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Management Quality and Carbon Emission Disclosures

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Abstract

Our paper explores the association between management quality and carbon emission disclosures. We assert that high-quality managers have more abilities and resources to measure and manage their firm's carbon emissions, leading to increased voluntary carbon emission disclosures. As expected, our results show that high-quality management is positively associated with the likelihood of carbon emission disclosures. After controlling for self-selection bias, we further find that high-quality management can enhance the positive effects of carbon emission disclosures on market value. Finally, we observe that high-quality managers are positively associated with reduced carbon emissions. Overall, our study offers an incremental contribution to the extant literature by showing that management quality is a key factor driving carbon emission disclosures.

Keywords: Management quality, carbon emission disclosure, market value

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1. Introduction

Given extreme climate change and global warming, carbon emission information disclosures, which provide information to capital investors, have received increasing attention. Although firms are not required to disclose their carbon emission information, some firms decide to provide this information voluntarily. This study analyzes the association between management quality and voluntary carbon emission disclosures.

The core objective of a firm's top management team is to create value for the firm by making value-added decisions that help the firm to improve its performance. Upper echelon theory indicates that the organization reflects its top management team (Hambrick and Mason 1984). The personal characteristics of top managers, such as cognitive structure, values, and beliefs, play a critical role in decision-making, thus influencing the firm's strategic choices (Hambrick and Mason 1984). Several studies document that management characteristics, including team size, education, functional background, gender, and tenure, have a significant impact on a firm's accounting choices, such as disclosures and earnings management, capital investment efficiency, innovations, and international diversification (Tihanyi, Ellstrand, Daily, and Dalton 2000; Carpenter, Geletkanycz, and Sanders 2004; Chemmanur and Paeglis 2005; Frinkelstein, Hambrick, and Cannella 2009; Cheng, Lee, and Shevlin 2016; Hambrick, Cho, and Chen 1996; Lai and Liu 2018; Zhang 2019). However, there is scarce research exploring whether top management team characteristics that reflect management team quality affect voluntary carbon information disclosures, carbon emission reduction, and firm value. Our paper aims to fill this gap.

Our research topic is important because environmental investments require managers with specific expertise and innovative attitudes. This enables them to quickly design and implement carbon emission reduction strategies, develop and provide green services and products, and effectively mitigate both the environmental and legal risks (Berrone and Gomez-Mejia 2009). To report carbon emission information and reduce carbon emissions, top managers must identify the footprint of carbon emissions, measure carbon emissions, and quantify their firm's contribution to carbon emissions.

Carbon emission information resides within different top management teams, including sustainability, treasury, and reporting team. Collecting, measuring, and reporting this information requires managers to work more closely with other team members. Additionally, carbon emission reports and reduction require different team managers to invest in technology for information collection, analysis, management, and reporting across the business. Top management with more resources and abilities can integrate information relating to regulations, carbon emissions, and financial data into a more cohesive carbon emission reporting process, thereby affecting the likelihood of voluntary carbon emission disclosures.

We posit that management quality can influence a firm's carbon emission disclosure decisions in several ways. First, high-quality managers have more knowledge to manage, measure, and report carbon emission of their firms, thus increasing management's abilities to make a net zero carbon emission strategy. Second, high-quality managers have more resources to allocate to environmental investments that help to investigate the source of carbon emissions and to reduce carbon emissions, leading to better carbon reduction strategies. Finally, higher-quality managers are more reputable, and they are more willingness to manage and reduce carbon emissions to avoid regulators' attention (Blacconiere and Patten 1994) and signal a carbon-reducing strategy to outsiders. These factors increase managers' willingness to voluntarily reveal their firm's carbon emission information.

To test our hypotheses, we use public firms in Taiwan as our research sample because these firms are subject to the Greenhouse Gas Reduction and Management Act (GGRMA) and are entrenched in a reasonably homogeneous institutional context. Under GGRMA, firms in high carbon-emitting industries are subject to governmental and political pressure to investigate carbon emissions.[1] In practice, firms in low carbon-emitting industries also engage in carbon emission investigations based on GGRAM. Nonetheless, firms undergoing carbon emission investigations are not required to disclose the carbon emission information publicly.

While there is no mandatory requirement, the Taiwan Securities and Exchange Act encourages firms to voluntarily reveal greenhouse gas (GHG) emissions (i.e., carbon emissions) and reduction information in corporate social responsibility reports. Carbon emission information can be found on the Market Observation Post System (MOPS) website.[2] Thus, investors and other stakeholders have a convenient channel to obtain carbon emission information. Furthermore, companies report their GHG emission information in corporate social responsibility (CSR) reports. To increase our sample size. we collect information on environmental sustainability from CSR reports and corporate websites.

We use several measures of top management characteristics to capture management quality, which is based on prior studies (e.g., Chemmanur and Paeglis 2005; Chemmanur, Paeglis, and Simonyan 2009). First, top management abilities rely on the team members' knowledge. Therefore, we use team members' education, prior working experience, and financial/accounting expertise to capture the abilities of top management. Specifically, expertise in financial and accounting typically has knowledge in financial reporting, compliance, and internal controls (Hoitash, Hoitash, and Johnstone 2012). Financial/accounting expertise working closely with sustainability, treasury, and reporting team members would be beneficial to integrate information

[1] These industries including electric, cement, iron and steel, optoelectronic and semiconductor, paper, textile, and printing and dyeing industries.

[2] https://emops.twse.com.tw/server-java/t58query.

related to regulations, carbon emissions, and financial data into a more cohesive carbon emission reporting process.

Second, we use the size of the top management team to capture the level of management team resources (e.g., Chemmanur and Paeglis 2005). Larger management teams are more likely to have necessary resources to manage and measure carbon emissions for their firms. Third, we consider management team reputation, measured by the number of nonprofit boards on which members of the top management team sit. Finally, to capture overall management quality, we employ common factor analysis to obtain a management quality score. We also create another proxy, a total score of management quality, by aggregating indicators from the five individual measures of top management characteristics.

Based on hand-collected voluntary carbon emission data from 2015 to 2020, our results show that high-quality management is positively associated with the likelihood of voluntary carbon emission disclosures. Specifically, we find a positive association between both the management quality score and the total score of management quality with voluntary carbon emission disclosures. Moreover, the results show that management team size, team members' prior working experience, team member education, team members with financial/accounting expert, and management reputation are positively associated with the voluntary disclosure of carbon emissions. In sum, we find that high-quality managers are more willingness to disclose carbon emission information.

Prior studies provide mixed results related to impact of carbon emission disclosures on firm/market value. On the one hand, carbon emission disclosures positively affect market value by signaling firm quality, thereby reducing information asymmetry (Griffin and Sun 2013; Schiemann and Sakhel 2019; Han, Huang, Liu, and Hsu 2023). On the other hand, carbon emission disclosures reduce market value because the disclosure of carbon emissions creates litigation risk, increases compliance costs, and imposes proprietary costs on the firm (Li, Richardson, and Thornton 1997; Matsumura, Prakash, and Vera-Muñoz 2014; Griffin, Lont, and Sun 2017).

After controlling for self-selection bias, we find that carbon emission disclosures are positively associated with firm value when the firm has high-quality management. In particular, we find that the positive evaluation effects are stronger for firms disclosing carbon emission information. Our findings suggest that top management quality has verifying effects on the disclosure of carbon emission information, thus resulting in a positive effect on market valuation. These findings offer an incremental contribution to the extant literature by demonstrating that management quality matters to investors in evaluating carbon emission information.

If voluntary emission disclosures signal management's ability and resources to measure and reduce carbon emissions, we would observe a negative relation between changes in management quality and changes in level of carbon emissions. By focusing on a subsample of firms disclosing

carbon emissions, we find that changes in management quality are, in fact, negatively associated with changes in the level of carbon emission. That is, increased management quality can lead to a decrease in carbon emissions. This finding is consistent with the notion that better management teams have better abilities and more resources to reduce carbon emissions. Thus, our study adds to prior literature by examining the determinants of carbon emission performance (e.g., Haque 2017).

Our study makes several contributions. First, prior research finds that management quality affects information quality, financing policies, and capital investment decisions (Chemmanur and Paeglis 2005; Chemmanur et al. 2009; Lai and Liu 2018). Our study extends this stream of literature by showing that management quality affects voluntary carbon emission disclosures.

Second, our research adds to a bunch of studies investigating the determinants of voluntary carbon emissions. One stream of literature finds that firm characteristics (e.g., firm size, leverage, market capitalization, firm performance), corporate governance characteristics (e.g., number of independent directors, sex of directors), and executive compensation are the main factors affecting voluntary carbon emission disclosures (Prado-Lorenzo, Rodriguez-Dominguez, Gallego-Alvarez, and Garcıa-Snchez 2009; Prado-Lorenzo and Garcia-Sanchez 2010; Liao, Luo, and Tang 2015; Ben-Amar, Chang, and McIlkenny 2017; Ott, Schiemann, and Günther 2017; Hollindale, Kent, Routledge, and Chapple 2019; Luo, Wu, and Zhang 2021). We show that management quality is an important driver influencing carbon emission disclosures, which distinguishes our investigation from existing studies.

Finally, our study complements current literature examining the impact of carbon emission disclosures on market value (Clarkson, Fang, Li, and Richardson 2013; Chapple, Clarkson, and Gold 2013; Matsumura et al. 2014; Clarkson, Li, Pinnuck, and Richardson 2015; Griffin et al. 2017; Han et al. 2023). We find that high-quality management can enhance the positive effects of carbon emission disclosures on firm value. This finding provides new evidence that disclosure of carbon emission information, provided by the high-quality management, can signal the quality of emission reduction for these firms, which reduces information asymmetry, thus leading to stronger positive market valuation.

2. Institutional Context, Literature, and Hypothesis Development

2.1. Carbon emission disclosure of Taiwan firms

Given extreme climate changes, managers have faced increasing pressure from investors and regulators to measure, disclose, and reduce the carbon emissions of their firms. In 2015, the Paris Agreement stated its objective to create a global framework for reducing global GHG

emissions by restraining global warming to well below 2°C. In Taiwan, the GGRM became effective in the fiscal year beginning July 1, 2015. Under GGRM, firms in high-emitting industries are required to review and/or test to determine the reliability of the GHG inventory and emissions reduction by the verification body. Firms must report emissions, allocations, and reductions of carbon dioxide equivalent to the governance agency. The GGRM also encourages firms in low-emitting industries to engage in carbon emission investigations. Despite the regulatory implications of the GGRM, carbon emission disclosure continues as a voluntary practice in Taiwan. That is, firms with carbon emission investigations are not required to disclose the information publicly.

