

**Corporate Financial Decisions under Climate related
Regulatory and Litigation Risk**



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Declaration of authenticity

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Dedication

I dedicate this thesis to my grandfather and grandmother, whose inspiration will always be with me and have given me the perseverance to achieve more throughout my career. Additionally, my father, Ajay Kumar Singh, and my brother, Dr Ashish Kumar, whose support and encouragement have been my guiding light throughout. This recognisable accomplishment is as much yours as it is mine.

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Sincerely,
Anand Kumar

Research Presentation

This thesis leads in the development of three interconnected papers, which have been presented at various international conferences and seminars. Below is the list of all the presentations.

1. Climate Change Laws and Policies and Corporate Debt Maturity Decisions has been presented at the *DCU Doctoral Colloquium*, Dublin in 2023.
2. Climate Change Laws and Policies and Corporate Debt Maturity Decisions has been presented at the *Mahidol University* seminar, Thailand in 2024.
3. Climate Change Laws and Policies and Corporate Debt Maturity Decisions has been presented at the *BAFA SWAG* Online Conference in 2024.
4. Climate Change Laws and Policies and Corporate Debt Maturity Decisions has been presented at the *Irish Academy of Finance Conference*, Dublin, Ireland in 2024.
5. From Pledges to Actions: Decoding Global Climate Laws has been submitted to the *DCU paper development workshop* at DCU Business School, Dublin in 2024.
6. Climate Litigation Risk and Corporate Cash Holdings has been submitted to the *DCU paper development workshop* at DCU Business School, Dublin in 2025.
7. Climate Change Laws and Policies and Corporate Debt Maturity Decisions has been presented at the *University of Warsaw*, GETM4 research secondment, Poland in 2025.
8. Climate Litigation Risk and Corporate Cash Holdings has been presented at the *University of Warsaw*, GETM4 research secondment, Poland in 2025.

The Chapters 2 of the thesis is in the second review stage of the Revise and Resubmit work in The British Accounting Review journal.

The Chapters 3, and 4 are currently being prepared for submission to ABS3-ranked finance journals.

List of Abbreviations

CBAM: Carbon Border Adjustment Mechanism

CCLW: Climate Change Laws of the World

CLP: Climate Laws and Policies

CLI: Climate Law Index

D&E: Developing and Emerging Economies

DRM: Disaster risk management

EU: European Union

FE: Fixed Effect

GHG: Greenhouse Gas Emissions

IV: Instrumental Variable

LDA: Latent Dirichlet Allocation

ML: Machine Learning

NAP: National Adaptation Plans

OLS: Ordinary Least Squares

ROT: Real Option Theory

SDG: Sustainable Development Goals

SSA: Sub-Saharan Africa

Sys-GMM: System Generalized Method of Moments

UNFCCC: United Nations Framework Convention on Climate Change

VIF: Variance Inflation Factor

List of Tables

Table 2.1 Percent of climate law and policies distribution by country	27
Table 2.4 The list of topics and associated keywords within each topic	39
Table 2.5 The list of defined topics in three distinct economies and associated keywords within each topic	51
Table 2.6 Difference in climate laws and polices themes in three distinct economies ...	64
Table 2.7 The list of defined topics on climate conventions and associated keywords within each topic	69
Table 3.1 Variable definitions.....	105
Table 3.2 Industry distribution.....	107
Table 3.3 Descriptive statistics	109
Table 3.4 Pairwise panel correlation.....	111
Table 3.5 Variance inflation factor (VIF).....	112
Table 3.6 Baseline: CLI and debt maturity relationship	116
Table 3.7 The Impact of CLI on debt maturity relationship	119
Table 3.8 Sectoral characteristics of CLI and debt maturity relationship	123
Table 3.9 Robustness: Sub-sample analysis	125
Table 3.10 Robustness: Alternative definition.....	127
Table 3.11 Robustness: Additional control variables	128
Table 3.12 Legal Origin: CLI and corporate debt maturity relationship	131
Table 3.13 National Governance: CLI and debt maturity relationship	134
Table 3.14 Non-linear: CLI and debt maturity relationship	137
Table 3.15 Financial constraints and CLI debt maturity relationship	139
Table 3.16 Macroeconomic shocks and CLI debt maturity across no-overlapping crisis and stable period	142
Table 3.17 Instrumental variable analysis.....	145
Table 4.1 Sample distribution	167
Table 4.2 Variable definitions.....	170
Table 4.3 Pairwise correlation matrix	175
Table 4.4 Variance inflation factor (VIF).....	176
Table 4.5 Full sample summary statistics	178
Table 4.6 Baseline: Different fixed effect model.....	180
Table 4.7 Persistence effect of climate litigation	184

