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Overview of research on carbon information disclosure

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Abstract Against the background of addressing global climate change and carbon emission reduction, corporate carbon information disclosure (CID) has become an important measure to achieve carbon emission reduction worldwide and a research hotspot closely investigated by the academia. This study provides a systematic overview of literature on CID, including its research trend, theoretical basis, disclosing features, influencing factors, and consequences. Results indicate that, first, CID has been increasing in recent years, but the content and quality of the disclosure still need to be improved. Second, the main influencing factors of CID include company features, corporate governance, environmental performance, institutional characteristics, and stakeholders. Third, the consequences of CID are based mainly on company performance, ecological environment, and investors' decision-making. Lastly, most studies have confirmed the positive effect of CID on company performance and investors' decision-making, but the nexus of environmental performance and corporate CID remains to be investigated. Several important future research directions are also proposed based on these results.

Keywords climate change, carbon emissions reduction, carbon information disclosure, green development

1 Introduction

Informatization has become an important means to enhance engineering management capacity and improve

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engineering management efficiency (Feng et al., 2018). Increasing environmental information disclosure is conducive to improve environmental engineering management benefits (Liu and Sun, 2010). Under the background of global warming, energy conservation, emission reduction, green development, and low-carbon economy have become global consensus (Hu et al., 2016). Governments are actively involved in global climate governance (Zhang et al., 2015) and have achieved important outcomes, such as the Kyoto Protocol and Paris Agreement (Haag, 2005; Lewis, 2016). In particular, many countries have set quantitative carbon emission reduction targets and strive to achieve control of global temperature rise within 2°C above the pre-industrial level (Seneviratne et al., 2018). For example, in the Intended Nationally Determined Contributions, the EU and its member states pledged to reduce greenhouse gas emissions by at least 40% by 2030 compared with the value in 1990, and China announced that its carbon intensity will be reduced by 60%–65% by 2030 compared with the amount in 2005¹⁾. Countries also commit to carbon reduction through the use of low-carbon technology and the carbon trading market. In December 2017, China launched the national carbon emission trading market, which is expected to exceed the EU's emission trading scheme (ETS) to become the world's largest carbon trading market (Cao et al., 2019; Chu et al. 2019).

Enterprises are universally acknowledged as primary carbon emitters. Whether a country can achieve its emissions reduction commitments and successfully transition into the low-carbon economic mode is inseparable from the low-carbon management by enterprises (Wang and Zhang, 2019; Zhang and Liu, 2019). Having relevant and comparable carbon information is the basis of carbon emission reduction by enterprises and environmental supervision by governments (Giannarakis et al., 2018). Carbon information disclosure (CID) can help relevant enterprises recognize their advantages and disadvantages in terms of carbon management, cultivate their awareness of the coordinated development of emission reduction and

1) <https://www4.unfccc.int/sites/submissions/indc/Submission%20Pages/submissions.aspx>

economic benefits, and provide investors with information on enterprises' carbon emissions and carbon assets to help them supervise and restrain the operation of these enterprises. In addition, the release of true and complete carbon information is a prerequisite for carbon emission trading; it helps regulate the carbon trading market, enhance the transparency of the market, and achieve high-quality carbon emission reduction (Matisoff et al., 2013; Liesen et al., 2015). Developed countries, such as the UK, the US, and Australia, have mandated enterprises to disclose carbon information (Australian Government, 2009; US Environmental Protection Agency, 2009; UK Government, 2013). In December 2017, the China Securities Regulatory Commission also explicitly required listed enterprises to disclose their main environmental information in their annual and semi-annual reports.

In this context, relevant enterprises have released their carbon information through various channels and means. Meanwhile, CID has elicited attention from the academic community and has become a research hotspot in environmental economics and management, which provides a theoretical and empirical basis for relevant enterprises to improve their CID awareness and enhance the transparency of carbon information. What is the research trend of CID? What research features and issues are presented? What are the influencing factors and consequences of CID? What topics are worth exploring further? These questions deserve further discussion. Therefore, this study systematically investigates literature on CID in recent years, determines the research trends and theoretical basis of CID, analyzes the CID status of enterprises, and describes the influencing factors and consequences of CID. On these bases, the study presents several important research directions.

The remainder of the paper is organized as follows. Section 2 shows the research trend of CID. Section 3 presents the theoretical basis of CID, and Section 4 depicts the current status of CID. Sections 5 and 6 explain the influencing factors and consequences of CID, respectively,

and Section 7 provides the conclusions and future research directions.

2 Research trend of CID

By searching using the keywords “carbon information disclosure”, “GHG (greenhouse gas) disclosure”, and “climate change disclosure” in the Web of Science database and by reading related literature, 79 articles were selected as the review object of this study. The articles focused on three topics, namely, features, influencing factors, and consequences of CID, and the numbers of relevant articles for these topics were 10, 42, and 27, respectively.

In terms of research content, existing literature that focused on the influencing factors of CID accounted for 53% of the total articles, followed by those focusing on the consequences of CID (33%). Figure 1 shows the publication of relevant literature by year. It shows that research on CID gradually emerged in 2005 and presented a fluctuating upward trend. Meanwhile, after 2011, the consequences of CID attracted the attention of scholars.

The articles on CID were distributed in 43 peer-reviewed journals and mainly published in the *Journal of Cleaner Production*, *Business Strategy and the Environment*, *Journal of Business Ethics*, *The British Accounting Review*, *Sustainability*, *Corporate Social Responsibility and Environmental Management*, and so on, as shown in Fig. 2. Notably, most studies on CID were published in journals indexed by SSCI.

With regard to the research samples, the selected studies mainly concentrated on European and American enterprises or enterprises at the global scale, such as Fortune Global 500. The main sources of disclosure data were Carbon Disclosure Project (CDP), corporate annual reports, social responsibility reports, sustainability reports, and other related reports (e.g., official website reports and questionnaires), as shown in Fig. 3. CDP is a non-

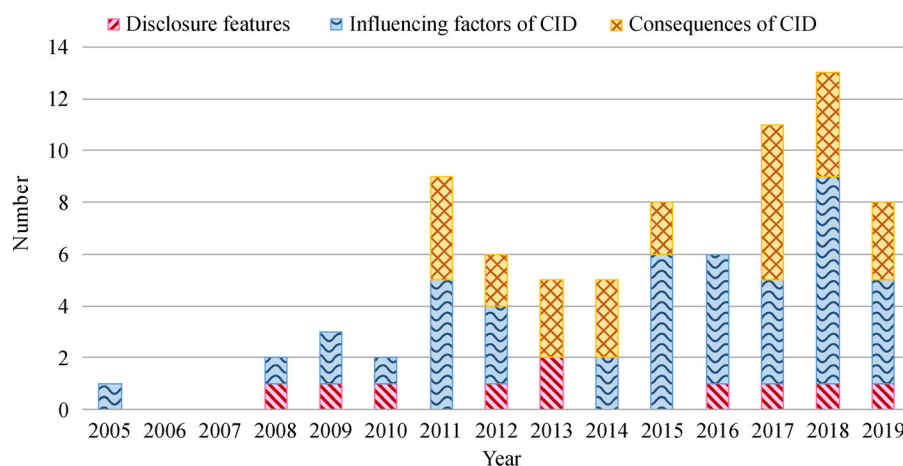


Fig. 1 Publication of relevant literature by year.