While there is no mandatory disclosure requirement, the Taiwan Securities Exchange Act (i.e., the Sustainable Development Best Practice Principles for TWSE Listed Companies 2014, 2020) encourages firms to voluntarily reveal GHG emissions. In practice, based on the GGRM, Taiwan public firms voluntarily provide carbon emission and reduction information in their CSR reports. Those disclosures can be found in MOPS.

2.2. Literature on voluntary carbon emission disclosure

A growing number of studies investigates the determinants of voluntary carbon emission disclosures. The literature shows that firm characteristics such as firm size, leverage, and market-to-book ratio are positively associated with the disclosure of carbon emissions, while return on equity is negatively associated with carbon emission disclosures (Prado-Lorenzo et al. 2009). Clarkson, Li, and Richardson (2008) find that firms with poor environmental performance are more likely to increase disclosures to obscure their poor performance. Luo, Lan, and Tang (2012) show that social, economic, and regulatory pressures are the main factors driving firms to report carbon emission information.

Furthermore, prior research shows that firms' corporate governance characteristics affect the disclosure of carbon emission information (Prado-Lorenzo and Garcia-Sanchez 2010; Peters and Romi 2014; Liao et al. 2015; Ben-Amar et al. 2017; Hollindale et al. 2019). Using a sample of US firms, Peters and Romi (2014) report that firms that create an environmental committee and employee a chief sustainability officer are more likely to reveal GHG emissions information. Liao et al. (2015) find that the number of independent board members and board gender diversity have a positive effect on voluntary disclosure of GHG emissions. Similarly, Ben-Amar et al. (2017), studying Canadian firms, find that the inclusion of female directors has a positive effect on voluntary carbon emission disclosures. Based on a sample of Australian firms, Hollindale et al. (2019) also find female directors are positively associated with voluntary carbon emission disclosures. Finally, Haque (2017) shows that board independence, board gender diversity, and environment-, social-, and governance-based compensation policies are positively related to carbon emission reduction initiatives. However, Prado-Lorenzo and Garcia-Sanchez (2010) show that the board of directors and carbon emission disclosure are inversely related.

Studies examining the economic consequence of carbon emission disclosures focus on stock market valuation, and the results are mixed. One stream of literature shows that carbon emission disclosures result in negative market valuation. For example, Griffin and Sun (2013) find that GHG emission disclosures result in positive returns to shareholders. Chapple et al. (2013) explore the impact of voluntary carbon emission disclosure on market value by analyzing 58 publicly traded Australian firms. They find that carbon-intense firms suffer a penalty of 6.57 percent of market capitalization. Clarkson et al. (2015) focus on European firms and find negative effects on firm market value. Using hand-collected carbon emission data for US firms, Matsumura et al. (2014) find that a negative relation exists between voluntary carbon emission and firm value. Further, they show that capital market investors impose more penalties on firms that do not reveal carbon emission information. Recently, using a sample of US firms, Griffin et al. (2017) find that the stock market reacts negatively to firms that do not report carbon emissions. In addition, they find that firms experience an increase in stock trading volume when they do reveal carbon information.

Another stream of literature finds that carbon emission disclosures positively affect firm value. Griffin and Sun (2013) show that firms that disclose information related to carbon emissions have positive market reactions. Also, Clarkson et al. (2013) find that voluntary environmental disclosures enhance value relevance, which can have positive impacts on firm value. Similarly, Han et al. (2023) indicate that voluntary carbon emission disclosures in Taiwanese firms have positive effects on firm value. Schiemann and Sakhel (2019) focus on European firms and find that firms revealing physical risks have lower information asymmetry measured by bid-ask spread.

However, no research explores whether management quality affects voluntary carbon emission disclosures. Based on hand-collected data for publicly listed Taiwanese firms, we fill this gap in the literature by exploring whether and, if so, how management quality influences firm's voluntary carbon emission disclosures.

2.3. Literature on upper echelon theory

Upper echelon theory indicates that the top managers' personal characteristics and group characteristics influence the firm's strategic decisions (Hambrick and Mason 1984). Prior studies (e.g., Chemmanura and Paeglis 2005; Chemmanur et al. 2009) use top management team size to measure for management team quality. The size of the top management team reflects the level of management team resources and abilities (Chemmanura and Paeglis 2005). Prior research shows that management team size is positively associated with team resources, which can improve decision making (Amason and Sapienza 1997).

Top management characteristics such as team members' education, prior working experience, and financial/accounting expertise reflect the knowledge and abilities of top

management. Education background can reveal manager ability, skills, and knowledge (Hambrick and Mason 1984). For example, top managers with a high level of education, such as an MBA degree, are more likely to possess sophisticated techniques to solve the problem, leading to better decision-making and performance (Barker and Mueller 2002). Lewis, Walls, and Dowell (2014) find that CEOs with an MBA degree are positively related to carbon emission disclosures. Lai and Liu (2018) indicate that management team members with an MBA degree can enhance the firm's reputation, reducing information asymmetry and lowering cost of capital.

Prior executive experience enables top managers to obtain information from their external relations, which helps develop essential insights into investment decisions (Tihanyi et al. 2000). Furthermore, prior executive experience can reflect managers' psychological abilities and tendencies, such as knowledge, skills, and values (Hambrick and Mason 1984), which affects managers' decisions. This suggests that top management members with prior executive experience have more abilities in making decisions.

The duties of Chief of financial officer (CFO) have a positive influence on firms' strategic and financial decisions (Ge, Matsumoto, and Zhang 2011; Core, Matsunaga, and Yeung 2011). Specifically, management team members with financial/accounting expertise are likely to improve the way they communicate with investors by revealing information. This implies management team members with financial/accounting expertise are more likely to increase information disclosures.

Finally, managers with memberships in other firms' boards of directors provide an effective channel for information flow among firms, facilitating the transmission of accounting knowledge and practices (Intintoli, Kahle, and Zhao 2018). In addition, managers with memberships in other firms' boards of directors are more reputable, which has positive effect on firm decisions (Chemmanura and Paeglis 2005).

2.4. Hypotheses development

We hypothesize that high-quality managers have more abilities and resources to measure and manage their firm's carbon emissions, leading to increased voluntary carbon emission disclosures. As discussed in section 2.3, based on upper echelon theory, we use several top management team characteristics to capture the quality of top management team. We first conjecture that larger management teams are more likely to have the abilities and resources to manage, measure, and report carbon emissions for their firms. For example, a larger management team size has more resources to allocate towards environmental investments to collect carbon emission data and to reduce carbon emissions. Furthermore, a larger management team size has an ability to efficiently address carbon emission problems by building a low-carbon ecosystem and creating better carbon reduction strategies.

Management team members with an MBA degree have a deep knowledge of business

management, making them more skilled in carbon emission decision making and more capable of identifying the benefits of voluntary carbon emission disclosures. Moreover, team members with an MBA degree can employ more sophisticated valuation techniques for making environmental investment decisions, helping the management team to make better carbon reduction choices.

Managers with prior executive experiences can access carbon emission manager and investment information from other firms, leading to increased willingness to report carbon emission information and to invest in carbon emission reduction. In addition, the appointment of managers with prior executive experience to the management team can positively affect the firm's reputation, reducing information asymmetry and mitigating financial constraints, which further leads to increased investments in carbon emission reductions.

Financial/accounting expertise typically encompasses the financial reporting, compliance, internal control knowledge (Hoitash et al. 2012). Such knowledge may allow them to works closely with sustainability, treasury, and reporting team members to integrate information relating to regulations, carbon emissions, and financial data into a more cohesive carbon emission reporting process. This leads to increased voluntary carbon emission disclosures.

Managers with memberships in other firms' board of directors are often more reputable, and they tend to proactively manage and reduce carbon emissions to avoid scrutiny by regulators. Additionally, the experience gained from their involvement with other firms can be shared with other team members in the sustainability team, thereby increasing the willingness and ability of management to collect, measure, and report carbon emissions.

As previously discussed, we predict that high-quality management, measured by team size, team members with an MBA degree, team members with prior executive experience, team members with memberships in other firms' boards of directors, and team members with financial/accounting expertise, is positively associated with voluntary disclosure of carbon emissions. This leads to our first hypothesis (in an alternative form):

H1: *High-quality managers are positively associated with the voluntary disclosure of carbon emissions.*

Prior studies show that corporate social responsibility (CSR) is positively associated with firm value (Servaes and Tamayo 2013). Furthermore, Servases and Tamayo (2013) find firms with higher customer awareness can enhance this positive association. Several studies show that voluntary environmental disclosures have positive effect on firm value. For example, Clarkson et al. (2013) find that voluntary environmental disclosures enhance value relevance, which can have positive impacts on firm value. Also, Han et al. (2023) show that by reducing information asymmetry, voluntary carbon emission disclosures are positively related to firm value. Focusing on voluntary environmental discloser quality, Plumlee, Brown, Hayes, and Marshall (2015) suggest that through the effect of both the cash flow and the cost of equity, voluntary

environmental quality is positively related to firm value.

