The Determinants and Impacts of Carbon Assurance: An International Study

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DEDICATION

To My Father (Houbao Fan) and My Mother (Huangyuan Leng)

Thank You for Your Love and Support

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STATEMENT OF AUTHENTICATION

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

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ABSTRACT

Protecting the environment is now a major aspect of corporate social responsibility and there is an increasing interest in carbon emissions reporting due to the growing pressure from major initiatives such as the Carbon Disclosure Project (CDP) and Global Reporting Initiative (GRI), which have exerted increasing pressure on firms to be more transparent about their non-financial information, including carbon emissions. Moreover, emissions trading systems (ETS) and carbon taxes in many countries have emerged as key public policies for reducing carbon emissions. Consequently, carbon disclosure has become a critical part of annual business reporting. However, voluntary carbon disclosure includes private information on future sustainability that external stakeholders cannot easily verify. It is questioned that some of the disclosed information might be subject to manipulation (i.e. 'greenwashing') by managers. Consequently, strong demand is emerging for independent assurance on greenhouse gas (GHG) disclosure. However, the literature on the assurance of carbon emissions remains very sparse (Simnett et al. 2009a; Datt et al. 2018) and prior studies have mainly focused on the incentives for voluntary adoption of carbon assurance from legitimacy and institutional perspectives, choice of assurance provider, the role of internal auditors in GHG reporting, the expertise required for GHG assurance and the development of an international standard for GHG assurance. Yet researchers' understanding of this new type of assurance is very limited given the scarcity of literature in this area. Thus, this thesis fills this gap by study carbon assurance from two perspectives, the determinants and the impacts of carbon assurance by utilising an international sample.

Firstly, this study provides an insight into the determinants of carbon assurance from information asymmetry perspective. Prior studies provide findings that a well-designed assurance process and demonstrable competencies in an assurance team can mitigate information asymmetry, thereby enhancing user confidence pertaining to the credibility of disclosure (Dhaliwal et al. 2011; Casey and Grenier 2014). Despite the existence of differentially informed managers and outsiders, there are few studies on carbon information asymmetry, thus motivates this research to focus on this unique type information asymmetry as a fundamental factor that leads the managerial decision to select an external assurer to verify their carbon emissions data. Drawing on information asymmetry theory and using data from the CDP, this study finds that firms with higher carbon information asymmetry between insiders and outsiders have greater incentives to voluntarily engage an external party for the independent assurance of their greenhouse gas statements. The results show that the proxies for carbon information asymmetry (e.g., greenhouse gas emissions, energy structure) are significantly associated with the adoption of carbon assurance. Further analyses suggest that the probability of carbon assurance is enhanced when carbon disclosure is inadequate to diminish information asymmetry. Finally, the sample companies adopted carbon assurance in addition to financial auditing. This highlights the key point that resolving carbon information asymmetry requires carbon assurance, which cannot be substituted for by financial auditing.

While carbon assurance is expected to influence investors' perceptions on the carbon information disclosed, there is limited knowledge on the effect of carbon assurance on disclosure. Thus the second step of this study is to explore how firms benefit from the purchase of carbon assurance, specifically the role carbon assurance plays in firms' voluntary carbon disclosure quality. Drawing on stakeholder engagement theory, the results show that assured companies tend to have greater carbon disclosure in the year after they obtain assurance than unassured companies. This relationship is stronger in stakeholder-oriented countries, countries with emissions trading schemes, and carbon-intensive industries. It is also found that external assurance accelerates the convergence of carbon disclosure (measured using standard deviation of disclosure score). These findings suggest that although auditors are not expected to be directly involved in the preparation of a carbon report, their recommendations may enhance managerial reporting capability and improve future carbon disclosure, implying carbon assurance plays a significant role in corporate carbon management.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

1.1 Motivation and Significance of the Study

There is growing scientific evidence that the average surface temperature has risen 0.85°C since 1880 and the planet is on track for more than 2°C and possibly more than 4°C further warming by the end of 2100 (IPCC 2014). As climate change intensifies, a wide range of climate-related risks to health and economic growth are projected (IPCC 2018). Climate change will cause serious damages, including shortages of food and water, decreased biodiversity and increased extreme weather in most inhabited regions in the world (IPCC 2014). The consensus is that human activities and influence are the predominant cause of climate warming. Thus, the Paris Agreement established a cap to limit global warming to well below 2°C, which requires a fundamental transition towards net-zero emissions in the future. This goal poses huge technological and economic challenges, but delaying action will significantly accelerate the risk (IPCC 2014; IPCC 2018). Reinforcing the global reaction to this hazard and eradicating fossil fuels entails a wide range of reduction choices, greater green investment, enhanced adaptation capacity and the stimulation of technological innovation (IPCC 2018). This may have huge implications for business operations and bottom lines. All companies, but particularly those with heavy carbon footprints, are expected to implement substantive measures to improve their carbon management systems, adequately assess climate-related risks and opportunities, and effectively build their resilience to climate challenges.

The growing interest in carbon emissions reporting and how market participants respond to the disclosure of relevant carbon information stems partly from increasing pressure from recent major initiatives such as the Carbon Disclosure Project (CDP) and Global Reporting Initiative (GRI), which have exerted increasing pressure on firms to be more transparent about their non-financial information, including carbon emissions. The growing interest can also be tied to the onset of emissions trading systems (ETS) and carbon taxes in many countries, which have emerged as key public policies for reducing carbon emissions. Consequently, carbon disclosure has become a critical part of annual business reporting. However, the quality and reliability of voluntarily disclosed information are criticised by many studies (Freedman and Jaggi 2005; Stanny and Ely 2008; Reid and Toffel 2009; Lyon and Maxwell 2011; Gouldson and Sullivan 2007; Doda et al. 2016), especially carbon emission information as the measurement of Scope

1, 2 and 3 carbon emissions are of high complexity.[1] In addition, voluntary carbon disclosure may involve information other than simply carbon emissions. For example, firms also disclose information on their carbon management and governance such as the set of positions in the management team that are directly responsible for climate change issues, the risk management procedures in place to deal with climate change risks and opportunities, the integration of climate change into business strategy and process, the internal carbon price used, the engagement in activities or events that have impacts on public policies regarding climate change, the established carbon emission reduction targets, the usage of renewable energy, etc. It is questioned that some of the disclosed information might be subject to manipulation (i.e. 'greenwashing') by managers. Greenwashing refers to managers' selectively disclosing positive information regarding corporate carbon performance while avoiding negative information (Lyon and Maxwell 2011). Consequently, strong demand is emerging for independent verification of reports on greenhouse gas (GHG) (GHG; Green and Li 2011; Luo and Tang 2014; Zhou et al. 2016; Becker et al. 1998; De Beelde and Tuybens 2015; Francis and Schipper 1999; Francis 2004; Hay and Davis 2004; Watts and Zimmerman 1990). External carbon assurance[2] is helpful to enhance the credibility of carbon information disclosed by firms (Zhou et al. 2016; Kolk et al. 2008). However, few regulations and standards apply to this assurance (Zhou et al. 2016). The International Auditing and Assurance Standards Board (IAASB) has issued ISAE 3410, which stipulates specific guidelines for GHG statement assurance (IAASB 2012).

Nevertheless, the literature on the assurance of carbon emissions remains very sparse (Simnett et al. 2009a; Datt et al. 2018). Prior studies have mainly focused on the incentives for voluntary adoption of carbon assurance from legitimacy and institutional perspectives (Green and Zhou 2013; Datt et al. 2018; Datt et al. 2018a; Datt et al. 2018b), choice of assurance provider (Huggins et al. 2011; Green and Taylor 2013), the role of internal auditors in GHG reporting

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[1]Scope 1 emissions are direct emissions pertaining to sources owned or controlled by the entity, while Scope 2 relate to an entity's emissions, which are indirect GHG emissions from energy transferred to and consumed by the firm (e.g., the utilisation of purchased electricity). Scope 3 emissions are indirect and are associated with employee commutes, business travel, waste disposal, product disposal, the leasing of assets, and so on (www.epa.gov/aintrnt.gh.index).

[2] The term carbon assurance used in this study refers to assurance of carbon emission disclosure which should comply with third party verification standards aknowleged by CDP and should meet the criteria of relevance, competency, independence, terminology, methodology and availability. For example, AA1000AS, ASAE3000, Australia National Greenhouse and Energy Regulations 2 (NGER Act), ISAE 3410, Assurance Engagements on Greenhouse Gas Statements, Verification under the EU Emissions Trading Scheme (EU ETS) Directive and EU ETS related national implementation laws, etc. For details, please refer to: https://www.cdp.net/en/guidance/verification.

(Trotman and Trotman 2013), the expertise required for GHG assurance (Green and Li 2011), the development of an international standard for GHG assurance (Cohen and Simnett 2014). Yet researchers' understanding of this new type of assurance is very limited given the scarcity of literature in this area (KPMG 2015) and there is limited knowledge on the effect of carbon assurance on disclosure. Therefore, this study fills this gap by exploring the determinants and impacts of carbon assurance.

Firstly, this study provides an insight into the determinants of carbon assurance from information asymmetry perspective. A convergence of opinions is seen in the literature that auditors and assurance providers are independent of firm managers and can assess the fairness of the information disclosed thanks to their professional expertise and skill in processing and reporting information (Leftwich 1983; Blackwell et al. 1998). Prior studies provide findings that a well-designed assurance process and demonstrable competencies in an assurance team can mitigate information asymmetry, thereby enhancing user confidence pertaining to the credibility of disclosure (Dhaliwal et al. 2011; Casey and Grenier 2014). Thus, assurance is a differentiated tool that allows a company to signal a degree of reliability of the underlying information, not just a standardised commodity determined exclusively by regulation (Ball et al. 2012). Watts and Zimmerman (1990)posit that firms with opaque information bear the cost of information asymmetry, which incentivises firms to adopt expensive assurance. Despite the existence of differentially informed managers and outsiders, there are few studies on carbon information asymmetry, thus motivates this research to focus on this unique type of information asymmetry as a fundamental factor that leads the managerial decision to select an external assurer to verify their carbon emissions data.

While carbon assurance is expected to influence investors' perceptions of the carbon information disclosed, there is limited knowledge on the effect of carbon assurance on disclosure. Thus, after examining the factors that influence managers' adoption of carbon assurance, this study further explores how firms benefit from the purchase of carbon assurance, specifically the role carbon assurance plays in firms' voluntary carbon disclosure quality. These perspectives have not been explored in the literature. By employing stakeholder engagement theory (Edgley et al. 2010), this study argues that independent verification on carbon disclosure help enhance firms' internal reporting systems thus contributing to a better disclosure quality in the future. When a firm involves an assurance on its carbon disclosure, the assurance provider could benefit managers by providing professional knowledge and advice on the how and what to disclose as they have a better understanding on the needs of external stakeholders for carbon information. In addition, assurance providers could identify defects in firms' internal control systems and reporting process which help enhance the carbon reporting and management systems. Such interaction is expected to positively influence firms' future carbon reporting.

1.2 The Objectives and Research Questions of the Study

This study aims to answer two research questions. First, what factors motivate managers to engage voluntary independent carbon assurance on their carbon information disclosed? Second, how does such third party assurance impact firms' future carbon disclosure?

In order to answer these questions, two objectives are identified. The first objective is to identify the determinants of managers' purchase of carbon assurance from information asymmetry perspective at firm level. The second objective is to explore the relationship between carbon assurance and carbon disclosure quality. Information asymmetry theory, carbon information asymmetry theory, stakeholder engagement theory and institutional theory are employed to guide the design of the research methodology, to address the questions and to achieve the objectives.

1.3 Research Methodology of the Study

Quantitative approach involves "the generation of data in quantitative form, which can be subjected to rigorous quantitative analysis in a formal and rigid fashion" (Goddard and Melville 2004). Quantitative strategy allows the formulation and verification for hypothesis, and helps to reveal causal explanations and fundamental laws (Easterby-Smith and Thorpe 1991; Amaratunga et al. 2002).

This study utilises an international dataset and adopts quantitative research methods. Firstly, a descriptive analysis will be used to illustrate the carbon assurance patterns in different countries and industries based on the study of the 6-year carbon assurance data and other carbon-related information. Secondly, to assess the determinants of carbon assurance and the relationship between carbon assurance and carbon disclosure quality, logistic panel analysis will be employed. The sample for this study is extracted from the CDP database. The detailed research design, including sample selection, research model specification and measurements, for each research objective are presented and discussed in Section 4.4 and Section 5.4, respectively.

1.4 Contributions of the Study

Contrary to previous studies on sustainability (Casey and Grenier 2014), this study focuses solely on carbon assurance. This study makes unique contributions to the literature on green accounting and carbon assurance.

First, this study contributes to the literature on carbon assurance which is an important dimension of carbon accounting. There has been little study on this emerging practice (Datt et al. 2018), so this study extends the research on financial auditing to carbon assurance because carbon emissions are a serious threat to sustainability (Lash and Wellington 2007). Performing carbon assurance requires specific skills, knowledge, and expertise and is governed by separate standards (IAASB 2012; Tang 2019; Datt et al. 2018; Datt et al. 2018b). Firms are expected to have specific capabilities to reduce carbon emissions under a range of jurisdictional and institutional pressures (Luo et al. 2013). Carbon mitigation is a unique dimension of the broader concept of CSR (Strike et al. 2006; Walls et al. 2011), which deserves a separate study.

Second, to my best knowledge, this is the first study to use carbon information asymmetry theory to explain the adoption of carbon assurance. Reducing carbon information asymmetry entails carbon assurance that cannot be substituted with financial auditing. This study uses innovative proxies, namely the quantity of emissions, type of fuels used and membership in a carbon-intensive sector, to capture different aspects of carbon information asymmetry underlying managerial incentives to adopt GHG assurance. The fact that firms in this study purchased carbon assurance in addition to financial auditing implies that carbon information asymmetry is a distinct dimension of information asymmetry concerning the authenticity of carbon information.

Third, this study significantly validates and increases the applicability of information asymmetry theory in a nonfinancial setting by providing evidence that indicates the reactions of firms to global warming. Based on the fact that managers tend to use private informed data to contextualise their carbon performance and camouflage their inferior carbon policy, this study provides inferences that carbon assurance can enhance value (by reducing transaction costs), conditional on the severity of the carbon knowledge gap among the key stakeholders of a firm (Schiemann and Sakhel 2019).

Fourth, this study is the first to provide empirical evidence of the effectiveness of carbon assurance in enhancing carbon disclosure from stakeholder engagement aspects. Prior studies on carbon assurance have mainly focused on the incentives for voluntary adoption of carbon assurance, choice of assurance provider, the role of internal auditors in GHG reporting, the expertise required for GHG assurance, the development of an international standard for GHG assurance. However, while carbon assurance is expected to impact users' perceptions, there is limited knowledge on the effect of carbon assurance on disclosure. This study documents that the engagement of carbon assurance can improve firms' carbon reporting systems so as to lead to a better future carbon disclosure.

Fifth, this study enhances the understanding of the role of the institutional context in carbon disclosure and assurance. There is no research on how these industrial and national factors moderate the link between carbon assurance and carbon disclosure. Last, Edgley et al. (2010) show the importance of stakeholder engagement in environmental assurance. The findings reinforce the validity and appropriateness of this concept in the carbon assurance practice. The evidence should assist assurance practitioners, regulators, and users of carbon reports in obtaining a better knowledge of this indispensable practice in today's low-carbon economy.

Finally, instead of using data from financial statements or CSR reports (Kolk 2003; Ballou et al. 2006), this study utilises data from the CDP. The CDP database encompasses the most complete and consistent information in comparison to alternative sources (Luo et al. 2012). In contrast to sustainability or CSR reports, which are subject entirely to managers' discretion, CDP employs a single set of guidelines that all participants are required to comply with, which ensures comparable responses between firms and minimises manipulation of the carbon data.

1.5 Structure of the Thesis

This thesis is structured as follows:

Chapter 1 provides the introduction of an overview for the whole research including the motivation and significance of the study, the objectives and research questions, the research methodology employed and the contributions of the study.

Chapter 2 presents the theoretical framework employed to explain the determinants of independent carbon assurance and the impacts of engaging carbon assurance on firms' carbon disclosure quality. In this chapter, information asymmetry theory, carbon information asymmetry theory, stakeholder engagement theory and institutional theory are presented.

Chapter 3 provides a systematic review of the related literature. As carbon disclosure and assurance is a relatively new emerging field, previous studies on environmental, sustainability and financial accounting are also discussed in addition to studies on carbon area.

Chapter 4 presents the examination of the first research objective: What are the motivations of firms to voluntarily engage carbon assurance on their carbon disclosure? This chapter focuses on the link between carbon assurance and carbon information asymmetry. Drawing on carbon information asymmetry theory, it is predicted that companies with higher carbon information asymmetry between insiders and outsiders have a greater incentive to voluntarily engage an external party for the independent assurance of their greenhouse gas statements. The results show that the three proxies adopted in this study, namely the quantity of emissions, energy structure and membership in carbon-intensive sectors, are significantly positive with the adoption of carbon assurance.

Chapter 5 investigates the impacts of carbon assurance on corporate carbon disclosure quality. Drawing on stakeholder engagement theory, it is documented that firms engaging carbon assurance tend to have better carbon disclosure in the subsequent year than unassured firms. This relationship is more pronounced for firms in stakeholder-oriented countries, firms in countries with emissions trading schemes, and firms operating in carbon-intensive sectors. The results also show that third party assurance accelerates the convergence of carbon disclosure (measured using standard deviation of disclosure score). These findings suggest that although auditors are not expected to be directly involved in the preparation of a carbon report, their recommendations may enhance managerial reporting capability and improve future carbon disclosure, implying carbon assurance plays a significant role in corporate carbon management.

Finally, Chapter 6 concludes the entire research. In this chapter, the key findings of the study are summarised followed by a discussion on the main contributions. The implications of this study for policymakers, investors, corporate managers are also considered and discussed. Finally, the limitations of this study and potential opportunities for future study are presented. Figure 1.1 provides an overview of the structure of this thesis:

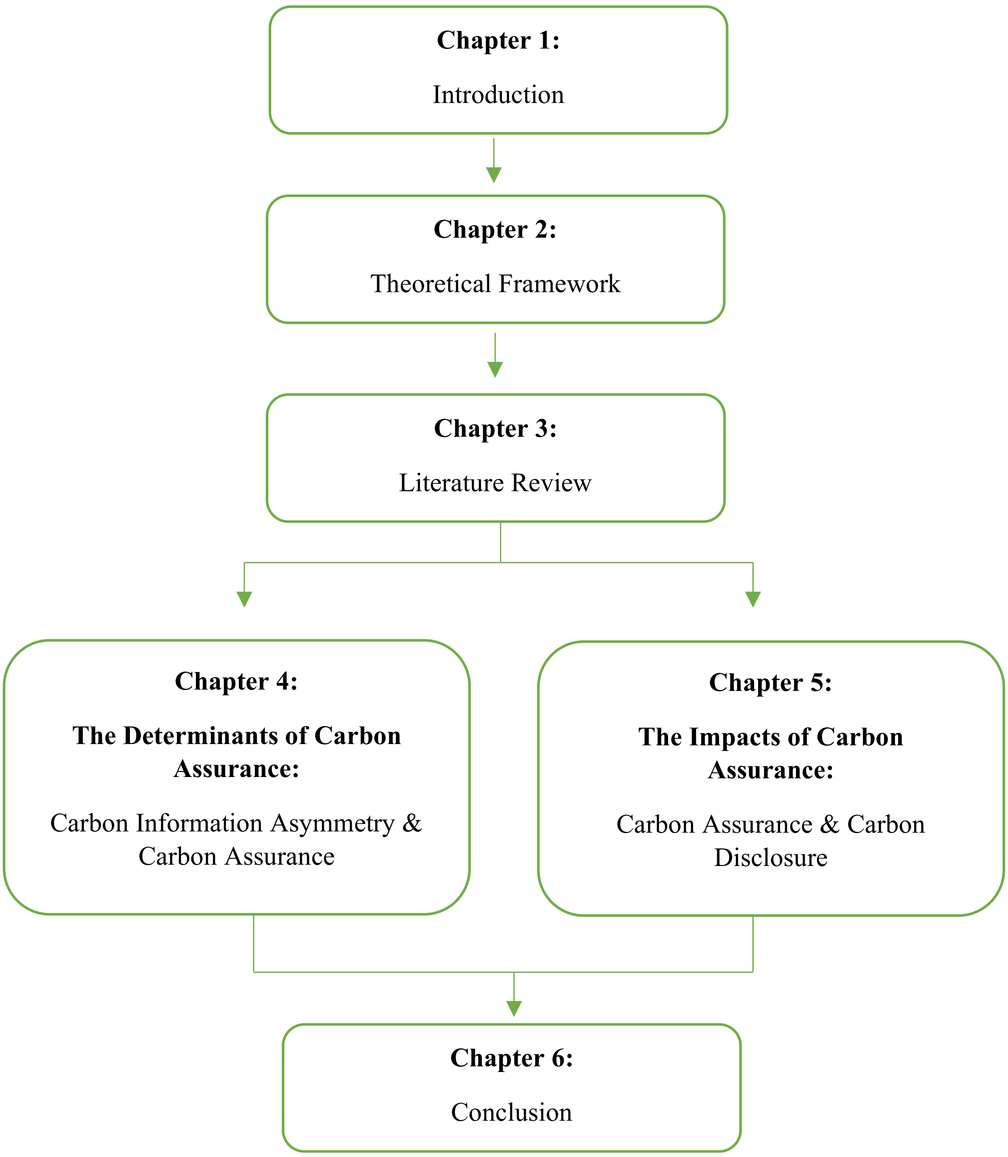

Figure 1. 1: Structure of the Thesis

CHAPTER 2 THEORETICAL FRAMEWORK

2.1 Introduction

This chapter discusses the theoretical framework of this study. To answer the two research questions, multiple theories that are employed in previous studies related to financial auditing and sustainability assurance are applied.

In examining the first research question, the motivations of managers' decision on carbon assurance adoption, information asymmetry theory is employed and based on which, carbon information asymmetry is developed in this study. Information asymmetry theory is often used to explain the role of auditing in financial statements. For instance, Chow et al. (1988) argue that financial auditing arises because of financial information asymmetry, the agency problem and related costs. This study extends this argument to carbon assurance, proposing that the adoption of voluntary GHG assurance is motivated by a need to reduce carbon information asymmetry between firms and their external stakeholders. Carbon information asymmetry is a unique dimension of information asymmetry. First, carbon accounting for GHG quantification entails entirely different types of knowledge and expertise than conventional financial accounting. In addition, voluntary disclosure of carbon information involves private information owned by managers. Outsiders are unable to access this information. Finally, because managers may be less committed to climate change, their carbon disclosure may not meet ethical standards[3]. Thus, third-party verification is necessary to add credibility to carbon disclosures. The assurer's objectives are to provide reasonable or limited assurance that a firm's carbon disclosure contains no material misstatements and has been prepared in accordance with applicable standards (IAASB 2012). Innovative variables are used in this study to proxy for carbon information asymmetry underlying managerial incentives to adopt GHG assurance.

To examine the second research question, the effects of carbon assurance on carbon disclosure, stakeholder engagement theory and institutional theory are employed. Stakeholder engagement theory emphasizes interaction, communication, and cooperation between management and groups of stakeholders, including assurers. This study argues that assurance of carbon reports may improve their clients' reporting systems so as to lead to a better future carbon disclosure. The underlying rationale is that, first, a firm engages carbon assurer to verify its information

[3] Climate change has evolved from an ethical issue to one that has material impacts on financial performance, position and prospects. Information about the impacts of climate change should be considered as key to a reasonable investor's decision making, and therefore as material in a disclosure context.

on emissions. Such engagement helps the firm understands the needs of external stakeholders for carbon-related information. Second, on completion of assurance, an auditor usually provides managers with a letter containing recommendations for fixing flaws in internal control and current reporting systems (Gay and Simnett 2018). Managers may subsequently use these recommendations to prepare their future carbon reports. This interactive mechanism is expected to positively impact firms' future carbon disclosure. Furthermore, this study examines the effect of carbon assurance on other aspects of carbon disclosure, i.e. whether carbon disclosure exhibits some sign of convergence under the influence of assurance. According to institutional theory, elements of institutions tend to reduce variety toward organizational homogeneity. DiMaggio and Powell (2012) contend that isomorphism is the process that best describes this homogeneity, and the external environment (such as competition and institutional pressures to adaptation and adoption of new values, norms, and attitudes) drive these isomorphic changes. Isomorphism takes place via three mechanisms: coercive (external pressures exerted by other organizations such as governmental bodies), normative (stemming from professionalization) and mimetic (regarding the inclination of firms to imitate one another) processes (DiMaggio and Powell 2012; Scott 2013). Moreover, institutionalization is impacted by the continuously changing environment, and firms impact one another to absorb the changes (DiMaggio and Powell 2012). Institutional theory has been applied to analyze organizational participation in carbon emissions trading (Pinkse and Kolk 2009).

Figure 2.1 summarises the theoretical frameworks employed to address the two research questions. The remainder of this chapter will discuss these theories in detail to explain the determinants of carbon assurance and the impacts of carbon assurance on carbon disclosure.

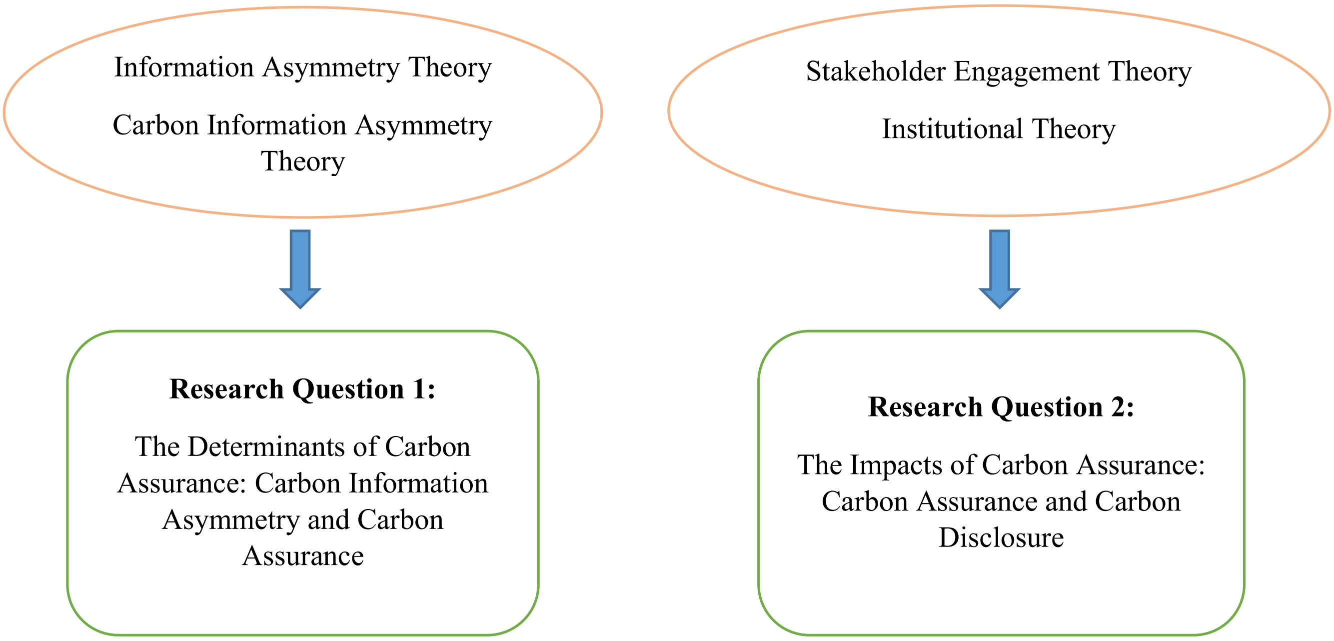

Figure 2. 1: Theoretical Framework for the Two Research Questions

2.2 Information Asymmetry Theory

Myers (1984) indicates that managers who act as agents of shareholders possess more knowledge of their firms than market participants. As such, this poses a challenge for external stakeholders to accurately undertake evaluation of a firm. Consequently, potential investors take price protection (e.g., with a discount of firm value) as compensation for the disadvantage of information asymmetry. This implies that firms with opaque information bear the cost of information asymmetry in an efficient market (not the uninformed users). Thus, information asymmetry creates adverse selection costs of external financing for firms. When these firms seek external funding, they face higher equity costs, which reduces the value of the investment and the firm (Watts and Zimmerman 1990).