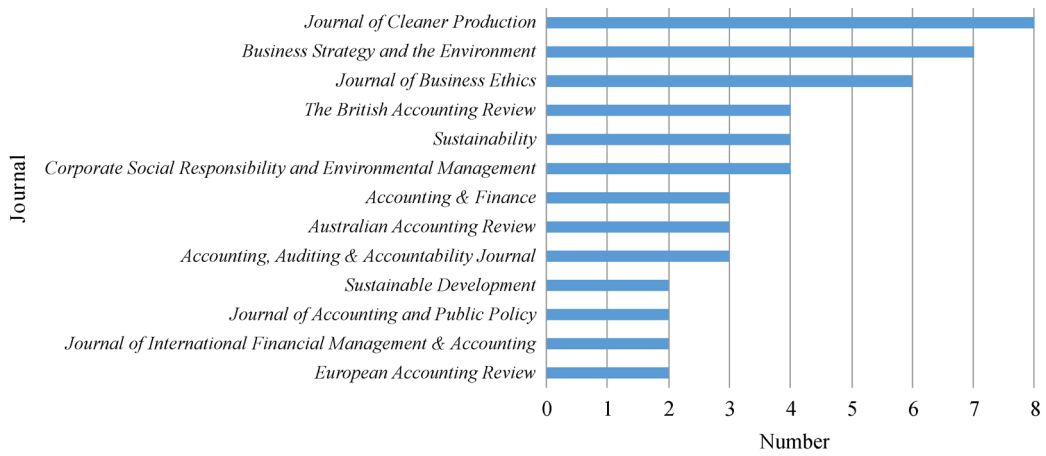


Fig. 2 Distribution of main journals for CID publication.

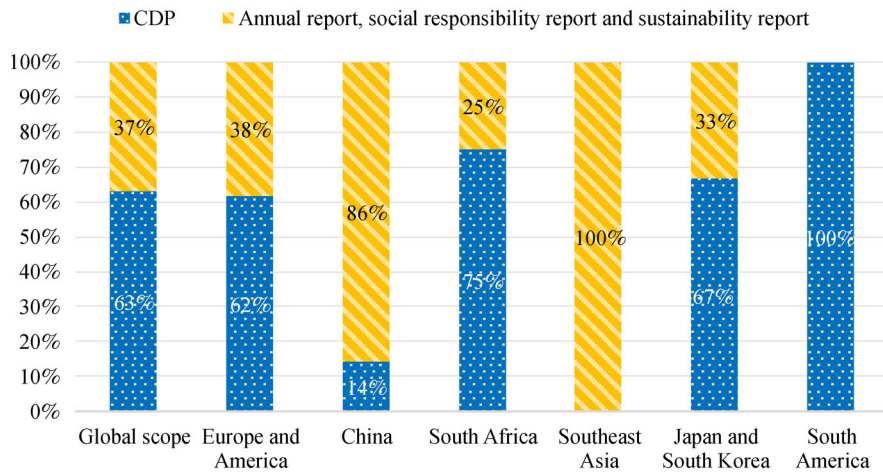
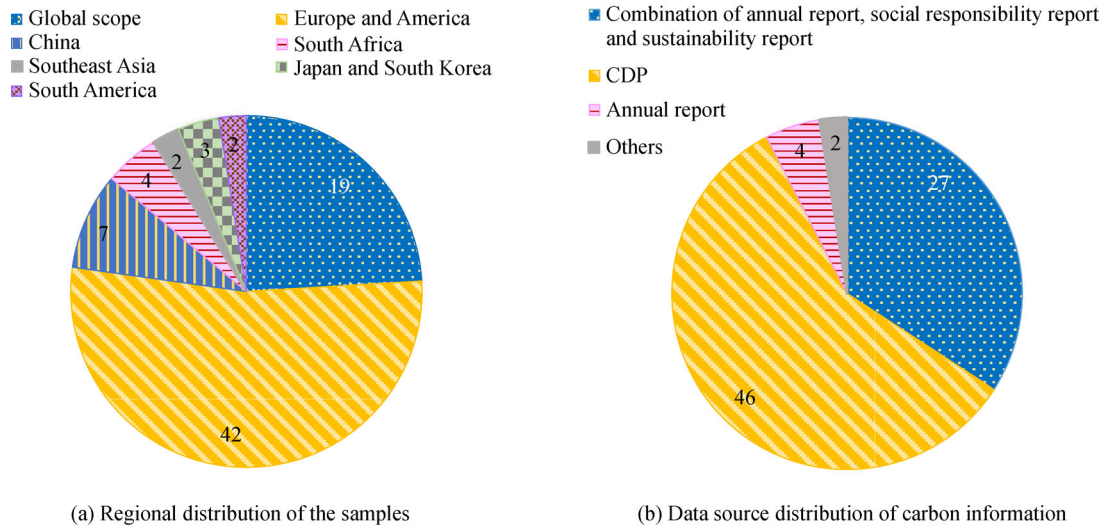


Fig. 3 Distribution of samples.

governmental organization founded in 2000; it initially disclosed the carbon information of companies in the Financial Times Global 500 (Stanny and Ely, 2008). By 2018, over 7000 enterprises covering more than 50% of the global stock market value have disclosed their carbon information through CDP¹, which is known for its high objectivity and authority (Kim and Lyon, 2011).

Figure 3(a) shows that more than 50% of relevant studies focused on Europe, America, and other developed countries, but only a few were conducted on developing countries. Figure 3(b) shows that empirical research based on CDP occupied the mainstream of relevant research, followed by the combination of corporate reports (annual, social responsibility, and sustainability reports), and only a few studies were based solely on corporate annual report. Specifically, as shown in Fig. 3(c), the data sources for the studies at the global scale (Europe, America, Japan and South Korea, and South America) were mainly based on CDP. Meanwhile, the data sources for the studies on China and Southeast Asia were primarily based on annual, social responsibility, sustainability, and other multi-channel corporate reports.