Our paper extends these studies and considers the effect of management team quality on firm value. Prior studies (e.g., Allen and Faulhaber 1989; Chemmanur and Paeglis 2005) indicate that high-quality managers can enhance investor trust in the equity market by conveying more credible information about the firm's fundamental value, thereby reducing information asymmetry. As such, a firm's top management quality can have verifying effects on the disclosures of carbon emission information. In other words, high-quality managers who voluntarily reveal carbon emission information can improve investors' trust in the firm by showing that they are better able to manage the firm's carbon emissions. This is consistent with the notion that voluntary disclosures reduce information asymmetry between managers and investors (Healy, Hutton, and Palepu 1999; Healy and Palepu 2001), thereby improving firm value. This leads to our second hypothesis:

H2: *High-quality managers have a positive effect on the voluntary disclosure of carbon emissions, which, in turn, increases firm value.*

Finally, we explore whether high-quality managers are more likely to reduce carbon emissions. Corporate management usually acts in a self-interested manner and is unwilling to invest in carbon emission reduction because such decisions require long-term investments without providing immediate financial gains (Liao et al. 2015). Moreover, prior studies indicate that environmental investments require executives with specific expertise and innovative attitudes, enabling them to quickly design and implement carbon emission reduction strategies, develop and provide green services and products, and mitigate environmental and legal risks (Berrone and Gomez-Mejia 2009). This implies that management team quality may play an important role in carbon emission reduction. If high-quality managers can effectively reduce carbon emissions, then better top management characteristics should lead to a decrease in carbon emissions. By analyzing the relationship between changes in top management quality and changes in carbon emission levels, we investigate whether higher quality managers possess more resources and abilities to manage and reduce their firm's carbon emissions. Thus, we state our third hypothesis:

H3: *High-quality managers are positively associated with reduced carbon emissions.*

3. Research Design

3.1. Measure of management quality

To measure management quality, we follow previous research (Chemmanur and Paeglis 2005; Chemmanur et al. 2009; Lai and Liu 2018) and collect information about top executives'

work tenure, previous career, educational background, and associations of directors in other firms from the corporate database of Taiwan Economic Journal (TEJ).

We identify management quality, along several characteristics of top management, including size of top management (*MTSIZE*), top management with MBA degree (*MPMBA*), top management with prior career track of executive officers (*MPEXE*), top management with other firms' membership of directors (*MTBOARD*), and top management with career path of finance or accounting expertise (*MPFERT*).

Although we use the measures of top management (*MTSIZE*, *MPMBA*, *MPEXE*, *MTBOARD*, and *MPFERT*) to capture management quality, each measure of management quality has inevitable limitations as a proxy of the original unobservable construct. Thus, we employ common factor analysis, which has been widely used in previous research (e.g., Gaver and Gaver 1993; Guay 1999; Chemmanur and Paeglis 2005, Chemmanur et al. 2009), to extract a single management quality score (*MQUALITY*) for the individual measures of top management, which is more likely to reflect the variables common to the observable measure of management quality. Appendix A provides a detailed description of the common factor analysis of the management quality score.

Furthermore, another measure is calculation of the total score from the five individual variables of management quality. For each variable of *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*, a binary variable equal to one if it is greater than the median, and zero otherwise. Total score of management quality (*SCOREMQUALITY*) is an aggregate of the five binary variables, which is between 0 and 5.

3.2. Measure of carbon emissions disclosure

We manually collect data on direct (scope 1) and indirect (scope 2) carbon emissions. Next, we aggregate direct and indirect carbon emission amounts to obtain a single carbon emission measure.

To capture whether firms reveal carbon emission information, we create a binary variable, *DISCO2*, which equals to 1 if a firm reports carbon emission information to MOPS in year *t*, and 0 otherwise.

3.3. Disclosure of carbon emissions and management quality

We first analyze whether management quality is associated with managers' willingness to voluntarily disclose their firm's carbon emission information. To explore the relation between management quality and carbon emission disclosure choice, we employ the Probit model:

$$DISCO2_t = \beta_0 + \beta_1 QOM_{t-1} + \beta_2 FRNSALE_{t-1} + \beta_3 ENV\_ISO_{t-1} + \beta_4 ENV\_IRRG_{t-1} + \beta_5 INSINVESTOR_{t-1} + \beta_6 SIZE_{t-1} + \beta_7 BTM_{t-1} + \beta_8 LEV_{t-1} + \beta_9 CGRANK_{t-1} + \sum \beta_i IndFE + \sum \beta_i YearFE + v_t \quad (1)$$

where *DISCO2* is a binary variable that is equal to 1 if a firm reports carbon emission to MOPS in year *t*, and zero otherwise. The coefficient of the main variable (*QOM*) is β_1. A positive coefficient on *QOM* represents a positive relation between the quality of management and the disclosure of carbon emissions. To assess the quality of management (*QOM*), we use both a management quality score (*MQUALITY*) and a total score of management quality (*SCOREMQUALITY*).[3]

For control variables (Matsumura et al. 2014), we include average tenure of top management (*MTENURE*).[4] In addition, we include environmental-related variables (*ENV_ISO* and *ENV_IRRG*), foreign sales (*FRNSALE*), and institutional investors (*INSINVESTOR*), as suggested by Han et al. (2023). Furthermore, we incorporate firm size (*SIZE*) and expect that larger firms are more likely to release information on carbon emissions. We also include firm growth, using the ratio of book value-to-market value (*BTM*). In addition, we add financial leverage (*LEV*) and expect that firms with higher leverage are more likely to reveal information of carbon emissions. Several studies find that firms' disclosure choices related to carbon emissions are associated with the likelihood of a certain corporate governance structure, such as an independent board of directors and the inclusion of female directors (Prado-Lorenzo and Garcia-Sanchez 2010; Amran, Lee, and Devi 2014; Liao et al. 2015; Ben-Amar et al. 2017; Hollindale et al. 2019). Thus, we control for the corporate governance effect by using a ranking value of corporate governance evaluation results (*CGRANK*). Appendix B provides definitions of all variables used in this study.

Finally, industry dummies for two-digit TEJ codes of industry classification are included to control for industry fixed effects. We also add year dummies to control for year fixed effects. In the Equation (1), we cluster the standard errors at the firm level.

3.4. Market value, carbon emission disclosure, and management quality

As described in H2, we assert that a firm's top management quality can have verifying effects on the disclosure of carbon emission information, resulting in positive effects on market

[3] We provide supplementary analyses for each variable of management quality (*MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, *MTBOARD*) in section 4.5.

[4] In their empirical models, Chemmanur and Paeglis (2005) show that heterogeneity in tenure of top management is highly correlated with average tenure of top management. We only include average tenure of top management as an additional control variable in our empirical analyses. When we replace average tenure of top management with heterogeneity tenure of top management, our findings are similar.

valuation. Therefore, we explore whether management quality improves the market value of firms that reveal carbon emission information.

Because firms can voluntarily choose to disclose carbon emissions, the empirical test on market value has a self-selection bias. To control for self-selection, we employ a two-stage estimating approach (Heckman 1979).[5] We add instrumental variables: *FRNSALE*, *ENV_ISO*, *ENV_IRRG*, *INSINVESTOR* and *BTM*. These variables are correlated with the Heckman first-stage model of carbon emission disclosures but have not been included in the second-stage model of market value.[6]

To evaluate the market value of carbon emission disclosures and management quality, we use the valuation model from the balance sheet, which is widely used in previous literature (e.g., Barth and McNichols 1994; Campbell, Sefcik, and Soderstrom 2003; Matsumura et al. 2014; Han et al. 2023). We estimate the inverse Mill's ratio (*IMR*) from the first-stage model of carbon emission disclosure. We then include *IMR* value in the second-stage of market value model:

$$\begin{aligned} MV_t = {} & \beta_0 + \beta_1 DISCO2_t + \beta_2 QOM_t + \beta_3 DISCO2_t \times QOM_t + \beta_4 MTENURE_t + \beta_5 SIZE_t \\ & + \beta_6 LEV_t + \beta_7 ORTNI_t + \beta_8 CGRANK_t + \beta_9 SALES + \beta_{10} PTB + \beta_{11} CAPINT + \beta_{12} SRET \\ & + \beta_{13} IMR + \sum \beta_i IndFE + \sum \beta_i YearFE + v_t \end{aligned} \quad (2)$$

where *MV* is *MKTVAL* scaled by total assets; *MKTVAL* is the market value of common stock, which is computed as outstanding shares (in NT$ millions) multiplied by price per share at the end of the year; and *DISCO2* is a binary variable that is equal to 1 if a firm reports carbon emission to MOPS in year *t*, and zero otherwise.

Examining H2, we expect positive coefficients on the interaction terms between quality of management (*QOM*) and the variable of carbon emission disclosure (*DISCO2*). We use two proxies for management quality (*QOM*): *MQUALITY* and *SCOREMQUALITY*. We predict a positive coefficient on the interaction term (*DISCO2* × *QOM*).

Consistent with previous studies on valuation model (Barth and McNichols 1994; Campbell et al. 2003; Matsumura et al. 2014; Han et al. 2023), we control for *SIZE* and *LEV*; we predict

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[5] We use the limited information maximum likelihood method instead of the full information maximum likelihood (FIML) method because the two-stage estimator of limited information maximum likelihood is more robust than FIML (Wooldridge 2002, p. 566). We also estimate the regression using FIML, and the results are not changed (data not reported).

[6] Prior research (Larcker and Rusticus 2010; Lennox, Francis, and Wang 2012) propose that to control for self-selection effectively, the exclusion conditions must restrict at least one independent variable in the Heckman first-stage model, which must not correlate with the dependent variable in the second-stage model. The exclusion conditions can alleviate the coefficient bias of multicollinearity from the first-stage model to the second-stage model. *IMR* is included in the market value model to control for self-selection. The value of variance inflation factor on the inverse Mill's ratio (IMR) is <3, suggesting no multicollinearity in our empirical models.

a positive effect on *SIZE* and a negative effect on *LEV*. To control for firm performance, we include a variable on operating income (*ORTNI*) and predict a positive effect. We control for the corporate governance ranking (*CGRANK*) and predict a positive effect. Following Ioannou, Li, and Serafeim (2016), we also control for the sales (*SALES*), market value to book value of equity (*PTB*), capital intensity (*CAPINT*) and stock return (*SRET*).

Finally, industry dummies for two-digit TEJ codes of industry classification are included to control for industry fixed effects. We also add year dummies to control for year fixed effects. In the Equation (2), we cluster the standard errors at the firm level.

