The Determinants of Climate Risk Disclosure in Malaysian Banking Sector: A Conceptual Framework

Cheah Chee Keong[1], Wong Kok Yaw[2] Nakesvari A/P Shanmugam[3], Tan Kock Lim[4], Ong Hock Siong[5], Kong Yin Mei[6], Devagi Erusan[7] , and Adam Arif Lee Aik Keang[8]

[1] Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Malaysia,
cckeong@utar.edu.my
[2] Faculty of Accountancy, Finance & Business, Tunku Abdul Rahman University of Management and Technology, Malaysia,
[3] Faculty of Accountancy, Finance & Business, Tunku Abdul Rahman University of Management and Technology, Malaysia,
[4] School of Business, UOW Malaysia KDU Penang University College, Malaysia,
[5] Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Malaysia,
[6] Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Malaysia,
[7] Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Malaysia,
[8] Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Malaysia,

Abstract. Climate change poses substantial physical and transitional risks to Malaysian banks through impacts on their customers and loan portfolios. Despite BNM guidance encouraging climate risk management and disclosure, reporting remains limited. This study develops a conceptual framework grounded in stakeholder theory to examine determinants of voluntary climate risk disclosure using mixed methods. The framework proposes bank governance and bank specific characteristic shape transparency through pressures from stakeholders demanding fuller reporting. Specifically, board oversight, gender diversity, bank capital, profitability and size are hypothesized to influence disclosure. Machine learning text analysis will quantify reporting disclosure before panel regressions test relationships with hypothesized determinants. This localized study addresses a gap on climate risk disclosure practices in Malaysia's emerging economy context. Findings can guide policy and industry initiatives aimed at improving transparency and resilience of the banking sector to climate change. Enhanced disclosure better equips stakeholders to assess bank exposures and risk management strategies.

Keyword: Climate risk disclosure, Malaysia Bank, Bank governance, Machine learning, Text Mining.

1   Introduction

Climate change poses substantial physical and transitional risks to Malaysian banks through impacts on their customers and loan portfolios. Physical risks arise from increasing extreme weather events while transitional risks stem from policy, technology, and market changes during the shift to a low-carbon economy [1-4]. These climate-related risks can undermine asset values and lead to credit losses, especially in climate-vulnerable sectors like agriculture, energy, and real estate [3-4,5]. Despite these risks, research shows disclosure of climate-related risks in the Malaysian finan-

cial sector remains limited compared to developed countries [4,6]. Meaningful and comparable climate risk disclosures are critical for accurate risk assessments and financial stability in Malaysia's bank-centric financial system. However, insufficient disclosure reduces transparency for stakeholders and may lead to improper risk pricing and financial instability [7-9].

Central bank stress tests reveal Malaysian banks face significant climate transition and physical risks, underscoring the urgency of enhancing climate risk disclosure and management [10]. The Bank Negara Malaysia (BNM) advocates adoption of the Task Force on Climate-related Financial Disclosures (TCFD) framework to improve climate transparency. However, Malaysian bank disclosure remains below TCFD recommendations [3-4]. This lack of adequate and consistent climate risk disclosure inhibits proper pricing of climate risks that could destabilize the financial system. Banks play an increasingly vital role in mitigating climate change risks given their intermediary position in capital allocation [1-2,9,11]. As major lenders, banks in Malaysia and elsewhere have the capacity to influence sustainable practices [12-13]. Central to this effort is the disclosure of climate-related risks, a key aspect of corporate transparency that enables stakeholders to make informed decisions [14-15].

This paper examines the determinants of bank climate risk disclosure in Malaysia. Prior studies have focused on developed economies, with minimal research on emerging markets with different regulatory and cultural contexts [7,16-19]. Understanding the drivers of disclosure in Malaysia can inform policies to improve transparency and oversight. As climate change accelerates globally, financial institutions play an increasingly vital role in mitigating environmental risks [1-2,9,11,20]. Banks in particular have the capacity to influence and contribute to sustainable practices [12-13]. Central to this effort is the disclosure of climate-related risks, a key aspect of corporate transparency that enables stakeholders to make informed decisions [14-15]. However, despite growing climate change awareness, research on the specific factors influencing bank climate risk disclosure in Malaysia remains limited. This study addresses this significant gap by exploring the determinants of bank climate risk disclosure in Malaysia. However, despite growing climate change awareness, research on the specific factors influencing bank climate risk disclosure in Malaysia remains limited. This study addresses this significant gap by exploring the determinants of bank climate risk disclosure in Malaysia.