3 Theoretical basis of CID

In terms of theoretical perspective, relevant scholars mainly explained CID research from six aspects: Stakeholder theory, legitimacy theory, institutional theory, signal theory, agency theory, and voluntary disclosure theory. This study sorts out relevant literature based on these theoretical perspectives, as shown in Table 1.

(1) Stakeholder theory and legitimacy theory

The input resources of various stakeholders are the foundation of corporate development, and enterprises need to actively meet the needs and expectations of stakeholders to ensure their survival and development (Deegan and Blomquist, 2006). Under the background of global warming, all walks of life in the society should pay close attention to the energy saving and emission reduction of enterprises, and CID is an effective response of enterprises to stakeholders' need for information on environmental issues, such as carbon emission reduction. For example, on the basis of stakeholder theory, Cotter and Najah (2012) reported that the extent and quality of corporate CID are positively correlated with institutional investors' expecta-

Table 1 Theoretical applications in CID research

Theoretical basis	Research perspective		
	Disclosure features	Influencing factors of CID	Consequences of CID
Stakeholder theory	Stanny (2013); Depoers et al. (2016)	Prado-Lorenzo et al. (2009); Prado-Lorenzo and Garcia-Sanchez (2010); Cotter and Najah (2012); Liao et al. (2015); Liesen et al. (2015); Gonzalez-Gonzalez and Zamora Ramirez (2016); Guenther et al. (2016); Córdova et al. (2018); Faisal et al. (2018); Giannarakis et al. (2018); Jaggi et al. (2018); Tang and Demeritt (2018); Akbaş and Canikli (2019); He et al. (2019)	Liesen et al. (2015)
Legitimacy theory	Stanny (2013); de Faria et al. (2018)	Freedman and Jaggi (2005); Prado-Lorenzo and Garcia-Sanchez (2010); Cowan and Deegan (2011); Gallego-Álvarez et al. (2011); Luo et al. (2012); Gonzalez-Gonzalez and Zamora Ramirez (2016); Halkos and Skouloudis (2016); Kalu et al. (2016); Giannarakis et al. (2017; 2018); Li et al. (2017; 2018); Córdova et al. (2018); Jaggi et al. (2018); Tang and Demeritt (2018); Akbaş and Canikli (2019); He et al. (2019); Lemma et al. (2019); Luo (2019)	Pellegrino and Lodhia (2012); Liesen et al. (2017); Qian and Schaltegger (2017); Ganda (2018)
Institutional theory	Kolk et al. (2008)	Prado-Lorenzo and Garcia-Sanchez (2010); Grauel and Gotthardt (2016); Faisal et al. (2018); Akbaş and Canikli (2019); Hollindale et al. (2019)	–
Signal theory	–	Peng et al. (2015); Li et al. (2017); Luo (2019)	Lemma et al. (2019); Li et al. (2019)
Agency theory	–	Prado-Lorenzo et al. (2009); Prado-Lorenzo and Garcia-Sanchez (2010); Amran et al. (2014); Ben-Amar and McIlkenny (2015); Tauringana and Chithambo (2015); Kalu et al. (2016); Giannarakis et al. (2018); Zhou et al. (2018); Krishnamurti and Velayutham (2018); Akbaş and Canikli (2019)	Zhou et al. (2018)
Voluntary disclosure theory	–	Giannarakis et al. (2017; 2018)	Kim and Lyon (2011); Griffin and Sun (2013); Matisoff (2013); Matsumura et al. (2014); Lee et al. (2015); Bimha and Nhamo (2017); Griffin et al. (2017); Lemma et al. (2019); Li et al. (2019)

1) <http://www.tanjiaoyi.com/article-26289-1.html>

tions for this information. Liesen et al. (2015) confirmed that the pressure of external stakeholders is a determinant of corporate CID.

Table 1 shows that most studies were based on legitimacy theory, which holds that if an enterprise's business activities do not conform to social norms or values, then the legitimacy of its business activities cannot be guaranteed, and its survival and development will be difficult (Suchman, 1995). For example, on the basis of legitimacy theory, Freedman and Jaggi (2005) argued that enterprises located in countries that have ratified the Kyoto Protocol have high disclosure indexes. Stakeholder theory reflects the pressure from shareholders, creditors, and other individuals or groups, whereas legitimacy theory reflects the pressure from all social values. CID is the process of legitimacy management of enterprises. Therefore, obtaining legitimacy is an important motivation for relevant enterprises to deal with environmental issues (Cho and Patten, 2007). In addition, the high legitimacy of an enterprise indicates that it has a good corporate reputation and easy access to social resources.

(2) Institutional theory, signal theory, and agency theory

Institutional theory is a branch of legitimacy theory (Faisal et al., 2018), but it is more specific than legitimacy theory and regards information disclosure as a tool to cope with institutional pressure (Bansal and Roth, 2000). Institutional theory holds that external institutional expectations prompt enterprises to gradually adjust their behavior to satisfy requirements (Meyer and Rowan, 1977). It was successfully applied by Prado-Lorenzo and Garcia-Sanchez (2010) and Grauel and Gotthardt (2016) in their research. The background of the national system affects the CID behavior of enterprises.

Signal theory (Connelly et al., 2011) indicates that corporate management can deliver "low-carbon" signals to stakeholders through CID, thus reducing the information asymmetry between enterprises and stakeholders, providing conditions for external investors to fully understand the development situation of relevant enterprises, and changing investors' views and related decisions on the enterprises. Therefore, relevant enterprises tend to disclose good news or positive information to the market to improve their reputation or access to resources (Luo et al., 2012; Ben-Amar et al., 2017).

According to agency theory, CID is beneficial for reducing the information asymmetry between insiders and external shareholders and therefore decreases agency costs (Healy and Palepu, 2001; Giannarakis et al., 2018).

(3) Voluntary disclosure theory

According to voluntary disclosure theory (Verrecchia, 1983), enterprises with good performance tend to voluntarily disclose information that is difficult to imitate by those with poor performance; as a result, adverse selection of stakeholders is avoided, excess returns are realized, and efficient allocation of resources in the capital market is

promoted (Clarkson et al., 2008), such as reducing the capital costs of enterprises (Dhaliwal et al., 2011).

As shown in Table 1, several studies applied only one theory to study the influencing factors or consequences of CID. For instance, Cowan and Deegan (2011) and Li et al. (2018) studied the influencing factors of CID based solely on legitimacy theory. The study of Amran et al. (2014) was based only on agency theory. However, other studies used a combination of several theories in their analyses. For example, Giannarakis et al. (2018) utilized four theories (stakeholder, legitimacy, agency, and voluntary disclosure) to study the influencing factors of CID.