3.5. Changes in carbon emissions and changes in management quality

To analyze whether high-quality management is more likely to reduce carbon emission levels, we employ difference regression approaches to provide evidence on the causal relation between management quality and lower carbon emission levels.[7] If high-quality managers reduce the amount of carbon emissions, then high-quality management should be negatively related to an increase in carbon emissions. To explore the relation between changes in management quality and changes in the level of carbon emissions, we use a difference regression model:

$$\Delta QCO2_t = \beta_0 + \beta_1 \Delta QOM_t + \beta_2 \Delta SIZE_t + \beta_3 \Delta LEV_t + \beta_4 \Delta CGRANK_t + \beta_5 \Delta SALES + \beta_6 \Delta PTB + \beta 7 \Delta CAPINT + \beta_8 \Delta SRET + \sum \beta_i IndFE + \sum \beta_i YearFE + v_t \quad (3)$$

where Δ*QCO2* is the change in the amount of carbon emissions (*QCO2*), and all other variables are calculated as change in level from the prior year to the current year. We predict a negative coefficient on the change management quality (Δ*QOM*). We use two proxies for the change management quality (Δ*QOM*): Δ*MQUALITY* and Δ*SCOREMQUALITY*.

3.7. Sample selection

To achieve their corporate social responsibility and promote sustainable development, some public firms in Taiwan voluntarily reveal climate-related information such as GHG emissions based on the voluntary principles outlined in the Sustainable Development Best Practice Principles for TWSE Listed Companies (2014, 2020) in its CSR reports.[8] These disclosures are commonly found in the MOPS.

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[7] Using the difference regression can mitigate concerns about unobservable omitted characteristics of time-invariant, resulting in lower of the standard errors in the difference regression, and increasing statistic power.

[8] https://twse-regulation.twse.com.tw/m/en/LawContent.aspx?FID=FL052368

Based on GHG emission and reduction information in MOPS, we manually collect carbon emissions information on environmental sustainability from CSR reports and corporate websites. This is because companies are required to report their GHG emission information in CSR reports. The data include information about direct (scope 1) and indirect (scope 2) carbon emissions. We choose our sample period from 2015 to 2020 for two reasons. First, GGRM became effective in the first fiscal year beginning after July 1, 2015.[9] Second, we end our sample period in 2020 to avoid the confounding effects of the Covid-19 pandemic from 2021-2022.

Our other data come from various databases. First, our financial data are obtained from the financial report database of TEJ, and our measures of management quality are collected from the corporate database of TEJ. The corporate governance evaluation results are hand-collected from the corporate governance evaluation system conducted by the Securities and Futures Institute for the Taiwan Stock Exchange Corporation and the Taipei Exchange.

Of the original 13,279 firm-year observations, we exclude 4,432 observations for which data necessary to conduct our empirical analyses are missing, including financial data (2,910 firms), top executive data (826 firms), and corporate governance data (696 firms). The final sample contains 3,719 Taiwanese firm-year observations for firms reporting carbon emission information (the DISCO2 sample) and 5,128 Taiwanese firm-year observations without carbon emissions disclosure (the NDISCO2 sample). Table 1 provides the sample distribution of observations by year and industry.

Panel A of Table 1 provides the sample distribution of carbon emissions disclosures for the respective DISCO2 and NDISCO2 samples from 2015 to 2020. The results indicate that a slight increase in observations in the DISCO2 subsample, from 38.83% in 2015 to 46.81% in 2020. Conversely, a decreasing trend is observed in the NDISCO2 subsample from 61.17% in 2015 to 53.18 3% in 2020.

Panel B of Table 1 presents the industry distribution of the 8,847 firm-year observations for DISCO2 and NDISCO2 samples. Of the DISCO2 sample, several industries are more likely to disclose carbon emissions. A half of the observations (49.21%) come from the information sector, followed by chemical (8.34%), mechanical electronics (6.24%), textile and synthetic fiber (4.95%), and other (4.52%).[10] In contrast, some industries are less likely to report carbon emissions. More than a half of the NDISCO2 observations come from the information sector (50.68%), followed by chemical (9.93%), mechanical electronics (8.89%), and other (5.87%).

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[9] https://oaout.epa.gov.tw/law/EngLawContent.aspx?lan=E&id=253

[10] In the industry classifications of the TEJ database, the information industry consists of computer systems, motherboards, optoelectronics/IO, electronic components, network equipment, semiconductors, electronic instruments, communication apparatus, IT channels, consumer electronics, software service, and other electronics.

Table 1 Distribution of Carbon Emission Disclosure

Panel A: Distribution of carbon emission disclosure by year					
	Total	DISCO2 observation		NDISCO2 observation	
Year	N	N	%	N	%
2015	1,347	523	38.83	824	61.17
2016	1,419	560	39.56	859	60.54
2017	1,434	574	40.03	860	59.97
2018	1,509	646	42.81	863	57.19
2019	1,553	674	43.40	879	56.60
2020	1,585	742	46.81	843	53.18
Total	8,847	3,719	42.04	5,128	57.96

Panel B: Distribution of carbon emission disclosure by industry					
	Two-digit industry code	DISCO2 observations		NDISCO2 observations	
Industry		n	%	n	%
Cement	11	58	1.56	13	0.25
Food products	12	123	3.31	48	0.94
Petrochemical and rubber	13	128	3.44	79	1.54
Textile and synthetic fiber	14	184	4.95	141	2.75
Mechanical electronics	15	232	6.24	456	8.89
Electric wire	16	24	0.65	36	0.70
Chemical	17	310	8.34	509	9.93
Ceramic and glass	18	25	0.67	10	0.20
Papermaking	19	23	0.62	11	0.21
Iron and steel	20	138	3.71	183	3.57
Rubber and tire	21	45	1.21	24	0.47
Automobile	22	48	1.29	30	0.59
Information	23	1,830	49.21	2,599	50.68
Construction and building	25	157	4.22	360	7.02
Transportation, all	26	97	2.61	63	1.23
Tourism	27	63	1.69	153	2.98
Bank and insurance	28	15	0.40	5	0.10
General merchandise	29	51	1.37	107	2.09
Other	99	168	4.52	301	5.87
Total		3,719	100.00	5,128	100.00

Note: Table 1 provides year and industry distribution of disclosure on carbon emissions in Taiwan from 2015 to 2020. There are 3,719 firm-year observations with carbon emission disclosure in the Taiwanese MOPS (DISCO2 sample) and 5,128 firm-year observations without carbon emission disclosure (NDISCO2 sample). The industry codes follow industry classifications of TEJ database.

4. Empirical Results

4.1. Descriptive statistics

Panel A of Table 2 reports summary statistics for our variable of interest, carbon emission disclosures, as well as an individual measure of management quality, management quality score, and control variables used in the model analysis. The average percentage of carbon emission disclosure (*DISCO2*) is approximately 42%, indicating that less than a half of firms are likely to voluntarily reveal carbon emission information to MOPS. The average level of carbon emission (*QCO2*) is significantly more than the median *QCO2*, representing substantial carbon emitters, consistent with the finding of Matsumura et al. (2014). Further, the average management quality score (*MQUALITY*) is close to zero, which is higher than the median value (−0.07). This finding is similar to that of Chemmanur and Paeglis (2005) and Chemmanur et al. (2009). The average total score of management quality (*SCOREMQUALITY*) is 2.73, which is close to the median value (3.00).

Table 2, Panel A also shows that the average management team size (*MTSIZE*) is 4.43, the average percentage of top management with MBA degree (*MPMBA*) is 37%, the average percentage of top management with prior career track of executive officers (*MPEXE*) is 26%, the average percentage of top management with career path of finance or accounting expertise (*MPFERT*) is 21%, the top managers with other firms' membership of directors (*MTBOARD*) are 1.17, and the average tenure of top management (*MTENURE*) is 9.32.

Panel B of Table 2 provides the difference in means (medians) test for two subsamples when the full sample is separated by firms that voluntarily disclose carbon emissions to MOPS (DISCO2) and those that do not (NDISCO2). We present *t*-tests of the means and Wilcoxon rank-sum tests of the medians for each of the samples. The average management quality score (*MQUALITY*), total score of management quality (*SCOREMQUALITY*), and management quality variables (i.e., *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*) are significantly larger for the DISCO2 sample than for the NDISCO2 sample. However, the average tenure of top management (*MTENURE*) is insignificantly different between the two samples. These results support H1 that high-quality managers increase the likelihood of disclosure on carbon emission information to MOPS.

Table 2, Panel B also compares the mean or median difference of control variables for the two samples. Both the firm size (*SIZE*), the book-to-market ratio (*BTM*), and sales (*SALES*) are higher for DISCO2 firms than for NDISCO2 firms. The means and medians of *CGRANK, MKTVAL*, and *ORTNI* are also larger for DISCO2 firms than for NDISCO2 firms. These findings suggest that disclosing firms have higher market value, better operating performance, and better corporate governance than non-disclosing firms.

Table 2 Descriptive Statistics

Panel A: Sample summary statistics

Variable	Mean	Q1	Median	Q3	SD
DISCO2	0.42	0.00	0.00	1.00	0.49
QCO2 (in metric tons)[a]	1,163,158.25	4,695.00	51,379.19	363,237.00	4,418,828.93
MQUALITY	0.00	−0.54	−0.07	0.45	0.99
SCOREMQUALITY	2.73	2.00	3.00	4.00	1.31
MTSIZE	4.43	2.00	3.00	6.00	3.82
MPMBA	0.37	0.00	0.33	0.52	0.32
MPEXE	0.26	0.00	0.20	0.50	0.30
MPFERT	0.21	0.00	0.17	0.33	0.26
MTBOARD	1.17	0.00	1.00	2.00	1.74
MTENURE	9.32	5.27	8.55	12.65	5.36
FRNSALE	0.55	0.12	0.66	0.92	0.38
ENV_ISO	0.02	0.00	0.00	0.00	0.13
ENV_IRRG	0.02	0.00	0.00	0.00	0.14
INSINVESTOR	0.42	0.24	0.41	0.60	0.23
SIZE	15.40	14.38	15.20	16.19	1.47
BTM	0.99	0.53	0.87	1.30	0.71
LEV	0.42	0.28	0.42	0.55	0.18
CGRANK	3.16	1.00	3.00	5.00	2.13
SALES	14.86	13.87	14.79	15.85	1.81
PTB	1.90	0.91	1.35	2.13	2.99
CAPINT	0.31	0.01	0.02	0.06	3.31
SRET	0.13	−0.13	0.04	0.26	0.49
MKTVAL (NT$ millions)	14,447.05	1,392.00	3,220.00	8,722.00	47,497.48
ORTNI (NT$ millions)	922.07	−0.36	150.72	576.34	3,301.30