2   Literature Review

Climate change and its associated risks have gained significant attention from various stakeholders, including financial institutions, governments, and investors [6,16,18-19]. In the context of Malaysia, where climate-related challenges are becoming increasingly apparent, understanding the determinants of bank climate risk disclosure is crucial for sustainable economic development and risk mitigation [6,13]. Research on climate risk disclosure has rapidly expanded in scope and attention over the past two decades. While early studies centered on corporate environmental reporting in non-banking sector [16,21], the spotlight has shifted to examining financial institution dis-

closure specifically, an evolution catalyzed by the landmark of TCFD recommendations [3-4,12-13].

The theoretical terrain guiding scholarly work in this domain encompasses stakeholder perspectives [14-15,22]. Stakeholder theory analyzes pressures exerted on banks by shareholders, activists, and clients demanding greater transparency. Related literature has examined how stakeholder pressures influence the level and quality of sustainability disclosures by banks [13-15,23-24]. Banks and other financial institutions make many disclosures through annual reports, financial statements, press releases, and other published materials [23]. These disclosures contain important information about a bank's financial health, risk exposures, business strategies, and more [13,25-27]. However, the volume of disclosures makes it difficult for investors, regulators, and researchers to efficiently analyze this information [28-30]. Content analysis and text mining techniques have emerged as useful methods for examining bank disclosures and extracting meaningful insights [29-30]. Moreover, the content analysis and text mining can help quantify bank climate disclosures and assess how they align with rising stakeholder demands [29,31]. These methods provide empirical evidence to advance stakeholder-grounded research on bank transparency.

Recently, there has been growing interest in studying bank disclosures around climate-related risks and strategies [11-12,20,32-33]. The evolution of this literature reveals an expanded scope moving beyond purely firm-level analysis to the banking sector specifically, while also extending geographical coverage [12,16,18,26,33]. Recent work displays a refined emphasis on elucidating the needs and incentives of disclosure producers and users. However, integrated understanding of disclosure drivers, quality, and impacts remains limited, particularly for developing country banking contexts like Malaysia [6]. Focused efforts to address this knowledge gap through localized mixed methods research could provide guidance for enhancing climate risk disclosure and transparency across the financial system [4]. Therefore, there is essential to explore the conceptual framework of a research paper that investigates the determinants of bank climate risk disclosure in Malaysia.

2.1   Board Size

The composition and characteristics of a bank's board of directors can influence its climate risk disclosure practices. As part of their oversight role, boards are responsible for ensuring appropriate risk management policies are in place, including those related to climate risks [18]. This suggests that boards with greater capacity will be better positioned to understand the importance of climate risk disclosure and ensure high quality reporting [18]. One structural factor that contributes to board capacity is board size, defined as the total number of directors. Several studies have found that larger boards are associated with more extensive climate risk disclosures by banks.

Larger boards contribute to more extensive climate risk disclosure through several interrelated mechanisms. Specifically, more directors provide broader expertise, as a wider range of specialized skills (including sustainability and climate change experience) can inform oversight of disclosures [27,34-35]. Bigger boards also enhance monitoring of bank management to ensure adequate climate risk assessment and reporting. The greater manpower of larger boards increases capacity to engage with stakeholder demands for transparency and devote attention to disclosure issues

[17,35]. Finally, board independence improves with size as no single director or small coalition can dominate decision-making, enabling independent boards to better represent stakeholder information needs [17,35]. Together, these expertise, monitoring, manpower, and independence benefits allow larger boards to facilitate more comprehensive climate risk reporting [36]. The hypothesis for this proposed study is as follows:

H1: There is an association between board size and improved bank climate risk disclosure.