Notably, several correlations were observed between different theories. Specifically, stakeholder theory and legitimacy theory complement each other. The main reason for improving the legitimacy of companies is to cope with the pressure from stakeholders. Meanwhile, legitimacy theory and institutional theory reflect macro and micro perspectives of the same issue, respectively. In addition, several studies on the consequences of CID were mainly based on legitimacy theory and voluntary disclosure theory. Other studies were not based on a theoretical framework but relied on previous empirical evidence to propose a hypothesis.

4 Disclosure features of carbon information

Several scholars investigated the features of corporate CID by focusing on carbon information data sources, disclosure content, disclosure mode, disclosure quality, disclosure quantity, and other aspects. The research viewpoints are summarized as follows.

First, related research on CID is based more on CDP reports than on corporate reports (e.g., annual, social responsibility, and sustainability reports) due to their well-recognized advantages. Although CDP and corporate reports can be used to present the carbon emissions of enterprises, data in CDP reports are collected through questionnaires, and the reports are highly structured compared with corporate reports. Many scholars pointed out that CDP reports provide more comprehensive and comparative information than corporate reports do (Stanny and Ely, 2008; Reid and Toffel, 2009; Luo et al., 2012; Stanny, 2013).

Second, several scholars conducted research on disclosure contents (de Faria et al., 2018) and comparability of contents (Depoers et al., 2016; Herold and Lee, 2017; Wegener et al., 2019). Their results suggest that the comparability of carbon information disclosed by different channels remains weak. For example, de Faria et al. (2018) took 48 Brazilian enterprises from 2014 to 2016 as samples to determine the most disclosed factors in corporate reports of enterprises participating in CDP. Depoers et al. (2016) analyzed 140 listed enterprises in the French SBF 120

index from 2007 to 2009 and found that the GHG emissions disclosed in corporate annual reports are lower than those disclosed in CDP reports. When the data disclosed by the two channels are different, enterprises increase the traceability of annual report data. Wegener et al. (2019) examined 19 Canadian enterprises from 2004 to 2015 as samples and found that carbon information disclosed by different institutions are disconnected, and the data lack comparability.

Third, the number of enterprises implementing CID has been increasing in recent years (Akbaş and Canikli, 2019). However, most studies indicated that although the corporate response to CID is on the rise, the content and quality of disclosure are still insufficient (Kolk et al., 2008; Dragomir, 2012; Stanny, 2013; Liesen et al., 2015; Peng et al., 2015; Li et al., 2019). For example, Kolk et al. (2008) pointed out that although CDP successfully motivates investors to urge relevant enterprises to disclose their carbon information and the response rate of corporate disclosure continues to rise, CDP does not effectively encourage relevant enterprises to disclose reliable and comparable carbon emission data. Similarly, Dragomir (2012) argued that the reliability of carbon information disclosed by current enterprises is low, and the disclosure is more similar to “green washing” rather than improving corporate transparency. In addition, Green and Zhou (2013) suggested that the assurance of CID of enterprises gradually increases from the perspective of assurance practices.

Lastly, several studies indicated that the carbon information currently disclosed by enterprises does not meet the needs of investors (Harmes, 2011; Sullivan and Gouldson, 2012). Sullivan and Gouldson (2012) used the British retail industry as an example and found that the current corporate carbon disclosure provides insufficient information for investors.

In summary, many scholars have reached relatively consistent conclusions regarding the features or current situation of research on CID. In terms of data sources, CDP reports are more comprehensive and comparable than corporate reports. Carbon information disclosed through different channels differs, and the comparability among data are weak. In terms of the content and quality of disclosure, although the number of enterprises practicing CID has been increasing, the content and quality of disclosure are insufficient to satisfy the requirements of investors.

5 Factors that influence CID

Whether an enterprise is willing to disclose its carbon information and how often it will depend on many factors. In accordance with relevant empirical researches, this study analyzed the influencing factors of CID from the

following aspects: Enterprise features, corporate governance, environmental performance, institutional characteristics, and stakeholders. The specific influencing factors and corresponding effects are shown in Table 2.

5.1 Enterprise features

Many studies have investigated the effects of enterprise features or enterprise attributes on CID, and the main findings are summarized below.

On the one hand, enterprises with a large size (Freedman and Jaggi, 2005), strong profitability (Prado-Lorenzo et al., 2009; Faisal et al., 2018), high market value (Akbaş and Canikli, 2019), high foreign sales ratio (Stanny and Ely, 2008; Stanny, 2013; Halkos and Skouloudis, 2016), and low leverage ratio (Tauringana and Chithambo, 2015; Faisal et al., 2018) are inclined to practice CID. With 120 enterprises from 20 countries as samples, Freedman and Jaggi (2005) found that large enterprises prefer to disclose detailed pollution information. Stanny and Ely (2008) focused on 494 enterprises involved in CDP in 2007 and confirmed that enterprises with a large scale, history of disclosure, high proportion of foreign sales, and new assets are likely to respond to CID. Faisal et al. (2018) studied the influencing factors of CID based on the annual reports of 37 listed enterprises in Indonesia from 2011 to 2014. Their results showed that large, highly profitable, and minimally leveraged enterprises have high incentive to disclose carbon information to stakeholders.

On the other hand, enterprises with a history of disclosure (Stanny and Ely, 2008; Stanny, 2013; Peng et al., 2015) and a good reputation (Akbaş and Canikli, 2019) are likely to disclose carbon information. For instance, Peng et al. (2015) stated that when numerous enterprises implement CID in an industry, the entire industry becomes likely to implement CID. After studying 138 Turkish enterprises participating in CDP from 2014 to 2016, Akbaş and Canikli (2019) discovered that enterprises with a large size, high institutional ownership, high profits, and good reputation have a high probability of responding to CDP questionnaires and disclosing their carbon emissions.

In general, enterprise features are important factors that affect corporate CID, and the conclusions of previous research have basically reached a consensus. In early research, enterprise features were the main content of research on CID. Meanwhile, in recent years, enterprise features were often used as control variables in studies on the influencing factors of CID, thus playing an auxiliary role.