List of Figures

Figure 2.1 Distribution of worldwide climate laws and policies by category	29
Figure 2.3 Steps involved in data preprocessing	33
Figure 2.2 Optimal topic graph	37
Figure 2.4 Top 5 sectors of climate laws and policies focus areas	41
Figure 2.5 SSA countries climate laws and policies top 10 sectoral focus	52
Figure 2.6 Developing and emerging countries climate laws and policies top 10 sectoral focus.....	56
Figure 2.7 Advanced countries climate laws and policies sectoral focus.....	59
Figure 2.8 Three major international climate agreements timeframe	69
Figure 2.9 Count of climate laws & policies post-Earth summit.....	71
Figure 2.10 Count of climate laws & policies post-Kyoto protocol.....	73
Figure 2.11 Count of climate laws & policies post-Paris agreement.....	76

Table of Contents

Declaration of authenticity	i
Reporting of Gen AI Tool Use in Research Theses.....	ii
Dedication	iii
Acknowledgement	iv
Research Presentation	vi
List of Abbreviations	vii
List of Tables	viii
List of Figures.....	ix
Thesis Abstract	xiv
Chapter 1	1
1.1 Introduction.....	1
1.2 The research questions, methodology and findings.....	5
1.3 Thesis contributions	11
1.4 Thesis structure	17
Chapter 2	19
2.1 Introduction.....	20
2.2 Data source.....	27
2.3. Data Pre-processing	31
2.4. Methodology.....	33
2.5. Result	39
2.5.1 Key focus areas of climate laws and policies	39
2.5.1.1 Energy Efficiency and Power Generation.....	40
2.5.1.2 Climate Change Adaptation Policies and Disaster Management Plans	44
2.5.1.3 Reducing Emissions and Carbon Footprint	47
2.5.2. Climate laws and policies across different economies: Comparative Analysis.....	49
2.5.2.1 Sub-Saharan Africa (SSA)	51
2.5.2.2 Developing and Emerging Economies (D&E)	55
2.5.2.3 Advanced Economies.....	59
2.5.3 Climate Pledges and Evolution of Climate Law and Policies	67
2.5.3.1 Post Earth Summit	70

2.5.3.2 Post Kyoto Protocol	72
2.5.3.3 Post Paris Agreement	75
2.6 Conclusion	77
Chapter 3	83
3.1 Introduction.....	84
3.2 Literature review & hypothesis.....	93
3.2.1 CLP and its effect on firm.....	93
3.2.2 CLP and financial choice	94
3.2.3 CLP and corporate debt maturity	96
3.3 Data.....	100
3.4 Empirical Strategy: Climate law and debt maturity structure.....	102
3.4.1 Dependent variable	102
3.4.2 Independent variable	103
3.4.3 Control variables	103
3.5 Empirical Results	106
3.5.1 Descriptive statistics	106
3.5.2 Baseline results	112
3.5.3 Additional insights: Impact of CLI on Total debt and Short-term debt	117
3.5.4 Sectoral characteristics of CLP and corporate debt maturity relationships	120
3.6 Robustness Checks.....	124
3.6.1. Sub-sample analysis	124
3.6.2. Alternative measure of debt maturity.....	126
3.6.3. Additional control variables.....	127
3.7 Additional analysis.....	129
3.7.1 Legal origin analysis	129
3.7.2 National Governance.....	132
3.7.3 Examining the non-linear relationship of CLI.....	135
3.7.4 Examining the financially constrained firms	138

3.7.5 Analysis for the Covid-19 and Global financial crisis (GFC) period	140
3.8 Endogeneity test.....	143
3.8.1 Instrumental Variable.....	143
3.9 Conclusion	146
Chapter 4	148
4.1 Introduction.....	149
4.2 Literature Review.....	156
4.2.1 Litigation Risk and precautionary cash holdings.....	160
4.3 Data selection, variables, and empirical strategy	164
4.3.1 Matching procedure of climate litigated firm with non-climate litigated firm.....	165
4.3.2 Dependent variables	168
4.3.3 Independent variables	168
4.3.4 Control variables	169
4.3.5 Empirical Strategy.....	171
4.4 Empirical Results and Discussion.....	173
4.4.1 Pairwise correlation and multicollinearity test	173
4.4.2 Summary statistics	176
4.4.3 Baseline result	178
4.4.4 Persistence effect of climate litigation	181
4.4.5 Forward cash holdings and climate litigation	185
4.4.6 Litigation outcome	189
4.5 Robustness	190
4.5.1 Alternative definition	190
4.5.2 Placebo test	192
4.5.3 Alternative sampling	194
4.5.4 Control for non-climate litigations.....	196
4.6 Endogeneity	200
4.6.1 Lag model	200