2.2   Board Independent

The independent board ratio, defined as the proportion of independent directors on a bank's board, is positively associated with more extensive climate risk disclosure [17,36]. Independent directors enhance disclosure practices for several reasons. First, they are more likely to critically monitor and challenge management to ensure adequate risk assessment and transparency [35,37]. Executive directors may feel less inclined to scrutinize managerial decisions. Second, independent directors bring greater objectivity and reduce conflicts of interest that could inhibit disclosure, since executive pay is often tied to short-term financials. Finally, independent directors are better positioned to represent wider stakeholder demands for climate reporting in an unbiased manner [37].

   Empirically, studies find banks with a higher independent director ratio provide higher quality climate disclosures aligned with leading frameworks [17-18]. The independent perspective facilitates greater transparency. However, there are limits to independence. Boards overly dominated by outsiders may lack sufficient firm and industry expertise to appropriately evaluate climate risks, pointing to a need for an optimal independent ratio [17,35,37]. Additionally, simply having more independent directors may not suffice if their climate-related proficiencies and engagement are lacking [18,37]. In summary, independence generally enhances climate disclosure through improved monitoring, objectivity and stakeholder orientation, but extreme independence without relevant skills can be counterproductive. The hypothesis being put forth in this proposed research is:

H2: Independent director correlates with enhanced bank climate risk disclosure.

2.3   Board Gender Diversity

Having more women directors on bank boards has been shown to positively impact the quality and extent of climate risk disclosures [17]. One reason is that women directors often exhibit greater sustainability orientation and give higher priority to ESG issues like climate change compared to male directors [6,17,19]. Women's concern for environmental sustainability prompts demand within boards for greater transparency around climate risks and strategies [6,17]. Additionally, female directors enhance diversity of perspectives, experiences, and values on boards. This diversity expands boards' collective awareness of and responsiveness to a wide range of stakeholder needs, including for fulsome climate-related disclosures [17,19]. The varied view-

points brought by gender diverse boards lead to recognition of climate disclosure as an ethical imperative aligned with principles of transparency and accountability.

Furthermore, research finds that banks with higher female board representation provide more extensive and higher quality disclosures related to climate change risks and strategies. These empirical findings suggest women directors' sustainability focus, support for stakeholder orientation, and ethical values have tangible impacts on strengthening banks' climate risk reporting [6,19]. Through both bottom-up pressure and top-down oversight, the presence of women board members appears to drive positive changes in climate disclosure practices. Our hypothesized relationship for this proposed study is:

H3: Female director has a positive relationship with bank climate risk disclosure.

2.4   Bank Capital

Bank capital refers to the equity capital and retained earnings available to cover potential losses and risks [12,23]. Banks with higher capital levels tend to have greater capacity to assess and disclose climate-related risks in their lending portfolios and operations. Empirically, studies find a positive relationship between bank capital and climate risk disclosure [12]. Well-capitalized banks are better positioned to dedicate resources to analyzing complex climate risks and integrating them into public reporting frameworks, whereas undercapitalized banks may lack the financial capacity to develop robust climate risk management processes [38]. Furthermore, banks with higher capital levels tend to adopt a long-term outlook and have a stronger incentive to address climate risks that may materialize over longer horizons. Disclosure is a tool for demonstrating climate risk management and resilience for these forward-looking banks [38].

In a nutshell, bank capital provides crucial resources and incentives for more extensive disclosure of climate-related financial risks. Higher capital gives banks a buffer against potential valuation losses from undisclosed climate vulnerabilities, making them less reluctant to reveal climate risks. As financial regulators encourage climate risk management, well-capitalized banks are better equipped to respond through enhanced public reporting aligned with established frameworks [38]. Bank capital enables banks to dedicate efforts towards analyzing and disclosing complex, long-term climate risks. The hypothesis we aim to test is:

H4: Increased bank capital is connected with higher bank climate risk disclosure.