5.2 Corporate governance

Many studies conducted CID research from the perspective

Table 2 Related literature on influencing factors of CID

Influencing factor		Effect	Related literature
Enterprise features	Firm size	+	Freedman and Jaggi (2005); Prado-Lorenzo et al. (2009); Prado-Lorenzo and Garcia-Sanchez (2010); Rankin et al. (2011); Cotter and Najah (2012); Luo et al. (2012); Stanny (2013); Ben-Amar and McIlkenny (2015); Eleftheriadis and Anagnostopoulou (2015); Liao et al. (2015); Peng et al. (2015); Tauringana and Chithambo (2015); Gonzalez-Gonzalez and Zamora Ramirez (2016); Faisal et al. (2018); Giannarakis et al. (2018); Li et al. (2018); Akbaş and Canikli (2019)
	Profitability	+	Prado-Lorenzo et al. (2009); Gonzalez-Gonzalez and Zamora Ramirez (2016); Faisal et al. (2018); Akbaş and Canikli (2019)
	Market value	+	Akbaş and Canikli (2019)
	Foreign sales ratio	+	Stanny and Ely (2008); Stanny (2013); Gonzalez-Gonzalez and Zamora Ramirez (2016); Halkos and Skouloudis (2016)
	Disclosure history	+	Stanny and Ely (2008); Stanny (2013); Peng et al. (2015)
	Corporate reputation	+	Akbaş and Canikli (2019)
	Leverage ratio	-	Tauringana and Chithambo (2015); Ben-Amar et al. (2017); Faisal et al. (2018)
Corporate governance	Board independence	+	Amran et al. (2014); Liao et al. (2015); Jaggi et al. (2018); Krishnamurti and Velayutham (2018); He et al. (2019)
	Female directors	+	Prado-Lorenzo and Garcia-Sanchez (2010); Liao et al. (2015); Ben-Amar et al. (2017); Krishnamurti and Velayutham (2018); Hollindale et al. (2019)
	Board size	+	Tauringana and Chithambo (2015); He et al. (2019)
		-	Prado-Lorenzo and Garcia-Sanchez (2010)
	CEO-chair duality	+	Prado-Lorenzo and Garcia-Sanchez (2010)
		-	Amran et al. (2014); Krishnamurti and Velayutham (2018); He et al. (2019)
	Environmental committees	+	Rankin et al. (2011); Peters and Romi (2014); Liao et al. (2015); Córdova et al. (2018); Jaggi et al. (2018)
Environmental performance	Independent risk management committees	+	Krishnamurti and Velayutham (2018)
	Effectiveness of the board of directors	+	Ben-Amar and McIlkenny (2015)
	High carbon companies	+	Choi et al. (2012); Amran et al. (2014); Peng et al. (2015); Halkos and Skouloudis (2016); Ben-Amar et al. (2017); Ott et al. (2017); Jaggi et al. (2018); He et al. (2019); Lemma et al. (2019); Luo (2019)
	Low carbon companies	-	Dawkins and Fraas (2011); Gallego-Álvarez et al. (2011); Tauringana and Chithambo (2015); Guenther et al. (2016); Giannarakis et al. (2017; 2018)
	Environmental and carbon performance	0	Stanny and Ely (2008); Freedman and Jaggi (2011)
Institutional characteristics	Developed country	+	Amran et al. (2014); Grauel and Gotthardt (2016)
	Government regulation	+	Reid and Toffel (2009); Grauel and Gotthardt (2016); Guenther et al. (2016)
		-	Luo (2019)
	Policies and regulations	+	Cowan and Deegan (2011); Tauringana and Chithambo (2015)
	Kyoto Protocol	+	Freedman and Jaggi (2005; 2011); Gallego-Álvarez et al. (2011)
	Carbon trading market	+	Luo et al. (2012); Liesen et al. (2015); Luo (2019); Schiemann and Sakhel (2019)
	Environmental management systems	+	Rankin et al. (2011); Qian et al. (2018)
	Corporate social responsibility initiative	+	Halkos and Skouloudis (2016); Giannarakis et al. (2018)
Stakeholders	State-owned enterprises	+	Giannarakis et al. (2018); He et al. (2019)
		-	Choi et al. (2012)
	Stakeholders' pressure	+	Cotter and Najah (2012); Sullivan and Gouldson (2012); Liesen et al. (2015); Gonzalez-Gonzalez and Zamora Ramirez (2016); Kalu et al. (2016); Tang and Demeritt (2018); He et al. (2019)
	Media reports	+	Guenther et al. (2016); Li et al. (2017; 2018)

Note: +: positive effect; -: negative effect; 0: no effect.

of corporate governance, and the corresponding findings are provided below.

First, independent directors (Amran et al., 2014; Liao et al., 2015) and female directors (Prado-Lorenzo and Garcia-Sanchez, 2010; Ben-Amar et al., 2017) positively affect corporate CID. Prado-Lorenzo and Garcia-Sanchez (2010) used 283 enterprises participating in CDP in 28 countries as samples and found that the gender diversity of the board of directors is conducive to CID, whereas board size negatively affects CID. On the basis of the sustainability reports of 111 enterprises in 13 countries in the Asia-Pacific region, Amran et al. (2014) confirmed that enterprises with a large proportion of independent and female directors in the board have a high level of CID, whereas enterprises with CEO-chair duality¹⁾ have a low level of CID.

The impacts of board size and CEO-chair duality on the CID of enterprises are controversial. Prado-Lorenzo and Garcia-Sanchez (2010) argued that board size negatively affects corporate CID. Tauringana and Chithambo (2015) and He et al. (2019) stated that the carbon disclosure level is high when the board size is large. Prado-Lorenzo and Garcia-Sanchez (2010) argued that CEO-chair duality positively affects CID. However, several scholars pointed out that enterprises with CEO-chair duality have a low level of CID (Amran et al., 2014; Krishnamurti and Velayutham, 2018; He et al., 2019).

In addition, setting up an environmental committee in the board of directors is conducive to promoting CID (Rankin et al., 2011; Peters and Romi, 2014; Jaggi et al., 2018), but the establishment of independent risk management committees has no impact on CID (Krishnamurti and Velayutham, 2018). After analyzing enterprises listed in FT (Financial Times) 500 and S&P (Standard & Poor's) 500 from 2002 to 2006, Peters and Romi (2014) suggested that the establishment of environmental committees and having a Chief Sustainability Officer are conducive to GHG disclosure. The size, number of members, and number of meetings of environmental committees and the professional knowledge of the Chief Sustainability Officer also affect the possibility of CID. Ben-Amar and McIlkenny (2015) examined 200 enterprises participating in CDP in Canada as samples and reported that the effectiveness of the board of directors is positively related to corporate CID.

In summary, most studies have reached an agreement, that is, the proportion of independent directors, the proportion of female directors, the establishment of environmental committees in the board of directors, and the effectiveness of the board of directors positively affect corporate CID. Meanwhile, disputes about the impact of board size and CEO-chair duality on corporate CID still exist. Notably, several studies indicated that CEO-chair duality is not conducive to corporate CID.