Myers (1984) information asymmetry theory has contributed significantly to the understanding of corporate financial and nonfinancial decisions. For instance, drawing on information quality and agency cost perspectives, Fosu et al. (2016) argue that information asymmetry has negative impacts on firm value. Similarly, advocates of the theory maintain that private information enables informed managers to hide poor performance and that investors cannot distinguish between good and poor performance, which evokes selection bias and extra transaction costs

(Akerlof 1970). Further, information gaps can occur between managers and shareholders, between managers and creditors and between family and nonfamily directors. The relevant information can be financial or nonfinancial (Abdel-Khalik 1993). The negative effects incentivise directors to publicly disclose their private information, even without a legal requirement, to stimulate optimal allocation of capital (Verrecchia 2001) and lower transaction costs (Diamond and Verrecchia 1991).

Similarly, asymmetry of environmental information leads to voluntary social and environmental disclosure (Schiemann and Sakhel 2019). Simnett et al. (2009a) believe that financial disclosure only partially reflects firm value. Nonfinancial reports are needed to reveal firm value from various perspectives. Empirical studies support this notion. Using CSR scores from KLD STAT, Cho et al. (2013) reveal an association between disclosed CSR and information asymmetry. Cormier et al. (2011) find a reduction in the bid-ask spread due to corporate sustainability reports, and Dhaliwal et al. (2011) prove that firms that actively engage in CSR reporting are rewarded by the market with lower external financing costs. Similarly, Matsumura et al. (2014) report that GHG disclosure mitigates the undesirable effect that GHG emissions have on the firm value of US S&P 500 companies.

2.3 Carbon Information Asymmetry Theory

There is a consensus that separating ownership and control can result in information asymmetry between internal managers and external stakeholders. This asymmetry historically refers to financial information; however, it can be extended to nonfinancial information. Carbon information asymmetry is a unique dimension of information asymmetry. Yet carbon accounting for GHG quantification entails entirely different types of knowledge and expertise than conventional financial accounting. In addition, voluntary disclosure of carbon information involves private information owned by managers. Outsiders are unable to access this information. Finally, because managers may be less committed to climate change, their carbon disclosure may not meet ethical standards. Thus, third-party verification is necessary to add credibility to carbon disclosures. The assurer's objectives are to provide reasonable or limited assurance that a firm's carbon disclosure contains no material errors or omissions and the underlying GHG statement is prepared using applicable standards (IAASB 2012).

GHG emissions and activities are largely sourced in managers' private data, making them appropriate for external verification under the information asymmetry economics (Myers 1984).

This high information opacity does not allow users to evaluate a firm's fundamental value and reduces the quality of the decisions of investors who want to invest permanently in competitive low-carbon technologies. This is because measuring GHG emissions is a task of high complexity, and a sound accounting and management system is required to process the recording and calculation of carbon emissions (Luo and Tang 2014). Such a system is necessarily internal and is difficult to observe directly from the outside. Most stakeholders lack environmental competencies and have limited or inferior cognitive ability regarding carbon issues, whereas managers can access timely carbon information and have superior capacity to process this information. The divergent knowledge and interpretation of carbon information between inside managers and outside parties may lead to poor judgement and decisions. Thus, an independent qualified assurer is often called in to reduce knowledge asymmetry and vouch for the credibility of the voluntarily revealed information, as well as to ensure its accuracy and completeness (Datt et al. 2018). Assurance can not only improve the disclosure quality but also contributes to the long-term enhancement of environmental management and control systems (Healy and Palepu 2001), including carbon asset management.

2.4 Stakeholder Engagement Theory

Stakeholder engagement, sometimes referred to as stakeholder inclusivity, emphasizes interaction, communication, and cooperation between management and groups of stakeholders, including assurers. Engagement and inclusivity is the commitment of those who have impacts on and who are impacted by an organisation to be responsible to and to be engaged in problem identification and correction. Inclusivity is defined as the stakeholders to participate in "developing and achieving an accountable and strategic response to sustainability" in AA1000AS[4] and it emphasises the principals of materiality, inclusivity and responsiveness from the perspective of stakeholders. Based on stakeholder engagement theory (Edgley et al. 2010), assurance of carbon reports may improve their clients' reporting systems so as to lead to a better future carbon disclosure. The underlying rationale is that, first, assurers who adopt a stakeholder inclusivity approach understand better the needs of external stakeholders for carbon-related information particularly when an auditing firm's network comprises multifaceted clients (Edgley et al. 2010). Thus, such assurance engagement involves greater

[4] The AA1000 Assurance Standard (AA1000AS) is a standard for sustainability assurance issued by the AccountAbility, an independent, global, not-for-profit organisation promoting accountability, sustainable business practices and corporate responsibility.

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interaction with external stakeholders, therefore ensuring that social and environmental reporting is responsive, complete and satisfies stakeholders' need for information (Edgley et al. 2010; Thomson and Bebbington 2005; Owen et al. 2000). These auditors are able to raise critical consciousness of environmental reporting rather than just passively and unquestioningly accept information (Edgley et al. 2010) and their opinions reflect the demand of users for information on physical emissions, carbon risks, carbon strategy and investment, and so on. Assurer can help managers select appropriate information and determine the scope and depth of this disclosure, thus, the underlying GHG report can be made more relevant and comprehensive. Moreover, on completion of assurance, an auditor usually provides managers with a letter containing recommendations for fixing flaws in internal control and current reporting systems (Gay and Simnett 2018). Managers may subsequently use these recommendations to prepare their future carbon reports. This interactive mechanism is expected to have a positive impact on firms' future carbon disclosure.

Second, assurance activities are likely to strengthen a client's internal system (Baker and Owsen 2002; Elliott 1994). According to the authoritative guidelines (e.g. GRI, ISAE 3410), auditors need to identify deficiencies and recommend improvements to a company's environmental management systems (Deegan et al. 2006; Moroney et al. 2012). Stakeholder inclusivity allows assurers to work closely with clients to evaluate the strength of internal systems, test the validity of outputs, detect risk, and identify misstatements due to poor process design and/or inadequate controls (Olson 2010). Although an auditor is not expected to design control measures, the auditor is able to recommend or suggest broader options for how the auditee can improve the system for future reporting purposes. This is evident in the research of Manetti and Toccafondi (2012), who find that the majority of assurance statements they analyzed included consultation from stakeholders in the formulation of assurers' professional opinions, which is a common practice (Gay and Simnett 2018; Olson 2010).

Third, auditors often maintain contact with clients to make them aware of changes in reporting protocols or associated legislation throughout the auditing. Auditors may also inform clients of the changing demands of other stakeholders, such as the community, supply chain partners, employees, and not-for-profit organizations, during or after the current auditing period. This will ultimately reflect in improved carbon reporting. As discussed by Moroney et al. (2012), the benefit of such assurance is lagged. It gradually influences managers' behaviour and serves as a learning process for managers and stakeholders (Edgley et al. 2010).

Edgley et al. (2010) assess the managerial capture of social and environmental report assurance (SERA). Their qualitative data show that stakeholders are increasingly being included in SERA. Assurance is starting to help managers and stakeholders simultaneously and offer dual benefits. The assurance process can be described as "display[ing] some characteristics of a dialogical process, being stakeholder inclusive, demythologising and transformative, with assurors perceiving themselves as a 'voice' for stakeholders" (Edgley et al. 2010, , p532). With direct and indirect stakeholder inclusivity mechanisms, SERA influences managers' attitudes toward a large range of stakeholders and the wider community, which can benefit both managers and stakeholders. Nevertheless, there are still barriers in the dialogue of SERA, which can be removed by assurers via educative and transformative processes.

2.5 Institutional Theory

According to institutional theory, elements of institutions tend to reduce variety toward organizational homogeneity. DiMaggio and Powell (2012) contend that isomorphism is the best way to describe the process of such homogeneity, and the external environment (such as competitive rivalry, institutional pressures to adaptation and adoption of new values, norms, and attitudes) drive these isomorphic changes. Isomorphism takes place via three mechanisms: coercive (external pressures exerted by other organizations such as governmental bodies), normative (stemming from professionalization) and mimetic processes (concerning the propensities of firms to imitate one another) (DiMaggio and Powell 2012; Scott 2013). Furthermore, institutionalization is impacted by the external changeable environment, and firms interact with each other to imbibe the changes (DiMaggio and Powell 2012). Institutional theory has been applied to analyze organizational participation in carbon emissions trading (Pinkse and Kolk 2009).

Therefore, this study argues that corporate carbon disclosure tends to converge and this process is affected by external assurance. Third-party assurance is part of the external environment surrounding the firm, which represents outside influences from stakeholders. If a growing number of peer companies choose assurance, this is a coercive pressure on firms without assurance. Similarly, assurers may impose mimetic and normal pressure on their clients to implement a certain type of disclosure practice. Thus, the trend toward isomorphic practice will be more pronounced in companies with assurance than in those without assurance. Following de Aguiar and Bebbington (2014), this study uses the standard deviation of the carbon disclosure score as a measure of the convergence or homogeneity of carbon disclosure. It is expected that the standard deviation will be smaller in the cohort of assured companies than unassured companies. The test shows that assured companies not only obtained a higher disclosure score (84.19) than unassured companies (71.01), but also the standard deviation of the score for assured companies (14.36) is lower than that for unassured companies (16.18). Levene's test is run to assess the equality of standard deviations (variance) of the two disclosure scores and find the difference is significant at the 0.01 level (F = 52.01). This preliminary evidence is consistent with institutional theory. Despite assured CDP participants differ from one another in terms of size, economic activity, level of emissions, the volume of disclosures, their reports are more converged compared to the matched pair unassured cohort. One mechanism through which for the isomorphism to occur could be that the GHG monitoring, reporting, and verification process is gradually becoming institutionalized around the world particularly with ETS. External assurance (i.e. verification) not only enhances carbon disclosure but also accelerates the speed of isomorphism toward more comparable and consistent carbon reporting. This evidence corroborates the finding of de Aguiar and Bebbington (2014).

2.6 Concluding Remarks

This chapter has introduced four theories, namely information asymmetry theory, carbon information asymmetry theory, stakeholder engagement theory and institutional theory, that will be employed to explain the two research objectives.

Information asymmetry theory and carbon information asymmetry theory will be utilised in Chapter 4 to explain managers' decision to adopt carbon assurance. Three factors are identified as proxies for carbon information asymmetry. They are the quantity of emissions, energy structure and membership in a carbon-intensive sector. Firms with high volume of emissions, complicated energy structure and operating in carbon-intensive sectors are inherently subjective to high complex measurement of carbon emissions. Moreover, such information is largely gathered from managers' private data, which makes it hard to be observed, verified and evaluated by outside users (Myers 1984) who usually lack capability in processing carbon information while managers have timely access to these data and have superior capability in analysing the data. The divergent knowledge and interpretation of carbon information between inside managers and outside parties may lead to poor judgement and decisions and carbon information asymmetry arises. Thus, an independent qualified assurer is often called in to reduce such information asymmetry and vouch for the credibility of the voluntarily revealed information, as well as to ensure its accuracy and completeness (Datt et al. 2018).

Stakeholder engagement theory and institutional theory will be employed in Chapter 5 to explain the relationship between carbon assurance and carbon disclosure. Based on stakeholder engagement theory (Edgley et al. 2010), it is argued that assurance provider understands the needs of external stakeholders for carbon-related information better than managers, and they usually provide managers with a letter that includes recommendations for addressing issues they identified in the internal control and reporting systems, their engagement may help enhance firm's carbon reporting systems, which will contribute to better disclosure quality in the future. Institutional theory is utilised to explain the signs of convergence of carbon disclosure under the impacts of assurance.

CHAPTER 3 LITERATURE REVIEW

3.1 Introduction

This chapter will review the related literature in sustainability/carbon assurance. Specifically, carbon assurance practice and related regulations, the impact of climate change on business, financial versus carbon information asymmetry and financial versus GHG assurance, CSR/sustainability assurance and stakeholder engagement and managerial capture and impression management will be discussed. The purpose of the literature review is to provide comprehensive knowledge of carbon assurance and related area. Research ideas, research methodology and findings of key related studies will be summarised. The gaps and problems in carbon assurance study will be demonstrated and thus identify how this study will fill the gap and contribute to the study of carbon assurance.

3.2 Information Asymmetry and Carbon Assurance

3.2.1 Cost of information asymmetry

It is documented in previous studies that firms without transparent information bear the costs of information asymmetry in efficient markets. Therefore, information asymmetry brings adverse selection cost of external financing to enterprises, and these companies will face higher equity cost when seeking external funds, thus reducing the investment and value of the company(Watts and Zimmerman 1990).

Under the pecking order and agency cost theoretical frameworks, Fosu et al. (2016) use UK sample for the period 1995 to 2013 to explore the impacts of information asymmetry on firm value. Dispersion of analysts' forecasts and analysts' forecast error are used to proxy for information asymmetry. They document that there's a negative association between information asymmetry and firm value and this relation is conditional on debt financing, growth opportunities and financial crises.

Similarly, He et al. (2013) adopt a sample of Australian listed companies from a period of 2001-2008 to explore the relationship between information asymmetry and the cost of equity financing. By employing a refined proxy for information asymmetry in the study of Lin et al. (1995), namely the adverse selection element of the bid-ask spread of companies, they document a statistically significant and positive association between information asymmetry and return on equity and this relationship is more pronounced in financials, health care, oil and gas and utilities sectors. They argue that the rationale behind the inverse relationship is that when investors recognise that they are in an information disadvantage situation, they will diverse their investments to other places where they are more informed and their disadvantage is less. This will lead to a downward movement of price of securities with high information asymmetry and thus increases their capital cost (Easley and O'hara 2004).

By employing a global sample consisting of 13,019 companies from 1997 to 2007, Gao and Zhu (2015) study the impact of information asymmetry on capital structure. Their results suggest that information asymmetry has negative impacts on equity financing and has no significant impacts on debt financing. In addition, they find that companies subjective to lower levels of asymmetry in information have higher propensity to employ long-term debt financing as the cost of which is more susceptible to information. Furthermore, they document that the impact of information asymmetry on firm leverage is conditional on some institutional factors. Specifically, they argue that a healthier banking system and enforced bankruptcy environment help impel corporate borrowing as economies of scare could be achieved by financial intermediaries in lending activities while strongly enforced bankruptcy codes provide better investor protection. Thus when companies operating in a country with a more sophisticated and developed banking system and explicitly bankruptcy codes, the positive correlation between information asymmetry and firm debt financing is more pronounced.

3.2.2 Disclosure as a tool to reduce information asymmetry

Advocates of the theory maintain that private information enables informed managers to hide poor performance and that investors cannot distinguish between good and poor performance, which evokes selection bias and extra transaction costs (Akerlof 1970). Further, information gaps can occur between managers and shareholders, between managers and creditors and between family and nonfamily directors. In order to avoid the adverse selection of information asymmetry, firms try to disclose more to reduce the information asymmetry between internal managers and external stakeholders. The relevant information can be financial or nonfinancial (Abdel-Khalik 1993). Asymmetry of environmental information leads to voluntary social and environmental disclosure (Schiemann and Sakhel 2019). The negative impacts of information asymmetry incentivise firms to publicly disclose their private information.

Verrecchia (2001) discusses the information asymmetry element of the capital cost which refers to as the component that investors discount the equity issues of a firm when expecting the occurrence of transaction costs that could derive from adverse selection. Therefore, to improve the efficiency firms gain advantage from increasing information transparency, thus reducing the cost of capital that arises from information asymmetry element. Committing to a high level of public disclosure is effective for reducing information asymmetry. For example, companies could prepare financial statements using more transparent accounting standards and frameworks and build a more sophisticated disclosure system to improve the disclosure quality.

Similarly, asymmetry of environmental information leads to voluntary social and environmental disclosure (Schiemann and Sakhel 2019). Simnett et al. (2009b) believe that financial disclosure only partially reflects firm value. Nonfinancial reports are needed to reveal firm value from various perspectives. Empirical studies support this notion.

Using CSR scores from KLD STAT, Cho et al. (2013) examine the association between disclosed CSR and information asymmetry and how this relationship is affected by institutional ownership. The bid-ask spread is employed as the proxy for information asymmetry and find that firms that achieve higher CSR scores are more likely to have lower information asymmetry. Moreover, the negative CSR scores have a stronger impact in reducing information asymmetry. When examining the moderating role that institutional investors play on the relationship, they document a negative relationship between CSR scores and the bid-ask spread is weakened for firms with higher levels of institutional ownership as institutional investors are regarded to have an informational advantage regarding SCR performance as they generally have access to more information compared to other participants in the market and have superior capability in gathering and assessing information. On the contrary, less informed investors such as retail investors have less access to private and direct information from firms' managements outside the public channels thus broaden the information asymmetry gap.

Cormier et al. (2011) use a sample of Canadian companies, they first examine the impacts of two types of disclosure, namely social disclosure and environmental disclosure on the information asymmetry and then explore the drivers of social and environmental disclosure. By employing a simultaneous equations model and adopting share price volatility and bid/ask spread to proxy for information asymmetry between inside managers and outside investors they find that environmental disclosure, specifically the disclosure on environmental debts, risks and litigations reduces information asymmetry. Moreover, they document that environmental disclosure and social disclosure have a substitutional relationship in information asymmetry reduction. The results also suggest that firms with better performance in environmental issues, more media exposure, higher leverage and larger size tend to disclose more information on social and environmental issues.

Some carbon emissions studies focus on exploring the economic consequences of carbon emissions. For example, Chapple et al. (2013) study a sample of 58 disclosures of Australian firms by using a revised Ohlson (1995) model and find that carbon emissions are negatively related to firm value. More specifically, these carbon-intensive firms suffer an equity valuation discount of 6.57 per cent of market capitalisation.

In a Japanese context, Saka and Oshika (2014) examine the effect of carbon disclosure and carbon emissions on the firm value by using a sample of 1057 companies from 2006 to 2008. They find that carbon emissions negatively affect market equity capital, but carbon disclosure management has a positive impact on firm value and this impact is even stronger for firms in carbon-intensive sectors.

Likewise, Matsumura et al. (2014) find that voluntarily reported carbon emissions are inversely associated with the market value of firms on the S&P 500. Specifically, the results suggest a valuation discount of $US212 per ton of carbon emissions for US companies. Moreover, they show that firms without emission disclosure face even higher penalty.

Clarkson et al. (2015) document a similar result, though the valuation penalty is much more moderate and benign in the European context in which they conducted the research.

Dhaliwal et al. (2011) use independent CSR reports of around 650 U.S. firms to explore how voluntary CSR disclosure impacts the equity financing cost. Lead-lag approach is employed by them to address potential endogeneity issue and self-selection bias. The evidence shows that when firms receive higher cost of financing in the previous year, they are more likely to initiate CSR reporting in the current year. In other words, reducing equity financing cost motivates firm CSR reporting behaviour. They also explore the impacts of CSR reporting on firm's equity financing cost and find that firms disclosing CSR performance are rewarded by the market by enjoying a lower equity financing cost in the subsequent year.

Schiemann and Sakhel (2019) employ a sample of European firms over a period of 2011 to 2013 from CDP database to study the impacts of the disclosure of physical risk regarding climate change on the information asymmetry. They follow the previous study on information asymmetry (Glosten and Milgrom 1985; Leuz and Verrecchia 2000) and employ bid-ask spreads as the proxy for information asymmetry. Based on the framework of information economics, they find that firms voluntarily disclose the information of physical risks are exposed to lower information asymmetry between internal managers and external investors. This relationship is more pronounced for firms participating in an ETS which are subject to more stringent climate change regulations and policies.

3.2.3 Disclosure as a greenwashing tool that increases information asymmetry

One of the major United Nations Intergovernmental Panel on Climate Change (IPCC) climate policies involves monitoring, verification, and reporting (MVR) of carbon emissions. Nevertheless, some publicly revealed data (in particular, self-serving disclosures) only provide partial information and create uncertainty, which often obfuscates poor performance and thus enhances, instead of reducing, information asymmetry (Brown et al. 2009).

Some authors suspect that managerial motivation of CSR disclosure is insincere (Brooks and Oikonomou 2018) and this type of disclosure appears to be an exercise of greenwashing. Such disclosure is intended to protect the legitimacy of the reporting firm (Mathews 1997) and establish an artificial green identification that improves the brand value and image of the entity (Hahn and Kühnen 2013).

Greenwashing is a multifaceted term modelled on the phrase, "whitewashing", which indicates organised attempts to conceal unpleasant facts, particularly in a political paradigm. The purpose of greenwashing takes the same premise, except it involves using an apparently green facade in an environmental context. Greenwashing disclosure is structured to focus on positive factors and ignore negative effects to persuade the community that a firm is aware of the need for environmental protection and that their products and activities are sustainable. This provides a facade to disguise unsustainable corporate agendas and to repair public perception of a brand and thus maximise perceptions of legitimacy. Thus, without external monitoring and verification, this strategy amounts to corporate posturing and deceptive behaviour.

3.2.4 Needs for assurance to reduce information asymmetry

Therefore, voluntary information disclosure requires a mechanism to convey its credibility (Ball et al. 2000; Crawford and Sobel 1982; Stocken 2000). This creates demand, even in the absence of legally enforceable requirements, for external assurance among firm managers (Healy and Palepu 2001). A convergence of opinions is seen in the literature that auditors and assurance providers are independent of firm managers and can assess the fairness of the information disclosed thanks to their professional expertise and skill in processing and reporting information (Leftwich 1983; Blackwell et al. 1998).

Fuhrmann et al. (2017) conduct content analysis of GRI assurance reports of 600 European companies in 2008 and 2009 to study the impacts of the assurance process design on the information asymmetry. Following the previous studies of Leuz and Verrecchia (2000) and Hakim and Omri (2010), they employ Bid-ask spread as a proxy for information asymmetry and build OLS regression models to test the hypotheses. They provide findings that a well-designed assurance process, including high assurance level, more assurance-specific work steps, and demonstrable competencies in an assurance team can mitigate information asymmetry, thereby enhancing user confidence pertaining to the credibility of disclosure.

Thus, assurance is a differentiated tool that allows a company to signal a degree of reliability of the underlying information, not just a standardised commodity determined exclusively by regulation (Ball et al. 2012). Watts and Zimmerman (1990)posit that firms with opaque information bear the cost of information asymmetry, which incentivises firms to adopt expensive assurance.

3.2.4 Carbon assurance

The purpose of an independent carbon assurance is to ensure that the underlying GHG report is prepared in line with an appropriate protocol, so that the information is credible and useful for decision making. The MVR policy is implemented differently in different jurisdictions. For example, emission data for emitters whose emissions are above the threshold are recorded in the US Environmental Protection Agency's (EPA's) Clean Air Markets Division database. The publicly available disclosed GHG information is subject to the EPA monitoring provisions. In some countries (e.g., EU, China), carbon assurance is required for a small number of organisations—particularly those that participate in an Emission Trading Scheme (ETS) by an accredited assurance practitioner or provider. However, for most countries and the overwhelming majority of commercial organisations, carbon assurance remains voluntary. For example, in the United Kingdom (UK), it is mandatory for all listed firms to report GHG emissions, yet carbon assurance of the reported GHG emissions is optional (Liao et al. 2015). Under the setting of this study, companies that participated in a CDP survey were required to reveal their GHG emissions figures, but verification of the emissions was discretionary for the survey. In sum, carbon assurance is emerging as a burgeoning market and mainstream practice for accounting firms and other consultation organisations, and is playing an increasingly important role for corporate transition management towards a carbon-free future (Liao et al. 2015).

Simnett and Nugent (2007) is among the earliest studies to discuss the new emerging assurance on carbon emission disclosure. By analysing sustainability information disclosed by Australian firms in 2005, they find that only less than 10% firms report carbon emissions in their annual financial statements and only seven firms fully disclosed the information. They recommend firms to voluntarily disclose carbon information in their annual statements or standalone sustainability statements to ensure the completeness of carbon disclosure and emphasise the importance of having such disclosure audited or assured to improve the reliability and credibility of the disclosed information.

Green and Zhou (2013) is one of the earliest empirical research papers in examining carbon assurance practice. Drawing on a sample of over 3,000 firms internationally over a period of 2006 to 2008 from CDP database, they bring an insightful inspection on the new emerging assurance practice on carbon disclosure in the assurance market. They document that the number of firms employing third party assurance on carbon information disclosed is growing during the study period and this trend synchronises with the growing awareness of the public on climate change issue and the increasing demand for credible and reliable carbon disclosure. The results reported suggest that firms operating in European countries and carbon-intensive sectors tend to be more active in engaging third party carbon assurance and account for the highest percentage in carbon assurance adoption. In terms of assurance provider, the data shows that auditing firms dominate the market.

Olson (2010) identify the differences between financial auditing and carbon assurance. They point out that carbon assurance requires knowledge about the operations and production processes of clients and the underlying assumptions about the conversion of combustion data of different fuels to carbon emissions, as well as the basic accounting skills.

Huggins et al. (2011) discuss different types of GHG assurance and the requirements of proposed ISAE 3410 on GHG assurance providers. They highlight that firms with high Scope 1 emissions should use multi-disciplinary assurance providers who have both auditing expertise and subject matter knowledge to ensure the credibility and reliability of disclosed GHG information.

Unlike conventional auditing of financial statements, which is monopolised by the accounting firms, carbon assurance operations are sometimes conducted by entities from outside the accounting field. These non-accountants are usually experts in a relevant area, such as engineering, energy efficiency, and environmental management (Zhou et al. 2016). Accounting professionals and consulting companies provide different advantages for carbon assurance.

Green et al. (2017) firstly study the factors that drive managers decision of carbon assurance provider. They analyse the responses of 25 corporate officers from Australian companies to the survey questionnaire and find that firms tend to choose assurance teams and leaders who have better reputation and independence, as well as the superior capability in technical and assurance knowledge and communication skills. Thus building teams with efficient multidisciplinary capability is critical for assurance firms to gain competence in carbon assurance market.

Zhou et al. (2016) examine the factors that influence managers' decision of carbon assurance adoption and the assurance provider choice. They document that the business culture (whether firms are from a shareholder or stakeholder-orientated country) and the legal enforcement environment are significantly related to the firms' purchase of independent assurance on carbon disclosure. Specifically, firms from stakeholder orientation countries and countries with stringent legal enforcement environment tend to engage carbon assurance and this is relationship in conditional on corporate governance. In terms of the assurance provider choice, they document that firms from stakeholder orientation countries have a preference to choose accounting firms over consulting firms and this relationship is stronger for firms with superior corporate governance.