2.5   Bank Profitability

A number of studies have found evidence for a positive relationship between bank profitability and the extent of climate risk disclosure. Specifically, banks with higher profitability, as measured by return on assets, return on equity, or net interest income, tend to provide more extensive and higher quality disclosures related to climate change risks and strategies [12,38]. One explanation for this relationship is that profitable banks have greater financial and organizational resources to devote to climate risk analysis and reporting. More profitable banks can more easily bear the costs of developing climate risk models, scenario analyses, and disclosure frameworks aligned

with TCFD or other guideline [12,32]. Additionally, higher profit levels indicate successful management, which allows bank executives to focus attention on long-term issues like climate change that pose risks across different time horizons [8].

Furthermore, profitable banks face greater pressure from stakeholders such as shareholders, regulators, and financial markets to provide transparency into climate risks and opportunities. Banks with comfortable profit margins have less justification for resisting calls for more detailed climate disclosures from investors and regulators concerned about the financial stability implications [8,39]. Profitable banks also have reputational incentives to demonstrate social and environmental responsibility through sustainability reporting, whereas unprofitable banks may resist perceived costly disclosures [5,39]. In summary, theoretical perspectives and empirical findings concur that more profitable banks are better equipped and motivated to provide high quality, thorough disclosures related to climate change risks, strategies, and governance. This suggests financial performance facilitates climate risk transparency in the banking sector. The hypothesis of this proposed study is:

H5: There is a positive correlation between bank profitability and bank climate risk disclosure.

2.6   Bank Size

Most empirical studies find that larger banks provide more extensive climate risk disclosures [12,16]. Bank size is measured by total assets, market capitalization, or revenue [23]. There are several reasons for this positive association between size and climate disclosure. Larger banks have more resources and capabilities to devote to climate risk assessment, data analysis, and integration into reporting processes, whereas smaller banks may lack technical expertise [7,26,32-33]. Big banks also tend to have more diversified business activities and lending portfolios across geographies and sectors, exposing them to a wider range of climate risks to evaluate and disclose [7].

Furthermore, large banks face greater scrutiny from regulators, investors, and other stakeholders who are demanding increased climate transparency. This pressure motivates large banks to improve disclosure. Size also proxies for reputation—large banks have more reputational risk from insufficient climate reporting, providing incentives to disclose more [23,34]. Empirically, studies consistently demonstrate larger banks disclose more climate indicators, provide more forward-looking climate risk assessments, and better align with TCFD recommendations [12,16,18-19]. In summary, larger banks possess more resources and confront stronger public pressures, enabling more systematic and detailed disclosure of climate-related financial risks. Bank size appears to be a robust, positive determinant of the extent and quality of climate risk reporting. The hypothesis we will be testing in this proposed study is:

H6: Bank size is linked to more favorable bank climate risk disclosure.

In summary, this study posits six main hypotheses regarding the relationships between the independent and dependent variables. Board structure and composition shape the oversight and inclinations of the board, which ultimately influences the ex-

tent and quality of climate risk disclosure. Banks with larger, more independent, gender diverse and climate savvy boards are more likely to provide fulsome climate risk reporting aligned with leading disclosure frameworks. In terms of bank-specific characteristics, larger profitability banks and those with greater financial capacity, as measured by capital adequacy, exhibit higher disclosure motivation. This indicates that banks with more resources are better equipped to assess climate risks and integrate them into reporting processes.