4.6.2 System GMM.....	201
4.7 Conclusion	204
Chapter 5	207
5.1 Conclusion	207
5.2 Theoretical Implications	210
5.3 Practical and Policy Implications.....	211
5.4 Limitation and Future Research Directions	212
References.....	215
Appendix A.....	236
Appendix B	237
Appendix C	239
Appendix D	245

Corporate Financial Decisions under Climate related Regulatory and Litigation Risk

Anand Kumar

Thesis Abstract

As countries confront the escalating challenges of climate change, a central component of their response lies in formulating and implementing climate-related laws and policies. This thesis explores the implications of climate laws and policies (CLPs) on corporate financial decision-making, focusing on three interconnected aspects i.e., the thematic evolution of global CLPs, their impact on corporate debt maturity decisions, and the consequences of non-compliance with these laws and policies, which lead to climate litigation and its effects on corporate cash holdings.

The study begins by applying a machine learning-driven topic modelling approach to a global dataset of climate law and policies enacted across 198 countries between 1947 and 2023. It identifies three dominant themes: energy efficiency and power generation, climate change adaptation and disaster management, and emission reduction. It broadly finds thematic consistency across advanced, emerging, and Sub-Saharan African economies. Our analysis shows that in Sub-Saharan African economies, CLPs focus on resource and disaster management, and renewable energy strategies for improved electricity efficiency. In contrast, emerging, and advanced economies concentrate on CLPs to reduce emissions through targeted sectoral approaches. Our findings reveal a regulatory shift impose significant compliance costs and operational uncertainties for firms to achieve climate goals.

Building on this, the thesis develops a Climate Law Index to capture the changes in climate and policies implemented across 23 countries from 1997 to 2022. The analysis reveals that changes in climate laws and policies are associated with a decline of 106 basis points (1.74%) in firms' long-term debt. This decline is primarily attributed to increased compliance costs and regulatory uncertainty.

Lastly, recognising that firms face growing litigation risks for failing to comply with these climate laws and policies, the final chapter analyses climate-related lawsuits filed against the firms between 2004 to 2023. The finding reveals that litigated firms increase their cash holdings by 23 per cent supporting the precautionary motive theory.

Overall, the thesis offers new insights into how CLPs and litigation jointly influence corporate financial decision-making. The findings contribute to climate finance literature and offer insights for regulators, investors, and corporate managers.

Chapter 1

Introduction

1.1 Introduction

Climate change has emerged as one of the many challenges that the international community has to confront in the 21st century, with its far-reaching impacts on every country. According to World Bank projections, climate change has the potential to displace a staggering 216 million people within their own countries by 2050, with regions projected to experience significant internal migration as early as 2030.¹ In response to the threats posed by climate change, countries have increasingly focused on the formulation and implementation of climate-related laws and policies as a core component of their mitigation and adaptation strategies (Bogojević, 2023; Mohammed et al., 2013). Studies recognise that achieving the objectives of the 2015 Paris Agreement requires the adoption of new, robust, and comprehensive climate laws and policies (Bodansky, 2016; Falkner, 2016). According to the climate change law database, more than 5,000 climate laws and policies have been enacted in nearly 200 countries, highlighting the important role of legal and regulatory measures in the global response to climate change.²

The rapid and unprecedented rise in climate laws and policies presents a significant analytical challenge due to the lack of country-level uniformity in how they are categorised and assessed across existing datasets (Steinebach et al., 2024). The lack of uniformity in global climate laws and policies makes it challenging to draw reliable conclusions about the overarching trends, effectiveness, or gaps in existing laws and policies. To make sense of this fragmented landscape, researchers often rely on manual coding³ which means systematically reading and categorising global climate laws and policies documents (for example, Eskander et al., 2021; Nachmany et al., 2014). However, this approach is not only time-consuming and subjective but also struggles to keep up with the rapid enactment of climate laws and policies around the world. To overcome these limitations, more recently researchers have increasingly called for machine learning methods to analyse climate policy documents in a more objective and