Datt et al. (2019) employ legitimacy theory to explain the determinants of carbon assurance engagement. They utilise a sample of US firms that disclose carbon information to CDP from 2010 to 2013 to study how legitimacy threats impact the firm's decision on purchasing third party assurance on their carbon information disclosed. They argue that carbon assurance arises as a response to legitimacy threat from growing public awareness of climate change issue and increasingly stringent climate change policies and regulations. Carbon emission intensity, firm size and firm leverage are employed as proxies for legitimacy threats. The empirical results suggest that firms with higher carbon emission intensity and larger size are more likely to use carbon assurance as high emitters are more subjective to carbon legislation thus are under higher pressure to reduce carbon emissions and are exposed to greater legitimacy threats, which motivates firms to adopt carbon assurance to close the legitimacy gap.

By employing legitimacy theory and stakeholder theory, Datt et al. (2020) further investigate the firms' choice of carbon assurance provider. Based on a global sample of firms responding to CDP questionnaire from 2010 to 2014, they find that firms under higher pressure from stakeholders and climate change legislation are more likely to use accounting profession as assurance provider as accounting firms are superior in independency and assurance quality thus serving as a more credible signal for high quality disclosure. On the contrary, firms with established carbon governance, such as carbon reduction initiatives, carbon reduction incentives to staff and carbon disclosure transparency, prefer consulting firms over accounting firms as these firms are more motivated to improve their carbon management system and build up resilience capability to climate change rather than just achieve legitimacy purpose.

Despite the existence of differentially informed managers and outsiders, there are few studies on carbon assurance (Datt et al. 2018b; Zhou et al. 2016), thus motivates this research to focus on carbon information asymmetry as a fundamental factor that leads the managerial decision to select an external assurer to verify their carbon emissions data. The findings add direct empirical evidence to the scant literature on this topic.

3.3 Financial versus Carbon Information Asymmetry and Financial versus GHG Assurance

While financial statements focus on financial matters, carbon reports present information related to GHG emissions (including categorised removals) and carbon reduction activities over a particular period for a reporting entity for the decision making of users (ISAE 3410). Producing GHG statements may be required under a regulatory regime or may be voluntary. Various incentives exist for managers to manage earnings for purposes other than to provide a true and fair view of a firm's financial performance. Similarly, directors may make disclosures intended to alter the perceptions of stakeholders by hiding the firm's true carbon performance. Luo (2019) utilises a sample of Global 500 firms responding to CDP questionnaire over the period from 2008 to 2015 to examine the correlation between carbon disclosure level and firm's true carbon emission reduction performance and how this relationship is moderated by carbon institutions. The results suggest a statistically significant and negative relationship between carbon disclosure level and carbon performance. Legitimacy theory is employed to explain the relationship. It is argued that firms disclose more carbon information doesn't necessarily mean that they have better performance in carbon management. The rationale behind is that firms with higher volume of carbon emissions are under greater legitimacy threats, thus having motivation to provide more information and highlight the positive sides of their actions toward carbon reduction and carbon management. Moreover, the negative relationship between carbon disclosure level and carbon performance are found to be weakened in more stringent carbon institutions. Specifically, the negative relationship is less pronounced for firms in carbon-intensive sectors, firms operating in countries with stakeholder orientation and firms that participate in an ETS.

Thus, biased climate information can be provoked by external climate legislation and institutions. This problem is further exacerbated by the lack of internationally recognised methods for measuring and quantifying GHG emissions. Based on a sample of 243 Global 500 firms participating CDP, Tang and Luo (2016) examine the determinants of firms' disclosure behaviour of carbon information. They document that firms with larger size, operating in carbon-intensive industries and relying more on debt financing are more likely to provide comprehensive carbon disclosure. In terms of country-level institutional factors, results suggest that the level of carbon disclosure is higher in countries with ETS and more stringent climate legislation thus a more developed framework for carbon reporting and carbon assurance standards is needed.

The central concept in this study is carbon information asymmetry. There is consensus that separating ownership and control can result in information asymmetry between inside managers and outside stakeholders. This asymmetry historically refers to financial information; however, it can be extended to nonfinancial information. Carbon information asymmetry is a unique dimension of information asymmetry. Yet carbon accounting for GHG quantification entails entirely different knowledge and expertise than conventional financial accounting. In addition, voluntary disclosure of carbon information involves private information owned by managers. Outsiders are unable to access this information. Finally, because managers may be less committed to climate change, their carbon disclosure may not meet ethical standards. Thus, third-party verification is necessary to add credibility to carbon disclosures. The objectives of the assurer are to provide reasonable or limited assurance that a firm's GHG statement is free from material misstatements and has been prepared, in all material aspects, in accordance with applicable standards (IAASB 2012).

The literature suggests some significant differences between financial assurance and carbon assurance (Datt et al. 2018). Unlike traditional financial statement auditing, which is monopolised by the accounting profession, GHG assurance operations are sometimes conducted by practitioners who are not in the accounting profession. These non-accountants are usually experts of relevant field, for example, engineering, energy efficiency, and environmental management (Simnett et al. 2009a; Huggins et al. 2011). Accounting professionals and environmental consulting companies provide different advantages for carbon assurance (Simnett et al. 2009a; Olson 2010; Huggins et al. 2011; Green and Zhou 2013). Accounting professionals have a greater reputational capital advantage because of their flagship financial statement auditing services (Simnett et al. 2009a; Huggins et al. 2011); however, providers from consultation firms tend to be less expensive and are generally considered to have better subject expertise (Simnett et al. 2009a; Huggins et al. 2011; O'Dwyer et al. 2011). When taking GHG assurance, GHG assurers must assess risk and uncertainty, as a firm may not have a robust system in place to collect and process energy and carbon data. Moreover, GHG assurers use different investigative methods than traditional attestation (ISAE 3410). Further, a firm may have a unique internal control mechanism compatible with the complexity of its operations and the nature of its business (IAASB 2012).

In addition, misstatements might be related to the firm's organisational structure and boundaries and related parties (IAASB 2012). Therefore, methods for controlling risk and examining GHG emissions in carbon assurance are expected to differ significantly from methods used in conventional financial auditing.

3.4 CSR/Sustainability Assurance and Stakeholder Engagement

As global warming is intensified, business organizations are expected to play a role in stabilizing climate change (Luo et al. 2012). There are multiple stakeholder groups with diverse attitudes toward climate change. Advocates of stakeholder theory assert the importance of a company engaging with a broader set of stakeholders to ensure its long-term survival and success, as stakeholders (both financial and nonfinancial) provide critical resources to the company with the expectation that their interests will be borne in mind (Hannan and Freeman 1984; Simnett et al. 2009b; KPMG 2015).

Roberts (1992) uses 1986 Council on Economic Priorities (CEP) reports published by 130 companies from Fortune 500 over a period from 1984 to 1986 to investigate the drivers of corporate social responsibility disclosure based on stakeholder theory. The results suggest that the measurements of stakeholder power, strategic posture and economic performance are statistically significantly related to corporate social disclosure level.

By employing stakeholder theory, Van der Laan Smith et al. (2005) explore the impacts of country of origin on the corporate social disclosure. They argue that the role of a company and its stakeholders plays on annual corporate social disclosure varies across countries. The results show that large firms from stakeholder-orientated countries tend to have higher levels and quality of corporate social disclosure than firms from shareholder-orientated countries.

Given the emergence of sustainability-oriented stakeholders (i.e., those who have a sustainability mandate in their decision-making process) (Earl and Clift 1999; Al-Tuwaijri et al. 2004; Koellner et al. 2005; Dhaliwal et al. 2011), companies are expected to disclose increased environmental information (Gray and Bebbington 2001; Lacy et al. 2010). Nevertheless, the quality and credibility of this information have been questioned in light of the lack of public trust in business institutions (Riffkin 2014). The financial literature posits that auditing is critical to constraining opportunistic disclosure and reduce information asymmetry (Watts and Zimmerman (1990); (Wallace 1987; Perego and Kolk 2012; Moroney et al. 2012). Similarly, sustainability assurance is a key element of scrutinizing social and/or environmental information (Adams and Evans 2004; O'Dwyer and Owen 2005; Deegan et al. 2006). It acts as a monitoring tool for managers (Wong and Millington 2014) and catalyzes effective and constructive dialogue with a company's stakeholders (KPMG 2015). Edgley et al. (2010) contend sustainability assurance adds value for both management and stakeholders and links the accountability chain by engaging stakeholders in assurance processes (O'Dwyer and Owen 2005; Edgley et al. 2010). Simnett et al. (2009a) argue that sustainability assurance is critical because it assists firms in improving their environmental disclosure and reduces the incidence of opportunistic reporting. Notwithstanding, obtaining such assurance is voluntary and unregulated in most parts of the world. At present, there are no mandatory guidelines for carbon assurance despite the existence of a number of useful frames of reference (AccountAbility 2008); (GRI 2002), particularly ISAE 3000 and ISAE 3410 which guide specifically the assurance of GHG statements.

3.5 Managerial Capture and Impression Management

Prior literature has examined managerial incentives (such as *Impression management, legitimation*) to engage in environmental activities. Goffman (2002) suggests people can manage impressions of them by creating a front and concealment. Researchers have used this theory to reveal how a business constructs a false image of environmental accountability. Impression management in this context involves the opportunistic responses to climate change that refers to "greenwashing" behaviour. Greenwashing is a symbolic adherence to climate guidelines by exhibiting superficial gestures that do not decarbonize their operations (Moneva et al. 2006). The entity may strategically choose unregulated disclosure that does not address negative, systemic environmental consequences, but to alter the perceptions of users for legitimation purposes (Malsch 2013). Furthermore, impression management can also extend to voluntary environmental assurance where the process of assurance is controlled by the auditee. This activity is called managerial capture (Edgley et al. 2010) such assurance becomes a tool of legitimation by corporate managers (Power 1991; Edgley et al. 2010).

Despite this, this study provides emerging empirical evidence that things have been improving in recent years, perhaps because of enhanced public awareness of the severe climate change and environmental protection. For instance, Edgley et al. (2010) assess the benefits and stakeholder engagement of social and environmental report assurance (SERA). Their qualitative data show that stakeholders are increasingly being engaged in SERA. Assurance is starting to help managers and stakeholders simultaneously and offer dual benefits. The assurance process can be described as “display[ing] some characteristics of a dialogical process, being stakeholder inclusive, demythologising and transformative, with assurors perceiving themselves as a ‘voice’ for stakeholders” (Edgley et al. 2010, , p532). With engagement of stakeholders, SERA influences the attitudes of managers toward a large range of stakeholders and the wider community, which can benefit both managers and stakeholders. Nevertheless, there remain obstacles to dialogic SERA, which can be removed by assurers via educative and transformative processes. Similarly, O’Dwyer et al. (2011) suggest that the objective of engagement might be to seek legitimacy, in spite of this, auditors are inclined to work tightly with client managers and the users of the assurance statement, which can still improve the communication of the parties involved. In the context, carbon assurance shares many similarities with sustainability assurance. For example, both are none financial assurance and concerning general, or specific sustainability issue (i.e. carbon emissions). Most importantly, carbon assurance and sustainability assurance address the demand of none financial stakeholders (not just shareholders) who care about environmental problems. Thus, the stakeholder engagement theory is readily applicable in a climate change setting where more and more people are aware of the imminent threat of climate change. Although impression management remains a concern, the existence of other scenarios in which genuine managerial motives exist to boost carbon performance and stakeholder inclusivity in environmental/carbon assurance can not be ruled out (Edgley et al. 2010). This research thus uses this perspective to guide the hypothesis development in the following section.

CHAPTER 4 CARBON INFORMATION ASYMMETRY AND CARBON ASSURANCE

4.1 Introduction

The scientific literature demonstrates the growing effects of human activity on climate change (Stern et al. 2007). Corporations are considered to be responsible for reducing their carbon emissions to help stabilise climate change (Luo et al. 2012). Indeed, protecting the environment is becoming a major aspect of corporate social responsibility (CSR). Although the corporate disclosure of greenhouse gas (GHG) emissions information is critical for the decision-making of users of corporate reporting (Thornton and Hsu 2001), the quality and reliability of such disclosures are not guaranteed (Freedman and Jaggi 2005; Stanny and Ely 2008; Reid and Toffel 2009), given that Scope 1, 2 and 3 carbon emissions are difficult to measure.[5] Further, GHG statements may incorporate other carbon-related information (e.g., information on carbon risk or carbon governance) and activities that are subject to manipulation by managers (i.e., greenwashing). Greenwashing occurs when managers selectively disclose positive information regarding corporate carbon performance without fully disclosing negative information (Lyon and Maxwell 2011). Thus, there is an increasing demand for external carbon assurance to enhance the credibility of carbon information disclosed by firms (Huggins et al. 2011; Kolk et al. 2008). However, few regulations and standards apply to this assurance (Zhou et al. 2016). The International Auditing and Assurance Standards Board (IAASB) has issued ISAE 3410, which stipulates specific guidelines for GHG statement assurance (International Federation of Accountants 2012). Nevertheless, the literature on the assurance of carbon emissions remains very sparse (Simnett et al. 2009a; Datt et al. 2018). Thus, this study fills this gap by studying the association between carbon information asymmetry and independent assurance of GHG statements.

Information asymmetry theory is often used to explain the role of auditing in financial statements. For instance, Chow et al. (1988) argue that financial auditing arises because of financial information asymmetry, the agency problem and related costs. This study extends this argument to carbon assurance, proposing that the adoption of voluntary GHG assurance is motivated by a need to reduce carbon information asymmetry between inside managers and

[5] Scope 1 emissions are those directly emitted by sources owned or controlled by an entity, while the Scope 2 category consists of indirect GHG emissions from energy transferred to and consumed by the entity (e.g., the utilisation of purchased electricity). Scope 3 emissions are indirect and are associated with employee commutes, business travel, waste disposal, product disposal, the leasing of assets, and so on (www.epa.gov/aintrnt.gh.index).

outside stakeholders. This study identifies certain factors (the quantity of emissions, type of fuels used and membership in a carbon-intensive sector) as proxies for carbon information asymmetry. It is predicted that these factors are related to the adoption of independent assurance. Using data from the CDP, I empirically test the predictions. The CDP is a nongovernmental, nonprofit organisation that provides information about companies' GHG emissions and carbon activity and other GHG information. While carbon information disclosed to the CDP is comprehensive, some information cannot be readily verified by outside investors and stakeholders. Therefore, many firms choose to involve a third party to check their carbon disclosures. It is demonstrated that the degree of information asymmetry (actual or perceived by managers) drives the decision to adopt carbon assurance. The results are robust when I control for firm size, profitability, and leverage, which are potentially correlated with both carbon disclosure and the adoption of assurance. It is worth noting that the sample in this study covers large listed firms whose financial statements should be considered as transparent as they are audited by high-profile auditors. However, this does not necessarily mean that the carbon information disclosed by these firms is transparent. Thus, carbon disclosure should be taken separately from traditional financial disclosures.

The paper makes unique contributions to the literature on green accounting and carbon assurance. First, it is argued that assurance oriented to climate change is an important dimension in carbon accounting. However, few studies have considered this emerging practice (Datt et al. 2018), so this study extends the research on financial auditing to carbon assurance because carbon emissions are a serious threat to sustainability (Lash and Wellington 2007). Firms are expected to have specific capabilities to reduce carbon emissions under a range of jurisdictional and institutional pressures (Luo et al. 2013). Carbon mitigation is a unique dimension of the broader concept of CSR (Chatterji et al. 2009; Strike et al. 2006; Walls et al. 2011), which deserves a separate study. Second, to my best knowledge, this is the first study to use carbon information asymmetry theory to explain the adoption of carbon assurance. This study uses innovative variables to proxy for carbon information asymmetry underlying managerial incentives to adopt GHG assurance. Third, this research enhances the validity and applicability of information asymmetry theory in a nonfinancial setting by explaining the reactions of firms to global warming. Finally, instead of using data from financial statements or CSR reports (Kolk 2003; Ballou et al. 2006), this study utilises data from the CDP. The CDP database contains more complete and consistent information than alternative sources (Luo et al. 2012) as the CDP employs a single set of guidelines that all participants are required to comply with, which minimises manipulation of the carbon data. In sum, this study offers new and nuanced insights, which should prove useful for lawmakers in relation to the development of policy initiatives. Additionally, it may help accountants to provide services in a burgeoning and highly promising market.

The remainder of this paper is structured in the following manner. Section 2 elaborates the distinction between financial statement assurance and GHG statement assurance. Section 3 presents the literature and hypothesis development. Section 4 provides a description of the sample selection and research model, with Section 5 reporting the empirical results. A summary of the findings and a discussion of future research avenues is given in Section 6.

4.2 Hypotheses Development

4.2.1 Carbon information asymmetry and carbon assurance

GHG emissions and activities are largely sourced in managers' private data, making them appropriate for external verification under the concepts of information asymmetry economics (Myers 1984). This high information opacity does not allow users to evaluate a firm's fundamental value and reduces the quality of the decisions of investors who want to invest permanently in competitive low-carbon technologies. This is because measuring GHG emissions is a task of high complexity, and a sound accounting and management system is required to process the recording and calculation of carbon emissions (Luo and Tang 2014). Such a system is necessarily internal and is difficult to observe directly from the outside. Most stakeholders lack environmental competencies and have limited or inferior cognitive ability regarding carbon issues, whereas managers can access timely carbon information and have superior capacity to process this information. The divergent knowledge and interpretation of carbon information between inside managers and outside parties may lead to poor judgement and decisions. Thus, an independent qualified assurer is often called in to reduce knowledge asymmetry and vouch for the credibility of the voluntarily revealed information, as well as to ensure its accuracy and completeness (Datt et al. 2018). Assurance not only enhances the quality of disclosures but also contributes to the long-term improvement of environmental management systems (Healy and Palepu 2001), including carbon asset management. Following this reasoning, it can be argued that the greater the degree of carbon information asymmetry, the more likely it is that firms will adopt carbon assurance. With reference to this discussion, the following hypothesis is proposed:

H1: *There is a positive relationship between carbon information asymmetry and the adoption of external carbon assurance.*

Although carbon information asymmetry is ubiquitous in all businesses, not all firms that disclose carbon information adopt third-party assurance. We argue that this is because of the differing degrees of carbon information asymmetry among these firms. If this is a negligible issue, carbon assurance may be unnecessary. Only a severe information gap warrants external assurance, that is, only the benefit of closing such a gap would be sufficiently great to cover the cost of doing so (e.g., fees paid to the assurance providers). Hence, the net benefit of assurance is likely to accrue to firms with wide carbon information asymmetry. To empirically test this hypothesis, we must identify variables that can be used as proxies for carbon information asymmetry. Statistically significant coefficients of these proxy variables would imply that firms are motivated to adopt GHG assurance to bridge the gap of information between insiders and outsiders.

Carbon emissions

One factor underlying carbon information asymmetry is the quantity of GHG emissions, as it increases measurement complexity. GHG accounting involves managers' estimates of energy consumption, modelling inputs and assumptions, as well as the adoption of appropriate methodologies for quantifying Scope 1, 2 and 3 carbon emissions. The higher the carbon emissions, the more complex the methods used to account for GHG emissions and the more uncertain the assumptions (Nordhaus 1992). Further, heavy emissions are often sourced from multiple operations, products and services, and from multiple departments in a firm. Thus, they are linked with a variety of assets and liabilities and with a sophisticated organisational structure, and it is subsequently not practical or realistic for users to track their sources. This inevitably increases the knowledge gap between outsiders and insiders and erodes or even destroys stakeholders' trust and confidence in a firm's carbon report. Because firms with higher emissions are exposed to greater scrutiny from the public, corporate carbon opacity may raise serious concerns about a firm's impact on the climate and jeopardise its image and reputation (Patten 2002). This motivates managers to provide a clear and credible picture of a firm's carbon performance. Higher emissions exacerbate information opaqueness and highlight the need for independent assurance to guarantee the integrity of the reported information (Green and Li 2011). Thus, firms with excessive emissions tend to adopt expensive independent assurance to signal that they are concerned and responsible entities. Based on this argument, the volume of carbon emissions is adopted as the first proxy for carbon information asymmetry, from which the hypothesis is put forth as below:

H1a: *Firms with higher carbon emissions tend to adopt independent carbon assurance.*

Energy structure

Carbon information asymmetry is influenced by the quantity of GHG emissions and is linked to the sources and types of energies and fuels used that generate the emissions, as the emissions factor[6] varies across sources. For example, a firm may use a single source of fuel, such as coal, or it may use multiple types of energy, such as coal, gas, oil, bioenergy or other clean and renewable energies. Different types of energy and fuel produce different carbon emissions. The combustion of various types of fuel or the purchase of electricity, heat or cooling that is generated by different types of energy can complicate the measurement of fuel consumption and the conversion of fuel data into carbon emissions. The more different are the types of energy used by a firm, the more complex the process of carbon accounting, which aggravates inherent carbon information asymmetry. Thus, a firm that only consumes a single source of fuel, such as coal, or a firm that uses electricity that is generated by only a single source will have more straightforward carbon data than a firm that uses a mix of energy. Thus, the complexity of the energy structure is expected to positively relate to carbon information asymmetry. Therefore, the number of types of energy (fuel) used is chosen as the second proxy and form the following hypothesis:

H1b: *Firms with a more complex energy structure tend to adopt independent carbon assurance.*

Membership in a carbon-intensive sector

The next proxy for carbon information asymmetry is related to a firm's operation in a carbon-intensive sector. Eng and Mak (2003) and Patten (1992) find that environmentally sensitive industries tend to have higher pollution and are targeted by environmental legislation (Baumert et al. 2005; Brammer and Pavelin 2006). Carbon information asymmetry is higher in GHG-intensive sectors, due to the impact of carbon legislation, which mainly targets carbon-intensive sectors and the outcomes of the impacts are hard for outsiders to assess. For

[6] The emissions factor is a ratio that is applied in the calculation of carbon emissions. It represents the value of a given source of fuel/material/energy relative to units of activity or processes that are used to convert into GHG emissions (Mareddy et al. 2017).

example, the American Power Act of 2010 was expected to significantly affect sectors with heavy emissions.[7] Taxes and fees can be introduced to raise the direct costs of energy usage and to increase the indirect costs, such as compliance costs (Al-Tuwaijri et al. 2004), for firms in energy-intensive sectors. It is difficult for outsiders to fully understand and assess the net effects of carbon legislation, rules and standards on the operation and profitability of these firms, even though these firms are subject to extensive scrutiny from the government, media and public. Thus, the third proxy for carbon information asymmetry is membership in a carbon-intensive sector, and the hypothesis is formalised as below:

H1c: *Firms with membership in a carbon-intensive sector tend to adopt independent carbon assurance.*

Based on the literature (Luo et al. 2012; Luo and Tang 2015; Tang and Luo 2014), this study considers energy, utilities and materials to be carbon-intensive sectors based on firm Global Industry Classification Standard codes. Energy firms exploit non-renewable resources (fossil fuel), and this takes a toll on the environment. Additionally, entities in the utilities and materials sectors are major consumers of energy and produce high GHG emissions (Simnett et al. 2009a). Companies in these industries have large emissions footprints and are subject to significant carbon legislation and regulations. The difficulty that outsiders have in evaluating the effects of these regulations on a firm's business creates carbon information asymmetry.

4.2.2 Carbon disclosure and carbon assurance

Generally speaking, the current literature presents two theoretical assumptions regarding the role of carbon disclosure. The first view is that carbon disclosure faithfully reflects the underlying carbon emissions performance, corporate climate change policies and activities. This perspective can be termed the transparency assumption. For example, carbon disclosure can enhance transparency, so it may reduce the cost of capital and facilitate a reduction in any adverse effect GHG emissions may have on a firm's value (Matsumura et al. 2014). Therefore, carbon disclosure reduces carbon information asymmetry. Under the carbon information asymmetry theory, the greater the carbon information asymmetry, the higher the likelihood of

[7] This bill sets steadily decreasing limitations on carbon emissions in energy-intensive industries. It includes measures to invest in key energy technologies and promote innovation and job creation in the affected industries (https://archive.epa.gov/epa/climatechange/american-power-act-2010-111th-congress-june-2010.html).

the use of assurance. Thus, a negative association is expected between carbon disclosure and carbon assurance (H2a).

The second view can be called the corporate veil assumption, which proposes that corporate disclosure does not reveal true environmental performance. Disclosure could be utilised by managers as a tool to legitimise their behaviour (Gray 2000) and achieve certain goals, such as creating a green image for and favourable impression among stakeholders (Cho et al. 2013; Deegan 2002). Hopwood (2009) argues that this disclosure may even reduce the understanding of a company and its environmental activities. When such strategies succeed, the legitimacy of the company will be less questioned; thus, the disclosure may, in fact, provide misleading or biased information. Thus, this is not only a problem of 'doing the right thing for the wrong reason' (Schaltegger and Burritt 2010), but of deliberately attempting to promote the positive side of a firm through a sustainability disclosure while hiding unsatisfactory performance in a self-congratulatory manner (Owen et al. 2001). In the spirit of this critical argument, the disclosure probably does more harm than good (Gray 2010; O'Donovan 2002). This disclosure may act as a veil (Hopwood 2009) that covers unpleasant truths or creates an artificial green identification (Clarkson et al. 2011).