Panel B: Partition of sample by *DISCO2*

	DISCO2 (Obs. = 3,719)[b]		NDISCO2 (Obs. = 5,128)[b]		*t*-stat	Wilcoxon *z*-stat
Variable	Mean	Median	Mean	Median		
MQUALITY	0.31	0.16	−0.24	−0.21	27.04***	24.85***
SCOREMQUALITY	2.98	3.00	2.55	3.00	15.37***	15.67***
MTSIZE	5.47	4.00	3.68	3.00	20.41***	20.16***
MPMBA	0.40	0.40	0.34	0.33	7.90***	9.43***
MPEXE	0.29	0.25	0.24	0.14	7.80***	9.36***
MPFERT	0.25	0.20	0.17	0.13	14.92***	11.61***
MTBOARD	1.68	1.00	0.80	0.00	22.01***	21.53***
MTENURE	9.42	8.75	9.25	8.39	1.48	1.27

Table 2 Descriptive Statistics (continue)

Panel B: Partition of sample by *DISCO2*						
FRNSALE	0.56	0.68	0.54	0.64	2.65***	2.65***
ENV_ISO	0.03	0.00	0.01	0.00	7.50***	8.20***
ENV_IRRG	0.03	0.00	0.01	0.00	6.43***	6.93***
INSINVESTOR	0.48	0.48	0.38	0.36	20.17***	19.66***
SIZE	16.24	16.05	14.78	14.72	50.44***	46.15***
BTM	1.08	0.94	0.93	0.82	9.35***	9.34***
LEV	0.43	0.43	0.40	0.41	6.87***	6.65***
CGRANK	3.66	4.00	2.79	3.00	19.12***	18.79***
SALES	15.81	15.71	14.18	14.27	45.74***	44.88***
PTB	1.73	1.29	2.02	1.39	−4.97***	−5.68***
CAPINT	0.13	0.02	0.44	0.02	−2.67***	−0.46
SRET	0.13	0.06	0.12	0.02	0.63	4.71***
MKTVAL (NT$ millions)	27,279.68	7,240.00	5,140.38	1,964.50	19.35***	43.75***
ORTNI (NT$ millions)	1,818.28	408.96	272.12	77.59	19.48***	30.79***

Note: [a] *QCO2* is the amounts of carbon emissions. [b]DISCO2 sample is carbon emission disclosure. NDISCO2 sample is not carbon emission disclosure. We remove outliers by winsorizing all continuous variables at the top and bottom 1%. Two-sample test of means (medians) is based on *t*-statistic (Wilcoxon *z*-statistic). ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively. See Appendix B for definitions of variables.

Table 3 provides the Pearson (Spearman) correlations between our main variables under (over) the diagonal. Disclosure of carbon emissions (*DISCO2*) is positively correlated with our management quality measures (i.e., *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*), management quality score (*MQUALITY*) and total score of management quality (*SCOREMQUALITY*), consistent with H1 that high-quality managers are prone to increase disclosure of their carbon emission information.

MKTVAL and *DISCO2* are significant and positively correlated, suggesting that disclosing firms have higher market value than non-disclosing firms (Table 3). *MKTVAL* is positively correlated with individual measures of management quality (i.e., *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*), management quality score (*MQUALITY*) and total score of management quality (*SCOREMQUALITY*). These findings support H2 that high-quality managers are more prone to disclose carbon emission information, which improves market value.

The correlations between management quality score (*MQUALITY*), total score of management quality (*SCOREMQUALITY*) and individual measures of management quality (i.e., *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*) are significantly positive (Table 3). These findings suggest that the management quality score and the total score of management

Table 3 Pearson (Spearman) Correlation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) *MKTVAL*	1.00	0.47***	0.40***	0.27***	0.34***	0.16***	0.17***	0.17***	0.36***
(2) *DISCO2*	0.23***	1.00	0.26***	0.17***	0.21***	0.10***	0.10***	0.12***	0.23***
(3) *MQUALITY*	0.32***	0.29***	1.00	0.55***	0.73***	0.26***	0.56***	0.53***	0.68***
(4) *SCOREMQUALITY*	0.12***	0.16***	0.50***	1.00	0.52***	0.45***	0.50***	0.16***	0.63***
(5) *MTSIZE*	0.31***	0.23***	0.76***	0.33***	1.00	0.15***	0.19***	0.24***	0.42***
(6) *MPMBA*	0.05***	0.08***	0.20***	0.40***	0.07***	1.00	0.13***	−0.03***	0.16***
(7) *MPEXE*	0.12***	0.08***	0.44***	0.38***	0.07***	0.11***	1.00	−0.17***	0.29***
(8) *MPFERT*	0.11***	0.15***	0.63***	0.03***	0.32***	−0.04***	−0.20***	1.00	−0.09***
(9) *MTBOARD*	0.37***	0.25***	0.74***	0.46***	0.59***	0.12***	0.21***	−0.18***	1.00

Note: Pearson (Spearman rank) correlation matrix is provided under (above) the diagonal. We remove outliers by winsorizing all continuous variables at the top and bottom 1 percent. For parsimony, the values of variance inflation factors among control variables are not reported (all variance inflation factor values < 10).See Appendix B for definitions of variables. ***, **, * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

quality parsimoniously explain the intercorrelations between the individual measures of management quality.

4.2. Regression analysis

4.2.1. Management quality and voluntary carbon emission disclosure

H1 predicts that high-quality management is more willingness to voluntarily reveal carbon emission information. Columns (1) and (2) of Table 4 employ a Probit model of Equation (1) to analyze the relationship between management quality and choice to reveal carbon emission information. The management quality score (*MQUALITY*) and the total score of management quality (*SCOREMQUALITY*) are positively associated with the disclosure of carbon emissions. Namely, the coefficients on *MQUALITY* and *SCOREMQUALITY* are positive and significant (p-value < 0.05). These results support H1 that firms with higher management quality are more likely to disclose carbon emission information. Finally, the coefficients on the control variables *SIZE*, *BTM*, *LEV*, and *CGRANK* are positive and significant (p-value < 0.01). In other words, larger firms with higher financial leverage and better book-to-market ratio and corporate governance are more likely to disclosure on carbon emission information.

4.2.2. Market value effects of carbon emission disclosure and management quality

Next, we employ a regression model to test H2. To control for choice of disclosure on carbon emissions, we employ a two-stage approach to alleviate self-selection bias (Heckman 1979). Specifically, we calculate the inverse Mill's ratio (*IMR*) from the Heckman first-stage

Table 4 Probit Model For Disclosure of Carbon Emissions

	Dependent variable = *DISCO2*			
	(1) *QOM* = *MQUALITY*		(2) *QOM* = *SCOREMQUALITY*	
Variables	Coeff.	z-statistic	Coeff.	z-statistic
Intercept	9.028***	15.69	9.526***	17.85
QOM	0.124***	2.98	0.067**	2.12
MTENURE	0.003	0.50	0.001	0.09
FRNSALE	0.111**	2.28	0.112**	2.32
ENV_ISO	0.094	0.76	0.077	0.52
ENV_IRRG	−0.239**	−2.08	−0.242**	−2.10
INSINVESTOR	0.063***	2.37	0.039	0.j85
SIZE	0.601***	14.75	0.627***	16.04
BTM	0.095***	4.11	0.099***	5.22
LEV	0.643***	6.65	0.636***	5.80
CGRANK	0.017***	2.85	0.022***	3.66
IndFE	Yes		Yes	
YearFE	Yes		Yes	
Observations	8,847		8,847	
Pseudo-R^2	0.303		0.301	
Likelihood ratio χ^2	3,188.38***		3,125.18***	

Note: This table provides results for the probit model of disclosure on carbon emissions. The proxies for management quality (*QOM*) are management quality score (*MQUALITY*) and total score of management quality (*SCOREMQUALITY*). Columns (1) and (2) provide the coefficients and *z*-statistic for management quality score (*MQUALITY*) and total score of management quality (*SCOREMQUALITY*). We control year fixed effects and include industry fixed effects following the industry classifications of Taiwan Economic Journal database. *z*-statistics are calculated after we adjust standard errors clustered by firm. See Appendix B for definitions of variables. ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

model and then included it in the second-stage model. Table 5 provides the results of market value regression.

Column (1) of Table 5 show that the estimated coefficients on the *MQUALITY* and the interaction term of *DISCO2* × *MQUALITY* are positive and significant (*p*-value < 0.01).[11] When we replicate these results by employing total score of management quality (*SCOREMQUALITY*). That is, we estimate Equation (2) by replacing the quality of management (*QOM*) with *SCOREMQUALITY* and then testing its interaction with *DISCO2*. In column (2) of Table 5, we find similarly positive and significant coefficients on the *SCOREMQUALITY* and the interaction term

[11] We also provide mediation analysis of management quality score, carbon emission disclosure, and market value in Table A2.

of *DISCO2* × *SCOREMQUALITY* (*p*-value < 0.05). Taken together, the results in Table 5 show that voluntary carbon emission disclosures positively affect market value when firms have high-quality management.

Consistent with prior research on market value, we find positive and significant coefficients on *SIZE*, *ORTNI*, *CGRANK*, *PTB*, and *SRET* but a negative and significant coefficient on *LEV* (*p*-value < 0.05), indicating that larger firms with less financial leverage and better operating performance, market-to-book ratio, stock return, and corporate governance increase market value in Table 5.