¹ See <https://www.worldbank.org/en/topic/climatechange/overview#2> [Accessed 9 September 2023]

² See <https://climate-laws.org/> [Accessed 11 April 2025]

³ These methods involve classifying policy document texts based on predefined themes such as mitigation, adaptation, finance, or sectoral focus, but they are time-intensive and hard to scale across hundreds of jurisdictions.

scalable manner (Żółkowski et al., 2022; Juhász et al., 2024; Singh et al., 2024). However, no study to date has applied the unsupervised machine learning topic modelling approach to uncover latent themes and patterns within global climate laws and policies. Uncovering latent themes and patterns within global climate laws and policies is crucial for understanding the evolution, focus, and gaps in climate governance frameworks. As climate laws and policies continue to grow in number, analysing their underlying structure and key themes is essential for researchers and policymakers. Also, the analysis helps assess whether these laws and policy instruments align with global climate goals, support nations in implementing effective policies, and address specific sector challenges (Jordan & Huitema, 2014; Schoenefeld & Jordan, 2020; Dubash et al., 2021).

To address the gap in systematic, scalable, and objective analysis of climate laws and policies highlighted by previous studies and the limitations of manual coding methods, Chapter 2 of this thesis applies a machine learning-driven topic modelling technique (Latent Dirichlet Allocation, (LDA)) to analyse global climate legislation enacted between 1947 and 2023. Importantly, LDA approach offers a scalable and replicable method for extracting thematic structures from large text corpora without imposing pre-defined assumptions (Blei et al., 2003; Roberts et al., 2016). The selection of this methodology is informed by the recent studies that have shown the effectiveness of using a LDA method on environmental and regulatory texts (Ma & Wang, 2024; Maier et al., 2021). This method helps uncover patterns and trends within large collections of documents (Meier, & Eskjær, 2024; Davidson et al., 2025). Furthermore, a detailed analysis of global climate laws and policy documents enhances our understanding of the financial risks (such as increased compliance costs, exposure to regulatory penalties, shifts in capital allocation, or stranded asset risks) and compliance obligations that firms encounter due to the implementation of climate laws and policies (Krueger et al., 2020; Bolton & Kacperczyk, 2021).

Building on the insights generated through the large-scale climate law and policies document mapping, Chapter 3 of the thesis examines the financial implications of climate law and policies enactment on corporate financial decision-making, particularly regarding debt maturity decisions. The nascent research on climate laws and policies indicate that implementing climate laws and policies presents significant challenges for stakeholders such as lenders, investors, policymakers, and corporations (Krueger et al., 2020; Stroebel & Wurgler, 2021). According to Krueger et al. (2020),

institutional investors consider climate regulatory risk in their investment decisions. Additionally, the introduction of climate laws and policies (CLPs) poses a potential threat to firms' profit-maximising decisions while also considering the long-term interests of society (Muller & Sfrappini, 2022). While these climate laws and policies are essential for addressing global climate change issues, it often imposes significant compliance costs on firms, requiring firms to meet environmental standards, invest in cleaner technologies, modify operational practices and create uncertainty for firms (Teeter & Sandberg, 2017; Engau & Hoffmann, 2009). Also, the implementation of CLPs increases the regulatory risks for the firms primarily stemming from the imposition of climate-related regulations, which can adversely impact the access to capital for the firms (Ginglinger & Moreau, 2023; Seltzer et al., 2022). Overall, the economic consequences of the climate law and policies extend beyond environmental impacts, influencing corporate risk exposures and financial decision-making processes.

At the same time, non-compliance with CLPs can result in the threat of climate litigation. This has become a significant enforcement mechanism, increasing the risk for companies that do not adequately adhere to the CLPs.⁴ With an increasing number of climate-related litigations being filed, particularly against corporate actors (Peel & Osofsky, 2020; Setzer & Higham, 2023), firms must consider climate litigation as a new source of risk in their financial decision-making. Motivated by the rising number of climate-related litigation cases against companies, Chapter 4 of this thesis investigates the financial implications of climate litigation. Wonneberger & Vliegenthart (2021) state that a company involved in climate litigation, whether as a plaintiff or a defendant, can attract media attention and influence political agenda-setting on climate law and policies. Companies faced with climate lawsuits experience immediate direct and indirect impacts. In this context, a study by Sato et al. (2024) reveals that when a company experiences climate litigations, the defendant firms experience a 0.41 per cent decline in stock returns. Climate litigation exposes firms to legal liabilities, including reimbursement for potential damages, fines, and mandated changes in business practices (Sullivan & Gouldson, 2016). Also, climate litigation differs fundamentally from traditional litigation in its scope, intensity, and forward-looking impact. Unlike conventional lawsuits focused on