5.3 Environmental performance

Environmental performance factors often include the level of corporate carbon emissions and environmental performance. Existing relevant studies adopted three main viewpoints.

First, enterprises with high carbon emission levels are inclined to practice CID. Ben-Amar et al. (2017) argued that enterprises with high carbon emissions industries are likely to respond to investors' demands to disclose climate change risks. Meanwhile, in industries with high carbon emission levels, other factors may exert a significant positive impact on CID (Liao et al., 2015; Jaggi et al., 2018). Liao et al. (2015) indicated that corporate governance and establishment of environmental committees exert significant positive impacts on corporate CID in industries with low carbon intensity. Jaggi et al. (2018) also reported that in high-pollution industries, the impact of environmental committee, institutional ownership, and board independence on corporate CID is highly prominent.

Second, enterprises with low carbon emission levels and good environmental performance are inclined to disclose carbon information. Dawkins and Fraas (2011) found a positive correlation between environmental performance and climate change disclosure by examining the CDP data of S&P 500 enterprises. On the basis of the CDP data of Global 500 enterprises during 2008–2011, Guenther et al. (2016) reached a similar conclusion that enterprises' carbon emission performance is positively related to their disclosure of carbon emissions. Meanwhile, enterprises with good carbon emission performance in non-carbon-intensive industries, enterprises with good carbon emission performance in carbon-intensive industries, and enterprises with poor carbon emission performance in non-carbon-intensive industries have a CID degree that goes from high to low.

Third, several scholars argued that no relationship exists between environmental performance or carbon performance and CID (Stanny and Ely, 2008; Freedman and Jaggi, 2011). Stanny and Ely (2008) did not find evidence that enterprises in carbon-intensive industries are likely to implement CID.

Other studies showed that the determinants of responding to CID differ from those of releasing CID reports. Ott et al. (2017) used 11187 enterprises in 60 countries from 2006 to 2010 as samples and reported that the response of CID is positively related to enterprises' profitability, release of social responsibility report, and ISO14000 certification. Meanwhile, the release of CID is positively correlated with environmental performance, market concentration, and other factors.

In summary, the results on the impact of environmental performance factors on corporate CID are not in agree-

1) CEO-chair duality: The chairman of the company also serves as the CEO.

ment. Although the view that enterprises with high carbon emission levels prefer CID prevails slightly, many studies have argued that enterprises with low carbon emission levels prefer CID. Thus, further detailed studies and discussions are required.

5.4 Institutional characteristics

National background, government and regulatory authorities, laws, regulations, and policies also play important roles in enterprises' responses to carbon emission reduction. Several scholars have suggested that compared with enterprise features and stakeholders, national background characteristics and public and government attitudes have more serious impact on CID (Luo et al., 2012; Grauel and Gotthardt, 2016). The effects of institutional characteristics on corporate CID are summarized from the following five aspects.

First, several scholars have indicated that compared with enterprises in developing countries, those in developed countries are more inclined to implement CID. Amran et al. (2014) found that enterprises in developed countries are more likely to disclose climate change information in their sustainability reports than those in developing countries. Grauel and Gotthardt (2016) studied the impact of national background on the CID decision-making of listed enterprises based on CDP covering 2379 enterprises in 51 countries from 2011 to 2013. Their results indicated that the likelihood of enterprises from the common law legal system implementing CID in CDP reports is high.

Second, several scholars have argued that enterprises in regions with strict government regulation are inclined to implement CID (Reid and Toffel, 2009; Grauel and Gotthardt, 2016; Guenther et al., 2016). For example, after analyzing the CDP of S&P 500 enterprises in 2007 and 2008, Reid and Toffel (2009) found that enterprises under high pressure from shareholders and government regulation are likely to disclose their carbon information. Moreover, enterprises whose headquarters' locations are strictly regulated are inclined to disclose carbon information. Similarly, Grauel and Gotthardt (2016) confirmed that the response rate of CDP varies considerably among different countries in the world, and the degrees of strictness and execution of national environmental regulations are positively correlated with the CID tendency of enterprises. However, Luo (2019) argued that under the background of strict carbon regulation, the negative correlation between CID and carbon performance is weakened, that is, the feasibility of CID as a legitimate tool is weakened.

Third, other scholars have found that policies and regulations positively affect corporate CID. For instance, Cowan and Deegan (2011) confirmed that environmental regulations, such as the National Greenhouse and Energy Reporting Act of 2007, may force enterprises to voluntarily

disclose extensive carbon emission information. Taurin-gana and Chithambo (2015) used 215 listed enterprises in the FTSE (Financial Times and Stock Exchange) 350 index from 2008 to 2011 as samples and suggested that the release of the Department for Environment, Food, and Rural Affairs' guidance on greenhouse gas disclosure in the UK in 2009 has a positive impact on CID levels.

Fourth, the Kyoto Protocol (Freedman and Jaggi, 2005; 2011; Gallego-Álvarez et al., 2011), carbon trading market (Luo et al., 2012; Liesen et al., 2015; Schiemann and Sakhel, 2019), and other environmental regulatory means are conducive to enhancing the tendency of CID or have a positive moderating effect on the related impact of CID. Using 120 enterprises from 20 countries as samples, Freedman and Jaggi (2005) indicated that enterprises in countries that have signed the Kyoto Protocol tend to disclose more detailed carbon information than those that have not signed. Luo et al. (2012) and Liesen et al. (2015) considered EU's ETS in their control variables and found that ETS positively affects CID. According to Schiemann and Sakhel (2019), ETS is a moderating variable between carbon risk disclosure and information asymmetry, and the disclosure degree of the carbon risk of enterprises participating in ETS is negatively correlated with the information asymmetry of investors; meanwhile, that of enterprises not participating in ETS is the opposite. In addition, the existence of corporate environmental management systems (Qian et al., 2018; Rankin et al., 2011) and corporate social responsibility initiative (Halkos and Skouloudis, 2016; Giannarakis et al., 2018) also influences CID.

Fifth, several studies considered the nature of relevant enterprises when CID is involved. Giannarakis et al. (2018) and He et al. (2019) showed that state-owned enterprises are more inclined to disclose climate change information compared with private enterprises. By contrast, Choi et al. (2012) argued that state-owned enterprises disclose less greenhouse gas information than private enterprises do.

In summary, among all studies on the influencing factors of CID, those on institutional characteristics are more comprehensive, and they include eight perspectives, such as developed countries, government regulation, and policies and regulations. The theories applied in these studies are mainly legitimacy theory and institutional theory, and a consistent point of view has been obtained; that is, developed countries, regions with strict government regulation, policies and regulations, the Kyoto Protocol, the carbon trading market, and the state-owned nature of enterprises play important and positive roles in corporate CID.