Table 5 Disclosure of Carbon Emissions, Management Quality, and Market Value

	Dependent variable = *MV*			
	(1) *QOM* = *MQUALITY*		(2) *QOM* = *SCOREMQUALITY*	
Variables	Coeff.	*t*-statistic	Coeff.	*t*-statistic
Intercept	5.217***	4.61	4.513***	4.83
DISCO2	0.022	0.39	0.072	0.74
QOM	0.065***	2.83	0.051**	2.16
DISCO2 × *QOM*	0.115***	3.09	0.103***	2.58
MTENURE	−0.015	−0.13	−0.015	−0.10
SIZE	0.189***	4.36	0.157***	3.14
LEV	−1.443***	−7.03	−1.482***	−7.17
ORTNI	1.907**	2.46	1.896**	2.50
CGRANK	0.022*	1.72	0.022*	1.74
SALES	0.038	0.66	0.038	0.68
PTB	0.247***	2.74	0.247***	2.74
CAPINT	−0.003	−1.37	−0.003	−1.37
SRET	0.314***	3.43	0.314***	3.43
IMR	−0.406**	−2.06	−0.318*	−1.82
IndFE	Yes		Yes	
YearFE	Yes		Yes	
Observations	8,847		8,847	
Adjusted R^2	0.235		0.236	

Note: This table provides results to control for selection of carbon emission disclosure. We employ two-stage of Heckman (1979), and estimate the inverse Mill's ratio (*IMR*) from Equation (1) and then add *IMR* in the Equation (2) to correct for self-selection problem. *MV* is defined as *MKTVAL* divided by total assets. We include management quality score (*MQUALITY*) and total score of management quality (*SCOREMQUALITY*). We include industry fixed effects following the industry classifications of TEJ database. *t*-statistics are provided after we adjust standard errors clustered by firm. For parsimony, all variance inflation factor values among control variables are not reported, which are below 3. ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

4.3. Change in management quality and change in carbon emissions

To analyze further whether high-quality management is able to reduce carbon emission levels, we employ an analysis of the relation between change in top management quality and change in the amount of carbon emissions for firms disclosing carbon emission information. Specially, we estimate our difference regression model of Equation (3) by using a subsample of 2,538 firms that disclosed carbon emission information.

We find that change in management quality (Δ*MQUALITY*) is negative and significantly related to change in the amount of carbon emissions (Δ*QCO*2; p-value < 0.05). Similarly, when we replace change in management quality (Δ*MQUALITY*) with change in total score of management quality (Δ*SCOREMQUALITY*), the coefficient is also negative and significant (p-value < 0.05). These results support H3 that high-quality managers are positively associated with reduced carbon emissions. In sum, our findings suggest that higher quality managers have more resources and abilities to manage and reduce their firm's carbon emissions.

Table 6 Changes in Management Quality on Changes in Carbon Emissions

	Dependent variable = Δ*QC*O2			
	(1) Δ*QOM* = Δ*MQUALITY*		(2) Δ*QOM* = Δ*SCOREMQUALITY*	
Variable	Coeff.	*t*-statistic	Coeff.	*t*-statistic
Intercept	1.045	0.47	1.142	1.35
Δ*QOM*	−0.222**	−2.18	−0.215**	−2.07
Δ*MTENURE*	0.005	0.25	0.001	0.06
Δ*SIZE*	−0.435***	−3.60	−0.455***	−3.91
Δ*LEV*	−2.341***	−4.11	−2.343***	−4.15
Δ*CGRANK*	−0.339***	−5.80	−0.337***	−5.72
Δ*SALES*	−0.079	−0.74	−0.085	−0.79
Δ*PTB*	0.074**	1.96	0.069*	1.90
Δ*CAPINT*	0.038	1.26	0.038	1.26
Δ*SRET*	0.118***	2.65	0.120***	2.66
IndFE	Yes		Yes	
YearFE	Yes		Yes	
Observations	2,538		2,538	
Adjusted R^2	0.195		0.196	

Note: We estimate the percentage change in carbon emission as a function of change in management quality, controlling for other variables that are related to carbon emission disclosure. We include management quality score (*MQUALITY*) and total score of management quality (*SCOREMQUALITY*). We include industry fixed effects following the industry classifications of the TEJ database. *t*-statistics are provided after we adjust standard errors clustered by firm. See Appendix B for definitions of variables. ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

4.4 Supplementary analyses of change in individual management quality and change in carbon emissions

Table 7 reports the results of the relation between change in individual management quality and change in carbon emissions. We find that change in management quality measures (i.e., Δ*MTSIZE*, Δ*MPMBA*, Δ*MPFERT*, and Δ*MTBOARD*) are negative and significantly related to change in the amount of carbon emissions (Δ*QCO*2; *p*-value < 0.05). An improvement in individual management quality is generally accompanied by lower carbon emissions. These results suggest that firms with a larger management team, a higher percentage of team members with an MBA, and more team members with financial/accounting expertise, and better reputation are more likely to reduce carbon emissions.

4.5. Supplementary analyses of individual management quality on disclosure of carbon emissions and market value

Column (1) of Table 8 provides results to analyze the relation between individual variables of management quality and choice to reveal carbon emission information. The coefficients on the individual variables of management quality (i.e., *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*) are positive and significant (*p*-value < 0.10). Consistent with H1, firms with a larger management team, a higher percentage of team members with an MBA, and more team members

Table 7 Additional Test of Changes in Individual Management Quality on Changes in Carbon Emissions

	Dependent variable = Δ*QCO*2	
Variable	Coeff.	*t*-statistic
Intercept	1.863	0.92
Δ*MTSIZE*	−0.182**	−1.95
Δ*MPMBA*	−1.582**	−2.14
Δ*MPEXE*	−0.101	−0.86
Δ*MPFERT*	−1.716***	−2.99
Δ*MTBOARD*	−0.373***	−2.71
CONTROLS	Yes	
IndFE	Yes	
YearFE	Yes	
Observations	2,538	
Adjusted R^2	0.185	

Note: We estimate the percentage change in carbon emission as a function of change in management quality, controlling for other variables that are related to carbon emission disclosure. We include industry fixed effects following the industry classifications of the TEJ database. *t*-statistics are provided after we adjust standard errors clustered by firm. See Appendix B for definitions of variables. ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

Table 8 Additional Test of Individual Management Quality on Disclosure of Carbon Emissions and Market Value

	Dependent variable =			
	(1) *DISCO2*		(2) *MV*	
Variables	Coeff.	z-statistic	Coeff.	*t*-statistic
Intercept	9.206***	16.30	5.525***	6.75
MTSIZE	0.027**	2.42	0.018**	2.16
MPMBA	0.136***	2.71	0.093	1.02
MPEXE	0.077**	2.14	0.046	1.01
MPFERT	0.177***	2.60	0.187**	2.17
MTBOARD	0.010*	1.71	0.028	1.44
DISCO2			0.156**	2.41
MTSIZE × *DISCO2*			0.019**	2.49
MPMBA × *DISCO2*			0.246***	3.06
MPEXE × *DISCO2*			0.099**	2.03
MPFERT × *DISCO2*			0.272**	2.44
MTBOARD × *DISCO2*			0.045**	2.16
IMR			−0.191*	−1.80
CONTROLS	Yes		Yes	
IndFE	Yes		Yes	
YearFE	Yes		Yes	
Observations	8,847		8,847	
Pseudo-R^2/Adjusted R^2	0.305		0.207	

Note: This table provides results for each variable of management quality (*MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, *MTBOARD*). Columns (1) and (2) provide the coefficients and *z*-statistic for the probit model of disclosure on carbon emissions. Columns (3) and (4) provide the results of market value to control for selection of carbon emission disclosure. We employ two-stage of Heckman (1979), and estimate the inverse Mill's ratio (*IMR*) from Equation (1) and then add *IMR* in the Equation (2) to correct for self-selection problem. *MV* is defined as *MKTVAL* divided by total assets. We control year fixed effects and include industry fixed effects following the industry classifications of Taiwan Economic Journal database. *z*-statistics are calculated after we adjust standard errors clustered by firm. See Appendix B for definitions of variables. ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

with financial/accounting expertise, prior top management experience, and better reputation are more likely to voluntarily reveal carbon emission information.

Column (2) of Table 8 show a negative and significant coefficient on *IMR* (p-value < 0.10) after the correction for self-selection. The coefficient on *DISCO2* is positive and significant. This result indicates a significant relation between voluntary carbon emission disclosures and market value. As expected, we find individual variables of management quality are positively associated with market value. Specifically, the estimated coefficients on *MTSIZE* and *MPFERT* are positive and significant (p-value < 0.05). Consistent with H2, we find positive and significant coefficients

on the interaction terms between individual variables of management quality (i.e., *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*) and *DISCO2*. The results strongly support that voluntary carbon emission disclosures positively affect market value when firms have a larger management team, a higher percentage of team members with an MBA, and more team members with financial/accounting expertise, prior top management experience, and better reputation.

4.6. Supplementary analyses of individual management quality on market value for subsample of carbon emission disclosures

To provide further evidence on H2, we estimate the following Equation (4) separately for firms disclosing and not disclosing carbon emission information.

$$MV_t = \beta_0 + \beta_1 MTSIZE_t + \beta_2 MPMBA_t + \beta_3 MPEXE_t + \beta_4 MPFERT_t + \beta_5 MTBOARD_t + \beta_6 IMR + \beta_7 CONTROLS_t + \sum \beta_i IndFE + \sum \beta_i YearFE + v_t \quad (4)$$

We predict positive coefficients on the individual variables of management quality (*MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*). Columns (1) and (2) of Table 9 provide the results for subsamples of disclosing and non-disclosing firms, respectively. In column (1), the estimated coefficients on the individual variables of management quality (i.e., *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*) are positive and significant (p-value < 0.10) for firms that disclose carbon emission information. Focusing on firms that do not disclose carbon emission information in column (2), we only find a positive and significant coefficient on *MPFERT*. These results show that the positive effects of a larger management team, a higher percentage of team members with an MBA, and more team members with financial/accounting expertise, prior top management experience, and better reputation are strongest for firms disclosing carbon emission information.

4.7. Carbon emission disclosure, management quality, and carbon emission reduction

To provide additional analysis, we employ a logit regression to examine the relationship between carbon emission disclosure, management quality, and carbon emission reduction. Table 10 presents the results of the relationship between carbon emission disclosure, management quality, and carbon emission reduction.