⁴ Between June 2022 to May 2023, the number of climate change litigation cases increased to 2341 cases, out of which 190 were filed in last 12 months. See https://eprints.lse.ac.uk/124293/1/Global_trends_in_climate_change_litigation_2023_snapshot.pdf [Accessed on 30th August 2024].

past misconduct, climate cases often target firms' long-term contributions to Greenhouse gas emissions and failure to meet evolving climate law and policies, leading to mandated operational restructuring and strategic shifts. For instance, in 2021, the District Court in The Hague ordered Royal Dutch Shell to cut global emissions by 45% by 2030, compelling structural change beyond mere financial penalties.⁵ Moreover, climate litigation is accompanied by negative stock market reactions: a study reveals that when a climate-related lawsuit is filed or an unfavourable judgment is announced, the defendant firm's stock price drops on average by about 0.4%, and by even more (up to 1.5% loss) for big emitters in novel types of cases (Sato et al., 2024). Therefore, the third and the final part the thesis i.e, Chapter 4, is to enrich our knowledge and understanding of the impact that climate litigation risk has on influencing firm financing decisions, particularly with a focus on the corporate cash holding decisions.

Taken together, climate laws and policies and climate litigation represent a growing set of external pressures that can directly affect corporate financial strategies, particularly in areas such as debt maturity and cash management strategies. Meanwhile, a growing number of finance researchers have studied the climate risk using two proxies i.e., physical risk (such as hurricanes, temperature rise and droughts) (Massa, & Zhang, 2021; Lin et al., 2019; Dessaint and Matray, 2017; Hong et al., 2019; Basker & Miranda, 2018) and transition risk (such as transition to a low-carbon economy) (Seltzer et al., 2022; Caragnano et al., 2020; Reboredo & Ugolini, 2022; Ho & Wong, 2023). Broadly, the findings of these studies reveal that firms incorporate climate risk into their financial decision-making by decreasing financial leverage or holding more cash as a precautionary measure.

However, we have little to no knowledge about the firm level financial decisions in the wake of CLPs and climate litigation. Motivated by this gap, this thesis investigates the two major evolving global climate governance frameworks and its impact on corporate financial decision-making. In particular, it examines how cross-country CLPs implementation affect corporate debt maturity structures and how climate litigation risk influences corporate cash holding strategies. In doing so, the study contributes to emerging literature on climate finance, offering new insights for scholars, policymakers, investors, and corporate managers navigating the financial risks of a rapidly evolving

⁵ See <https://sustainablefutures.linklaters.com/post/102h0bi/shell-climate-case-digging-deeper-into-the-courts-legal-reasoning> [Accessed on 30th October 2024]

climate regulatory landscape.

1.2 The research questions, methodology and findings

This thesis examines how global CLPs and climate litigation shape corporate financial decision-making. Specifically, it explores three primary research questions: (1) What are the key focus areas of climate laws and policies across the world? (2) Do climate laws and policies influence corporate debt maturity structures? (3) Do climate litigations alter corporate cash-holding behaviour?

To answer the first research question, Chapter 2 utilise machine learning algorithms specifically designed for analysing datasets with a focus on prediction, classification, clustering, and natural language processing (Agrawal et al., 2019). Especially, machine learning techniques, such as LDA serve as a powerful tool for analysing large collections of textual data, including climate law and policy documents (Wanner et al., 2014). The application of machine learning offers multiple advantages, including generalisability, objectivity, replicability, and the ability to detect latent topic and themes from the corpus of text (El-Haj et al., 2019).