Globally, carbon disclosure remains a voluntary practice in most jurisdictions. For this reason, a number of researchers voice concerns regarding the credibility of this disclosure (e.g.,Haque and Deegan 2010; Stanny and Journal 2018; Kolk et al. 2008). Haslam et al. (2014) criticise the existing disclosures because they 'generate malleable, inconsistent and irreconcilable numbers and narratives'. The shortcoming of corporate carbon disclosure is reflected in the gap in expectations amongst stakeholders and corporate managers (Haque et al. 2016; Lodhia et al. 2012). Luo (2019) examines the relationship between the disclosure of carbon and carbon performance among Global 500 firms and indicates that legitimation is the primary purpose of carbon disclosure, and this motivation is more prevalent among firms with worse carbon reduction performance. Furthermore, there is a growing amount of anecdotal evidence that firms (e.g., carmakers and energy companies) misrepresent their true carbon performance in their carbon reporting, as well as its negative impact on climate change (Wasim 2019). These findings resonate with the critiques of previous authors, who tend to view voluntary disclosure as a 'corporate veil' (Gray 2010; Hopwood 2009) that can protect interior carbon-related information from outside scrutiny, which leads to increased information asymmetry despite the apparent openness with which it is reported. Under the theory of carbon information asymmetry, the higher the carbon information asymmetry, the greater the likelihood of using carbon assurance. Thus, a positive correlation between disclosure score and carbon assurance is expected (H2b). Given the ambiguity in views on the role of carbon disclosure, the following hypotheses are proposed:

H2a*: There is a negative relationship between disclosure score and carbon assurance.*

H2b*: There is a positive relationship between disclosure score and carbon assurance.*

The following figure shows the logic behind the relationship among carbon disclosure, carbon information asymmetry, and carbon assurance:

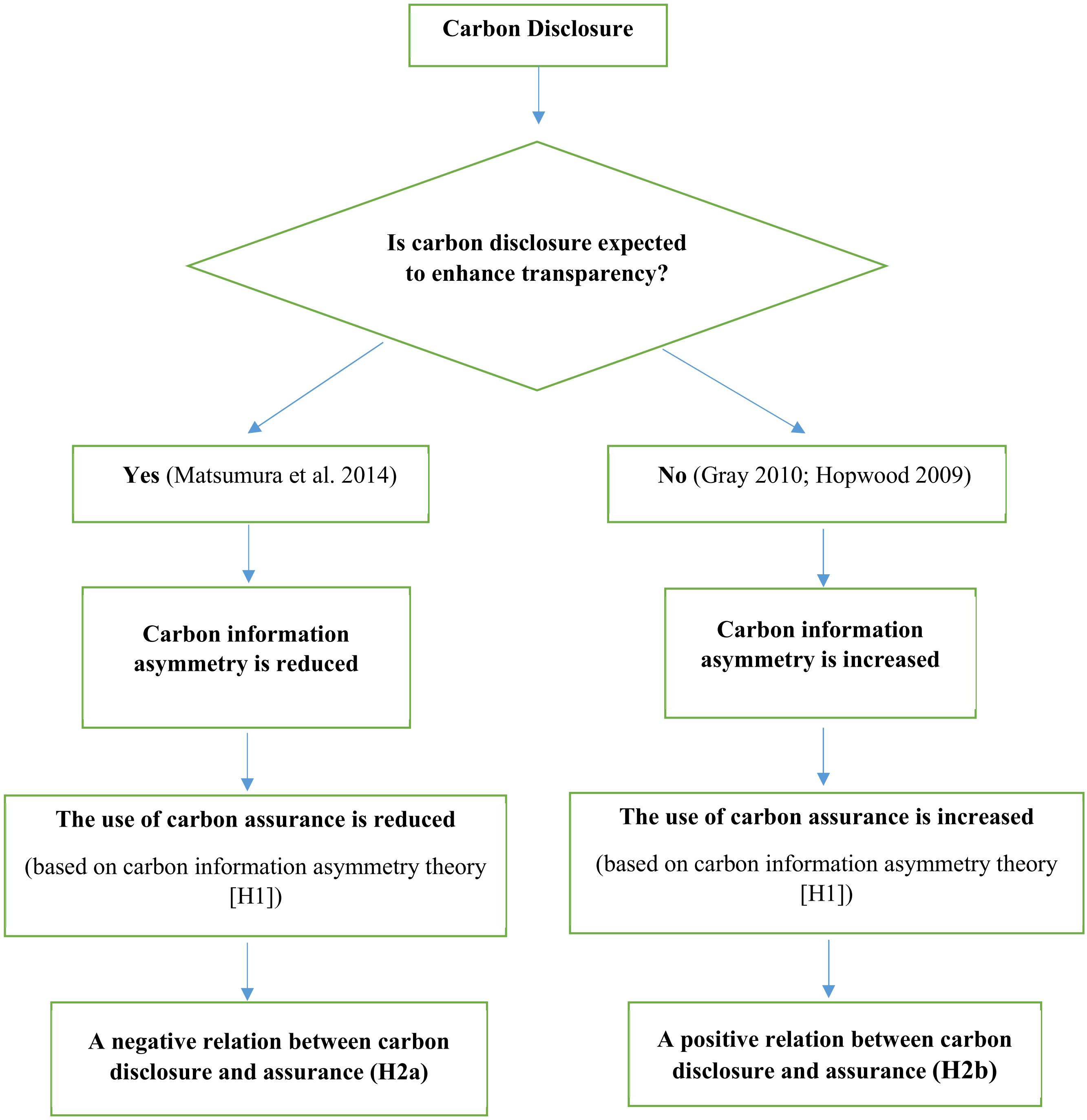

Figure 4. 1: Flow Chart of H2

4.3 Research Design

4.3.1 Sample selection

The carbon-related data employed within this study are obtained from the CDP database (CDP 2011–2015).[8] The study period commences in 2011 because CDP information is only complete and consistent from that year, and CDP 2015 data are the latest available at the time this study was undertaken. Table 4.1 depicts the process of sample selection, beginning with firms in receipt of the CDP survey questionnaire (28,154 company-years). Then the sample is filtered by companies with an 'Answered Questionnaire' response status (participating companies). The sample is further limited to companies that allow complete information on their Scope 1 and Scope 2 carbon emissions to be publicly available. Next, these companies are combined with those in Datastream and Worldscope, where financial data are obtained. After this screening process, the final sample is 4,573 observations. We use CDP data because the CDP is the largest, most comprehensive and most consistent dataset on corporate carbon reporting, which is especially important due to the diversity of locations where disclosures are made. The CDP is also the source of data for many previous studies (Kolk et al. 2008; Stanny and Ely 2008; Reid and Toffel 2009; Stanny 2013; Matsumura et al. 2014). CDP collects carbon information from the largest listed companies around the world. Participation in the survey is voluntary, and companies' responses are published by the CDP on its website. Finally, the CDP uses a standardised questionnaire that ensures comparable responses between entities, which is in contrast to sustainability or CSR reports, which are subject entirely to managers' discretion.

[8] CDP 2011–2015 reports provide carbon data from the year 2010 to 2014 for the participating company.

Table 4. 1: Sample Selection

	Total	CDP2010	CDP2011	CDP2012	CDP2013	CDP2014	CDP2015
Received questionnaire from the CDP in CDP2011–CDP2015	32,937	4,783	5,022	5,521	5,579	5,731	6,301
Less those that did not respond	19,372	2,734	2,886	3,258	3,249	3,387	3,858
Less observations for which carbon information is not publicly available	3,140	536	534	531	497	499	543
Less observations with missing values for carbon information	3,883	963	652	649	648	551	420
Less observations with other missing control variables	1,501	82	167	214	260	330	448
Final Sample	**5,041**	**468**	**783**	**869**	**925**	**964**	**1,032**
Firms with carbon assurance	3,429	271	472	582	649	706	749
Firms without carbon assurance	1,612	197	311	287	276	258	283

4.3.2 Research model

4.3.2.1 Carbon information asymmetry and carbon assurance

This empirical analysis investigates whether the proxies for carbon information asymmetry illustrate a significant association with the adoption of carbon assurance. The following three logistic regression models (Kolk and Perego 2010) with panel data are specified to test H1a, H1b and H1c:

$$\log\left[P(ASSU_{it}=1|X_{it})/\{1-P(ASSU_{it}=1|X_{it})\}\right]=X_{it}^{\top}\beta,$$

with

$$X_{it}^{\top}\beta=\beta_0+\beta_1Ein_{i,t}+\beta_5Size_{i,t}+\beta_6ROA_{i,t}+\beta_7LEV_{i,t}+\beta_8ENV_{i,t}+\beta_9Capin_{i,t}+\beta_{10}TobinQ_{i,t}+\beta_{11}STK+\beta_{12}ETS+Year\ Fixed\ Effects+Country\ Fixed\ Effects+\varepsilon \quad (1)$$

$$X_{it}^{\top}\beta = \beta_0 + \beta_2 Fueltype_{i,t} + \beta_5 Size_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LEV_{i,t} + \beta_8 ENV_{i,t} + \beta_9 Capin + \beta_{10} TobinQ_{i,t} + \beta_{11} STK + \beta_{12} ETS + Year\ Fixed\ Effects + Country\ Fixed\ Effects + \varepsilon \quad (2)$$

$$X_{it}^{\top}\beta = \beta_0 + \beta_3 CIS_{i,t} + \beta_5 Size_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LEV_{i,t} + \beta_8 ENV_{i,t} + \beta_9 Capin_{i,t} + \beta_{10} TobinQ_{i,t} + \beta_{11} STK + \beta_{12} ETS + Year\ Fixed\ Effects + Country\ Fixed\ Effects + \varepsilon \quad (3)$$

$\beta_1 Ein_{i,t}$ in model (1) is replaced with $\beta_2 Fueltype_{i,t}$ and $\beta_3 CIS_{i,t}$, respectively, in models (2) and (3).

Dependent and predictor variables

The dependent variable $ASSU_{it}$ equals 1 when firm *i* has its carbon emissions externally assured in year *t* and 0 otherwise. In models (1) to (3), each of the proxies is tested individually with the same control variables; all three proxies are included in model (4). *Ein* is a proxy for carbon information asymmetry and is measured as the total Scope 1 and 2 emissions in metric tons scaled by total sales in millions of dollars. H1a anticipates a positive sign for *Ein*. *Fueltype* is the firm's energy structure and is measured as the number of fuel types. Firms are required to select their fuel/material/energy type from a list provided by CDP and to identify the emission factor used to convert the data of the source into carbon emissions[9]. More complex energy structures result in higher carbon information asymmetry, enhancing the probability of adopting assurance. *CIS* equates to 1 if the firm operates as part of the materials, utilities or energy sector based on its Global Industry Classification Standard code and 0 otherwise.

Control variables

The empirical model controls for the influence of other variables on assurance. First, firm size is controlled. According to social-political theory, large-sized firms are subject to more stringent stakeholder scrutiny and media coverage in comparison to smaller sized firms

[9] For example, the list of fuel/material/energy types in the 2017 CDP questionnaire includes the following: Aviation gasoline; Biodiesels; Biogas; Brown coal; Crude oil; Electricity; Natural gas; Patent fuel; Petroleum coke; Shale oil; and Wood or wood waste. For details, please refer to: https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3 rackcdn.com/cms/guidance_docs/pdfs/000/000/224/original/CDP-Climate-Change-Reporting-Guidance.pdf?1478542692.

(Stanny and Ely 2008; Watts and Zimmerman 1990), and corporate carbon opacity may raise concerns about a firm's impact on the climate. Therefore, there is an expectation that firm size is associated with carbon assurance. Firm size (*SIZE*) equals the natural logarithm of total sales. Likewise, profitability (*ROA*) is controlled, as more profitable firms tend to engage carbon assurance because the cost of assurance is affordable (Luo et al. 2013). Previous studies indicate that leverage is associated with CSR disclosure, so this effect is also controlled: *LEV* equals total debts to total assets ((Hay and Davis 2004; Clarkson et al. 2008). *ENV* is the environmental pillar score from the Thomson Reuters ESG Asset4 database, which is used as a proxy for firms' environmental awareness. *Capin* is capital expenditure intensity, which is determined by dividing capital spending by total sales revenues at the end of the fiscal year. *TobinQ* is a proxy for financial performance to control for the influence of growth on carbon assurance (Clarkson et al. 2008). Further, *STK* represents the legal system; this dummy variable equals 1 if the firm is in a code law country and 0 otherwise (common law) (Archambault and Archambault 2003; Simnett et al. 2009b). *ETS* equals 1 if the firm is in a country with an operational ETS and 0 otherwise. *ETS* is controlled for the unhypothesised influences of a carbon-oriented institution in the firm's business environment. Finally, year and country fixed effects are also controlled. To minimise any potential impacts of outliers, all continuous variables are winsorised at the 1% and 99% levels. All definitions for variables are presented in Table 4.2.

Table 4. 2: Definitions of Variables

Variable	Description	Source
ASSU	A dummy variable equal to 1 if the company has assured either Scope 1 or Scope 2 carbon emissions and 0 otherwise	CDP
Ein	A proxy for carbon emissions, calculated as the ratio of total Scope 1 and Scope 2 emissions in metric tons to total sales in millions of dollars	CDP, Worldscope
Fueltype	A proxy for the complexity of the firm's energy structure, measured as the number of fuel types	CDP
CIS	A dummy variable equal to 1 if the firm is in a carbon-intensive sector (i.e., energy, materials, or utilities) and 0 otherwise	CDP
Disscore	Carbon disclosure score (excluding the score for carbon assurance), based on the Climate Disclosure Leadership Index, which measures the quality of the company's carbon disclosure to the CDP	CDP
SIZE	Natural logarithm of total assets, representing the size of the company	Worldscope
ROA	Return on assets, measured as net operating income divided by total assets at year end	Worldscope
LEV	Leverage, computed as long-term debt scaled by total assets at year end	Worldscope
ENV	An environmental score measuring the company's impact on living and nonliving natural systems, including the air, land, water, and complete ecosystems, and reflecting how well the company uses best management practices to avoid environmental risk and capitalize on environmental opportunities to generate long-term shareholder value	Thomson Reuters ASSET4
Capin	Capital intensity, measured as capital spending divided by total sales revenues at the end of the fiscal year	Worldscope
TobinQ	Total market value based on the year-end price and the number of shares outstanding, plus preferred shares, book value of long-term debt, and current liabilities, divided by book value of total assets	Worldscope
ETS	A dummy variable equal to 1 if the firm is in a country that has an operating national emissions trading scheme and 0 otherwise	CDP
STK	A dummy variable equal to 1 if the company is from a code law country and 0 if it is from a common law country	La Porta et al. (1997)
DISC	A dummy variable equal to 1 if the firm discloses its carbon information to the CDP and 0 otherwise	CDP
Disscore_Mean	Mean industry disclosure score	CDP

4.3.2.2 Carbon information asymmetry and carbon assurance

To assess the role of carbon disclosure, *Disscore* is introduced to test the impacts of carbon disclosure on the adoption of carbon assurance. *Disscore* is taken as a proxy for carbon disclosure. It is calculated by CDP using the Climate Disclosure Leadership Index methodology. The awarded score increases with the completeness and breadth of the answers the firm provides to the CDP questionnaire. The CDP questionnaire covers an extensive breadth of information associate with climate change, including carbon targets and initiatives, climate risks and opportunities; carbon strategies and governance; carbon accounting methodology; Scope 1, 2 and 3 emissions; energy consumption; climate initiatives; and engagement. Note that the disclosure score measures the comprehensiveness of carbon disclosure but not carbon reduction performance (Luo et al 2012).[10] Model (4) is used to test H2a and H2b. *Disscore* may have a negative (H2a) or positive (H2b) coefficient. Model (5) includes all four main independent variables in a single model:

$$\log\left[P(ASSU_{it} = 1|X_{it})/\{1 - P(ASSU_{it} = 1|X_{it})\}\right] = X_{it}^{\top}\beta,$$

with

$$\begin{aligned} X_{it}^{\top}\beta = {} & \beta_0 + \beta_4 Disscore_{i,t} + \beta_5 Size_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LEV_{i,t} + \beta_8 ENV_{i,t} + \beta_9 Capin_{i} \\ & + \beta_{10} TobinQ_{i,t} + \beta_{11} STK + \beta_{12} ETS + Year\ Fixed\ Effects \\ & + Country\ Fixed\ Effects + \varepsilon \end{aligned} \tag{4}$$

$$\begin{aligned} X_{it}^{\top}\beta = {} & \beta_0 + \beta_1 Ein_{i,t} + \beta_2 Fueltype_{i,t} + \beta_3 CIS_{i,t} + \beta_4 Disscore_{i,t} + \beta_5 Size_{i,t} \\ & + \beta_6 ROA_{i,t} + \beta_7 LEV_{i,t} + \beta_8 ENV_{i,t} + \beta_9 Capin_{i,t} + \beta_{10} TobinQ_{i,t} \\ & + \beta_{11} STK + \beta_{12} ETS + Year\ Fixed\ Effects \\ & + Country\ Fixed\ Effects + \varepsilon \end{aligned} \tag{5}$$

[10] For details on the CDP scoring methodology, please refer to the following link: https://www.cdp.net/en/cities/cities-scores/scoring-methodology.

4.4 Empirical Results

4.4.1 Descriptive statistics

Table 4.3 depicts the distribution of observations by country. The top five countries by number of observations engaging carbon assurance are the US (25.62% of total observations), the UK (16.47%), Japan (11.853%), France (7.54%) and Australia (5.51%). Table 4.4 indicates that the top sector for carbon assurance is industrials (19.16%), followed by financials (14.66%), consumer discretionary (11.68%), materials (11.11%) and consumer staples (9.69%). Table 4.5 presents the descriptive statistics for the variables in the study. The full sample comprises 4,573 firm-year observations, including 3,158 (69.06%) that had GHG emissions assured and 1,415 (30.94%) that did not. *T*-tests are also performed and it is found that firms that have their emissions assured tend to have a higher disclosure score, have higher carbon intensity, have a more complex energy structure, and belong to a carbon-intensive sector (i.e., energy, utilities or materials). In addition, firms that have their emissions assured are larger, are more profitable, and have better environmental performance than do firms that do not assure their emissions. All these results are consistent with the hypotheses and with prior studies regarding industry membership (Prado-Lorenzo et al. 2009; Zhou et al. 2016), size (Haniffa and Cooke 2005; Stanny and Ely 2008) and profitability (Simpson and Kohers 2002; Waddock and Graves 1997).

Table 4. 3: Distribution of Observations by Country

Country	Full Sample		ASSU = 1		ASSU = 0	
	N[a]	%[a]	N[b]	%[b]	N[c]	%[c]
Australia	264	5.24	181	5.28	83	5.14
Austria	30	0.60	27	0.79	3	0.19
Belgium	43	0.85	36	1.05	7	0.43
Canada	319	6.33	160	4.67	159	9.85
Denmark	89	1.77	57	1.66	32	1.98
Finland	89	1.77	68	1.98	21	1.30
France	282	5.59	262	7.65	20	1.24
Germany	199	3.95	175	5.11	24	1.49
Ireland	53	1.05	38	1.11	15	0.93
Italy	109	2.16	102	2.98	7	0.43
Japan	641	12.72	391	11.41	250	15.49
Luxembourg	12	0.24	5	0.15	7	0.43
The Netherlands	72	1.43	56	1.63	16	0.99
New Zealand	23	0.46	13	0.38	10	0.62
Norway	66	1.31	51	1.49	15	0.93
Portugal	33	0.65	30	0.88	3	0.19
Spain	136	2.70	126	3.68	10	0.62
Sweden	146	2.90	81	2.36	65	4.03
Switzerland	158	3.13	108	3.15	50	3.10
United Kingdom	863	17.12	576	16.81	287	17.78
United States	1,414	28.05	884	25.80	530	32.84
Total	5,041	100.00	3,427	100.00	1,614	100.00

ASSU = 1 if the firm has its carbon emissions assured and 0 otherwise.
%[a] is calculated as N[a] divided by the number of full sample (5,041).
%[b] is calculated as N[b] divided by the number of observations with carbon assurance (3,427).
%[c] is calculated as N[c] divided by the number of observations without carbon assurance (1,614).

Table 4. 4: Descriptive Analyses—Industry Frequencies

GICS Sector	Full Sample		*ASSU* = 1		*ASSU* = 0	
	N[a]	%[a]	N[b]	%[b]	N[c]	%[c]
Communication Services	143	2.84	110	3.21	33	2.04
Consumer Discretionary	680	13.49	400	11.67	280	17.35
Consumer Staples	454	9.01	328	9.57	126	7.81
Energy	310	6.15	224	6.54	86	5.33
Financials	685	13.59	507	14.79	178	11.03
Health Care	318	6.31	194	5.66	124	7.68
Industrials	965	19.14	649	18.94	316	19.58
Information Technology	460	9.13	253	7.38	207	12.83
Materials	539	10.69	381	11.12	158	9.79
Real Estate	212	4.21	149	4.35	63	3.90
Utilities	275	5.46	232	6.77	43	2.66
Total	5,041	100.00	3,427	100.00	1,614	100.00

ASSU = 1 if the firm has its carbon emissions assured and 0 otherwise.
%[a] is calculated as N[a] divided by the number of full sample (5,041).
%[b] is calculated as N[b] divided by the number of observations with carbon assurance (3,427).
%[c] is calculated as N[c] divided by the number of observations without carbon assurance (1,614).

Table 4. 5: Descriptive Statistics for Assurance

	Full Sample (N=5,041)			ASSU=1 (N=3,427)			ASSU=0 (N=1,614)			
Variable	Mean	Medi	SD	Mean	Medi	SD	Mean	Medi	SD	Mean Diff
Ein	0.28	0.04	0.88	0.32	0.04	0.93	0.19	0.03	0.73	-0.128***
Fueltype	4.56	4.00	2.82	4.85	4.00	2.89	3.93	3.00	2.54	-0.923***
CIS	0.22	0.00	0.42	0.24	0.00	0.43	0.19	0.00	0.39	-0.053***
Disscore	80.70	83.28	15.27	84.99	88.76	13.91	71.12	72.00	13.76	-13.865***
SIZE	16.55	16.39	1.61	16.89	16.72	1.57	15.79	15.62	1.45	-1.103***
ROA	0.05	0.04	0.06	0.04	0.04	0.06	0.05	0.05	0.07	0.006***
LEV	115.93	62.55	182.50	130.05	69.61	194.32	84.43	50.89	148.17	-45.625***
ENV	78.42	87.31	20.01	81.94	89.21	16.97	70.56	79.66	23.72	-11.384***
Capin	0.09	0.04	0.12	0.09	0.04	0.12	0.09	0.04	0.13	0.084**
TobinQ	1.61	1.29	0.95	1.55	1.26	0.86	1.74	1.38	1.10	0.185***
STK	0.58	1.00	0.49	0.54	1.00	0.50	0.67	1.00	0.47	0.128***
ETS	0.94	1.00	0.25	0.94	1.00	0.23	0.92	1.00	0.28	-0.029***

ASSU = 1 if the firm has its carbon information assured and 0 otherwise. ** $p < 0.05$, *** $p < 0.01$. Definitions of variables are provided in Table 4.2.

Table 4. 6: Correlation Matrix

	ASSU	*Disscore*	*Ein*	*Fueltype*	*CIS*	*SIZE*	*ROA*	*LEV*	*ENV*	*Capin*	*TobinQ*	*STK*	*ETS*
ASSU		0.09*	0.16*	0.06*	0.44*	0.33*	-0.06*	0.16*	0.25*	0.08*	-0.10*	-0.12*	0.05*
Disscore	0.02		0.34*	0.60*	0.02	-0.09*	0.00	0.04*	-0.00	0.61*	-0.04*	0.06*	-0.09*
Ein	0.15*	0.03		0.14*	0.22*	0.19*	0.01	0.07*	0.25*	0.12*	0.01	-0.12*	0.02
Fueltype	0.06*	0.05*	0.18*		0.01	0.01	-0.08*	-0.00	-0.07*	0.42*	-0.09*	0.02	-0.12*
CIS	0.42*	-0.02	0.20*	-0.00		0.28*	-0.05*	0.13*	0.21*	0.05*	-0.01	-0.09*	0.13*
SIZE	0.31*	-0.03	0.14*	-0.03*	0.26*		-0.29*	0.37*	0.32*	-0.00	-0.32*	-0.14*	0.09*
ROA	-0.04*	-0.02	-0.01	-0.10*	-0.03	-0.18*		-0.38*	-0.08*	0.02	0.71*	0.26*	0.01
LEV	0.04*	-0.00	-0.01	-0.03	0.04*	0.10*	-0.02		0.13*	0.07*	-0.25*	-0.12*	0.07*
ENV	0.26*	-0.03	0.23*	-0.02	0.20*	0.30*	-0.03*	0.02		-0.06*	-0.10*	-0.32*	0.15*
Capin	-0.04*	-0.00	-0.05*	0.09*	-0.01	-0.06*	-0.04*	-0.01	-0.09*		-0.02	-0.02	-0.10*
TobinQ	-0.09*	-0.01	-0.05*	-0.12*	-0.00	-0.29*	0.57*	0.00	-0.08*	-0.01		0.28*	0.01
STK	-0.12*	0.02	-0.09*	0.02	-0.08*	-0.14*	0.18*	-0.03	-0.27*	0.03*	0.20*		-0.16*
ETS	0.05*	-0.05*	0.02	-0.12*	0.13*	0.08*	0.02	0.02	0.16*	-0.09*	0.03*	-0.16*	

This table presents correlations between variables used in multivariate tests of H1 and H2. Pearson correlation coefficients are below the diagonal, and Spearman rank correlation coefficients are above the diagonal. Definitions of variables are provided in Table 4.2. * $p < 0.05$ (two-tailed).

Table 4.6 presents Pearson (below the diagonal) and Spearman (above the diagonal) correlations for results pooled for the sample years. The correlation between carbon intensity (*Ein*) and *ASSU* is significant and positive (Pearson coefficient = 0.07, $p < 0.01$; Spearman coefficient = 0.02, $p < 0.01$), which suggests that firms with higher carbon intensity are generally inclined to have their carbon information assured. Similarly, the relationships between *ASSU* and both *Fueltype* and *CIS* are significant and positive at the conventional level. These results do not contradict the argument that higher carbon information asymmetry incentivises managers to adopt voluntary carbon assurance. Overall, in examining the presence of any early signs of multicollinearity that might threaten the validity of the inferences (Tabachnick and Fidell 2007), I find that all the correlation coefficients are relatively low and no extreme correlations are present. Additionally, the variance inflation factor (VIF) value ranges from 1.22 to 1.90, indicating that multicollinearity not a serious issue in this study.

4.4.2 Results of logistic regression

4.4.2.1 Carbon information asymmetry and carbon assurance

Table 4.7 presents the empirical results of logistic panel regression (with standard errors in parentheses) on the link between the proxies for carbon information asymmetry and assurance. H1a predicts that higher carbon intensity is linked with higher carbon information asymmetry, which triggers carbon assurance, and is supported by the positive and significant coefficients of *Ein* in models (1) and (5). The findings from models (2) and (5) indicate that the coefficients of *Fueltype* are positive and significant. This evidence is consistent with H1b—that the adoption of carbon assurance increases with the complexity of a firm’s energy structure. H1c is also confirmed with the positive and significant coefficients of *CIS* in both models (3) and (5), which implies that firms in carbon-intensive sectors are more likely to adopt carbon assurance.

The interpretation of these results is that these proxies reflect different aspects of carbon information asymmetry. More specifically, the quantity of emissions captures the complexity of the entity’s organisational structure and is linked to multiple products manufactured with complex processing technology. This is one dimension of carbon information asymmetry. The type of fuel used is another source of information asymmetry because it proxies for the extensiveness and sophistication of carbon accounting methods and protocols for energy consumption and GHG emissions. Finally, the knowledge gap related to the effect of government policy on business is a complex issue that varies across carbon-intensive and non-carbon-intensive sectors. The findings of statistical associations between these proxies and the adoption of carbon assurance enhance the understanding of how carbon information asymmetry drives the demand for expensive carbon assurance. Note that these variables (e.g., energy structure, industry membership) are predetermined factors for adoption of carbon assurance that is not subject to the direct control of the incumbent management.

As for the control variables, firm size (*SIZE*) and profitability (*ROA*) have a significant and positive impact on the adoption of carbon assurance, whereas no significant results are found for legal system (*STK*), leverage (*LEV*) or capital expenditure intensity (*Capin*). The ability to manage environmental performance (*ENV*) facilitates the adoption of third-party assurance of carbon information, which is expected. Finally, the effect of *ETS* on carbon assurance is controlled, and the coefficient is found to be not significant.

Table 4. 7: The Determinants of Carbon Assurance—Logistic Panel Regression

	(1)	(2)	(3)	(4)	(5)
	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$
Ein_t	0.484***				0.408***
	(0.161)				(0.155)
$Fueltype_t$		0.254***			0.151***
		(0.051)			(0.049)
CIS_t			1.089***		0.568
			(0.402)		(0.388)
$Disscore_t$				0.111***	0.109***
				(0.008)	(0.008)
$SIZE_t$	21.967***	21.059***	22.282***	16.400***	15.970***
	(2.013)	(1.998)	(2.031)	(1.868)	(1.851)
ROA_t	2.935*	2.754	2.814*	2.644	2.771*
	(1.672)	(1.681)	(1.674)	(1.651)	(1.658)
LEV_t	-0.000	-0.000	-0.000	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ENV_t	0.046***	0.041***	0.045***	0.035***	0.031***
	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
$Capin_t$	2.992***	3.717***	2.639**	3.452***	2.517**
	(1.123)	(1.116)	(1.161)	(1.043)	(1.082)
TobinQ	-0.015	-0.032	-0.023	-0.029	0.015
	(0.162)	(0.161)	(0.163)	(0.153)	(0.152)
STK_t	0.723	0.600	0.635	0.554	0.400
	(1.071)	(1.071)	(1.073)	(0.981)	(0.979)
ETS_t	-0.200	-0.262	-0.208	-0.185	-0.143
	(0.403)	(0.401)	(0.402)	(0.401)	(0.403)
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	-64.344***	-62.283***	-65.173***	-55.259***	-54.589***
	(5.705)	(5.663)	(5.761)	(5.304)	(5.267)
N	5,041	5,041	5,041	5,041	5,041
χ^2	328.58***	330.17***	326.40***	390.35***	394.46***

Coefficients are estimated with logistic panel regression for the full sample of 5,051 observations. Standard errors are in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01. Definitions of variables are provided in Table 4.2.