2.7   Conceptual Framework

This study develops a conceptual framework grounded in stakeholder theory to examine how bank-level factors influence climate risk disclosure. At the core, stakeholder theory analyzes how the needs and demands of stakeholders shape organizational practices [14,22]. Banks have a diverse range of stakeholders, including shareholders, regulators, activists, and clients, who increasingly pressure for transparent climate risk reporting. Drawing on stakeholder theory, this study proposes that bank-level governance and resource variables impact responsiveness to demands for climate disclosure. Specifically, board size, board independence, female board representation, bank capital, bank size, and profitability are expected to positively influence climate risk reporting. Larger, more independent, and gender-diverse bank boards are theorized to be more attuned to stakeholder groups and exercise greater oversight of climate transparency [12,18,24,35]. Meanwhile, well-resourced banks with greater capital, size, and profitability are expected to have stronger capabilities to respond to stakeholder pressures for fulsome climate disclosures [12,16-17,19,31]. Testing these bank-level determinants within a stakeholder theory framework can shed light on how banks address demands for climate risk transparency.
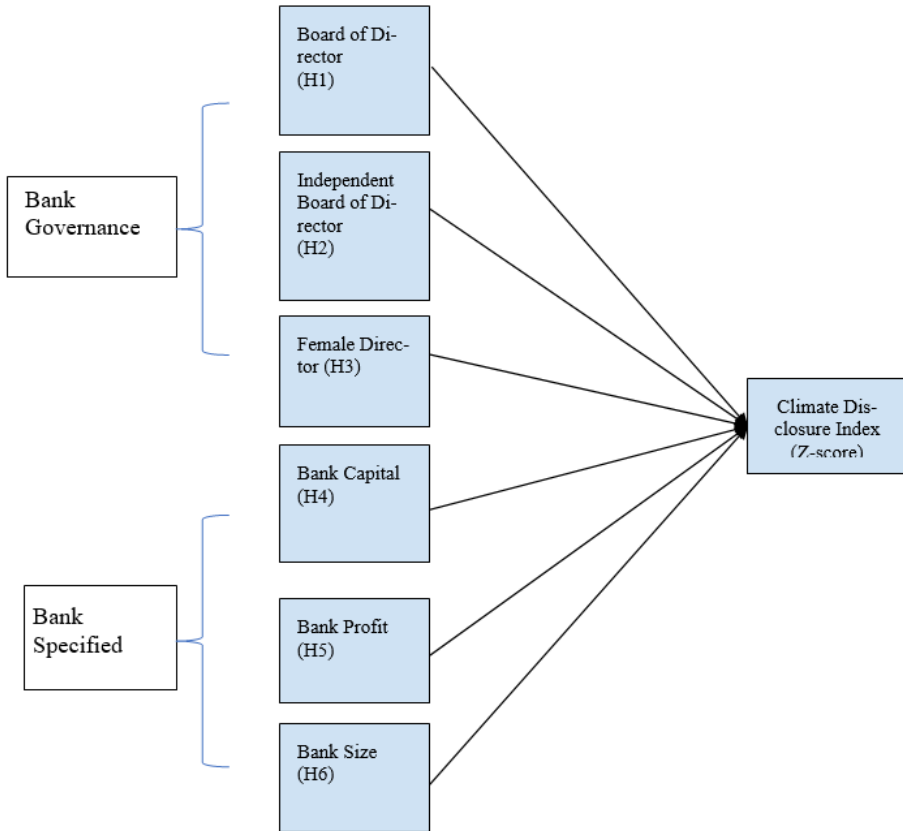
Fig 1. Research Conceptual Framework

3   Research Methodology

This study utilizes a two-step machine learning approach to measure the quality of bank climate risk disclosure by quantifying the thematic content in annual reports. In the first step, we use a neural language model called ClimateBert that has been pre-trained on a large corpus of climate-related texts to accurately extract paragraphs specifically discussing climate risks, opportunities, and strategies from bank annual reports [28,40]. A key strength of ClimateBert is its ability to semantically parse texts and identify climate-relevant disclosures even when they do not contain obvious keywords [28]. This allows more comprehensive extraction of subtle climate discussions compared to keyword searches. However, a limitation is that ClimateBert may overlook highly technical or implicit climate discussions.

After extracting the climate-related disclosures, the second step applies Structural Topic Modeling (STM) to inductively identify latent topics and themes within the disclosures based on word co-occurrence patterns [28]. STM is an unsupervised machine

learning technique that can efficiently analyze large bodies of text to uncover mean-ingful topics [41]. By quantifying the presence of critical climate disclosure themes for each bank, the STM output provides a multi-dimensional measure of disclosure quality [28,41].

A major advantage of STM is its unsupervised learning capability to efficiently ana-lyze large bodies of text and uncover hidden thematic structure without human input. However, a drawback is that the generated topics still require human interpretation which can introduce subjectivity [28,40]. By quantifying the presence of critical cli-mate disclosure themes for each bank, the STM output provides a multi-dimensional measure of disclosure quality [28,41]. The combined use of ClimateBert and STM aims to leverage their complementary strengths in identifying both explicit and latent climate disclosure themes. Nonetheless, future research could explore integrating oth-er techniques like sentiment analysis to develop even more robust automated disclo-sure quality measures.

