maritime Foundation of India*. 9, 1–29. doi: 10.1080/09733159.2013.798106

Tanaka, Y. (2004). Zonal and integrated management approaches to ocean governance: reflections on a dual approach in international law of the sea. *Int. J. Mar. Coast. Law* 19, 483–514. doi: 10.1163/1571808053310143

Tao, T., Madni, G. R., and Yasin, I. (2023). Mediating the performance of social organizations in context of social and organizational innovations in China. *PloS One* 18, e0281720. doi: 10.1371/journal.pone.0281720

Vickers, I., and Lyon, F. (2012). Beyond green niches? Growth strategies of environmentally-motivated social enterprises. *Int. Small Bus. J.* 32, 449–470. doi: 10.1177/0266242612457700

Virdin, J., Vegh, T., Jouffray, J. B., Blasiak, R., Mason, S., Österblom, H., et al. (2021). The Ocean 100: Transnational corporations in the ocean economy. *Sci. Adv.* 7, eabc8041. doi: 10.1126/SCIADV.ABC8041

Wiengarten, F., Pagell, M., and Fynes, B. (2013). The importance of contextual factors in the success of outsourcing contracts in the supply chain environment: The role of risk and complementary practice. *Supply Chain Manag* 18 (6), 630–643. doi: 10.1108/SCM-03-2013-0071

Wilson, C. D. H., Williams, L. D., and Kemp, S. (2012). An evaluation of the impact and effectiveness of environmental legislation in small and medium-sized enterprises: experiences from the UK. *Bus Strategy Environ.* 21, 141–156. doi: 10.1002/bse.720

Wu, Q., and Madni, G. R. (2021). Environmental protection in selected one belt one road economies through institutional quality: Prospering transportation and industrialization. *PloS One* 16, e0240851. doi: 10.1371/journal.pone.0240851

Young, O. R., Osherenko, G., Crowder, J., Crowder, L. B., Ogden, J., Wilson, J. A., et al. (2007). Solving the crisis in ocean governance: place-based management of marine ecosystems. *Environment* 49, 20–32. doi: 10.3200/ENVT.49.4.20-33

# Appendix

APPENDIX 1 Fuzzy scales (Li et al., 2020).

| Code | Language Term | L | M | U |
|---|---|---|---|---|
| 1 | No impact | 0 | 0 | 0.25 |
| 2 | Very low impact | 0 | 0.25 | 0.5 |
| 3 | Low impact | 0.25 | 0.5 | 0.75 |
| 4 | High impact | 0.5 | 0.75 | 1 |
| 5 | Very high impact | 0.75 | 1 | 1 |

APPENDIX 2 Direct relation matrix.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | (0.000,0.000,0.000) | (0.667,0.917,1.000) | (0.033,0.133,0.383) | (0.050,0.167,0.417) | (0.033,0.150,0.400) | (0.667,0.917,0.967) | (0.533,0.783,0.950) | (0.517,0.767,0.933) |
| $C_2$ | (0.317,0.567,0.800) | (0.000,0.000,0.000) | (0.150,0.367,0.617) | (0.033,0.167,0.417) | (0.033,0.167,0.417) | (0.417,0.667,0.900) | (0.250,0.500,0.750) | (0.250,0.500,0.750) |
| $C_3$ | (0.467,0.717,0.917) | (0.450,0.700,0.900) | (0.000,0.000,0.000) | (0.583,0.833,0.983) | (0.600,0.850,1.000) | (0.333,0.583,0.800) | (0.183,0.433,0.667) | (0.183,0.433,0.667) |
| $C_4$ | (0.483,0.733,0.950) | (0.517,0.767,0.983) | (0.433,0.683,0.917) | (0.000,0.000,0.000) | (0.617,0.867,1.000) | (0.600,0.850,1.000) | (0.350,0.600,0.850) | (0.350,0.600,0.850) |
| $C_5$ | (0.717,0.967,1.000) | (0.700,0.950,1.000) | (0.317,0.567,0.800) | (0.700,0.950,1.000) | (0.000,0.000,0.000) | (0.750,1.000,1.000) | (0.617,0.867,0.983) | (0.617,0.867,0.983) |
| $C_6$ | (0.683,0.933,1.000) | (0.633,0.883,1.000) | (0.000,0.033,0.283) | (0.017,0.067,0.317) | (0.000,0.017,0.267) | (0.000,0.000,0.000) | (0.583,0.833,1.000) | (0.583,0.833,1.000) |
| $C_7$ | (0.383,0.633,0.867) | (0.250,0.500,0.733) | (0.000,0.033,0.283) | (0.000,0.033,0.283) | (0.000,0.050,0.300) | (0.250,0.500,0.750) | (0.000,0.000,0.000) | (0.267,0.517,0.767) |
| $C_8$ | (0.217,0.467,0.717) | (0.317,0.567,0.817) | (0.000,0.017,0.267) | (0.000,0.017,0.267) | (0.000,0.033,0.283) | (0.267,0.517,0.767) | (0.233,0.483,0.733) | (0.000,0.000,0.000) |