4.4.2.2 The role of carbon disclosure

Column (4) in Table 4.7 details the results for the hypothesised impact of carbon disclosure on carbon assurance. *Disscore* has a positive coefficient at the 1% level of significance, which supports the hypothesis H2b. This implies that carbon disclosure might be used as a tool by managers to legitimise their behaviour and put a green image forward to the public, which is consistent with the arguments of Gray (2000) and Hopwood (2009). Such disclosure might provide biased or misleading information, rather than improving transparency (Hopwood 2009). As such, this may cause increased information asymmetry to prevail amongst managers and outside stakeholders, which eventually provokes the adoption of carbon assurance, as predicted by carbon information asymmetry theory.

The results support the corporate veil assumption rather than the transparency assumption in regard to corporate carbon disclosure. In addition, the findings echo the growing literature in this field. For instance, Cowan and Deegan (2011) reveal that GHG disclosures rose after the enactment of the Australian National Pollutant Inventory, but the disclosures did not increase transparency. Instead, these disclosures simply legitimised reactions aiming at reducing the gap between public expectations and actual carbon performance. In other words, disclosure may not reflect the actual level of carbon performance. Recent studies confirm these findings. For example, Li et al. (2018) provide evidence that the chance of GHG disclosure by Chinese firms participating in the CDP is largely influenced by environmental legitimacy. Further, Luo (2019) reinforces the notion that carbon disclosure is adopted for legitimisation. It is also of importance to note that contrary to the three proxies (CO_2, energy structure and sector membership), carbon disclosure is at the discretion of the incumbent directors. Overall, to the extent that carbon disclosure fails to reflect the underlying carbon performance, carbon assurance is demanded to help close the gap. Thus, the findings provide nuanced insight that sheds light on the dynamic interaction between carbon disclosure, carbon assurance and carbon information asymmetry.

4.4.3 Robustness tests

To ensure the reliability of the results and correct for potential endogeneity, such as reverse causality or sample selection bias, further robustness checks for all five models are performed. First, an alternative model—pooled logistic regression— is used to re-estimate all empirical models. The results presented in Table 4.8 are generally consistent with the baseline findings in Table 4.7. Second, a lead-lag approach (one-year lag of independent variables) is used to control for endogeneity and reverse causality. The results, presented in Tables 4.9, suggest that the inferences remain robust.

Table 4. 8: The Determinants of Carbon Assurance—Pooled Logistic Regression of Panel Data

	(1)	(2)	(3)	(4)	(5)
	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$
Ein_t	0.240***				0.258***
	(0.070)				(0.078)
$Fueltype_t$		0.112***			0.060***
		(0.017)			(0.017)
CIS_t			0.295***		0.135
			(0.095)		(0.118)
$Disscore_t$				0.073***	0.073***
				(0.004)	(0.004)
$SIZE_t$	8.376***	7.950***	8.363***	6.446***	6.305***
	(0.522)	(0.521)	(0.524)	(0.576)	(0.571)
ROA_t	1.268*	1.072	1.227*	1.371*	1.534**
	(0.745)	(0.723)	(0.740)	(0.765)	(0.768)
LEV_t	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ENV_t	0.018***	0.016***	0.018***	0.014***	0.012***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Capin_t$	1.119***	1.532***	1.086***	1.500***	1.024***
	(0.337)	(0.336)	(0.349)	(0.387)	(0.387)
TobinQ	0.063	0.045	0.051	-0.004	0.018
	(0.051)	(0.050)	(0.051)	(0.057)	(0.057)
STK_t	0.430	0.332	0.414	0.320	0.237
	(0.283)	(0.291)	(0.287)	(0.309)	(0.307)
ETS_t	-0.073	-0.111	-0.079	-0.161	-0.137
	(0.209)	(0.210)	(0.211)	(0.226)	(0.222)
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	-24.657***	-23.598***	-24.556***	-23.605***	-23.481***
	(1.489)	(1.482)	(1.493)	(1.608)	(1.593)
N	5,041	5,041	5,041	5,041	5,041
% Correctly predicted	73.92%	73.77%	73.35%	77.88%	78.36%
χ^2	690.73***	747.64***	698.75***	852.04***	877.89***

Coefficients are estimated with pooled logistic regression with robust standard errors for the full sample of 5,051 observations. Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. % correctly predicted shows the percentage that the models correctly predicted the outcome of carbon assurance adoption of the firms in the sample. Definitions of variables are provided in Table 4.2.

Table 4. 9: The Determinants of Carbon Assurance—Logistic Panel Regression Lead-Lag Approach

	(1)	(2)	(3)	(4)	(5)
	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$
Ein_{t-1}	0.621***				0.504***
	(0.192)				(0.181)
$Fueltype_{t-1}$		0.191***			0.104**
		(0.052)			(0.049)
CIS_{t-1}			1.128**		0.494
			(0.470)		(0.437)
$Disscore_{t-1}$				0.104***	0.103***
				(0.009)	(0.009)
$SIZE_{t-1}$	23.088***	22.072***	23.227***	17.094***	16.765***
	(2.463)	(2.439)	(2.478)	(2.158)	(2.147)
ROA_{t-1}	6.626***	6.617***	6.473***	6.118***	6.276***
	(2.108)	(2.101)	(2.102)	(2.017)	(2.018)
LEV_{t-1}	0.001	0.001	0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
ENV_{t-1}	0.041***	0.037***	0.040***	0.030***	0.027***
	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)
$Capin_{t-1}$	3.700***	4.504***	3.476**	4.394***	3.255**
	(1.403)	(1.375)	(1.446)	(1.229)	(1.276)
$TobinQ_{t-1}$	0.022	-0.023	-0.006	-0.001	0.045
	(0.200)	(0.198)	(0.199)	(0.180)	(0.180)
STK_{t-1}	1.516	1.407	1.461	1.066	0.892
	(1.234)	(1.214)	(1.222)	(1.088)	(1.085)
ETS_{t-1}	-0.427	-0.448	-0.416	-0.586	-0.590
	(0.509)	(0.506)	(0.506)	(0.492)	(0.494)
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	-66.881***	-64.424***	-67.218***	-56.042***	-55.502***
	(6.959)	(6.886)	(7.005)	(6.114)	(6.091)
N	3,689	3,689	3,689	3,689	3,689
χ^2	225.22***	227.67***	281.42***	281.42***	284.77***

Coefficients are estimated with logistic panel regression for the full sample of 3,689 observations. Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Definitions of variables are provided in Table 4.2.

Third, there may be endogeneity in the adoption of carbon assurance, as this study only includes firms that provide information to the CDP, which may indicate self-selection bias. To mitigate this concern, Heckman's two-stage test is performed. In the first step, the sample is augmented by including firms that chose not to disclose to the CDP. Logistic panel regression is used at this stage:

$$\log\left[P(DSIC_{it} = 1|X_{it})/\{1 - P(ASSU_{it} = 1|X_{it})\}\right] = X_{it}^{\top}\beta,$$

with

$$\begin{aligned} X_{it}^{\top}\beta = \beta_0 &+ \beta_1 DISC_{i,t-1} + \beta_2 Disscore\_Mean_{i,t} + \beta_3 CIS_{i,t} + \beta_4 SIZE_{i,t} \\ &+ \beta_5 ROA_{i,t} + \beta_6 LEV_{i,t} + \beta_7 ENV_{i,t} + \beta_8 Capin_{i,t} + \beta_9 STK_{i,t} \\ &+ \beta_9 ETS_{i,t} + Year\ Fixed\ Effects \\ &+ Industry\ Fixed\ Effects + Country\ Fixed\ Effects \\ &+ \varepsilon \end{aligned} \quad (6)$$

where *DISC* is a dummy variable equating to 1 if the company chooses to disclose its carbon information to the CDP and 0 otherwise. The independent variables are selected following prior research related to carbon disclosure (Matsumura et al. 2014; Zhou et al. 2016; Healy and Palepu 2001; Kwak et al. 2012). Firm size (*SIZE*), leverage (*LEV*), firm book-to-market ratio (*BM*), environmental performance (*ENV*) and profitability (*ROA*) are key variables that influence managers' disclosure (Kwak et al. 2012; Zhou et al. 2016; Luo 2019). Moreover, following Stanny (2013), a lagged disclosure, $DISC_{t-1}$, is employed to control for the company's previous year's disclosure to the CDP. It is found that companies that participate in CDP in the preceding year tend to disclose in the current year, as managers' disclosure behaviour tends to be sticky. Therefore, a positive coefficient of $DISC_{t-1}$ is expected. In addition, the mean industry disclosure score (*Disscore_Mean*) is included, which might also influence managers' disclosure decision. In the second step, the logistic panel regression with models (1) to (5) are rerun. The results, shown in Table 4.10, are unchanged from the results in Tables 4.7, although for brevity they are not discussed in detail.

Table 4. 10: The Determinants of Carbon Assurance—Heckman's Test

Step 1: Selection Mode - Decision to Disclose to the CDP
Step 2: Response Mode - Determinants of Adopting Carbon Assurance

Step 1	(1)	(2)	(3)	(4)	(5)
Selection Model	$DISC_t$	$DISC_t$	$DISC_t$	$DISC_t$	$DISC_t$
$DISC_{t-1}$	0.033	0.032	0.034	0.033	0.035
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
$Disscore\_Mean_t$	-0.006	-0.007	-0.006	-0.005	-0.004
	(0.012)	(0.012)	(0.012)	(0.011)	(0.011)
CIS_t	-0.233	-0.226	-0.229	-0.251	-0.249
	(0.181)	(0.180)	(0.183)	(0.179)	(0.180)
$SIZE_t$	5.690***	5.701***	5.698***	5.692***	5.718***
	(0.484)	(0.481)	(0.484)	(0.485)	(0.479)
ROA_t	1.028***	1.025***	1.030***	1.029***	1.025***
	(0.397)	(0.396)	(0.396)	(0.396)	(0.396)
LEV_t	-0.000*	-0.000*	-0.000*	-0.000*	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ENV_t	0.032***	0.032***	0.032***	0.032***	0.031***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$Capin_t$	0.367	0.392	0.359	0.354	0.321
	(0.286)	(0.287)	(0.285)	(0.285)	(0.277)
TobinQ	0.156	0.158	0.155	0.153	0.153
	(0.250)	(0.249)	(0.250)	(0.250)	(0.251)
STK_t	-0.036	-0.037	-0.035	-0.037	-0.034
	(0.079)	(0.079)	(0.079)	(0.079)	(0.079)
ETS	0.033	0.032	0.034	0.033	0.035
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	-16.973***	-16.973***	-16.995***	-17.038***	-17.128***
	(1.552)	(1.541)	(1.554)	(1.543)	(1.526)
χ^2	1.63	2.37	1.14	0.71	0.35
Step 2					
Response Model	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$	$ASSU_t$
Ein_t	0.105*				0.126**
	(0.058)				(0.061)
$Fueltype_t$		0.064***			0.039***

Table 4. 10: The Determinants of Carbon Assurance—Heckman's Test

		(0.015)			(0.014)
CIS_t			0.144		0.071
			(0.100)		(0.103)
$Disscore_t$				0.041***	0.041***
				(0.003)	(0.003)
$SIZE_t$	5.354***	5.281***	5.321***	4.236***	3.879***
	(0.571)	(0.562)	(0.601)	(0.658)	(0.556)
ROA_t	0.957*	0.880	0.925	0.957*	0.918
	(0.577)	(0.566)	(0.579)	(0.572)	(0.577)
LEV_t	0.000	0.000	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ENV_t	0.017***	0.017***	0.016***	0.013***	0.009***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.003)
$Capin_t$	0.775***	0.964***	0.767**	0.949***	0.703**
	(0.293)	(0.295)	(0.301)	(0.316)	(0.318)
STK_t	0.032	0.025	0.026	0.001	0.014
	(0.048)	(0.046)	(0.048)	(0.051)	(0.052)
ETS_t	0.247	0.200	0.232	0.179	0.139
	(0.254)	(0.261)	(0.258)	(0.258)	(0.260)
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	-16.230***	-16.280***	-16.061***	-15.428***	-14.311***
	(1.862)	(1.827)	(1.983)	(2.125)	(1.702)
N	9,618	9,618	9,618	9,618	9,618
Selected N	4,536	4,536	4,536	4,536	4,536
Non-selected N	5,082	5,082	5,082	5,082	5,082
Wald χ^2	909.29	874.53	934.45	909.29	1,230.69
Prob > χ^2	0.000	0.000	0.000	0.000	0.000
Log pseudo-likelihood	-5839.281	-5820.479	-5844.987	-5,562.519	-5,545.418

Definitions of variables are provided in Table 4.2. Coefficients are estimated with logistic panel regression for the sample of 9,618 observations. Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Finally, to address the further concern about reverse causality, Granger causality tests in panel datasets[11] on carbon assurance and carbon information asymmetry are performed. The proxies for carbon information asymmetry are found to have a significant Granger causal relationship with carbon assurance, while the causality of assurance to carbon information asymmetry is not significant. Therefore, there is no reverse causal effect between carbon information asymmetry and carbon assurance. Taken as a whole, the results of the robustness tests are inferentially identical to the main findings, which provides further persuasive circumstantial evidence that substantiates and vindicates the accuracy of the models and corroborates the hypotheses.

4.5 Conclusions

There is a clear trend for investors to identify and consider a firm's carbon-sensitive assets of a firm (Haigh and Shapiro 2011), and the quantity, format and venue of carbon disclosure are becoming relevant for their decision making (Hughes et al. 2001). Meanwhile, multiple regulated and unregulated reporting initiatives and frameworks abound around the world. For instance, the US Securities and Exchange Commission's Guidance for Disclosure Related to Climate Change outlines the conditions for public companies' disclosure of material information related to climate-associated risks and opportunities. More recently, it has become mandatory for listed UK companies to disclose carbon information in their annual directors' report.[12]

In this context, this study focuses on how carbon assurance is linked with carbon information asymmetry. The results show that the three proxies adopted in this study capture different aspects of carbon information asymmetry. First, the quantity of emissions is associated with the complexity of the organisational structure, nature of the products and unique manufacturing processing. Second, carbon information asymmetry

[11] The Granger causality test was originally designed for pairs of lengthy time series; however, it has recently been modified to incorporate panel dynamics. The extension of the original Granger methodology to panel data has the potential to improve upon the conventional Granger analysis for all of the reasons that panel analysis is generally preferable to cross-sectional or traditional time series analysis (see see Greene 2003, 308308).

[12] See https://www.gov.uk/government/speeches/energy-savings-opportunity-scheme and http://www.legislation.gov.uk/ukdsi/2013/9780111540169/contents.

is linked with the sophisticated technical carbon accounting protocols[13] used to quantify different types of energy sources that convert energy consumption to emissions. Thus, information asymmetry increases with the type of energy consumed. Finally, carbon information asymmetry is higher in a carbon-intensive sector with regard to the complex impact of government-imposed regulations on firm operation. With these novel proxies, the findings depict the overall corporate carbon information gap and demonstrate its unexplored consequence on carbon assurance. The results show that the coefficients of these variables retain their positive signs across all test models, and further analyses yield similar findings. Thus, this study provides evidence on the sensitivity of a specific carbon initiative—carbon assurance—to different dimensions and levels of carbon information asymmetry. Further, the findings unfold the channels (such as enhanced credibility and reduced transaction costs) through which prioritising external assurance generates value. Thus, this study validates and increases the applicability of information asymmetry theory in the context of climate change in a significant manner.

The in-depth empirical analyses discover a subtle distinction between carbon assurance and financial assurance in terms of their ability to inform stakeholders who care about firms' financial and nonfinancial performance. Through drawing on information asymmetry economics (Myers and Read 2001), and based on the fact that managers tend to use private informed data to contextualise their carbon performance and camouflage their inferior carbon policy, a direct inference from this study is that carbon assurance can enhance value (by reducing transaction costs), conditional on the severity of the carbon knowledge gap among the key stakeholders of a firm (Schiemann and Sakhel 2019).

However, the practice of carbon assurance is still in its early stage and is subsequently imperfect. Thus, the results are useful for regulators and accounting practitioners to take actions to improve the practice. Currently available guidelines for carbon assurance

[13] For example, Publicly Available Specification (PAS) 2050 published by the British Standards Institution (BSI), GHG Protocol Product Standard (GHG Protocol) convened by the World Resources Institute (WRI), World Business Council for Sustainable Development (WBCSD) and ISO 14067 Carbon Footprint of Products (ISO 14067) provided by the International Organization for Standardization (ISO), etc. Although the general principles of the above mentioned protocols are the same, the different criteria provided may lead to numerical differences in carbon footprint due to the inconsistency originate from the system boundary, cut-off criteria, biogenic carbon treatment, allocation, and other requirements.

originate from very different professional imperatives (IAASB 2012) (GRI, etc.). Assurers adopt different investigative procedures, ethical standards and independence requirements, some of which are proprietary (Deegan and Blomquist 2006). The diversity of methodologies, strategies and practitioners increases the complexity of assurance (Scalet and Kelly 2010; Waddock 2008; Simnett et al. 2009a). Thus, a set of legally enforceable principles or norms should be implemented to regulate this emerging market and practice. The fact that these firms purchased GHG assurance in addition to assurance of financial statements implies that carbon information asymmetry is a distinct dimension of information asymmetry concerning the authenticity of carbon information. Thus, governmental and professional bodies need to consider whether carbon assurance should be made compulsory.

It is acknowledged that this study has several limitations. First, only large listed firms are considered in the research design, thus it is wise to exercise caution when applying the results to small or unlisted firms. Second, the sample is only inclusive of firms that participate in the CDP, other ways that firms may choose to disclose their GHG information (e.g., sustainability statements) are not considered. Finally, as alluded to earlier, although there are concerns about the assurance methodology used, this research does not examine how the assurance is conducted by different assurance providers (e.g., accounting firms or consultant firms). This is left to future studies.

To extend the study, future researchers may explore the causal effects of information asymmetry on assurance in different contexts. The unregulated carbon assurance market is still in its infancy, yet is quickly evolving into a sophisticated, specialised and competitive market (Green and Li 2011). However, little is known about how practitioners implement GHG assurance standards in practice, which is worth future research. In addition, it is important to explore how carbon assurance can help firms improve carbon reduction performance, carbon management systems, and corporate carbon governance. Moreover, the relationship between firm value and carbon performance, including carbon reduction activities and assurance, is a promising area of investigation. Finally, accounting students need to be equipped with adequate knowledge of how to implement new accounting and assurance standards for GHG statements. Thus, it is necessary for university accounting faculties to develop teaching materials for future generations of accountants who aspire to practice in a GHG-restricted planet.

CHAPTER 5 CARBON ASSURANCE AND CARBON DISCLOSURE

5.1 Introduction

Growing concern about the intense global warming (Stern et al. 2007) has enhanced the pressure on firms to set carbon reduction targets and undertake initiatives to mitigate carbon emissions (Romar 2009; Galbreath 2011; Depoers et al. 2016; Ioannou and Serafeim 2017). A wide range of stakeholders increasingly require firms to disclose carbon information for their decision making (Matsumura et al. 2014; Griffin et al. 2017). However, many studies criticize the quality and reliability of voluntarily disclosed information (Freedman and Jaggi 2005; Stanny and Ely 2008; Reid and Toffel 2009; Lyon and Maxwell 2011; Gouldson and Sullivan 2007; Doda et al. 2016). Consequently, strong demand is emerging for independent verification of reports on greenhouse gas (GHG) (GHG; Green and Li 2011; Luo and Tang 2014; Zhou et al. 2016; Becker et al. 1998; De Beelde and Tuybens 2015; Francis and Schipper 1999; Francis 2004; Hay and Davis 2004; Watts and Zimmerman 1990) 2015 Paris Agreement on Climate Change). Although carbon assurance is an extension of financial assurance, many nuances distinguish the two (see Table 5.1). Moreover, carbon assurance also differs from conventional CSR/sustainability assurance. First, carbon assurance focuses only on the carbon-related issues while CSR assurance covers general social and environmental issues. Second, carbon assurance entails specialized climate knowledge and expertise, and the service is often provided not only by accounting firms but also by consulting firms (non-accountants) and the audit team usually includes energy experts, engineers and chemists (IAASB 2012). Third, the risks of misstatement in a GHG statement involved factors that differ from those that are associated with CSR assurance. The accuracy of measurement of carbon emissions is influenced by scientific, regulatory, and physical factors. It is also affected by energy structure, degree of complexity of operations and the nature of business (ISAE 3410). Thus, carbon assurer must assess the adequateness of internal controls for emissions (ISAE 3410, 33R, para. A79–A80) and check these factors that can increase misstatement, e.g., duplicate counting; omission of a significant category of emissions, such as scope 3 emissions (fugitive emissions); abnormal emissions (ISAE 3410, para. A88 (a), (e), (f)); misclassification of emissions sources and unrealistic, biased judgements or estimates (ISAE 3410, para. A88 (g)). Hence, given the uniqueness of this practice, carbon assurance deserves its own analysis and it comprises a significant part of the business of the accounting profession (Simnett et al. 2009b). Yet researchers' understanding of this new type of assurance is very limited given the scarcity of literature in this area (KPMG 2015). This study fills this void by examining the effect of assurance on carbon disclosure. These insights have not been documented in the literature.

Table 5. 1: A Comparison of Financial Auditing and Carbon Auditing

Financial Reporting Area	Financial Reporting and Auditing Characteristics in Developed Nations	GHG Reporting and Auditing Characteristics
Competencies required	Complex accounting and auditing skills are required, with certifications such as Certified Public Accountant necessary, and skills are well developed as part of broad professional services offered by numerous firms at the global and local levels. Documentation requirements from non-accounting competencies in areas such as facilities, engineering, supply chain operations, and others are fully established to give credibility to such things as the financial value of raw materials or finished goods inventory.	There are no global standards for the competencies required to either report on or assure GHG reporting, which has given rise to the large number of firms claiming to provide this service. Some jurisdictions that require accreditation, such as California in the United States, have already begun to address this issue. Required skills include a mix of accounting, environmental, and operational knowledge and (in the case of multinational organizations) global presence and reach.
Benefits of audits	Assures investors and other stakeholders of financial strength, controls to protect against fraud, and accountability for anomalous information	Assures investors, suppliers, customers, and other stakeholders of environmental impact improvements, confidence in making sound operational decisions, and support for environmentally conscientious brand recognition
Risks of audits	Poorly done audits can result in undetected fraud, misleading information, and loss of investor confidence, with the potential for fines and criminal prosecution for systematic and pervasive problems.	The wide range of firms claiming to assure reported data can lead to great variance in the quality of assurance opinions. In some cases, the opinion may be nothing more than a management letter suggesting improvements. There is a risk that uneducated readers may rely more on a third-party assurance than is warranted by the quality of the report.

This table is excerpted from Olson (2017). GHG = greenhouse gas.

Prior studies have mainly focused on the incentives for voluntary adoption of carbon assurance (Zhou et al. 2016; Green and Zhou 2013; Datt et al. 2018; Datt et al. 2018a; Datt et al. 2018b), choice of assurance provider (Huggins et al. 2011; Green and Taylor 2013), the role of internal auditors in GHG reporting (Trotman and Trotman 2013), the expertise required for GHG assurance (Green and Li 2011), the development of an international standard for GHG assurance (Cohen and Simnett 2014). However, while carbon assurance is expected to impact users' perceptions, there is limited knowledge on the effect of carbon assurance on disclosure.

Based on stakeholder engagement theory (Edgley et al. 2010), it is argued that assurance of carbon reports may improve their clients' reporting systems so as to lead to a better future carbon disclosure. The underlying rationale is that, first, a firm engages carbon assurer to verify its information on emissions. Such engagement helps the firm understands the needs of external stakeholders for carbon-related information. Second, on completion of assurance, an auditor usually provides managers with a letter containing recommendations for fixing flaws in internal control and current reporting systems (Gay and Simnett 2018). Managers may subsequently use these recommendations to prepare their future carbon reports. This interactive mechanism is expected to have a positive impact on firms' future carbon disclosure.

The sample comprises a cohort of the largest listed companies in the world that participated in the CDP (previously the Carbon Disclosure Project) survey from 2010 to 2015. The comprehensiveness of disclosure is measured using the CDP's Climate Disclosure Leadership Index (CDLI). The empirical evidence supports the theoretical predictions and shows that subsequent carbon disclosure is significantly higher among assured companies than unassured companies. The results are consistent with prior literature (Watts and Zimmerman 1990; Francis 2004; Hay and Davis 2004; Kolk and Perego 2010; Adams and Evans 2004; O'Dwyer and Owen 2005; Deegan and Blomquist 2006; Huggins et al. 2011; Cohen and Simnett 2014) in the sense that auditing is not only essential to enhancing the credibility in the eyes of external users, but also helps the internal process for the preparation of environmental reports. In addition, it is found that this relationship is more pronounced in stakeholder-oriented countries, in countries with an emissions trading scheme (ETS), and in carbon-intensive sectors (CISs), which further supports the stakeholder engagement argument.

This study contributes to the literature in a number of ways. First, contrary to previous studies on sustainability (Casey and Grenier 2014), this study focuses solely on carbon assurance as performing carbon assurance requires specific skills, knowledge, and expertise and is governed by separate standards (IAASB 2012; Tang 2019; Datt et al. 2018; Datt et al. 2018b) and methods used by firms for controlling risk and examining GHG emissions in carbon assurance are expected to differ significantly from methods used in conventional financial auditing. Thus, carbon assurance is an important dimension in carbon accounting and it is distinct from sustainability assurance, which deserves a separate study. Second, to my knowledge, this study is the first to provide empirical evidence of the role of carbon assurance in enhancing carbon disclosure. Third, this study enhances the understanding of the role of the institutional context in carbon disclosure and assurance. There is no research on how these industrial and national factors moderate the link between carbon assurance and carbon disclosure. Last, Edgley et al. (2010) show the importance of stakeholder engagement in environmental assurance. The findings reinforce the validity and appropriateness of this concept in the carbon assurance practice. The evidence should assist assurance practitioners, regulators, and users of carbon reports in obtaining a better knowledge of this indispensable practice in today's low-carbon economy.

The rest of this study is organized as follows. Section 2 discusses the research background and hypotheses of the study. The data and methodology are presented in Section 3. Section 4 reports and discusses the empirical results, and Section 5 summarizes the main findings and the implications of the study for future research.

5.2 Hypotheses Development

5.2.1 Carbon assurance and carbon disclosure

Prior literature suggests that the adoption of sustainability assurance can be perceived as a dialogical process, being stakeholder inclusive and transformative (Edgley et al. (2010). This approach allows assurers to directly (e.g. face to face interview) or indirect (e.g. via media conference) communicate with clients, users, managers, and staff of the auditee and enhance the ability to interact with both the outside stakeholders and the internal members during decision-making processes (Gray 2000; Owen et al. 2000; Manetti and Toccafondi

2012). Thus, external auditors may assist managers in identifying carbon-related risks and opportunities, assess the costs and benefits of long-term green investment, set reasonable carbon reduction targets, evaluate carbon performance, and so on. It can be argued that stakeholder-inclusive assurance has a positive impact on subsequent carbon reporting. The rationale is articulated in the following discussion.