We find positive and statistically significant coefficients on carbon emission disclosure (*DISCO2*) in columns (1) and (2). For example, the coefficient on *DISCO2* is 3.731 (z-statistic is 4.72) in column (1), and that is 3.927 (z-statistic is 5.19) in column (2). An increase in

Table 9 Additional Test of Individual Management Quality on Market Value For Subsample of Carbon Emission Disclosures

	Dependent variable = *MV*			
	(1) Sample of *DISCO2* = 1		(2) Sample of *DISCO2* = 0	
Variables	Coeff.	*t*-statistic	Coeff.	*t*-statistic
Intercept	4.276***	3.89	17.384***	2.77
MTSIZE	0.004*	1.83	−0.006	−0.29
MPMBA	0.153***	4.25	0.065	0.50
MPEXE	0.020**	2.18	0.163	0.93
MPFERT	0.062***	3.12	0.336*	1.89
MTBOARD	0.009**	1.98	0.013	0.42
MTENURE	−0.004	−0.69	−0.005	−0.81
IMR	−0.159**	−2.45	0.003	0.23
CONTROLS	Yes		Yes	
IndFE	Yes		Yes	
YearFE	Yes		Yes	
Observations	3,719		5,128	
Adjusted R^2	0.241		0.226	

Note: This table provides results to control for selection model of disclosing carbon emissions on the market value. We estimate the inverse Mill's ratio (*IMR*) from the full sample, and then include it for the subsample *DISCO2* = 1 and *DISCO2* = 0, respectively. *MV* is defined as *MKTVAL* divided by total assets. We include industry fixed effects following the industry classifications of the TEJ database. *t*-statistics are provided after we adjust standard errors clustered by firm. For parsimony, all variance inflation factor values among control variables are not reported, which are below 3. See Appendix B for definitions of variables. ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

carbon emission disclosure is generally accompanied by reducing carbon emissions. When we turn to interaction term (*MQUALITY* × *DISCO2*) between carbon emission disclosure and management quality, column (2) reports a positive and significant coefficient on the interaction term (coefficient is 0.829 and *z*-statistic is 3.65). These results provide that a reduction in carbon emission is positively associated with carbon emission disclosures for firms with high-quality management.

Table 10 Carbon Emission Disclosure, Management Quality, and Carbon Emission Reduction

	Dependent variable = *REDUCE_CO2*			
	(1)		(2)	
Variable	Coeff.	*z*-statistic	Coeff.	*z*-statistic
Intercept	1.586	0.22	1.185	0.16
DISCO2	3.731***	4.72	3.927***	5.19
MQUALITY			0.918***	4.16
MQUALITY × *DISCO2*			0.829***	3.65
MTENURE	0.023	0.71	0.026	0.78
SIZE	0.358***	3.42	0.399***	4.58
LEV	0.235**	2.25	0.290***	3.31
CGRANK	0.142**	1.97	0.132*	1.90
SALES	0.078	0.50	0.093	0.61
PTB	0.052	0.61	0.049	0.57
CAPINT	0.016	0.69	0.012	0.48
SRET	0.243**	2.13	0.254**	2.17
IMR	2.165**	2.41	2.183**	2.46
IndFE	Yes		Yes	
YearFE	Yes		Yes	
Observations	8,847		8,847	
Pseudo-R^2	0.377		0.379	

Note: We estimate the logit model of carbon emission reduction. The dependent variable (*REDUCE_CO2*) is a binary variable that is equal to one if the firm has a negative percentage change in carbon emission, and zero otherwise. We include industry fixed effects following the industry classifications of the TEJ database. *t*-statistics are provided after we adjust standard errors clustered by firm. See Appendix B for definitions of variables. ***, **, and * indicate significant percentages (two-tailed) at the 1%, 5%, and 10%, respectively.

5. Conclusion

This study investigates the association between management quality and carbon emission disclosures. We posit that high-quality management has more abilities and resources to measure, manage, and report their firm's carbon emissions, leading to increased voluntary carbon emission disclosures. Based on a sample of Taiwan public firms, we find that, in fact, the presence of high-quality managers is positively associated with the likelihood of a firm's voluntary disclosure of carbon emission.

We further explore whether management quality matters to investors in assessing carbon emission disclosures. After controlling for self-selection bias, we find that carbon emission

disclosures are positively associated with firm value when the firm has high-quality management. Specifically, the positive evaluation effects of high-quality management are stronger for firms that disclose carbon emission information. Thus, the quality of a firm's top management a has verifying effect on the disclosure of carbon emission information, resulting in a positive effect on firm value.

Finally, focusing on a subsample of firms that disclose carbon emission information, we show that an improvement in management quality is positively associated with reduced carbon emissions. This evidence suggests that high-quality managers have more abilities and resources to manage their firms' carbon emissions, leading to a reduction in carbon emission. Overall, our research offers an incremental contribution to the literature by showing that management quality matters to voluntary carbon emission disclosures.

Our study is subject to several limitations that open up opportunities for future research. To address our research question, we include direct emissions (scope 1) and indirect emissions (scope 2) from energy to capture carbon emission information, but we do not include indirect emissions from supply chain and employees (scope 3) due to the unavailability of data. Future research can include this measure for carbon emissions. Second, voluntary disclosures are subject to managerial discretion, and thus the reliability of carbon emissions information may be in question (Kolk, Levy, and Pinkse 2008; Schiemann and Sakhel 2019). Future research may employ mandatory carbon emission disclosures to address climate-related issues.

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Appendix A

Common Factor Analysis of Management Quality Score

To isolate the unobservable characteristics of management quality, Chemmanur and Paeglis (2005) employ common factor analysis to build a factor underlying management quality variables, which is more likely to capture an observable measure of management quality. Therefore, we use common factor analysis on the *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD* variables to extract a management quality score (*MQUALITY*). Table A1 provides the common factor analysis. Panel A reports communalities, which are calculated from regressing management quality score on the individual variables of management quality.

Harman (1976) proposes that the number of factors to estimate the original correlations between variables should be equal to the number of aggregated eigenvalues required to be greater than the aggregate of communalities. Panel A also shows that the aggregated communalities are fewer than the aggregated eigenvalues for *MQUALITY*. The results suggest that one factor is likely to interpret parsimoniously the intercorrelations between the individual variables. Finally, Panel A provides correlations between *MQUALITY* and the respective variables of management quality. Panel B summarizes the descriptive statistics of *MQUALITY*.

Table A1. Common factor analysis of management quality factor

Panel A: Five variables of management quality and MQUALITY					
MQUALITY	*MTSIZE*	*MPMBA*	*MPEXE*	*MPFERT*	*MTBOARD*
Community estimates	0.660	0.085	0.183	0.357	0.621
Eigenvalues of the reduced correlation	2.012	1.233	1.039	0.943	0.816
Correlations	0.763	0.255	0.371	0.566	0.735

Panel B: Descriptive statistics						
	Mean	Min	Q1	Median	Q3	Max
MQUALITY	0.000	−2.225	−0.538	−0.068	0.449	3.960

Mediation analysis of management quality score, carbon emission disclosure, and market value

H2 predicts that high-quality managers (*MQUALITY*) have a positive effect on the voluntary disclosure of carbon emission (*DISCO2*), which, in turn, increases firm value (*MV*). We employ bootstrapping approach for significance testing of mediation effect, as suggested by Preacher and Hayes (2004).

Table A2. Summary of mediation effects

	Estimate	Standard Error	Bootstrap Standard Error	*z*-statistic
Total Effect	0.145	0.018	0.015	7.97***
Direct Effect	0.108	0.019	0.016	5.70***
Indirect Effect	0.037	0.006	0.005	6.62***
Proportion Mediated	25.578	4.979	4.238	5.14***

DISCO2 is a mediation that interprets the relationship between *MQUALITY* and *MV*. A total effect of *MQUALITY* on *MV* in the summary is 0.145. The direct effect of *MQUALITY* is 0.108 and the indirect effect mediated by the *DISCO2* is 0.037 (the difference between total effect and direct effect of *MQUALITY* on *MV*). Notice that the indirect (mediation) effect is significant (*z*-statistic = 6.62) and 26% of the total effect of *MQUALITY* is mediated by *DISCO2*.

Appendix B

Variable definitions

Variables	Definition	Source
DISCO2	A binary variable equal to one if the public firm discloses carbon emissions on CSR reports from MOPS, and corporate websites in Taiwan, and zero otherwise.	MOPS
QCO2	The level of carbon emissions (in metric tons).	MOPS
MQUALITY	Management quality score, which is estimated from common factor analysis on *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD.*	TEJ
SCOREMQUALITY	Total score is calculated from the five individual variables of management quality. For each variable of *MTSIZE*, *MPMBA*, *MPEXE*, *MPFERT*, and *MTBOARD*, a binary variable equal to one if it is greater than the median, and zero otherwise. Total score of management quality is an aggregated value of the five binary variables, which is between 0 and 5.	TEJ
MTSIZE	Number of top managers who have served as executive officers of vice-president or higher positions within the TMTs.	TEJ
MPMBA	Proportion of top managers with a master degree level of business administration (MBA) within the TMT.	TEJ
MPEXE	Proportion of top managers who have served as executives of vice-president and above before they joined the firms.	TEJ
MPFERT	Proportion of top managers with finance or accounting expertise such as chief financial officer, chief accounting controller, and auditor within the TMT.	TEJ
MTBOARD	Number of top managers who have served as members of other organizations' board of directors.	TEJ
MTENURE	Average number of years that top managers have been working within the TMT.	TEJ
FRNSALE	Proportion of foreign sales to total sales.	TEJ
ENV_ISO	A binary variable equal to one if the public firm has gotten ISO accreditation for ISO in its production of greenhouse gases, and zero otherwise.	TEJ
ENV_IRRG	A binary variable equal to one if the public firm has disclosed irregular environmental issues, and zero otherwise.	TEJ
INSINVESTOR	Proportion of a public firm's ownership obtained by institutional investors.	TEJ
SIZE	Natural log of the firm's total assets at the end of the year.	TEJ
BTM	Proportion of a firm's book value of total assets to market value of total assets at the end of the year.	TEJ
LEV	Proportion of total liability to total assets at the end of the year.	TEJ
CGRANK	Ranking value from 7 to 1, where the ranking is based on the range of total score in corporate governance evaluation results: 7 (81%−100%), 6 (66%−90%), 5 (51%−65%), 4 (36%−50%), 3 (21%−35%), 2 (5%−20%), and 1 (0%−5%). The corporate governance evaluation results are conducted by the Securities and Futures Institute for Taiwan Stock Exchange Corporation and the Taipei Exchange, which is disclosed in the corporate governance evaluation system.	CGES
MKTVAL	Market value of common stock, which is computed as outstanding shares (in NT$ millions) multiplied by price per share at the end of the year.	TEJ
ORTNI	Operating income (in NT$ millions) at the end of year.	TEJ
SALES	Natural log of (one plus total sales) at the end of the year.	TEJ
PTB	Market value of equity divided by book value of equity.	TEJ
CAPINT	Capital expenditures divided by sales.	TEJ
SRET	Stock return at the of the year.	TEJ