This machine learning-derived disclosure quality metric is then used as the depend-ent variable in a panel regression analysis to test determinants. Specifically, we esti-mate static panel models with bank and year fixed effects, clustering standard errors at the bank level. Key independent variables measuring bank-level governance (board size, independence, gender diversity) and bank specifics (capital, profitability, size) are drawn from annual reports.

This study utilizes a panel data set of publicly traded commercial banks operating in Malaysia over the period 2010-2022. The data source from annual reports which are used to gather the climate risk disclosures for machine learning content analysis as well as bank-level financial and governance data for the regression models. Banks are sampled using a stratified random sampling technique to ensure representative cover-age of small, medium, and large banks in the market. The panel spans 2010-2022, providing an extensive time dimension of the panel allows for analysis of climate dis-closure trends over time [42]. The panel is strongly balanced with no missing observa-tions. The baseline panel regression model specification is as follows:

$$\text{Disclosure}_{it} = \alpha + \beta 1 \text{Bod}_{it} + \beta 2 Ln\text{INDP}_{it} + \beta 3 \text{Female}_{it} + \beta 4 \text{CAR}_{it} + \beta 5 \text{ROA}_{it} + \beta 6 \text{Size}_{it} + f_i + \varepsilon_{it}$$

Where,

α=intercept

Disclosure= Machine Learning-derived Climate Disclosure Score

LnBoD= Natural Log of Bank Board of Director

INDP=Bank Independent Director Ratio

Female=Bank Female Directors Percentage

CAR=Bank Capital

ROA=Bank Return on Asset

Size=Bank Size

f_i=Bank fixed effect,

ε_i =error term.

   The model is estimated using pooled OLS, fixed effects (FE), and random effects (RE) specifications with standard errors clustered at the bank-level to address autocorrelation and heteroskedasticity concerns [42-43]. Hausman specification tests help select between fixed and random effects models. In addition, Breusch-Pagan Lagrange multiplier tests assess whether pooled OLS or random effects panel regression is most appropriate for the data structure. Moreover, F-test on the joint significance of the fixed effects in which a significant p-value indicates fixed effects are appropriate and preferred over pooled OLS [43].
   Panel regression is well-suited for this study as it controls for unobserved heterogeneity in climate reporting practices across banks using bank fixed effects [42]. The panel structure with multiple years per bank also provides more informative data compared to pure cross-sectional analysis. Panel models help address omitted variable bias and endogeneity issues that may arise in studying disclosure determinants [42-43].
   Robustness checks include alternative panel estimators like dynamic GMM models and models addressing endogeneity concerns through instrumental variables or lagged predictors [42-43]. The integrated machine learning text analysis and panel regression modeling provides a rigorous test of how bank-level factors put forth by stakeholder theory shape climate risk disclosure.

4   Conclusion

This study develops a conceptual framework grounded in stakeholder theory to examine determinants of bank climate risk disclosure in Malaysia. The framework proposes that disclosure is influenced by bank-level governance and bank-specifics pressures. Specifically, board size, independence, gender diversity, bank capital, size, and profitability are hypothesized to impact climate reporting. The methodology uses machine learning text analysis of annual reports to quantify disclosure quality. This measure is then modeled using panel regression with bank and year fixed effects to test relationships with bank-level factors. The integrated machine learning and econometric approach provides rigor in evaluating how stakeholder-relevant governance and financial variables shape climate transparency.
   Key expected findings are that disclosure is positively associated with board size, independence and female representation due to oversight and resources. Moreover, capital, profitability and bank size may also exhibit positive relationships as banks fear compliance risks and relevant costs from non-disclosure. By identifying disclosure drivers, results can inform regulatory and industry efforts to improve climate risk management through enhanced transparency. This research addresses a gap on climate reporting determinants in emerging economies like Malaysia. It advances stakeholder perspectives on how bank governance and characteristics influence risk disclo-

sure. The study also demonstrates innovative machine learning text analysis methods for disclosure research. Further opportunities exist to examine the impacts of improved climate transparency on financial stability and environmental performance.

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