First, assurers who adopt a stakeholder inclusivity approach understand better the needs of external stakeholders for carbon-related information particularly when an auditing firm's network comprises multifaceted clients (Edgley et al. 2010). Thus, such assurance engagement involves greater interaction with external stakeholders, therefore ensuring that social and environmental reporting is responsive, complete and satisfies stakeholders' need for information (Edgley et al. 2010; Thomson and Bebbington 2005; Owen et al. 2000). These auditors are able to raise critical consciousness of environmental reporting rather than just passively and unquestioningly accept information (Edgley et al. 2010) and their opinions reflect the demand of users for information on physical emissions, carbon risks, carbon strategy and investment, and so on. Assurer can help managers select appropriate information and determine the scope and depth of this disclosure, thus, the underlying GHG report can be made more relevant and comprehensive.

Second, assurance activities are likely to strengthen a client's internal system (Baker and Owsen 2002; Elliott 1994). According to the authoritative guidelines (e.g. GRI, ISAE 3410), auditors need to identify deficiencies and recommend improvements to a company's environmental management systems (Deegan et al. 2006; Moroney et al. 2012). Stakeholder inclusivity allows assurers to work closely with clients to evaluate the strength of internal systems, test the validity of outputs, detect risk, and identify misstatements due to poor process design and/or inadequate controls (Olson 2010). Although an auditor is not expected to design control measures, the auditor is able to recommend or suggest broader options for how the auditee can improve the system for future reporting purposes. This is evident in the research of Manetti and Toccafondi (2012), who find that the majority of assurance statements they analyzed included consultation from stakeholders in the formulation of assurers' professional opinions, which is a common practice (Gay and Simnett 2018; Olson 2010).

Third, auditors often maintain contact with clients to make them aware of changes in reporting protocols or associated legislation throughout the auditing. Auditors may also inform clients of the changing demands of other stakeholders, such as the community, supply chain partners, employees, and not-for-profit organizations, during or after the current auditing period. This will ultimately reflect in improved carbon reporting. As discussed by Moroney et al. (2012), the benefit of such assurance is lagged. It gradually influences managers' behavior and serves as a learning process for managers and stakeholders (Edgley et al. 2010). Thus, I propose the first hypothesis:

Hypothesis 1: There is a positive association between carbon assurance and subsequent carbon disclosure.

5.2.2 The influence of institutional context

Next, the influence of carbon institutions (e.g., norms, standards, regulations, or accepted practices) on the link between assurance and disclosure is examined. Prior studies argue that a country's institutional context, such as the civil law environment and legal enforcement, impacts firms' sustainability strategies (Kolk and Perego (2010); Chen and Bouvain (2009), and CSR disclosure (e.g., García-Sánchez et al. 2016). Martínez-Ferrero and García-Sánchez (2017) show that voluntary assurance of sustainability reports derives from coercive, normative, and mimetic forces related to legal and cultural strength and industry pressure for assurance. Luo (2019) find that three carbon-regulated institutional factors—namely, a stakeholder orientation culture, the existence of a national ETS, and affiliation with a CIS—have impacts on carbon control practices.

5.2.2.1 Stakeholder versus shareholder orientation

The difference between common law and code law systems is acknowledged as a valid proxy for the extent of the market relative to the political determination of corporate reporting (Ball et al. 2000; La Porta et al. 1997). Briefly stated, in common law countries, a so-called shareholder model (as opposed to a stakeholder model) or contractarian system prevails in which maximization of shareholder wealth is the primary purpose of business and the role of other stakeholder groups is less emphasized. Thus, firms tend to deal with investors at arm's length, and increased demand for information on financial performance is expected (Jaggi and Low 2000). A communitarian system with a stakeholder orientation is more likely to be adopted in a code law country, where an organization has social responsibilities beyond merely achieving economic efficiency, and such responsibilities are not only to their shareholders but to all stakeholders. This leads to the expectation that firms in these countries show higher environmental and social reporting (Tang and Luo 2016; Dawkins and Fraas 2011; Reid and Toffel 2009; Van der Laan Smith et al. 2005) and sustainability assurance (Kolk and Perego (2010). In a similar vein, Zhou et al. (2016) reveal greater demand for carbon assurance in stakeholder-oriented countries and found that this assurance may substitute for weaker legal enforcement in the monitoring of corporate climate change activities. In the context, people with stakeholder orientation have a higher expectation of socially responsible behavior. Thus, it is predicted that firms in stakeholder-oriented nations are more likely to engage independent assurers in their decisions to disclose, and stakeholders expect auditors to assist managers to improve carbon transparency. This institutional arrangement encourages greater cooperation and interaction between auditors and auditees on carbon reporting issues. This argument is consistent with prior literature (Zhou et al. 2016) that finds that carbon assurance may play a larger role in stakeholder-oriented countries in the absence of robust legal institutions. This discussion leads to formalize the following hypothesis:

Hypothesis 2a: Carbon assurance has a stronger impact on carbon disclosure in countries with a tendency toward stakeholder protection.

5.2.2.2 ETS

The carbon-specific regulation is another component of the institutional context (Huggins et al. 2011; World Bank 2014; Zhou et al. 2016). Because of strong political resistance and companies' reluctance to support regulatory policies (e.g., carbon tax), an ETS (also referred to as a *cap and trade system*) is often seen as a favorable policy instrument. The decentralized and competitive nature of an ETS provides flexibility and enables cost-effective carbon reduction. Under an ETS, emissions are commercialized, which internalizes an otherwise external environmental cost that can transcend the tense relationship between economic development and climate stabilization. Operating a carbon market (ETS) requires higher standards for carbon monitoring, measurement and reporting (Luo et al. 2012; Luo et al. 2013; Luo 2019). Therefore, investors and stakeholders have a greater demand for verified carbon information. Thus, it can be argued that the effects of carbon assurance on disclosure will be strengthened in an ETS setting.

Hypothesis 2b: The existence of an ETS enhances the relationship between carbon disclosure and carbon assurance.

5.2.2.3 CIS

Materials, energy, and utilities are identified as CISs (Tang and Luo 2016)[14] and these sectors represent 26.2%, 28.3%, and 33.3% of total reported Scope 1 and 2 emissions of Global 500 companies, respectively (*CDP (2012)*. Carbon-intensive companies undergo intense scrutiny and are regulated under stringent legislation. Managers likely have stronger incentives to engage external stakeholders, including assurance providers, to improve carbon disclosure (Mock et al. 2007). Therefore, it can be argued that carbon assurance probably becomes an institutionalized practice in such environmentally sensitive sectors and carbon assurers can build more expertise and competence and are able to assist managers in their carbon reporting capacity. For all of these reasons, the effect of carbon assurance is expected to be stronger for companies in carbon-intensive compared to those in non-intensive industries. Thus, the following hypothesis is proposed:

Hypothesis 2c: Affiliation with a CIS moderates the relationship between carbon disclosure and assurance.

5.3 Research Design

5.3.1 Sample selection

The sample for this study is extracted from the CDP database. CDP is an independent not-for-profit organization that collects information related to GHG of the largest listed

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[14] See https://www.cdproject net/en-US/What WeDo/CDPNewsArticlePages/GHG-targets-FTSE100-UK-Climate-Change-Act.aspx.

companies in the world using a standardized questionnaire. Although participation in the survey is up to managerial discretion, the CDP provides comprehensive and consistent data used in many prior studies (Kolk et al. 2008; Stanny and Ely 2008; Reid and Toffel 2009; Stanny 2013; Matsumura et al. 2014). The sample period (2010–2015) covers the most recent data available at the time of this study. Sample selection commences in 2010 because CDP assurance information only became complete in 2010. Table 5.2 shows the sample selection process begins with all companies that received the CDP survey request (32,937 company-years). Then I filter the companies with an "Answered Questionnaire" response status (i.e., participating companies) and limit the sample to companies that disclosed in publicly available reports with quantified Scope 1 and 2 emissions [15] Next, these companies are merged with those in the database of Worldscope and Datastream, from which I obtain the financial data required for the study. This process results in a final sample of 6,056 observations of Scope 1 or Scope 2 assurance (of which 5,749 is Scope 1 assurance and 5,856 is Scope 2 assurance).

Table 5. 2: Sample Selection

Received questionnaire from CDP for 2010–2015	32,937
Less those not responding	(19,372)
Less observations in which carbon information was not disclosed publicly and	(6,606)
Less observations with missing values for control variables	(903)
Observations with carbon assurance for analysis	6056
No. of observations involving Scope 1 assurance	5,749
No. of observations involving Scope 2 assurance	5,856

5.3.2 Model specification

5.3.2.1 The measurement of carbon disclosure

In this study, comprehensiveness of carbon disclosure is measured as an index (0-100) scored per CDP disclosure rating guidelines (CDP 2016) based on the firm's responses to the questionnaire (Lee et al. (2015). According to the guidelines (refers to CDLI

[15] Scope 1 emissions are direct emissions from sources owned or controlled by the entity. Scope 2 emissions are indirect emissions associated with energy that is transferred to and consumed by the entity. Scope 3 emissions are emissions from employee business travel, external distribution/logistics, disposal of products and services of the company, etc.

methodology), companies are awarded more points if they disclose more relevant and quantitative information with specific case examples (Cotter and Najah 2012). The methodology also takes into account the importance and materiality of specific climate change information. For example, 6 points are given to companies that report gross Scope 1 or 2 GHG data, because these data are very important for assessing exposure to climate risk. The carbon disclosure score of a firm is calculated as the total points awarded divided by the total possible points multiplied by 100[16]. The awarded score increases with the degree of comprehensiveness of carbon disclosure; a high score indicates that executives are responsive to stakeholders to provide carbon performance data. Note the score for assurance is excluded from the overall score in this study to avoid a mechanical relationship between the assurance and disclosure scores.

Using the CDLI as a proxy has specific advantages because participating companies follow the single standardized survey format, and procedures for data collection, reporting, and rating are consistent for all companies; thus, analysis, contrast and comparisons of the data are made meaningful. According to a 2013 survey conducted by GlobeScan and SustainAbility, the CDP disclosure index had the highest credibility of all sustainability ratings and rankings surveyed (SustainAbility 2013). In summary, in the absence of internationally recognized carbon reporting protocol, corporate disclosure to CDP is globally consistent, which allows for a straightforward interpretation of results and increases the power of the statistical tests in the study.

5.3.2.2 The measurement of carbon institutional context

Regarding a shareholder versus stakeholder orientation (Van der Laan Smith et al. 2005; Etzion 2007; Simnett et al. 2009b), a firm that is domiciled in a common (civil) law country is considered to have a shareholder (stakeholder) orientation (Porta et al. 1998; Jaggi and Low 2000; Archambault and Archambault 2003). *STK* is a dummy variable equal to 1 if the firm is in a stakeholder-oriented country and 0 otherwise. The variable *ETS* equals 1 if the firm is in a country with a national ETS and 0 otherwise. Finally, following Luo (2019),

[16] A firm must answer all applicable questions; questions left blank reduce the number of points awarded. However, firms are not penalized for not answering questions that do not apply to them. See the CDP Scoring Methodology (2016) for more details.

I introduce the dummy variable *CIS,* which equals 1 if the firm is in a CIS and 0 otherwise (see Table 5.3).

5.3.2.3 Empirical models

Comprehensiveness of carbon disclosure and carbon assurance

As the effects of carbon assurance on carbon disclosure are expected to be lagged, instead of using a contemporaneous method, I adopt a lead-lag model to test the first hypothesis:

$$\begin{aligned} D\_SCORE_{it} = {} & \beta_0 + \beta_1 S1\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} \\ & + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects \\ & + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \end{aligned} \tag{1}$$

$$\begin{aligned} D\_SCORE_{it} = {} & \beta_0 + \beta_1 S2\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} \\ & + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects \\ & + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \end{aligned} \tag{2}$$

$$\begin{aligned} D\_SCORE_{it} = {} & \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} \\ & + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects \\ & + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \end{aligned} \tag{3}$$

The dependent variable *D_SCORE* is the carbon disclosure score excluding the score for carbon assurance. *S1_ASSU* (*S2_ASSU*) is coded 1 for assurance of Scope 1 (Scope 2) emissions and 0 otherwise. *ASSU* is coded 1 for assurance of either Scope 1 or Scope 2 emissions and 0 otherwise. It is expected that β_1 is positive (Hypothesis 1).

I consider the following control variables (Luo 2019). *CEI* represents the intensity of carbon emissions. It is measured as total Scope 1 and Scope 2 carbon emissions divided by total sales. Compared to absolute carbon emissions, the intensity of carbon emissions takes into account the level of output of products and services, which produces more reasonable comparisons across companies and reporting periods (Hoffman 2007). Companies with higher carbon emissions tend to disclose more, as greater emissions are subject to more carbon regulations and public attention. *lnTA* stands for firm size, measured as the natural logarithm of the company's total assets. Larger companies are expected to report more carbon information (Cormier et al. 2005; Gray and Bebbington 2001; Jones and Levy 2007). *LEV* is the leverage ratio, which equals total debts divided by total assets. Preliminary evidence suggests that firm risk is positively associated with environmental responsibility (Hill and Jones 1992). *ENV* is an environmental score measuring a company's impact on living and nonliving natural systems. It is obtained from the Thomson Reuters ASSET4 Database (Cheng et al. 2014). A positive coefficient is expected for *ENV*.[17] *ROA* is return on assets. Clarkson et al. (2011) use the intensity of research and development (*RDIN*), measured as research and development expenses divided by total assets, as a proxy for unobservable management talent or capability (Murphy 1999), which may link to better carbon disclosure. Finally, Tobin's Q is used as an indicator of the degree of information asymmetry. I expect a positive correlation between *TOBINQ* and carbon disclosure (Anderson and Frankle 1980; Callan and Thomas 2009; Healy and Palepu 2001) (See Table 5.3).

[17] The reason we include both *CEI* and *ENV* is that carbon emissions might be capturing the effect of a firm's general environmental performance. We also conducted a robustness test by excluding this variable in our main model, the results are qualitatively the same and our inferences still sustain.

Table 5. 3: Definitions of Variables

Variable	Description	Source
D_SCORE	Carbon disclosure score, based on the Climate Disclosure Leadership Index (CDLI) methodology, which measures the quality of the company's carbon disclosure to CDP.	CDP
S1_ASSU	A dummy variable equal to 1 if the company has assured Scope 1 carbon emissions and 0 otherwise.	CDP
S2_ASSU	A dummy variable equal to 1 if the company has assured Scope 2 carbon emissions and 0 otherwise.	CDP
ASSU	A dummy variable equal to 1 if the company has assured either Scope 1 or Scope 2 carbon emissions and 0 otherwise.	CDP
CEI	Intensity of carbon emissions, calculated as total carbon emissions divided by total sales.	CDP, Worldscope
lnTA	Natural logarithm of total assets, representing the size of the company.	Worldscope
LEV	Leverage ratio, computed as long-term debt scaled by total assets at year end.	Worldscope
ENV	Environmental score measuring the company's impact on living and nonliving natural systems, including the air, land, water, and complete ecosystems, and reflecting how well the company uses best management practices to avoid environmental risk and capitalize on environmental opportunities to generate long-term shareholder value.	ASSET4
ROA	Return on assets, measured as net operating income divided by total assets at year end.	Worldscope
RDIN	Intensity of research and development, measured as research and development expenses divided by total assets at the beginning of the period.	Worldscope
TOBINQ	Tobin's Q is measured as the market value of common equity plus the book value of preferred stock and the book value of long-term debt and current liabilities divided by the book value of total assets.	Datastream
STK	A dummy variable coded 1 if the responding company is from a code law country and 0 if it is from a common law country.	La Porta et al. (1997)
ETS	A dummy variable equal to 1 if the firm is in a country that has an operating national emissions trading scheme and 0 otherwise.	CDP
CIS	A dummy variable equal to 1 if the firm is in a carbon-intensive sector (i.e., energy, materials, or utilities) and 0 otherwise.	CDP
S1_ASSUCOVER	Level of assurance of Scope 1 emissions, classified into five categories: less than 20%, 21%–40%, 41%–60%, 61%–80%, or 81%–100%, coded as 1, 2, 3, 4, and 5, respectively.	CDP
S2_ASSUCOVER	Level of assurance of Scope 2 emissions, classified into five categories: less than 20%, 21%–40%, 41%–60%, 61%–80%, or 81%–100%, coded as 1, 2, 3, 4, and 5, respectively.	CDP
BM	The firm's book-to-market ratio.	Worldscope
DISC	A dummy variable equal to 1 if the firm discloses its carbon information to the CDP and 0 otherwise.	CDP
ESG	Environmental, social, and governance criteria.	ASSET4
CRI	Carbon reduction initiatives (Haque 2017). calculated by adding 1 if the answer is yes to the following 8 questions and 0 otherwise: (1) Does the company engage any emissions trading initiative? (2) Does the company show an initiative to reduce, reuse, recycle, substitute, phase out or compensate CO_2 equivalents in the production process? (3) Does the company evaluate the commercial risks and/or opportunities in relation to climate change? (4) Does the company report on initiatives to recycle, reduce, reuse or phase out fluorinated gases such as HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) or SF6 (sulfur hexafluoride)? (5) Does the company report on initiatives to reduce, substitute, or phase out ozone depleting (CFC-11 equivalents, chlorofluorocarbon) substances? (6) Does the company make use of renewable energy? (7) Does the company have processes in place to improve its energy efficiency? (8) Does the company report on initiatives to reduce, reuse, substitute or phase out toxic chemicals or substances?	ASSET4

The moderating role of institutional context

To assess the moderating role, I introduce three institutional variables into Models (4) to (6) and three interaction terms, *STK_ASSU, ETS_ASSU,* and *CIS_ASSU.*

$$D\_SCORE_{it} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 STK_{i,t} + \beta_{10} STK\_ASSU_{i,t-1} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \tag{4}$$

$$D\_SCORE_{it} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ETS_{i,t} + \beta_{10} ETS\_ASSU_{i,t-1} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \tag{5}$$

$$D\_SCORE_{it} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 CIS_{i,t} + \beta_{10} CIS\_ASSU_{i,t-1} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \tag{6}$$

As hypothesized, the function of carbon assurance in improving carbon disclosure and minimizing information asymmetry is predicted stronger for firms in countries with a stakeholder orientation, in an ETS environment, and in a CIS.

5.4 Results and Discussion

5.4.1 Descriptive results

Table 5.4 provides the distribution of observations of assured and unassured companies. It shows that the response rate to the CDP questionnaire has increased over time. In addition, the number of companies that have assured emissions (either Scope 1 or Scope 2) has grown steadily from 2009 (62.93%) to 2014 (70.46%), which confirms the increasing demand for assuring carbon disclosure globally. This can be attributed to a heightened awareness of climate change among investors, stakeholders, regulators, and the general public.

Table 5. 4: Observations of Assured and Unassured Companies

			Assurance					Scope 1 Assurance					Scope 2 Assurance		
Year	**Total**	**Yes**	**%**	**No**	**%**	**Total**	**Yes**	**%**	**No**	**%**	**Total**	**Yes**	**%**	**No**	**%**
2009	321	202	62.93	119	37.07	175	171	97.71	4	2.29	175	150	85.71	25	14.29
2010	892	461	51.68	431	48.32	839	454	54.11	385	45.89	888	393	44.26	495	55.74
2011	1,037	611	58.92	426	41.08	1,029	597	58.02	432	41.98	1,024	555	54.20	469	45.80
2012	1,145	731	63.84	414	36.16	1,070	724	67.66	346	32.34	1,127	680	60.34	447	39.66
2013	1,280	874	68.28	406	31.72	1,268	869	68.53	399	31.47	1,270	825	64.96	445	35.04
2014	1,381	973	70.46	408	29.54	1,367	961	70.30	406	29.70	1,371	917	66.89	454	33.11
Total	6,056	3,852	63.61	2,204	36.39	5,748	3,776	65.69	1,972	34.31	5,855	3,520	60.12	2,335	39.88

As carbon assurance is lagged 1 year, the sample period for assurance is from 2009 to 2014.

Table 5.5 exhibits, as expected, the average disclosure score is significantly higher for the assured group (84.186) than for the unassured group (71.012). The mean disclosure score for the group with Scope 1 assurance is 84.408 versus 72.269 for the group without Scope 1 assurance; this difference is significant ($t = 29.296$, $p < 0.01$). Similar significant results are found for Scope 2 assurance, with 85.066 for the assured group and 72.381 for the unassured group. These results render preliminary support for the first hypothesis.

Table 5. 5: T-tests of Disclosure for the Assured and Unassured Groups

Variable	Yes	Mean (Yes)	No	Mean (No)	Difference	t
$ASSU_{t-1}$	3,852	84.186	2,204	71.012	13.174***	32.615
$S1\_ASSU_{t-1}$	3,776	84.408	1,972	72.269	12.159***	29.296
$S2\_ASSU_{t-1}$	3,520	85.066	2,335	72.381	12.702***	32.186

Paired-samples t tests are performed to test the difference in mean disclosure scores for the assured and unassured groups. Definitions of variables are provided in Table 5.3. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table 5.6 presents descriptive statistics for the variables used[18]. The full sample includes 6,056 observations (of which 5,748 for Scope 1 assurance and 5,855 involve Scope 2 assurance). Table 5.7 displays the disclosure scores grouped by country, it reveals the United States has the largest number of observations, making up almost 21% of assured observations in the sample. The presence of multicollinearity between variables is examined in the correlation matrix in Table 5.8. Table 5.8 shows that the correlations between variables included in the sample are relatively low and no extreme correlation is found, thus multicollinearity is likely not a serious concern in the estimation of the models in this study.

[18] Throughout, all variables are winsorized at the 1st and 99th percentiles to avoid extreme values (Luo et al 2012). Results and conclusions are qualitatively identical when winsorization is made at the 3rd and 97th percentiles.

Table 5. 6: Descriptive Statistics

Variable	N	Mean	Median	S.D.
D_SCORE_t	6,056	79.39	82.33	16.40
$S1\_ASSU_{t-1}$	5,748	0.66	1.00	0.47
$S2\_ASSU_{t-1}$	5,855	0.60	1.00	0.49
$ASSU_{t-1}$	6,056	0.64	1.00	0.48
CEI_t	6,056	249.27	47.22	453.48
$lnTA_t$	6,056	16.27	16.28	1.43
LEV_t	6,056	0.19	0.18	0.13
ENV_t	6,056	71.69	85.58	29.06
ROA_t	6,056	0.05	0.04	0.05
$RDIN_t$	6,056	0.01	0.00	0.02
$TOBINQ_t$	6,056	23.02	22.35	15.97
STK_t	6,056	0.45	0.00	0.50
ETS_t	6,056	0.59	1.00	0.49
CIS_t	6,056	0.24	0.00	0.43

Definitions of variables are provided in Table 5.3.

Table 5. 7: Descriptive Summary of Disclosure Scores by Country/Region

	Observations With Assurance					Observations Without Assurance				
Country	N	Mean	Median	Min	Max	N	Mean	Median	Min	Max
Argentina	1	70.76	70.76	70.76	70.76					
Australia	176	82.79	86.21	25.00	98.96	80	67.97	69.23	25.00	94.78
Austria	27	82.90	86.97	49.00	98.96	9	66.31	61.00	47.00	92.00
Belgium	23	83.39	87.46	62.00	98.96	8	71.57	77.00	40.00	93.00
Brazil	76	81.29	85.34	25.79	98.96	46	73.16	75.50	46.00	96.00
Canada	147	79.71	84.32	30.82	98.96	170	69.59	71.00	28.00	98.96
Chile	1	95.82	95.82	95.82	95.82	1	53.00	53.00	53.00	53.00
China	3	93.54	97.91	83.76	98.96	2	81.89	81.89	80.00	83.79
Colombia	2	97.91	97.91	96.87	98.96	4	60.00	58.50	40.00	83.00
Cyprus						4	65.75	64.50	50.00	84.00
Czech Republic	1	36.63	36.63	36.63	36.63					
Denmark	57	78.99	80.89	25.00	98.96	36	66.13	64.50	46.00	92.00
Finland	83	89.30	95.66	36.14	98.96	42	77.21	78.68	36.23	98.96
France	241	84.06	88.11	29.31	98.96	37	63.50	62.12	34.55	98.96
Germany	168	85.36	90.23	25.00	98.96	69	67.85	70.00	25.00	98.96
Guernsey	2	86.42	86.42	85.38	87.47	1	69.69	69.69	69.69	69.69
Hong Kong	32	83.31	86.51	49.09	98.92	2	40.50	40.50	39.00	42.00
India	82	82.63	86.94	34.15	98.96	37	69.74	73.00	34.00	98.96
Indonesia						1	45.00	45.00	45.00	45.00
Ireland	31	83.16	84.32	51.36	98.96	11	79.25	78.00	51.00	92.68
Israel	6	84.50	86.50	66.45	98.96	2	96.87	96.87	95.91	97.83
Italy	93	83.64	87.01	36.00	98.96	15	75.76	78.38	25.00	98.96
Japan	341	85.05	90.00	25.00	98.96	299	73.45	75.00	25.00	98.96
Luxembourg	3	85.55	86.97	70.73	98.96	8	57.60	57.50	34.00	83.76
Malaysia	2	70.59	70.59	55.30	85.89					
Mexico	6	76.81	82.76	41.38	98.96	2	72.13	72.13	65.26	79.00
Netherlands	64	83.68	88.21	44.80	98.96	29	70.21	70.00	26.00	98.96
New Zealand	9	80.08	75.96	60.00	98.96	13	73.70	69.69	67.00	93.00
Norway	78	81.64	84.06	47.00	98.96	27	73.97	74.00	28.00	93.00
Philippines	2	60.29	60.29	51.92	68.67	1	51.15	51.15	51.15	51.15
Portugal	36	88.30	92.56	64.28	98.96	5	71.89	66.00	52.00	96.86
Russia	2	60.65	60.65	55.30	66.00	5	48.40	50.00	33.00	65.00
Singapore	7	78.27	79.10	63.09	94.78	2	83.00	83.00	72.00	94.00
South Africa	168	90.15	94.57	52.97	98.96	79	81.43	83.00	55.00	96.87
South Korea	150	88.55	92.95	27.00	98.96	16	76.53	78.57	25.00	98.96

Table 5. 7: Descriptive Summary of Disclosure Scores by Country/Region

Spain	123	85.82	90.59	36.14	98.96	9	66.80	71.90	25.00	96.00
Sweden	95	81.68	84.41	41.59	98.96	95	74.27	75.00	34.00	97.91
Switzerland	125	86.29	90.27	39.47	98.96	80	67.76	67.76	25.00	95.82
Taiwan	50	81.27	84.56	38.33	98.96	9	60.02	64.00	37.00	81.00
Thailand	5	96.45	96.86	91.64	98.96	4	74.68	76.36	62.00	84.00
Turkey	10	89.39	91.64	62.37	98.96	21	83.09	88.00	44.00	96.87
USA	798	84.89	89.56	25.00	98.96	604	70.72	72.00	25.00	98.96
United Kingdom	526	81.75	84.36	25.00	98.96	319	68.79	70.89	25.00	98.96
Total	3852	84.19	88.32	25.00	98.96	2204	71.01	72.94	25.00	98.96

N= number of observations. Mean, median, minimum, and maximum are values of disclosure scores.