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中文粹要

管理品質與碳排放揭露

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摘　要

本論文主要探討管理品質與碳排放揭露間關係。本文推論高品質的管理團隊擁有更多的能力與資源以進行公司的碳排放檢測與管理，因而增加自願性的碳排放揭露。如同研究預期，本研究的結果顯示高品質的管理團隊與碳排放揭露呈正相關。在控制自我選擇偏差後，本文進一步發現高品質的管理團隊可以增強碳排放揭露對市值的正面影響。最後，本研究發現高品質的管理團隊與減少碳排放呈正相關。總而言之，本研究顯示管理品質為影響碳排放揭露的關鍵因素，對現有文獻提供了增額貢獻。

關鍵詞：管理品質、碳排放揭露、市值

本文榮獲「2022 年會計理論與實務研討會」最佳論文獎。作者感謝領域主編、兩位匿名評審委員以及 2022 年中華會計教育學會年會評論人謝佳純教授以及參與者給予寶貴意見，文中言論由作者自行負責。
數據可用性：本文使用的數據可從公開資料來源取得。

1. 研究議題

鑒於極端的氣候變化和全球暖化，碳排放資訊揭露已廣為關注，這也提供資本投資者相關資訊。本研究主要探討管理品質與自願碳排放資訊揭露間關係。公司高層管理團隊的核心目標是透過有效決策為公司創造價值，以提升公司經營績效。高階管理理論指出，組織反映了其高階管理團隊 (Hambrick and Mason 1984)。然而，管理團隊品質中高階管理團隊特徵是否影響公司自願揭露碳排放資訊、碳排放減少和公司價值的研究較少。本研究旨在填補此研究缺口。此研究主題極為重要，環境投資需要特定專業知識和創新態度的管理者，使管理者能夠有效設計和實施碳排放降低策略，開發並提供綠色產品和服務，並有效地減緩環境和法律風險 (Berrone and Gomez-Mejia 2009)。為了提供碳排放資訊和降低碳排放量，高階管理者必須辨認碳排放的足跡、測量碳排放並量化其對公司碳排放的影響。碳排放資訊存在於公司內部不同的高階管理團隊中，包括永續發展、財務與報告團隊。收集、測量和報告這些碳排放資訊需要管理者密切地與其他團隊成員合作。此外，碳排放報告和減碳需要不同的團隊管理者在整個業務中致力於訊息收集、分析、管理和報告的技術。擁有更多資源和能力的高階管理團隊能夠將法規、碳排放和財務資料整合於碳排放報告流程中，因而提高公司自願碳排放資訊揭露的可能性。

2. 研究假說

本研究推論高品質的管理團隊擁有更好的能力和資源來衡量和管理其公司的碳排放，進而提高其自願碳排放的揭露。根據高階管理理論，本文採用幾個高階管理團隊特徵來捕捉高階管理團隊的品質。首先，本研究推測規模大的管理團隊擁有更佳能力和資源來管理、衡量和報告公司的碳排放量。例如，規模大的管理團隊投資更多資金於環境，以收集碳排放數據並減少碳排放。此外，規模大的管理團隊能夠有效解決碳排放問題，打造低碳生態系統並制定更好的減碳與排碳政策。

擁有工商管理碩士學位的管理團隊成員對商業管理有深入了解，使其在碳排放決策方面更加熟練，更能增進自願碳排放揭露的好處。此外，擁有工商管理碩士學位的團隊成員能應用複雜的估值技術進行環境投資決策，以幫助管理團隊做出更好的減碳決策。

具有管理經驗的管理者可以從其他公司獲取碳排放管理和投資訊息，進而提高報導碳排放資訊和願意投資於降低碳排放量。此外，具有管理經驗的管理團隊成員的任命可能對公司的聲譽產生積極影響，降低訊息不對稱以緩解財務限制，進而增加投資於減碳排放方案。

財務 / 會計專業通常包括具財務報導、法規和內部控制知識 (Hoitash et al. 2012)。這些知識使管理團隊能夠與可持續性、財務和報告團隊成員更密切地溝通，將與法規、碳排放和財務資料相關的訊息整合於碳排放報告流程中。提高自願碳排放揭露。

在其他公司擔任董事會成員的管理團隊通常有更高的聲譽，傾向於積極管理和降低碳排放，以避免監管機構的審查。此外，從其他公司所獲得的經驗易與可持續發展團隊的成員共享，從而增加管理層收集、衡量和報告碳排放的意願和能力。

如前述討論，本研究預期高品質的管理團隊 (通過團隊規模大小、擁有工商管理碩士學位的成員、擁有過去管理經驗的成員、擁有擔任其他公司董事會成員、擁有財務 / 會計專業知識的成員) 與自願碳排放揭露呈正相關。本研究假說為：

H1：*高品質的管理團隊與自願碳排放揭露呈正相關。*

過去的研究發現企業社會責任 (CSR) 與公司價值呈正相關 (Servaes and Tamayo 2013)。研究顯示自願環境揭露對公司價值有正面影響。例如，Clarkson et al. (2013) 發現，自願環境揭露提升價值相關性，這對公司價值產生正向影響。同樣，Han et al. (2023) 指出，通過降低訊息不對稱，自願碳排放揭露與公司價值呈正相關。Plumlee et al. (2015) 發現自願環境揭露與公司價值呈正相關。

本文擴展此研究脈絡，考慮了管理團隊品質對公司價值的影響。先前的研究 (Allen and Faulhaber 1989; Chemmanur and Paeglis 2005) 指出高品質的管理團隊可以透過提供更可靠的公司價值訊息以提高投資者對股票市場的信任，進而減少訊息不對稱。因此，公司高階管理品質對碳排放訊息的揭露具有驗證效果。換句話說，高品質管理者自願揭露碳排放訊息，使投資人更能理解公司對於碳排放管理的能力，從而提高投資者對公司的信任。這與自願揭露降低管理者和投資者間訊息不對稱，有助提高公司價值的觀點一致 (Healy et al. 1999; Healy and Palepu 2001)。故推導出第二個假說：

H2：*高品質的管理團隊對自願碳排放揭露有正向影響，進而提高公司價值。*

最後，本文探討高品質的管理團隊是否能降低碳排放。如果高品質的管理團隊能夠有效減少碳排放，那麼更好的高階管理團隊特徵應該能減少碳排放。透過高階管理團隊品質的變動與碳排放量變動間關係，本研究提出第三個假說：

H3：*高品質的管理團隊與降低碳排放呈正相關。*

3. 研究方法

為實踐企業社會責任並促進可持續發展，台灣上市公司根據《TWSE 上市公司永續發展最佳實務守則》，研究期間為 2004 年至 2020 年中的自願揭露原則，在其企業社會責任報告中自願揭露與氣候相關的訊息，如溫室氣體排放。這些揭露都報導在 MOPS 系統中。根據 MOPS 的溫室氣體排放訊息，本文亦從企業社會責任報告和公司網站手工收集環境可持續性的碳排放訊息。主要為公司需要在企業社會責任報告中報告其溫室氣體排放訊息。資料包括直接 (範圍 1) 和間接 (範圍 2) 的碳排放量。本文選擇 2015 年至 2020 年的樣本期間有兩個主要原因。首先，GGRM 於 2015 年 7 月 1 日後才開始生效。其次，研究期間結束於 2020 年以避免 2021 年至 2022 年新冠疫情之影響。首先，本文使用 Probit 模型檢測管理品質對於碳排放資訊的揭露可能性 (H1)。其次，本文採用兩階段估計方法 (Heckman 1979) 分析管理品質對於碳排放資訊揭露具有驗證效果，進而對市場評價產生影響 (H2)。將碳排放資訊揭露第一階段模型估計了 Inverse Mill's 比值 (IMR)。再將 IMR 比值置入市場價值模型第二階段進行估計。最後，為了探討管理品質變動與碳排放變動間關係 (H3)，本文也使用了差分迴歸模型。

4. 研究結果

實證結果顯示，管理團隊品質與自願揭露碳排放資訊之可能性間存在正相關。此外，研究結果顯示，管理團隊的規模、成員的工作經驗、教育背景、財務 / 會計專業成員和管理聲譽與碳排放自願揭露呈正相關。此結果代表高品質的管理團隊更願意揭露碳排放訊息。此外，當公司高階管理團隊品質對於碳排放資訊的揭露具有驗證效應時，對公司價值亦產生正面影響。最後，針對揭露碳排放資訊的公司子樣本，本研究發現管理品質的提升與碳排放量的降低呈正相關。此結果證實高品質的管階管理團隊在管理公司碳排放擁有更多能力和資源，進而降低碳排放量。總而言之，本研究在學術文獻上提供了增額貢獻，顯示管理品質對於自願碳排放揭露的重要性。

5. 研究貢獻

本研究在文獻貢獻可從幾個面向闡述：第一、過去文獻發現管理品質影響訊息品質、融資政策和資本投資決策 (Chemmanur and Paeglis 2005; Chemmanur et al. 2009; Lai and Liu 2018)。本文提供管理品質會影響公司碳排放自願性揭露，擴增此研究領域的相關文獻。第二、本文的研究豐富了有關自願碳排放揭露決定因素的文獻。本研究提供管理品質是影響

碳排放揭露的重要決定因素，能區別本研究與現有文獻之差異。第三、本研究補充有關碳排放揭露對市場價值的文獻 (Clarkson et al. 2013; Chapple et al. 2013; Matsumura et al. 2014; Clarkson et al. 2015; Griffin et al. 2017; Han et al. 2023)。本研究發現高品質的管理團隊能夠提高碳排放揭露對公司價值的正面影響。此研究結果提供了新的實證，即高品質管理團隊能提供碳排放訊息揭露，以標示自願揭露公司減碳的有效政策，因而減少訊息不對稱，提高投資者對碳排揭露公司的正面市場評價。