5.5 Stakeholders

Stakeholders and public opinion are also crucial in

corporate response to carbon emission reduction. The main arguments in relevant researches can be summarized into two aspects.

First, investors, markets, and social pressures play important roles in encouraging voluntary CID. For instance, after examining 500 enterprises in the FTSE index in 2009, Cotter and Najah (2012) suggested that the level and quality of CID are related to the expectations of institutional investors for this information. Kalu et al. (2016) found that social pressure and financial market are key determinants of CID on the basis of the annual reports of 126 real estate enterprises in Malaysia in 2013. In addition, by using 176 enterprises in the FTSE 100 index as samples, Tang and Demeritt (2018) argued that economic interests, social pressure, and regulatory pressure are important drivers of corporate CID.

Second, several scholars have identified the impact of media reports on corporate CID and indicated that media reports can effectively promote information disclosure. Guenther et al. (2016) argued that as one of the stakeholders, the media positively affects corporate CID. Similarly, in their study of Chinese firms in heavy-pollution industries from 2009 to 2014, Li et al. (2017) reported that the greater the pressure of public opinion caused by the media is, the more carbon information is disclosed by a firm. Moreover, media reporting can positively moderate the effect of CID on equity financing costs. On the basis of China's CDP report from 2008 to 2012, Li et al. (2018) used media reports to reflect environmental legitimacy and found that low environmental legitimacy of enterprises equates to high CID probability.

In general, existing studies on the influencing factors of CID mainly highlighted the influence of enterprise features, corporate governance, environmental performance, institutional characteristics, and stakeholders. Enterprise features and institutional characteristics are the most frequently considered factors in existing studies, and the findings of relevant studies have reached relatively high consensus. In recent years, enterprise features have been mostly used as control variables in the research on other influencing factors. The effects of environmental performance, board size, and CEO-chair duality in the corporate governance factor on CID remain controversial and require further investigation in the future.

6 Consequences of CID

Compared with research on the influencing factors of CID, that on the consequences of CID is slightly insufficient. Relevant studies often focused on four aspects, namely, the impact of CID on enterprise performance, ecological environment, investors' decision-making, and others.

6.1 Enterprise performance

For the impact of CID on enterprise performance, most relevant studies have shown that CID positively affects firm value (Griffin and Sun, 2013; Matsumura et al., 2014; Saka and Oshika, 2014), corporate financial performance (Borghei et al., 2018; Ganda, 2018), agency cost (Zhou et al., 2018), and various benefits (Blanco et al., 2017). For example, on the basis of the carbon emission data of listed enterprise in the S&P 500 index from 2006 to 2008, Matsumura et al. (2014) confirmed that the mid-value of enterprises with CID is significantly higher than that of enterprises without CID. Borghei et al. (2018) analyzed the content of annual reports of Australian enterprises from 2009 to 2011 and discovered that the return on assets of enterprises increases within one year after CID. On the basis of the annual reports of listed manufacturing enterprises in China from 2010 to 2014, Zhou et al. (2018) found that high CID quality equates to a low agency cost of enterprises.

However, several scholars have discovered that due to the high cost of disclosure, CID cannot provide good economic benefits to relevant enterprises and even reduces the profitability of enterprises (Griffin et al., 2017; Lee et al., 2015). In particular, Lee et al. (2015) used South Korean enterprises participating in CDP from 2008 to 2009 as samples and argued that voluntary carbon disclosure negatively affects the shareholder value.

In addition, other studies have reported that corporate CID has no correlations with firm value (Bimha and Nhamo, 2017) nor is it conditionally related (Kim and Lyon, 2011). For instance, by using the top 100 enterprises of JSE (Johannesburg Stock Exchange) as samples, Bimha and Nhamo (2017) studied the correlations between CID and stock price fluctuation and found that after the enterprises that regularly or irregularly participate in CDP disclose carbon information, the changes in their stock prices are almost equally affected. Kim and Lyon (2011) did not find direct evidence that CDP can increase the corporate shareholder value. However, when the external environment becomes sensitive to climate change, participation in CDP can increase the shareholder value of the enterprise.

6.2 Ecological environment

Several studies showed that CID is beneficial to carbon emission reduction and ecological environment improvement (Akpalu et al., 2017; Qian and Schaltegger, 2017). For example, on the basis of the CDP reports of Global 500 enterprises from 2008 to 2012, Qian and Schaltegger (2017) found that improvement of corporate CID encourages enterprises to improve their carbon performance.

However, most studies suggested that CID does not

contribute to carbon reduction and ecological improvement (Matisoff, 2013; Liesen et al., 2015; Tang and Demeritt, 2018) or has a limited effect (Knox-Hayes and Levy, 2011; Liesen et al., 2017; Broadstock et al., 2018). For example, Matisoff (2013) discovered that CID programs in the US do not affect the carbon emissions or intensity at the factory level. Similarly, Knox-Hayes and Levy (2011) argued that CID does not necessarily significantly reduce carbon emissions. Liesen et al. (2017) used 433 European enterprises from 2005 to 2009 as samples and argued that CID and carbon performance are only marginally related.

6.3 Investors' decision-making

Environmental disclosure may help enterprises signal their environmental improvement behavior to the market, and CID must be associated with consumer decision-making in order to achieve carbon emission reduction (Matisoff, 2013; Matisoff et al., 2013). With regard to the impact of CID on investors' decision-making, two main arguments can be found.

On the one hand, most studies affirmed that CID may have an impact on investors' decision-making, including positive (Griffin et al., 2017; Haigh and Shapiro, 2011; Liesen et al., 2017; Motoshita et al., 2015) and negative (Lee et al., 2015) impacts. For instance, Haigh and Shapiro (2011) argued that carbon emission reports play a certain role in investors' assessment of corporate governance. Through analysis of an Internet survey on Japanese residents, Motoshita et al. (2015) pointed out that CID may help encourage consumers to show low-carbon preference in shopping mode, but Lee et al. (2015) argued that investors tend to view CID as bad news.

On the other hand, several studies were skeptical about the impact of CID on investors' decision-making. For instance, Harmes (2011) argued that mainstream investors are unlikely to neglect enterprises' inherent weaknesses because of their CID and then make a moral investment in them. In particular, Sullivan and Gouldson (2012) found that voluntary CID in the market cannot meet the needs of investors.