Table 5. 8: Correlation Matrix

	D_SCORE_t	$ASSU_{t-1}$	CEI_t	$lnTA_t$	LEV_t	ENV_t	ROA_t	$RDIN_t$	$TOBINQ_t$	STK_t	ETS_t	CIS_t
D_SCORE_t		0.41*	0.08*	0.22*	0.05*	0.19*	-0.05*	-0.01	0.01	0.07*	-0.02	0.01
$ASSU_{t-1}$	0.39*		0.16*	0.29*	0.08*	0.25*	-0.06*	-0.02	-0.02	0.08*	0.02	0.09*
CEI_t	0.05*	0.14*		-0.10*	0.29*	-0.02	0.01	-0.02	-0.01	-0.09*	-0.10*	0.58*
$lnTA_t$	0.22*	0.29*	-0.01		0.05*	0.39*	-0.26*	-0.05*	-0.30*	0.06*	-0.10*	0.02
LEV_t	0.05*	0.07*	0.19*	0.05*		0.00	-0.10*	-0.09*	-0.02	-0.04*	-0.02	0.18*
ENV_t	0.17*	0.22*	-0.04*	0.42*	0.02		-0.01	0.33*	0.13*	0.14*	0.06*	-0.05*
ROA_t	-0.03*	-0.04*	-0.09*	-0.23*	-0.13*	0.04*		0.20*	0.14*	-0.26*	-0.18*	-0.07*
$RDIN_t$	-0.02	-0.06*	-0.20*	-0.05*	-0.17*	0.15*	0.17*		0.35*	0.17*	0.01	-0.07*
$TOBINQ_t$	0.01	-0.02	-0.13*	-0.29*	-0.08*	0.01	0.09*	0.22*		0.19*	0.14*	-0.11*
STK_t	0.06*	0.08*	-0.08*	0.06*	-0.05*	-0.02	-0.24*	0.09*	0.19*		0.46*	-0.04*
ETS_t	-0.02	0.02	-0.11*	-0.10*	-0.02	-0.03	-0.18*	-0.02	0.13*	0.46*		-0.03*
CIS_t	-0.00	0.09*	0.53*	0.03*	0.16*	0.01	-0.09*	-0.18*	-0.11*	-0.04*	-0.03*	

This table presents correlations between variables used in multivariate tests for both hypotheses. Pearson correlation coefficients appear below the diagonal, and Spearman rank correlations appear above the diagonal. Definitions of variables are provided in Table 5.3. * represents significance (two-tailed) at 5%.

5.4.2 The impacts of carbon assurance on carbon disclosure

Table 5.9 reports the regression results from Models (1) to (6). The initial results unveil that assurance (of either Scope 1 or Scope 2 emissions or total emissions) is positively associated with carbon disclosure scores in the subsequent year. Specifically, the coefficients of *S1_ASSU* are positive and significant at the 1% level in Models (1) and (4). Comparable evidence of a strong association is also documented for *S2_ASSU.* The results, therefore, corroborate Hypothesis 1 that assurance has a discernible impact on the carbon disclosure of the assured firms.

Table 5. 9: The Impacts of Carbon Assurance on Carbon Disclosure

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S1\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S2\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

it	Predicted Sign	(1) *D_SCORE*	(2) *D_SCORE*	(3) *D_SCORE*	(4) *D_SCORE*	(5) *D_SCORE*	(6) *D_SCORE*
$S1\_ASSU_{t-1}$	+	10.848***			8.242***		
		(28.43)			(20.93)		
$S2\_ASSU_{t-1}$	+		10.858***			8.387***	
			(29.94)			(22.55)	
$ASSU_{t-1}$	+			11.269***			8.582***
				(30.56)			(22.43)
CEI_t	+				0.001	0.001***	0.001
					(1.35)	(2.73)	(1.24)
$lnTA_t$	+				2.434***	2.376***	2.404***
					(14.08)	(14.13)	(14.14)
LEV_t	+				1.752	1.247	1.608
					(1.18)	(0.85)	(1.10)
ENV_t	+				0.042***	0.043***	0.046***
					(6.10)	(6.39)	(6.71)
ROA_t	+				12.754***	11.980***	11.761***
					(3.28)	(3.15)	(3.10)
$RDIN_t$	+				6.519	8.798	6.434
					(0.59)	(0.81)	(0.60)
$TOBINQ_t$	+				0.077***	0.075***	0.075***
					(4.87)	(4.82)	(4.79)
Constant		35.500***	38.681***	34.855***	-3.601	-0.588	-3.487
		(2.73)	(3.00)	(2.65)	(-0.28)	(-0.05)	(-0.27)
Year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Country fixed		Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
No. of observations		5748	5855	6056	5748	5855	6056
R^2		0.352	0.367	0.370	0.395	0.409	0.411
Adjusted R^2		0.346	0.360	0.364	0.388	0.402	0.404

Definitions of variables are provided in Table 5.3. Coefficients are estimated with linear regression with robust standard errors for the full sample of 6,056 observations. t statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The findings in Table 5.9 make good intuitive sense in a number of respects. First, as discussed by Hay and Davis (2004), financial auditing enhances the quality of accounting information and constrains earnings management. Comparable evidence is also documented in the environmental assurance literature (Moroney et al. 2012). Coupled with the findings in the mainstream literature, the results provide fresh evidence that carbon assurance is positively associated with the comprehensiveness of corporate carbon disclosure.

Second, carbon accounting is a relatively new area, and no globally accepted standards are available for carbon reporting. This highlights the complexity and uncertainty of collecting, measuring, and reporting carbon information. Hence, even the management of a company may not be familiar with the information needs of stakeholders and the requirements for carbon disclosure. Carbon assurance has therefore emerged as an effective tool for carbon management. With assistance from assurance, a firm is able to complete a comprehensive carbon report. The results imply that directors strategically engage competent assurers in their decisions regarding carbon disclosure.

Regarding the control variables, the coefficient of *CEI* is positive—and significant in Model (5)—which indicates that firms with higher carbon emissions tend to disclose more carbon information. This is consistent with the prior literature (Deegan 2007; Bebbington and Larrinaga-González 2008; Luo 2019). *lnTA* has a significant positive coefficient as expected (Luo 2019). A comparable finding is evident for *ENV.* The results are intuitively appealing in that environmental management and carbon management are inherently interrelated (Liao et al. 2015; Luo and Tang 2015; Luo et al. 2013; Reid and Toffel 2009). The association between *D_SCORE* and *ROA* is positive and significant, which is consistent with Moroney et al. (2012). *TOBINQ* has a positive and significant relationship with the disclosure score as Luo (2019) reported. The significant signs of *CEI, lnTA, ENV, ROA,* and *TOBINQ* highlight the importance of including them in the model. No significant relationship is found for *LEV* and *RDIN.*

5.4.3 The moderating role of institutional context

This section examines whether carbon-regulated institutions have an impact on the link between carbon disclosure and assurance. The interaction term *STK_ASSU* in Table 5.10 is positive and significant at the 1% level, suggesting relationship between assurance and disclosure is conditional on the legal environment and the effects of carbon assurance is weaker in countries with a shareholder orientation, The results are consistent with Hypothesis 2a, implying legal system and carbon assurance play a complementary rather than substitutional role in promoting carbon disclosure in a stakeholder-focused environment, which corroborates stakeholder engagement theory.

Table 5. 10: The Moderating Role of Institutional Context

$$D_{SCORE_{it}} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 STK_{i,t} + \beta_{10} ASSU\_STK_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$D_{SCORE_{it}} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ETS_{i,t} + \beta_{10} ASSU\_ETS_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$D_{SCORE_{it}} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 CIS_{i,t} + \beta_{10} ASSU\_CIS_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

	(1) *D_SCORE*	(2) *D_SCORE*	(3) *D_SCORE*	(4) *D_SCORE*
$ASSU_{t-1}$	7.350***	6.744***	7.643***	7.655***
	(18.12)	(15.89)	(19.83)	(19.94)
CEI_t	0.000	0.000	0.000	
	(0.34)	(0.19)	(0.36)	
$lnTA_t$	2.228***	2.114***	2.223***	2.221***
	(13.39)	(12.63)	(13.39)	(13.39)
LEV_t	1.699	1.699	1.450	1.465
	(1.19)	(1.19)	(1.02)	(1.03)
ENV_t	0.040***	0.040***	0.042***	0.042***
	(6.03)	(6.05)	(6.29)	(6.28)
ROA_t	12.180***	11.909***	11.693***	11.597***
	(3.28)	(3.22)	(3.16)	(3.14)
$RDIN_t$	-0.138	0.156	1.601	1.329
	(-0.01)	(0.01)	(0.15)	(0.13)
$TOBINQ_t$	0.073***	0.072***	0.073***	0.073***
	(4.78)	(4.71)	(4.81)	(4.81)

Table 5. 10: The Moderating Role of Institutional Context

STK_t	0.000			
	(.)			
STK_ASSU_{t-1}	4.261***			
	(6.65)			
ETS_t		-1.555		
		(-1.33)		
ETS_ASSU_{t-1}		4.636***		
		(8.18)		
CIS_t			-7.186***	-7.163***
			(-4.93)	(-4.92)
CIS_ASSU_{t-1}			6.156***	6.174***
			(7.56)	(7.60)
Constant	-3.338	3.588	3.508	3.590
	(-0.26)	(0.28)	(0.28)	(0.28)
Year fixed effects	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
No. of observations	6006	6006	6006	6006
R^2	0.422	0.424	0.423	0.423
Adjusted R^2	0.415	0.418	0.417	0.417

Definitions of variables are provided in Table 5.3. *STK_ASSU, ETS_ASSU,* and *CIS_ASSU* are interaction terms used to test the impact of interactions between carbon assurance and the three institutional factors (*STK, CIS,* and *ETS*) on disclosure scores. *t* statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The interaction term ETS_ASSU in Table 5.10 is positive and significant, confirming that the existence of an ETS strengthens the association between carbon assurance and disclosure score (Hypothesis 2b). This is attributed to the heavily carbon-regulated environment in countries with an ETS. Last, the interaction term CIS_ASSU is significantly positive supporting Hypothesis 2c. The intuition behind the finding is that Carbon-intensive companies undergo intensive review by stakeholders and are regulated by various government agencies. Carbon assurance could help these firms with more comprehensive carbon disclosure to legitimize their activities in such a strictly monitored environment. Therefore, the effects of carbon assurance on carbon disclosure are stronger for companies in carbon-intensive industries compared to those in non-intensive industries, which are less scrutinized by regulators. In sum, the spatial and temporal analysis uncovers that the nuance of the dynamic effects of carbon assurance is conditional on the carbon-related institutions around firms.

5.4.4 The influence of carbon assurance on isomorphic changes in carbon disclosure

I next examine the effect of carbon assurance on other aspects of carbon disclosure, i.e. whether carbon disclosure exhibits some sign of convergence under the influence of assurance. According to institutional theory, elements of institutions tend to reduce variety toward organizational homogeneity. DiMaggio and Powell (2012) contend that isomorphism is the process that best describes this homogeneity, and the external environment (such as competition and institutional pressures to adaptation and adoption of new values, norms, and attitudes) drive these isomorphic changes. Isomorphism takes place via three mechanisms: coercive (external pressures exerted by other organizations such as governmental bodies), normative (arising from professionalization) and mimetic (referring to the tendencies of firms to copy one another) processes (DiMaggio and Powell 2012; Scott 2013). Furthermore, institutionalization is impacted by the external environment, which itself is constantly changing, and firms influence one another to absorb these changes (DiMaggio and Powell 2012). Institutional theory has been applied to analyze organizational participation in carbon emissions trading (Pinkse and Kolk 2009).

Therefore, I argue that corporate carbon disclosure tends to converge and this process is affected by external assurance. Third-party assurance is part of the external environment surrounding the firm, which represents outside influences from stakeholders. If a growing number of peer companies choose assurance, this is a coercive pressure on firms without assurance. Similarly, assurers may impose mimetic and normal pressure on their clients to implement a certain type of disclosure practice. Thus, the trend toward isomorphic practice will be more pronounced in companies with assurance than in those without assurance. Following de Aguiar and Bebbington (2014), I use the standard deviation of the carbon disclosure score as a measure of the convergence or homogeneity of carbon disclosure. It is expected that the standard deviation will be smaller in the cohort of assured companies than unassured companies. The test shows that assured companies not only obtained a higher disclosure score (84.19) than unassured companies (71.01), but also the standard deviation of the score for assured companies (14.36) is lower than that for unassured companies (16.18). Levene's test is run to assess the equality of standard deviations (variance) of the two disclosure scores and find the difference is significant at the 0.01 level (F = 52.01). This preliminary evidence is consistent with institutional theory. Despite assured CDP participants differ from one another in terms of size, economic activity, level of emissions, the volume of disclosures, their reports is more converged compared to the matched pair unassured cohort. One mechanism through which for the isomorphism to occur could be that the GHG monitoring, reporting, and verification process is gradually becoming institutionalized around the world particularly with ETS. External assurance (i.e. verification) not only enhances carbon disclosure but also accelerates the speed of isomorphism toward more comparable and consistent carbon reporting. This evidence corroborates the finding of de Aguiar and Bebbington (2014).

5.4.5 Robustness checks

5.4.5.1 Adopting a change analysis model

To ensure the robustness of the baseline results, I perform a number of sensitivity tests. First, I compare carbon disclosure scores of a firm before and after assurance using a change model. A significant change in carbon disclosure subsequent to the assurance provides stronger evidence of the effect of assurance. The model is specified below:

$$\begin{aligned}\Delta\text{D\_SCORE}_{it} = {} & \beta_0 + \beta_1 \Delta S1\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} \\ & + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} \\ & + Year\ Fixed\ Effects + Country\ Fixed\ Effects \\ & + Industry\ Fixed\ Effects + \varepsilon\end{aligned} \quad (7)$$

$$\begin{aligned}\Delta\text{D\_SCORE}_{it} = {} & \beta_0 + \beta_1 \Delta S2\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} \\ & + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} \\ & + Year\ Fixed\ Effects + Country\ Fixed\ Effects \\ & + Industry\ Fixed\ Effects + \varepsilon\end{aligned} \quad (8)$$

$$\Delta \text{D\_SCORE}_{it} = \beta_0 + \beta_1 \Delta ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \quad (9)$$

The results are presented in Table 5.11. The coefficients of $\Delta S1\_ASSU_{t-1}$, $\Delta S2\_ASSU_{t-1}$, and $\Delta ASSU_{t-1}$ are significant and positive, which shows that firms' carbon disclosure increase when they initiate or resume carbon assurance. This result reinforces the main inference of the study.

Table 5. 11: The Impacts of Carbon Assurance on Carbon Disclosure—Change Analysis

$$\Delta \text{D\_SCORE}_{it} = \beta_0 + \beta_1 \Delta S1\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\Delta \text{D\_SCORE}_{it} = \beta_0 + \beta_1 \Delta S2\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\Delta \text{D\_SCORE}_{it} = \beta_0 + \beta_1 \Delta ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

	Predicted Sign	(1) *ΔD_SCORE*	(2) *ΔD_SCORE*	(3) *ΔD_SCORE*	(4) *ΔD_SCORE*	(5) *ΔD_SCORE*	(6) *ΔD_SCORE*
$\Delta S1\_ASSU_{t-1}$	+	3.770***			3.738***		
		(8.55)			(8.49)		
$\Delta S2\_ASSU_{t-1}$	+		3.483***			3.470***	
			(8.54)			(8.52)	
$\Delta ASSU_{t-1}$	+			3.608***			3.587***
				(8.17)			(8.13)
CEI_t	+				0.001	0.001	0.001
					(1.33)	(1.30)	(1.39)
$InTA_t$	+				-0.469***	-0.490***	-0.462***
					(-3.21)	(-3.43)	(-3.22)
LEV_t	+				-0.110	-0.684	-0.461
					(-0.08)	(-0.53)	(-0.36)
ENV_t	+				-0.002	0.003	0.001
					(-0.35)	(0.45)	(0.18)
ROA_t	+				4.253	4.614	4.626
					(1.25)	(1.38)	(1.37)
$RDIN_t$	+				6.311	7.732	7.511
					(0.66)	(0.83)	(0.80)
$TOBINQ_t$	+				-0.004	-0.004	-0.004
					(-0.30)	(-0.33)	(-0.27)
Constant		2.509	27.943***	30.196***	10.308	33.943***	35.785***
		(0.27)	(3.04)	(3.26)	(1.08)	(3.59)	(3.76)
Year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects		Yes	Yes	Yes	Yes	Yes	Yes
No. of observations		4122	4214	4248	4122	4214	4248
R^2		0.053	0.052	0.050	0.058	0.056	0.054
Adjusted R^2		0.041	0.040	0.038	0.044	0.043	0.040

Definitions of variables are provided in Table 5.3. *t* statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.4.5.2 The U.S. effect

The U.S. effect is examined in light of the lower rate of adoption of assurance among U.S. firms (Simnett et al. 2009a; Zhou et al. 2016) and the fact that U.S. firms make up the largest share of the sample. I rerun the analysis excluding U.S. observations. In general, the results (not shown) are consistent with those presented in Tables 5.7 and 5.8. Specifically, i observe that assurance has a stronger impact in a stakeholder-oriented country. Comparable evidence is found with regard to the moderating effects of *ETS* and *CIS.*

5.4.5.3 Level of carbon assurance

In a financial audit, reasonable assurance would deliver a higher level of assurance than limited assurance which may have a critical impact on disclosure (Deegan and Blomquist (2006); Moroney et al. (2012). In the context of this study, carbon assurance has a unique distinction: Assurance often does not cover 100% of the emissions of the auditee, whereas all assets and liabilities are covered in a financial audit regardless of reasonable or limited assurance. Thus, I examine the effect of the proportion of emissions covered (i.e. the level of assurance) in an assurance. A higher disclosure score is expected when full assurance is provided (i.e., 80% to 100% emissions are covered) than partial assurance (less than 80% covered). Thus, I rerun the analysis using *S1_ASSUCOVER* and *S2_ASSUCOVER* as proxies for the level of assurance. Specifically, the level of assurance is coded into five categories: less than 20% (coded as 1), 21%–40% (2), 41%–60% (3), 61%–80% (4), and 81%–100% (5). The models are as follows:

$$\begin{aligned} \text{D\_SCORE}_{it} = {} & \beta_0 + \beta_1 S1\_ASSUCOVER_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} \\ & + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} \\ & + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects \\ & + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \end{aligned} \quad (10)$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S2\_ASSUCOVER_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \quad (11)$$

The results are shown in Table 5.12. The positive and significant sign of *S1_ASSUCOVER* and *S2_ASSUCOVER* suggest that the higher the level of assurance, the higher the carbon disclosure score. These results further nuance my knowledge that carbon disclosure is a function of the level of carbon assurance (not just the adoption of the practice).

Table 5. 12: The Effect of Level of Carbon Assurance on Carbon Disclosure

$$D\_SCORE_{it} = \beta_0 + \beta_1 S1\_ASSUCOVER_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$D\_SCORE_{it} = \beta_0 + \beta_1 S2\_ASSUCOVER_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

	Predicted Sign	(1) *D_SCORE*	(2) *D_SCORE*
$S1\_ASSUCOVER_{t-1}$	+	1.853***	
		(12.98)	
$S2\_ASSUCOVER_{t-1}$	+		1.352***
			(12.07)
CEI_t	+	0.002***	0.002***
		(4.14)	(3.06)
$lnTA_t$	+	3.796***	3.750***
		(11.84)	(11.34)
LEV_t	+	-0.687	0.244
		(-0.29)	(0.10)
ENV_t	+	0.075***	0.091***
		(6.83)	(7.99)
ROA_t	+	9.722**	10.156**
		(2.06)	(2.02)
$RDIN_t$	+	18.691	17.229
		(0.91)	(0.83)
$TOBINQ_t$	+	0.066**	0.063**
		(2.45)	(2.25)
Constant		9.138*	11.341**
		(1.74)	(2.09)
Year fixed effects		Yes	Yes
Country fixed effects		Yes	Yes
Industry fixed effects		Yes	Yes
No. of observations		4605	4406
Adjusted R^2		0.409	0.394

Definitions of variables are provided in Table 5.3. Coefficients are estimated with linear regression with robust standard errors for the full sample of 5,685 observations. *t* statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.4.5.4 Heckman's two-stage tests

I examine potential self-selection bias in this exploratory study in light of the voluntary nature of participation in the CDP survey, which could potentially result in an endogeneity problem with a biased or nonrandom sample. Thus, I perform Heckman's two-stage tests. In the first stage, the following disclosure choice model is estimated:

$$DISC_{i,t} = \beta_0 + \beta_1 lnTA_{i,t} + \beta_2 LEV_{i,t} + \beta_3 BM_{i,t} + \beta_4 ENV_{i,t} + \beta_5 ROA_{i,t} + \beta_6 DISC_{i,t-1} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon \quad (12)$$

where *DISC* is a dummy variable coded 1 if the company disclosed its carbon information and 0 otherwise. The independent variables are selected following previous studies (Matsumura et al. 2014; Zhou et al. 2016; Healy and Palepu 2001; Kwak et al. 2012): Firm size ($lnTA$), leverage (*LEV*), book-to-market ratio (*BM*), environmental performance (*ENV*), and profitability (ROA). Moreover, I include a lagged indicator, $DISC_{t-1}$, to control for the sticky pattern in manager's disclosure decisions (Stanny (2013).

In the second stage, I rerun the regression with Models (1) to (3). The results, which are reported in Table 5.13, are generally consistent with the baseline results in Table 5.9. Given that *MILLS* calculated from the first-stage model is nonsignificant, endogeneity is not a serious concern, suggesting my primary inferences are robust.

Table 5. 13: Heckman's Two-Stage Analysis

Step 1: Selection Model -- Decision to Disclose to CDP

$$DISC_{i,t} = \beta_0 + \beta_1 lnTA_{i,t} + \beta_2 LEV_{i,t} + \beta_3 BM_{i,t} + \beta_4 ENV_{i,t} + \beta_5 ROA_{i,t} + \beta_6 DISC_{i,t-1} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

Step 2: Response Model -- Impacts of Carbon Assurance on Carbon Disclosure

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S1\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S2\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

	(1)	(2)	(3)
Response Model	*D_SCORE*	*D_SCORE*	*D_SCORE*
$S1\_ASSU_{t-1}$	8.380***		
	(21.290)		
$S2\_ASSU_{t-1}$		8.710***	
		(23.800)	
$ASSU_{t-1}$			9.134***
			(24.260)
CEI_t	0.000	0.001***	0.001
	(0.380)	(3.080)	(1.200)
$LnTA_t$	2.591***	2.480***	2.457***
	(14.480)	(14.470)	(14.230)
LEV_t	1.865	1.947	2.230
	(1.250)	(1.350)	(1.540)
ENV_t	0.054***	0.048***	0.050***
	(6.890)	(6.320)	(6.580)
ROA_t	13.882***	13.985***	13.959***
	(3.490)	(3.650)	(3.660)
$RDIN_t$	1.765	9.708	7.216
	(0.160)	(0.900)	(0.670)
$TOBINQ_t$	0.075***	0.073***	0.074**
	(4.730)	(4.740)	(4.840)
Constant	32.601***	36.290***	34.736***
	(10.870)	(12.590)	(12.040)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Selection Model			
$lnTA_t$	0.191***	0.187***	0.179***
	(6.820)	(6.750)	(6.520)
LEV_t	0.055	0.032	0.007
	(0.240)	(0.140)	(0.03)

Table 5. 13: Heckman's Two-Stage Analysis

BM_t	-0.127*	-0.117	-0.120
	(-1.660)	(-1.540)	(-1.590)
ENV_t	0.011***	0.010***	0.010***
	(11.150)	(11.030)	(11.040)
ROA_t	2.643***	2.703***	2.556***
	(4.180)	(4.320)	(4.150)
$DISC_{t-1}$	3.562***	3.538***	3.550***
	(29.030)	(29.630)	(29.720)
Constant	-5.487***	-5.410***	-5.289***
	(-12.400)	(-12.420)	(-12.260)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
MILLS	1.944	1.395	1.230
	(1.460)	(1.090)	(0.940)
No. of observations	7,034	7,121	7,296
Censored	1,347	1,347	1,347
Uncensored	5,687	5,774	5,947

Definitions of variables are provided in Table 5.3. Coefficients are estimated with linear regression with robust standard errors for the full sample of 5,685 observations. *t* statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.4.5.5 Absolute carbon emissions

Recent studies assert that the intensity of carbon emissions provides a fairer comparison across different companies and different reporting periods (Hoffmann and Busch 2008). Despite this, for the sake of rigorousness, I also perform a sensitivity test using absolute carbon emissions. The results (not tabulated) do not alter my inferences from the baseline findings.

5.4.5.6 Impression management

As alluded to earlier, there is a concern that the positive association documented in this study may be driven by impression management. To detect impression management, one must use a reliable method to measure environmental performance, because the purpose of impression management is to hide inferior performance (Power 1991; Edgley et al. 2010). Thus, I include an additional variable—*ESG* (environmental, social, and governance score)—to measure environmental performance. *ESG* covers many actions, including the efficiency of resource use, emissions reduction, innovation, and CSR strategy (Refinitiv

2019). Thus, a higher *ESG* means the firm takes proactive initiatives for environmental protection. Such firms tend to adhere to a high standard of ethical behavior and demonstrate integrity, honesty, and trustworthiness in their business processes. If disclosure and assurance are driven by impression management/legitimation, disclosure would be largely symbolic, rhetorical, and lacking in substance (Moneva et al. 2006) and no real or concrete actions are taken to address climate change issues. Therefore, *ESG* can be used to capture impression management incentive because such activity would lead to a negative association between ESG and disclosure score.

After I control for this proxy for impression management in both Heckman steps, the results still hold (see Table 5.14). Furthermore, the coefficient of *ESG* is significant and positive, which suggests that impression management probably does not motivate the sample firms. This is consistent with the prior literature, which argues that regardless of managerial capture, assurance is becoming stakeholder inclusive and tends to transform attitudes of managers toward their accountability to stakeholders and the natural environment (Edgley et al. 2010).