We employ LDA to systematically examine a corpus of 3,229 CLPs enacted globally between 1947 and 2023, to uncover latent thematic structures within these CLPs (Black et al., 2022; Cai et al., 2019). Unlike traditional text analysis that relies on word frequency, LDA identifies relationships between terms and topics by treating documents as mixtures of probabilistic topics, each represented as a distribution over words (Blei et al., 2003). Also, LDA does not require predetermined dictionaries or categories, reducing researcher bias and enhancing interpretability (Treude & Wagner, 2019). The LDA algorithm estimates the topic-word distribution using the equation:

$$\phi_{d,v} = \frac{(nd,k+\alpha)}{(\sum_k(nd,k+\alpha))} \text{-----} (1.1)$$

Where, $\phi_{d,v}$ is the probability of word in document, nd, k is the number of words in document assigned to topic, and α is the Dirichlet prior smoothing parameter. Following the model proposed by Blei et al. (2003), the study initialise the algorithm with varying numbers of topics ($k = 2, 4, 5, 10, 20$) and tune the hyperparameters α . High α implies documents exhibit most topics and low α means documents contain only a few topics. To validate the clarity of topics, the study retains those configurations with the highest topic coherence based on exclusivity, frequency, and interpretability (Roberts et al., 2016). We further use K-means clustering with the Elbow method to optimise cluster

selection by plotting within-cluster sum of squares and identify the optimal number of topics point (Cui, 2020; Kedia et al., 2018).

The LDA model reveals three globally dominant themes: (1) *Energy Efficiency and Power Generation*, (2) *Climate Change Adaptation and Disaster Management*, and (3) *Emission Reduction and Carbon Footprint Mitigation*. The topics derived using LDA reflect a prioritisation of sustainable energy use, climate resilience planning, and regulatory measures to curb emissions. Chapter 2 further disaggregated by economic groups shows that advanced economies primarily concentrated on climate adaptation policies and carbon trading systems, while emerging economies CLPs emphasised on renewable energy generation and disaster resilience. In contrast, Sub-Saharan African countries directed their CLPs implementation efforts toward agricultural resilience, water resource management, and climate resilient infrastructure development.

Additionally, Chapter 2 investigates the evolution of CLPs' focus across three major international climate conventions, i.e., Post Earth Summit, Post Kyoto Protocol, and Post Paris Agreement. The analysis of Earth Summit period (1992–1996) reveals that climate laws and policies focused largely on (i) *Air Emission Impact Assessment and Environmental Protection Activities*, (ii) *Tariff Law Amendment for Sustainable Power Plant Sources*, and (iii) *Forest Conservation Programme and Sector Fund Allocation for Climate Change and Protection*. The Kyoto Protocol period (1997–2015) marked a shift toward emissions reductions, national action plans, and market-based compliance instruments. An LDA analysis on the Kyoto Protocol period reveals four distinct themes: (i) *Forest Protection Law and Fund for change*, (ii) *Disaster Risk Management and Adaptation Plan*, (iii) *Greenhouse Gas Emission and Carbon Reduction Plan*, and (iv) *Electricity Efficiency and Source of Power Production*.

Finally, after the Paris Agreement (2016 onwards), CLPs emphasised financial accountability, emissions transparency, and long-term decarbonisation targets. An LDA analysis on the post-Paris agreement period reveals three distinct themes: (i) *Electricity Efficiency planning, Carbon control in Transport Sector, and EU Support*, (ii) *Law and Regulation for Greenhouse Gas and Carbon Emission Control*, and (iii) *Policy and Strategy for Climate Change Adaptation and Management*. Together, these findings provide a structured understanding of the thematic dimensions of global CLPs, laying the groundwork for investigating their implications for corporate financial behaviour in the Chapter 3.

The second research question is examined through a firm-level empirical analysis of firm debt maturity decisions in response to country-level climate laws and policies enactments. To do this, Chapter 3 constructs a novel CLI using data from 23 developed countries between 1997 and 2022. Following Simintzi et al. (2015), the CLI is computed using the following equation:

$$CLI_{c,t} = CLI_{c,t-1} + R_{c,t} \text{-----} (1.2)$$

In the above equation, $R_{c,t}$ is an indicator variable that takes the value 1 if a new climate law or policy was introduced in country in year, and 0 otherwise. The CLI is thus a country-year-level index that evolves based on the cumulative number of climate laws and policies passed in the country. The CLI is designed to quantify the cumulative count of climate law and policies enactment by aggregating the number of new climate-related laws and policies enacted each year in each country. It treats each climate law and policy enactment as a unitary measure of legal intensity, with the CLI representing the cumulative count of CLPs over time. The index ranges between 0 and 16 across the sample period from 1997 to 2022. Upon the construction of CLI, Chapter 3 uses CLI as the primary explanatory variable in the following regression model:

$$Debt\ maturity_{it} = \beta_0 + \beta_1 CLI_{c,t-1} + X_{i,t-1} + firm_i + ind_j * time_t + \varepsilon_{it} \text{-----} (1.3)$$

In the above equation, $Debt\ maturity_{it}$ is the proportion of long-term debt to total debt for firm in year, $CLI_{c,t-1}$ is the cumulative climate laws and policies index for country and year, $X_{i,t-1}$ is a vector of firm-wise year level controls variables, and $firm_i$ is a firm and $ind_j * time_t$ is industry and year fixed effect respectively. ε_{it} is the error term. For all the regression equation, we cluster the standard errors at the firm level to account for the issues of heteroscedasticity and autocorrelation.