In addition, other scholars conducted research on CID from the perspective of carbon labeling. Liu et al. (2016) reviewed studies on carbon labeling and argued that carbon labeling places positive and negative pressure on manufacturers, retailers, and other investors. Sorensen (2009) posited that consumers may not notice the existence of carbon labeling, but Upham et al. (2011) pointed out that carbon labeling helps consumers make more sensible choices.

6.4 Other aspects

Several studies reported that CID can improve corporate

transparency and reduce information asymmetry. For example, Matisoff et al. (2013) used CDP reports from 2003 to 2010 as samples and found that CID can improve corporate transparency in Japan, EU, and energy-intensive industries. On the basis of the CDP reports of 717 European enterprises from 2011 to 2013, Schiemann and Sakhel (2019) confirmed that the information asymmetry between investors and enterprises that voluntarily disclose carbon physical risk is lower than that between investors and enterprises that do not disclose carbon information.

Other studies identified the impact of CID on capital cost and cost of equity capital. With JSE100 enterprises from 2010 to 2015 as samples, Lemma et al. (2019) confirmed that the quality of CID is negatively correlated with capital costs. On the basis of listed enterprises in Chinese heavily polluted industries from 2009 to 2013, Li et al. (2019) found that CID reduces the cost of equity capital, and the degree of marketization positively moderates the negative correlations between CID and cost of equity capital.

In addition, several studies indicated that CID can improve stock market liquidity (Krishnamurti and Velayutham, 2018), promote carbon management systems (Tang and Luo, 2014), enhance corporate reputation (Knox-Hayes and Levy, 2011), and improve organizational legitimacy (Pellegrino and Lodhia, 2012).

In general, studies on the consequences of CID are relatively few and need to be further explored in the future. Whether corporate CID can improve firm value and corporate financial performance and influence investors' decision-making remain controversial at present. Nevertheless, the positive economic consequence of CID clearly prevails. Regarding the impact of CID on the ecological environment, existing studies had different opinions, but most studies showed that CID has not played a positive role in carbon emission reduction or ecological environment improvement. Therefore, whether corporate CID can improve the ecological environment needs to be further explored to obtain robust research conclusions. In addition, existing studies on the consequences of CID revealed the characteristics of weak theoretical framework and lack of impact mechanisms. Specifically, most theoretical applications are only based on legitimacy theory or voluntary disclosure theory without the combination with other theories. Most previous studies grazed only the surface of the issue and did not perform an in-depth investigation of the impact mechanisms.

7 Conclusions and future research directions

This study focused on researches on CID worldwide. It reviewed the research trend, theoretical bases, and features of CID and related studies on the influencing factors and

consequences of CID in recent years. Several conclusions were soundly drawn as follows.

First, in the research on the features of CID, the disclosure data were mostly from CDP reports. Although the proportion of enterprises disclosing carbon information is increasing, the content and quality of disclosure are still insufficient to satisfy the requirements of investors, and the comparability of carbon information is weak.

Second, in the research on the influencing factors of CID, a consensus has been reached regarding the effects of many factors on corporate CID, including enterprise feature (firm size, profitability, foreign sales ratio, disclosure history, corporate reputation, and leverage ratio), institutional characteristics (developed countries, government regulation, policies and regulations, the Kyoto Protocol, carbon trading market, corporate environmental management systems, corporate social responsibility initiative, and enterprise nature), corporate governance (independent directors and female directors), and stakeholders (investors, market and social pressure, and media reports). However, several disputes about the impact of environmental performance and corporate governance (board size and CEO-chair duality) on corporate CID still exist.

Lastly, in the research on the consequences of CID, although different arguments exist regarding the impact of corporate CID, most studies affirmed the positive role of CID on enterprise performance and investors' decision-making. However, most studies also indicated that CID does not significantly contribute to carbon emission reduction and ecological environment improvement.

Relevant research work is still in its infancy due to the short history of CID practice, and certain problems still need to be solved in future research. On the basis of existing literature and the actual need for a global response to climate change, this study also proposed several important research directions for CID to be explored in the future.

First, in terms of research content, further attention should be paid to the related consequences of CID. Compared with the research on influencing factors, the research on the consequences of CID is relatively scarce. Given that stakeholders concentrate on corporate carbon management, relevant enterprises face increasing carbon reduction challenges and legitimacy pressure. They need to understand the impact of CID in various aspects. Therefore, the consequences of CID (not only economic consequences but also non-economic consequences, such as corporate sustainable development, technological progress, and social welfare) should be provided increased attention.

Second, the impact mechanism should be explored in depth when the influencing factors and consequences of CID are concerned. Existing literature focused on the "direct effect" of the influencing factors and consequences

of CID, whereas the research on the influence mechanism, including the indirect effect, is scarce. Exploration of such an impact mechanism constitutes an important direction for further understanding the impact of CID. Meanwhile, institutional characteristics and environmental performance have been proven to be important influencing factors of corporate CID, and whether heterogeneity exists in the consequences of enterprises with different institutional characteristics and environmental performance is worth exploring. Specifically, future research could investigate whether the various consequences of CID are consistent between developed and developing countries and between high-carbon and non-high-carbon enterprises in developing countries.

Third, multiple theories must be integrated into the research on CID to provide a solid theoretical foundation for such research. In existing literature, stakeholder theory, legality theory, and agency theory have been widely applied in the study of factors affecting CID. However, studies on the consequences of CID lack a theoretical basis, and several of them are based only on legitimacy theory or voluntary disclosure theory. Future research needs to incorporate more theoretical foundations to predict and explain existing problems in an in-depth manner.

Fourth, we should not only focus on whether CID is implemented in enterprises, but also pay attention to the quality of CID. The research objects should focus more on developing countries and high-carbon and heavy-pollution enterprises. As mentioned above, the objects in existing research were mainly enterprises in developed countries of Europe and America or the world's top 500 enterprises dominated by the tertiary industry. Studies on developing countries, such as China with high-carbon emissions, and enterprises in high-carbon-emission industries are few. In fact, studies based on high-carbon-emission samples are likely to reflect the relevant impacts of CID and have more significance in carbon emission reduction and green development than those based on low-carbon-emission samples.

Lastly, under different disclosure channels, whether heterogeneity exists in the research results on corporate CID is worth exploring. For instance, existing data from CID research were mainly obtained from CDP and corporate reports, and data from different channels are not comparable. Whether heterogeneity exists in the influencing factors and consequences of corporate CID remains to be investigated using data from different disclosure channels. Meanwhile, carbon information disclosed via online platforms and media should be paid increased attention. In the future, with the progress and diffusion of big data mining techniques, additional micro-level data from online platforms and media will become available for CID research, and these will provide solid and rich research conclusions.

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