Table 5. 14: Heckman's Two-Stage Analysis—With ESG

Step 1: Selection Model -- Decision to Disclose to CDP

$$DISC_{i,t} = \beta_0 + \beta_1 lnTA_{i,t} + \beta_2 LEV_{i,t} + \beta_3 BM_{i,t} + \beta_4 ENV_{i,t} + \beta_5 ROA_{i,t} + \beta_6 DISC_{i,t-1} + \beta_7 ESG_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

Step 2: Response Model -- Impacts of Carbon Assurance on Carbon Disclosure

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S1\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ESG_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S2\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ESG_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ESG_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

	(1)	(2)	(3)
Response Model	*D_SCORE*	*D_SCORE*	*D_SCORE*
S1_ASSU$_{t-1}$	8.152***		
	(19.57)		
S2_ASSU$_{t-1}$		8.390***	
		(21.54)	
ASSU$_{t-1}$			8.794***
			(22.01)
CEI$_t$	-0.000	0.001**	0.000
	(-0.43)	(2.40)	(0.36)
lnTA$_t$	2.054***	2.083***	1.957***
	(10.60)	(11.09)	(10.38)
LEV$_t$	1.872	2.345	2.462
	(1.19)	(1.53)	(1.61)
ENV$_t$	0.034***	0.043***	0.035***
	(2.81)	(3.67)	(3.03)
ROA$_t$	12.263***	13.402***	12.521***
	(2.94)	(3.31)	(3.12)
RDIN$_t$	5.953	10.871	8.979
	(0.51)	(0.96)	(0.80)
TOBINQ$_t$	0.067***	0.066***	0.065***
	(4.07)	(4.07)	(4.00)
ESG$_t$	0.133***	0.108***	0.125***
	(7.34)	(6.11)	(7.09)
Constant	34.125***	35.800***	35.783***
	(10.53)	(11.42)	(11.43)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Selection Model			
lnTA$_t$	0.163***	0.158***	0.150***
	(4.68)	(4.56)	(4.36)
LEV$_t$	0.298	0.260	0.235
	(1.10)	(0.96)	(0.88)
BM$_t$	-0.183**	-0.185**	-0.185**
	(-2.01)	(-2.04)	(-2.06)
ENV$_t$	0.010***	0.010***	0.009***

Table 5. 14: Heckman's Two-Stage Analysis—With ESG

	(6.27)	(6.02)	(5.93)
ROA_t	2.575***	2.688***	2.475***
	(3.49)	(3.67)	(3.45)
$DISC_{t-1}$	3.555***	3.525***	3.540***
	(24.83)	(25.40)	(25.49)
ESG_t	0.017***	0.018***	0.018***
	(5.80)	(6.03)	(6.13)
Constant	-5.921***	-5.828***	-5.710***
	(-10.98)	(-10.94)	(-10.82)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
MILLS	1.833	1.256	0.768
	(0.229)	(0.393)	(0.607)
No. of observations	5,920	5,994	6,153
Censored	896	896	896
Uncensored	5,024	5,098	5,257

Definitions of variables are provided in Table 4.3.
t statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

I also test whether disclosing firms engage in specific substantive carbon reduction actions. I use an index of carbon reduction initiatives (*CRI*) for this test. *CRI* index reflects firm-specific activities such as the use of renewable energy; improving energy efficiency and engaging in emissions trading; managing climate risks; and undertaking programs to mitigate or phase out carbon emissions. Table 5.3 detailed the emission activities employed to build the CRI index. The higher the CRI, the more active the firms in environmental actions (Haque 2017). If a firm is inclined to engage in impression management, it is unlikely to devote substantial resources to these activities, and vice versa. Therefore, I add *ESG* and *CRI* to the test model (see Table 5.15). Negative coefficients for these two action-based variables would support, whereas positive coefficients would lead to rejecting the impression management assumption. The results show positive and significant coefficients for *ESG* and *CRI,* so the impression management motivation is rejected. Taken as a whole, the results provide fresh insight that reflects strategic changes in corporate responses to climate change due to growing coercive, memetic, and normal institutional pressure witnessed in the past decade or so.

Table 5. 15: Heckman's Two-Stage Analysis—With ESG and CRI

Step 1: Selection Model -- Decision to Disclose to CDP

$$DISC_{i,t} = \beta_0 + \beta_1 lnTA_{i,t} + \beta_2 LEV_{i,t} + \beta_3 BM_{i,t} + \beta_4 ENV_{i,t} + \beta_5 ROA_{i,t} + \beta_6 DISC_{i,t-1} + \beta_7 ESG_{i,t} + \beta_7 CRI_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

Step 2: Response Model – Impacts of Carbon Assurance on Carbon Disclosure

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S1\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ESG_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 S2\_ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ESG_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

$$\text{D\_SCORE}_{it} = \beta_0 + \beta_1 ASSU_{i,t-1} + \beta_2 CEI_{i,t} + \beta_3 InTA_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ENV_{i,t} + \beta_6 ROA_{i,t} + \beta_7 RDIN_{i,t} + \beta_8 TOBINQ_{i,t} + \beta_9 ESG_{i,t} + Year\ Fixed\ Effects + Country\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon$$

	(1)	(2)	(3)
Response Model	*D_SCORE*	*D_SCORE*	*D_SCORE*
S1 ASSU$_{t-1}$	8.014***		
	(19.21)		
S2_ASSU$_{t-1}$		8.287***	
		(21.29)	
ASSU$_{t-1}$			8.650***
			(21.63)
CEI$_t$	-0.000	0.001*	-0.000
	(-0.88)	(1.87)	(-0.13)
lnTA$_t$	1.837***	1.834***	1.718***
	(9.15)	(9.41)	(8.80)
LEV$_t$	1.827	2.235	2.370
	(1.17)	(1.46)	(1.55)
ENV$_t$	0.022*	0.029**	0.021*
	(1.71)	(2.37)	(1.77)
ROA$_t$	11.927***	12.955***	12.160***
	(2.87)	(3.20)	(3.04)
RDIN$_t$	1.634	6.125	4.318
	(0.14)	(0.54)	(0.38)
TOBINQ$_t$	0.065***	0.063***	0.062***
	(3.92)	(3.87)	(3.81)
ESG$_t$	0.116***	0.090***	0.108***
	(6.29)	(4.98)	(5.95)
CRI$_t$	0.666***	0.747***	0.734***
	(4.04)	(4.65)	(4.58)
Constant	38.164***	40.367***	40.225***
	(11.27)	(12.31)	(12.30)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Selection Model			
lnTA$_t$	0.163***	0.158***	0.150***
	(4.68)	(4.56)	(4.36)
LEV$_t$	0.298	0.260	0.235
	(1.10)	(0.96)	(0.88)
BM$_t$	-0.183**	-0.185**	-0.185**
	(-2.01)	(-2.04)	(-2.06)

Table 5. 15: Heckman's Two-Stage Analysis—With ESG and CRI

ENV_t	0.010***	0.010***	0.009***
	(6.27)	(6.02)	(5.93)
ROA_t	2.575***	2.688***	2.475***
	(3.49)	(3.67)	(3.45)
$DISC_{t-1}$	3.555***	3.525***	3.540***
	(24.83)	(25.40)	(25.49)
ESG_t	0.017***	0.018***	0.018***
	(5.80)	(6.03)	(6.13)
Constant	-5.921***	-5.828***	-5.710***
	(-10.98)	(-10.94)	(-10.82)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
MILLS	1.561	0.963	0.467
	(0.306)	(0.512)	(0.755)
No. of observations	5,920	5,994	6,153
Censored	896	896	896
Uncensored	5,024	5,098	5,257

Definitions of variables are provided in Table 4.3.
t statistics are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Thus, the results significantly nuance some findings in the extant literature. Prior studies form the consensus that assurance and reporting can be coproduced following a series of acts performed by auditors and auditees (e.g., Power 1991). The results suggest the auditing process is not necessarily a one-way influence of manager on auditor (managerial capture). Instead, carbon assurance can create a cooperative, mutually influencing situation that may eventually enhance both transparency of carbon disclosure and managerial accountability for the climate (Edgley et al. 2010). In other words, the series of acts performed by auditors and auditees can be constructive and interactive, create a dialogic relationship, and achieve a positive outcome. The empirical results nuance some conclusions of the prior literature regarding the dynamic relationships between auditor and auditee and between assurance and disclosure.

5.5 Concluding Remarks

There is a scientific consensus that anthropogenic GHG causes global warming. Extensive studies have been devoted to carbon management, whereas carbon assurance is somewhat under-researched. The purpose of this study is to examine the link between voluntary carbon disclosure and external carbon assurance using a theoretical perspective based on stakeholder engagement. This study has several key findings. First, companies with carbon assurance have higher overall carbon disclosure scores on average in a subsequent year. Second, the effects of carbon assurance on carbon disclosure vary with the presence of carbon institutions. Finally, carbon assurance may enhance the effect of institutionalization of carbon disclosure practices. Overall, the evidence demonstrates the effect of engaging a carbon assurer: Assurance adds certainty to carbon disclosures by not only boosting the confidence of users of the immediate carbon report but also enhancing the comprehensiveness and transparency of subsequent carbon disclosures. The cornerstone of the study is the stakeholder engagement theory. This theory emphasizes interaction, communication, and cooperation between management and groups of stakeholders, including assurers. As a result, firms with carbon assurance tend to have a better understanding of the expectations of stakeholders; thus, they can align their disclosures with stakeholder needs. Hence, the findings enhance the validity and applicability of stakeholder engagement theory and institutional theory. The findings in this study may help policymakers use carbon assurance together with other policy instruments to achieve a better outcome toward the goal of limiting global warming to below 1.5°C.

In summary, as the current literature does not completely explain the impacts of carbon assurance on carbon disclosure, this study fills a few gaps: first, using an innovative method of content analysis to codify disclosure and compare it between firms with and without assurance, the study shows a quantified dynamic effect of carbon assurance on disclosure. Second, I decompose the relative roles and disentangle the effect of carbon assurance on the immediate versus lagged carbon disclosure. Assurance is costly, so recognition of the effect should help firms to maximize the benefit of carbon assurance. Further, with additional robust tests that provide inferentially identical findings to the main results, the study documents persuasive circumstantial evidence that substantiates and vindicates the accuracy of this model and corroborates stakeholder engagement theory. Finally, I find spatial heterogeneity in the relationship between carbon disclosure and assurance, which indicates an asymmetric effect of carbon assurance on disclosure in different institutional contexts.

I admit a number of limitations to this study. For example, the method only measures the comprehensiveness of carbon report but does not consider the detailed content of the disclosure. Furthermore, the sample used in this study only includes the largest companies; thus, caution is needed when extending these results to small firms. In addition, caution should be taken when generalizing the results to firms that do not participate in the CDP survey. Despite these caveats, the evidence provided by this research illuminates the link between carbon assurance and disclosure, to my knowledge the empirical evidence has not been seen in the extant literature.

This research has practical implications. A general consensus is formed that the myriad challenges of the Paris Agreement put pressure on firms to undertake measures to enhance energy and carbon productivity. Firms face risks and opportunities in meeting stringent carbon mitigation targets and use negative emissions technologies, adopt fossil fuel divestment strategies and decarbonize their business operations. Thus, carbon management becomes an utmost priority in corporate sustainability strategy development. This study aims to enrich understanding of the dynamics related to firm carbon management, disclosure and assurance. Despite this, the effects of carbon assurance have been virtually unexplored in the academic literature, knowledge of the dynamic effects is still very limited. Thus, there are enormous opportunities for further research for the emerging practice. For instance, disclosure is only one aspect of the overall corporate carbon management system (Tang and Luo 2014). Future studies may consider how carbon assurance can help firms strengthen their carbon management capability as a whole. Moreover, since carbon assurance and disclosure vary across institutions, future studies could examine the issue under other contexts, such as various corporate governance, economic, or financial systems. In addition, prior literature finds an association between cultural factors and sustainability assurance (Martínez-Ferrero and García-Sánchez 2017); thus, the effect of culture on carbon assurance is an interesting topic. Finally, few studies have examined how carbon assurance is practiced, so the knowledge of the differences in methodology, expertise, and approach between financial audits and carbon audits is scant. Thus, researchers could investigate carbon assurance using a case study methodology to offer further insights into this emerging practice.

CHAPTER 6 CONCLUSION

6.1 Introduction

There is a growing interest in carbon emissions reporting which has enhanced the pressure on firms to set carbon reduction targets and undertake initiatives to mitigate carbon emissions (Romar 2009; Galbreath 2011; Depoers et al. 2016; Ioannou and Serafeim 2017). This interest stems partly from increasing pressure from recent major initiatives such as the Carbon Disclosure Project (CDP) and Global Reporting Initiative (GRI), which have exerted increasing pressure on firms to be more transparent about their non-financial information, including carbon emissions. The growing interest can also be tied to the onset of emissions trading systems (ETS) and carbon taxes in many countries, which have emerged as key public policies for reducing carbon emissions. A wide range of stakeholders increasingly require firms to disclose carbon information for their decision making (Matsumura et al. 2014; Griffin et al. 2017). Consequently, carbon disclosure has become a critical part of annual business reporting. However, the quality and reliability of such disclosures are not guaranteed (Freedman and Jaggi 2005; Stanny and Ely 2008; Reid and Toffel 2009). Consequently, strong demand is emerging for independent verification of reports on greenhouse gas (GHG) (GHG; Green and Li 2011; Luo and Tang 2014; Zhou et al. 2016; Becker et al. 1998; De Beelde and Tuybens 2015; Francis and Schipper 1999; Francis 2004; Hay and Davis 2004; Watts and Zimmerman 1990). Nevertheless, the literature on the assurance of carbon emissions remains very sparse (Simnett et al. 2009a; Datt et al. 2018). Thus, this thesis aims to fill this gap by providing a comprehensive study on both the determinants and impacts of carbon assurance.

This chapter summarises the key findings of this study, the main contributions, the implications of this study for policymakers, investors and corporate managers, limitations of the study and the recommendations for potential future research.

6.2 Key Findings

Based on international samples of firms participating CDP over the period of CDP2010 to CDP2015, this study provides a comprehensive understanding of carbon assurance by exploring both the determinants of carbon assurance and the impacts of carbon assurance on carbon disclosure level. The key findings of the study are discussed in detail in this section.

6.2.1 Carbon information asymmetry and carbon assurance

There is a clear trend for investors to identify and consider a firm's carbon-sensitive assets of a firm (Haigh and Shapiro 2011), and the quantity, format and venue of carbon disclosure are becoming relevant for their decision making (Hughes et al. 2001). Meanwhile, multiple regulated and unregulated reporting initiatives and frameworks abound around the world. For instance, the US Securities and Exchange Commission's Guidance for Disclosure Related to Climate Change outlines the conditions for public companies' disclosure of material information related to climate-associated risks and opportunities. More recently, it has become mandatory for listed UK companies to disclose carbon information in their annual directors' report.

This study focuses on the link between carbon assurance and carbon information asymmetry. The results of this study show that the three proxies adopted in this study capture different aspects of carbon information asymmetry. First, the quantity of emissions is associated with the complexity of the organisational structure, nature of the products and uniqueness of the manufacturing processes. Second, carbon information asymmetry is linked with the sophisticated technical carbon accounting protocols used to quantify different types of energy sources that convert energy consumption to emissions. Thus, information asymmetry increases with the type of energy consumed. Finally, carbon information asymmetry is higher in a carbon-intensive sector with regard to the complex impact of government-imposed regulations on firm operations. Using these novel proxies, the findings of the study depict the overall corporate carbon information gap and demonstrate its unexplored consequence on carbon assurance. The results show that the coefficients of these variables retain their positive signs across all test models, and further analyses yield similar findings. Thus, this study provides evidence on the sensitivity of a specific carbon initiative—carbon assurance—to different dimensions and levels of carbon information asymmetry. Further, the findings indicate the channels (such as enhanced credibility and reduced transaction costs) through which prioritising external assurance generates value. Thus, this study significantly validates and increases the applicability of information asymmetry theory within the context of climate change.

The in-depth empirical analyses determine a subtle distinction between carbon assurance and financial assurance with reference to their ability to inform stakeholders who care about firms' financial and nonfinancial performance. Drawing on information asymmetry economics (Myers and Read 2001) and based on the fact that managers tend to use private informed data to contextualise their carbon performance and camouflage their inferior carbon policy, a direct inference from this study is that carbon assurance can enhance value (by reducing transaction costs), conditional on the severity of the carbon knowledge gap among the key stakeholders of a firm (Schiemann and Sakhel 2019).

6.2.2 Carbon assurance and carbon disclosure

There is a scientific consensus that anthropogenic GHG causes global warming. Extensive studies have been devoted to carbon management, whereas carbon assurance is somewhat under-researched. The purpose of this study is to examine the link between voluntary carbon disclosure and external carbon assurance using a theoretical perspective based on stakeholder engagement. This study has several key findings. First, companies with carbon assurance have higher overall carbon disclosure scores on average in a subsequent year. Second, the effects of carbon assurance on carbon disclosure vary with the presence of carbon institutions. Finally, carbon assurance may enhance the effect of institutionalization of carbon disclosure practices. Overall, the evidence of this study demonstrates the effect of engaging a carbon assurer: Assurance adds certainty to carbon disclosures by not only boosting the confidence of users of the immediate carbon report but also enhancing the comprehensiveness and transparency of subsequent carbon disclosures. The cornerstone of the study is the stakeholder engagement theory. This theory emphasizes interaction, communication, and cooperation between management and groups of stakeholders, including assurers. As a result, firms with carbon assurance tend to have a better understanding of the expectations of stakeholders; thus, they can align their disclosures with stakeholder needs. Hence, the findings of this study enhance the validity and applicability of stakeholder engagement theory and institutional theory.

6.3 Key Contributions

This thesis focuses solely on carbon assurance to provide an overview of this new emerging assurance practice. By employing an international sample of largest companies participating in CDP questionnaire over a 6-year period, this study makes a number of contributions to the literature on environmental accounting and carbon assurance.

First, carbon assurance deserves a separate study as it is an important dimension in carbon accounting and it is distinct from traditional financial auditing. The fact that firms in this study purchased carbon assurance in addition to financial auditing implies that carbon information asymmetry is a distinct dimension of information asymmetry concerning the authenticity of carbon information. The literature suggests some significant differences between financial assurance and carbon assurance (Datt et al. 2018). Traditional financial statement auditing is performed by the accounting profession while carbon assurance operations requires specific skills, knowledge, and expertise of relevant field like engineering, energy efficiency, and environmental management and carbon assurance is governed by separate standards (IAASB 2012; Tang 2019; Datt et al. 2018; Datt et al. 2018b). Accounting professionals and environmental consulting companies provide different advantages for carbon assurance (Simnett et al. 2009a; Olson 2010; Huggins et al. 2011; Green and Zhou 2013). Accounting professionals have a greater reputational capital advantage because of their flagship financial statement auditing services (Simnett et al. 2009a; Huggins et al. 2011); however, providers from consultation firms tend to be less expensive and are generally considered to have better subject expertise (Simnett et al. 2009a; Huggins et al. 2011; O'Dwyer et al. 2011). When taking GHG assurance, GHG assurers must assess risk and uncertainty, as a firm may not have a robust system in place to collect and process energy and carbon data. Moreover, GHG assurers use different investigative methods than traditional attestation (ISAE 3410). Further, a firm may have a unique internal control mechanism compatible with the complexity of its operations and the nature of its business (IAASB 2012). In addition, misstatements might be related to the firm's organisational structure and boundaries and related parties (IAASB 2012). Therefore, methods for controlling risk and examining GHG emissions in carbon assurance are expected to differ significantly from methods used in conventional financial auditing. Therefore, carbon assurance deserves a separate study. However, research on this emerging practice still remains sparse (Datt et al. 2018b). This thesis enriches the understanding of this new type of assurance by examining carbon assurance from two perspectives—the determinants of the adoption of carbon assurance and the impacts of carbon assurance, thus contributing to the green accounting and assurance literature.

Second, this is the first study to use carbon information asymmetry theory to explain the motivation of adopting carbon assurance. Reducing carbon information asymmetry entails carbon assurance that cannot be substituted with financial auditing. I use innovative proxies, namely the quantity of emissions, type of fuels used and membership in a carbon-intensive sector, to capture different aspects of carbon information asymmetry underlying managerial incentives to adopt GHG assurance. Specifically, emission volume is associated with the complexity of the organisational structure, nature of the products and unique manufacturing processing. Moreover, carbon information asymmetry is linked with the sophisticated technical carbon accounting protocols used to quantify different types of energy sources that convert energy consumption to emissions. Therefore, the more complex the energy structure, the higher the carbon information asymmetry. Finally, carbon information asymmetry is higher in a carbon-intensive sector with regard to the complex impact of environmental regulations on firm operation. With these innovative proxies for carbon information asymmetry, the findings of this study describe the overall corporate carbon information asymmetry and provide evidence on its unexplored impacts on carbon assurance. Thus, this study provides first-hand evidence of the sensitivity of carbon assurance to different dimensions and levels of carbon information asymmetry. Further, the findings unfold the channels (such as enhanced credibility and reduced transaction costs) through which adopting third party assurance creates value. Thus, this study contributes to the information asymmetry literature by proposing a new type of information asymmetry—carbon information asymmetry.

Third, this study significantly validates and increases the applicability of information asymmetry theory in a nonfinancial setting by providing evidence that indicates the reactions of firms to global warming. Based on the fact that managers tend to use private informed data to contextualise their carbon performance and camouflage their inferior carbon policy, this study provides inferences that carbon assurance can enhance value (by reducing transaction costs), conditional on the severity of the carbon knowledge gap among the key stakeholders of a firm (Schiemann and Sakhel 2019).

Fourth, this study is the first to provide empirical evidence of the effectiveness of carbon assurance in enhancing carbon disclosure from stakeholder engagement aspects. Prior studies on carbon assurance have mainly focused on the incentives for voluntary adoption of carbon assurance, choice of assurance provider, the role of internal auditors in GHG reporting, the expertise required for GHG assurance, the development of an international standard for GHG assurance. However, while carbon assurance is expected to impact users' perceptions, there is limited knowledge on the effect of carbon assurance on disclosure. This study documents that firms with carbon assurance tend to have a better understanding of the expectations of stakeholders; thus, they can align their disclosures with stakeholder needs. Specifically, assurers who adopt a stakeholder inclusivity approach understand better the needs of external stakeholders for carbon-related information. Thus, such assurance engagement involves greater interaction with external stakeholders, therefore ensuring that social and environmental reporting is responsive, complete and satisfies stakeholders' need for information (Edgley et al. 2010; Thomson and Bebbington 2005; Owen et al. 2000). In another word, assurer can help managers select appropriate information and determine the scope and depth of this disclosure, thus, the underlying GHG report can be made more relevant and comprehensive. In addition, assurance providers could help strengthen a client's internal system (Baker and Owsen 2002; Elliott 1994) by identifying deficiencies and detecting risks of existing reporting system and providing recommendations on improving a company's environmental management systems and enhancing the design of internal control systems (Deegan et al. 2006; Moroney et al. 2012).

Fifth, this study enhances the understanding of the role of the institutional context in carbon disclosure and assurance. There is no research on how these industrial and national factors moderate the link between carbon assurance and carbon disclosure. Last, Edgley et al. (2010) show the importance of stakeholder engagement in environmental assurance. The findings reinforce the validity and appropriateness of this concept in the carbon assurance practice. The evidence should assist assurance practitioners, regulators, and users of carbon reports in obtaining a better knowledge of this indispensable practice in today's low-carbon economy.

Sixth, as the current literature does not completely explain the impacts of carbon assurance on carbon disclosure, this research uses an innovative proxy for carbon disclosure and compares it between firms with and without assurance to show a quantified dynamic effect of carbon assurance on disclosure. Moreover, this study decomposes the relative roles and disentangle the effect of carbon assurance on the immediate versus lagged carbon disclosure. Assurance is costly, so recognition of the effect should help firms to maximize the benefit of carbon assurance. Further, with additional robust tests that provide inferentially identical findings to the main results, this study documents persuasive circumstantial evidence that substantiates and vindicates the accuracy of this model and corroborates stakeholder engagement theory. Spatial heterogeneity is found in the relationship between carbon disclosure and assurance, which indicates an asymmetric effect of carbon assurance on disclosure in different institutional contexts.

Finally, instead of using data from financial statements or CSR reports (Kolk 2003; Ballou et al. 2006), I utilise data from the CDP. The CDP database encompasses the most complete and consistent information in comparison to alternative sources (Luo et al. 2012). In contrast to sustainability or CSR reports, which are subject entirely to managers' discretion, CDP employs a single set of guidelines that all participants are required to comply with, which ensures comparable responses between firms and minimises manipulation of the carbon data. The CDP is the source of data for many previous studies (Kolk et al. 2008; Stanny and Ely 2008; Reid and Toffel 2009; Stanny 2013; Matsumura et al. 2014). CDP collects carbon information from the largest listed companies around the world. Participation in the survey is voluntary, and companies' responses are published by the CDP on its website.

6.4 Potential Implications and Recommendations

The practice of carbon assurance is still in its early stage and remains imperfect. Thus, the results are useful for regulators and accounting practitioners to take actions to improve their practice. Currently available guidelines for carbon assurance originate from very different professional imperatives (IAASB 2012). Assurers adopt different investigative procedures, ethical standards and independence requirements, some of which are proprietary (Deegan and Blomquist 2006). The diversity of methodologies, strategies and practitioners increases the complexity of assurance (Scalet and Kelly 2010; Waddock 2008; Simnett et al. 2009a). Thus, a set of legally enforceable principles or norms should be implemented to regulate this emerging market and practice. The fact that these firms purchased GHG assurance in addition to assurance of financial statements implies that carbon information asymmetry is a distinct dimension of information asymmetry concerning the authenticity of carbon information. For this reason, governmental and professional bodies need to consider whether carbon assurance should be made compulsory.

This study has practical implications. A general consensus is formed that the myriad challenges of the Paris Agreement put pressure on firms to undertake measures to enhance energy and carbon productivity. Firms face risks and opportunities in meeting stringent carbon mitigation targets and use negative emissions technologies, adopt fossil fuel divestment strategies and decarbonize their business operations. Thus, carbon management becomes an utmost priority in corporate sustainability strategy development. This study aims to enrich understanding of the dynamics related to firm carbon management, disclosure and assurance. Despite this, the effects of carbon assurance have been virtually unexplored in the academic literature, knowledge of the dynamic effects is still very limited. Thus, there are enormous opportunities for further research for the emerging practice. For instance, disclosure is only one aspect of the overall corporate carbon management system (Tang and Luo 2014). Future studies may consider how carbon assurance can help firms strengthen their carbon management capability as a whole. Moreover, since carbon assurance and disclosure vary across institutions, future studies could examine the issue under other contexts, such as various corporate governance, economic, or financial systems. In addition, prior literature finds an association between cultural factors and sustainability assurance (Martínez-Ferrero and García-Sánchez 2017); thus, the effect of culture on carbon assurance is an interesting topic. Finally, few studies have examined how carbon assurance is practised, so the knowledge of the differences in methodology, expertise, and approach between financial audits and carbon audits is scant. Thus, researchers could investigate carbon assurance using a case study methodology to offer further insights into this emerging practice.

6.5 Limitations and Future Research Opportunities

I acknowledge that this study has several limitations. First, I only consider large listed firms in the research design, thus it is wise to exercise caution when applying the results to small or unlisted firms. Second, the sample of this research is only inclusive of firms that participate in the CDP, other ways that firms may choose to disclose their GHG information (e.g., sustainability statements) are not considered. Third, caution should be taken when generalising the results to firms that do not participate in the CDP survey. Fourth, there might be potential missing variables in the regression models which might impact the decision of adoption of carbon assurance. Finally, as alluded to earlier, although there are concerns about the assurance methodology used, this research does not examine how the assurance is conducted by different assurance providers (e.g., accounting firms or consultant firms). I leave this to future studies.

To extend this study, future researchers may explore the causal effects of information asymmetry on assurance in different contexts. The unregulated carbon assurance market is still in its infancy, but it is quickly evolving into a sophisticated, specialised and competitive market (Green and Li 2011). However, little is known about how practitioners implement GHG assurance standards in practice and what are the determinants and impacts of different types of carbon assurance providers, which is worth studying in the future. Another interesting topic related to this research may be exploring the interrelationships between information asymmetry and firm voluntary carbon disclosure, and how relationship may affect the management decision on carbon assurance. In addition, it is important to explore how carbon assurance can help firms improve carbon reduction performance, carbon management systems and corporate carbon governance. Moreover, the relationship between firm value and carbon performance, including carbon reduction and assurance, is a promising area of investigation. Finally, accounting students need to be equipped with adequate knowledge of how to implement new accounting and assurance standards for GHG statements. Thus, it is necessary for university accounting faculties to develop teaching materials for future generations of accountants who aspire to practice in a GHG-restricted planet.

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