Chapter 3 demonstrates a negative relationship between CLI and the use of long-term debt. It supports that the enactment of CLP influences firms' debt maturity choices, leading firms to reduce reliance on long-term debt and favour short-term debt. The empirical findings reveal that enactment of one additional climate-related law or policy in a given country-year is associated with a 1.74% (106 basis point) decline in the share of long-term debt. In terms of economic meaning, the estimated coefficient signals that firms adjust their debt maturity choices in response to increased climate-related regulatory risks, anticipating stricter operational constraints and higher borrowing costs from financial institutions.

The observed decline in long-term debt in response to higher CLI can be

understood through the lens of Institutional theory and Real options theory. These theories provide a robust framework for understanding the shift toward decline in long-term debt as firms navigate the financial and regulatory pressures induced by CLP implementation. Institutional theory posits that organisations must conform to societal expectations, regulatory norms, and institutional pressures to maintain legitimacy and secure resources (Hickson et al., 1971). The implementation of the CLP requires firms to adjust their financial strategies, including debt maturity decisions, to comply with regulatory expectations, avoid penalties, and uphold legitimacy and acceptance within their institutional environments (Meyer & Rowan, 1997; Hickson et al., 1971). Real options theory emphasizes the strategic value of short-term debt in preserving financial flexibility to navigate regulatory uncertainty (Myers, 1977; Trigeorgis, 1996; Dixit & Pindyck, 1994). In the context of CLP implementation, the option to wait allows firms to delay irreversible commitments, such as long-term debt covenants, until CLP trajectories stabilise (Myers, 1977; Della-Seta et al., 2020) and the option to abandon enables firms to exit high-carbon projects if climate laws render them unviable, minimizing exit costs compared to rigid long-term debt obligations (Trigeorgis, 1996; Battiston et al., 2017). Moreover, by relying less on long-term debt, firms signal their financial strength and liquidity to invest in climate-friendly initiatives promptly, demonstrating its commitment to meeting CLP related regulatory requirements (Stulz, 2000).

Additionally, to address concerns that not all the CLPs are homogeneous, Chapter 3 conducts a sectoral analysis and finds that the impact is especially pronounced in the energy and transport sectors. This aligns with the assumption that these sectors are particularly vulnerable to transition risks. Additionally, the further analysis reveals that legal origin, national governance structures, macroeconomic conditions, and financially constraints factors moderate the relationship between CLI and long-term debt. Notably, the Chapter 3 observes a U-shaped relationship between CLI and long-term debt, indicating that as CLI increases, firms initially reduce the share of long-term debt. However, the squared term of CLI is positive and significant, suggesting that CLI are associated with an increase in long-term debt beyond a certain threshold. The observed U-shaped relationship indicates that initially, firms perceive CLPs implementation as a risk to long-term planning. Therefore, firms prefer short-term debt to preserve financial flexibility. However, as CLPs' regulatory regimes mature and firms understand compliance pathways, the cost of adaptation declines, and firms prefer long-term debt.

Based on signalling theory, it is plausible to argue that in the wake of ongoing implementation of CLPs, firms will invest in low-carbon technologies, ESG alignment, and decarbonisation strategies. These actions serve as credible signals to stakeholders of the firm's commitment to regulatory compliance, financial resilience, and long-term sustainability in response to CLP implementations. At this stage, firms are more willing to return to longer-term debt as future risks become more predictable and manageable. Chapter 3 employs the instrumental variable analysis and lagged model to address the endogeneity concerns. Importantly, the results are robust to sub-sample analysis, alternative measures of debt maturity definition, and adding additional control variable analysis.