APPENDIX 3 Normalized fuzzy direct relation matrix.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | (0.000,0.000,0.000) | (0.099,0.136,0.148) | (0.005,0.020,0.057) | (0.007,0.025,0.062) | (0.005,0.022,0.059) | (0.099,0.136,0.143) | (0.079,0.116,0.140) | (0.076,0.113,0.138) |
| $C_2$ | (0.047,0.084,0.118) | (0.000,0.000,0.000) | (0.022,0.054,0.091) | (0.005,0.025,0.062) | (0.005,0.025,0.062) | (0.062,0.099,0.133) | (0.037,0.074,0.111) | (0.037,0.074,0.111) |
| $C_3$ | (0.069,0.106,0.136) | (0.067,0.103,0.133) | (0.000,0.000,0.000) | (0.086,0.123,0.145) | (0.089,0.126,0.148) | (0.049,0.086,0.118) | (0.027,0.064,0.099) | (0.027,0.064,0.099) |
| $C_4$ | (0.071,0.108,0.140) | (0.076,0.113,0.145) | (0.064,0.101,0.136) | (0.000,0.000,0.000) | (0.091,0.128,0.148) | (0.089,0.126,0.148) | (0.052,0.089,0.126) | (0.052,0.089,0.126) |
| $C_5$ | (0.106,0.143,0.148) | (0.103,0.140,0.148) | (0.047,0.084,0.118) | (0.103,0.140,0.148) | (0.000,0.000,0.000) | (0.111,0.148,0.148) | (0.091,0.128,0.145) | (0.091,0.128,0.145) |
| $C_6$ | (0.101,0.138,0.148) | (0.094,0.131,0.148) | (0.000,0.005,0.042) | (0.003,0.010,0.047) | (0.000,0.003,0.039) | (0.000,0.000,0.000) | (0.086,0.123,0.148) | (0.086,0.123,0.148) |
| $C_7$ | (0.057,0.094,0.128) | (0.037,0.074,0.108) | (0.000,0.005,0.042) | (0.000,0.005,0.042) | (0.000,0.007,0.044) | (0.037,0.074,0.111) | (0.000,0.000,0.000) | (0.039,0.076,0.113) |
| $C_8$ | (0.032,0.069,0.106) | (0.047,0.084,0.121) | (0.000,0.003,0.039) | (0.000,0.003,0.039) | (0.000,0.005,0.042) | (0.039,0.076,0.113) | (0.034,0.071,0.108) | (0.000,0.000,0.000) |

APPENDIX 4 Fuzzy total relationship matrix.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | (0.029,0.097,0.318) | (0.123,0.224,0.457) | (0.009,0.045,0.228) | (0.010,0.048,0.232) | (0.007,0.045,0.229) | (0.119,0.217,0.441) | (0.101,0.197,0.432) | (0.099,0.195,0.431) |
| $C_2$ | (0.063,0.158,0.408) | (0.021,0.086,0.312) | (0.024,0.073,0.250) | (0.009,0.049,0.227) | (0.008,0.048,0.226) | (0.076,0.170,0.417) | (0.053,0.145,0.393) | (0.053,0.145,0.394) |
| $C_3$ | (0.108,0.235,0.518) | (0.110,0.242,0.528) | (0.014,0.051,0.228) | (0.099,0.168,0.358) | (0.100,0.168,0.358) | (0.092,0.221,0.502) | (0.064,0.190,0.475) | (0.064,0.190,0.476) |
| $C_4$ | (0.116,0.248,0.551) | (0.124,0.261,0.568) | (0.073,0.143,0.362) | (0.019,0.058,0.245) | (0.101,0.169,0.372) | (0.131,0.263,0.554) | (0.092,0.221,0.525) | (0.092,0.221,0.527) |
| $C_5$ | (0.156,0.298,0.565) | (0.160,0.307,0.578) | (0.059,0.133,0.351) | (0.113,0.185,0.377) | (0.017,0.059,0.246) | (0.161,0.303,0.562) | (0.137,0.275,0.549) | (0.137,0.275,0.550) |
| $C_6$ | (0.120,0.208,0.430) | (0.118,0.210,0.440) | (0.004,0.027,0.205) | (0.005,0.029,0.209) | (0.002,0.022,0.202) | (0.028,0.087,0.300) | (0.107,0.195,0.423) | (0.107,0.195,0.424) |
| $C_7$ | (0.067,0.143,0.369) | (0.051,0.132,0.362) | (0.002,0.020,0.181) | (0.001,0.019,0.181) | (0.001,0.020,0.182) | (0.049,0.127,0.354) | (0.013,0.057,0.250) | (0.051,0.128,0.352) |
| $C_8$ | (0.043,0.118,0.343) | (0.058,0.135,0.363) | (0.002,0.016,0.175) | (0.001,0.015,0.174) | (0.001,0.016,0.175) | (0.050,0.124,0.348) | (0.045,0.118,0.339) | (0.012,0.052,0.242) |

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APPENDIX 5 Clear total relationship matrix.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0.133 | 0.253 | 0.076 | 0.079 | 0.076 | 0.245 | 0.228 | 0.226 |
| $C_2$ | 0.195 | 0.123 | 0.102 | 0.079 | 0.078 | 0.206 | 0.182 | 0.182 |
| $C_3$ | 0.267 | 0.273 | 0.081 | 0.191 | 0.19 | 0.253 | 0.225 | 0.225 |
| $C_4$ | 0.28 | 0.293 | 0.171 | 0.09 | 0.193 | 0.292 | 0.255 | 0.256 |
| $C_5$ | 0.318 | 0.326 | 0.161 | 0.205 | 0.09 | 0.321 | 0.297 | 0.298 |
| $C_6$ | 0.238 | 0.241 | 0.058 | 0.06 | 0.053 | 0.122 | 0.226 | 0.226 |
| $C_7$ | 0.178 | 0.168 | 0.047 | 0.046 | 0.047 | 0.163 | 0.088 | 0.163 |
| $C_8$ | 0.154 | 0.17 | 0.043 | 0.042 | 0.043 | 0.159 | 0.153 | 0.083 |