Having established that climate law and policies affect corporate debt maturity decisions, the next logical step is to examine what happens when firms fail to comply with these climate laws and policies. Chapter 4 turns to the legal enforcement dimension by investigating whether such non-compliance leads to climate-related litigation and, in turn, whether it affect corporate financial behaviour, specifically examining the cash-holding decisions. The third and the last research question explores the financial implications of climate litigation, focusing on the precautionary motive for cash holdings.

To answer the third research question, in Chapter 4, we manually construct a firm-level dataset of US based climate-related lawsuits involving publicly listed companies from 2004 to 2023. This dataset was derived from the Sabin Centre for Climate Change Law's comprehensive archive of climate litigation cases in the United States. Chapter 4 identify 125 firm-year climate litigation observations and acknowledges the large imbalance between the climate litigated firms versus non-climate litigated firms. To address this issue, following the methodology of Arena & Julio (2015), the study uses a criteria-based matching procedure to create a control group by pairing each climate-litigated firm with a comparable non-litigated firm from the same industry. Subsequently, the control group was then refined by matching firms based on three key financial characteristics: (i) return on assets (ROA) in the prior year, (ii) change in ROA (ΔROA), and (iii) market-to-book ratio in the prior year. Further, the study first applied a strict matching for each variable to fall within ± 20 percent of the climate litigated firm's variable. If no match was found, the criteria were relaxed to allow for ± 0.01 differences. In case of multiple matches, a distance metric based on the absolute differences in these three variables is calculated, and the firm with the smallest cumulative distance is

selected. Furthermore, to ensure long-term comparability, only control firms with at least ten years of data following the match year were retained. This comprehensive matching strategy resulted in a final sample of 2,046 firm-year observations covering 152 unique firms.

The study then uses the following regression equation model to examine the relation between climate litigation and firm cash holdings:

$$Cash_{it} = \beta_0 + \beta_1 litigation_{i,t} + \delta Controls_{i,t} + Industry\ fixed\ effect_j + Year\ fixed\ effect_t + \epsilon_{i,t} \quad \text{-----}(1.4)$$

In the above equation, $Cash_{i,t}$ is the level of cash and cash equivalents held by firm in year, scaled by total assets, and $litigation_{i,t}$ is a binary variable equal to 1 if the firm is involved in a climate-related lawsuit in the year, and 0 otherwise. Recognising that the typical climate litigation timeline from filing to settlement in our sample is approximately three years, we assign the dummy value for three consecutive years after the filing. $Controls_{i,t}$ represents a vector of firm-specific financial controls. The empirical model includes industry fixed effects to control for time-invariant factors specific to industries. Additionally, the study employs the year fixed effects to capture common shocks or trends that affect all firms each year.

The baseline regression indicates a 23% increase in cash holdings among climate litigated firms, and dynamic models reveal that this effect persists up to four years the post-climate litigation. The precautionary motive theory, proposed by Keynes in 1936, provides a theoretical explanation for this increase in cash holdings. According to this theory, firms accumulate cash to mitigate potential future uncertainties and to address financing constraints. This theoretical lens is supported by prior literature, such as Opler et al. (1999), which finds that firms during uncertainties and limited access to capital markets hold significantly more cash to manage uncertainty. Chapter 4 argues that climate litigation introduces significant legal uncertainty due to its complexity and prolonged timelines. Unlike traditional litigation, such as securities class actions, climate litigations often involve intricate scientific evidence and forward-looking climate scenarios, making litigation outcomes harder to predict. Also, substantial legal costs compound this uncertainty. For instance, Sato et al. (2024) estimate the average economic cost of an adverse climate litigation ruling at approximately USD 360 million, with even non-adverse cases incurring USD 3 million in legal defence costs. Researchers document that firms with litigation risk face lower credit ratings and higher loan spreads, deterring

lenders and increasing borrowing costs (Arena, 2018; Ni & Yin, 2018). Similarly, Hutton et al. (2014) find that litigated firms are less likely to rely on external debt or equity issuance due to higher perceived risk among investors and lenders, resulting in elevated interest rates and cost of equity.

Given the litigation-induced uncertainty and firm face external financial constraints increasing cash reserves can mitigate the financial and operational shocks associated with climate litigation, maintain stability, and signal resilience to stakeholders. Chapter 4 reinforces the precautionary motive by illustrating how firms prioritise cash holding to navigate potential financial shocks, such as those induced by climate litigation.

To further test the robustness of our findings and address potential endogeneity concerns, we conduct several additional analyses. First, we include the lag values of the explanatory variables to assess pre-trend effects and test for reverse causality that is, whether firms with rising cash levels are more likely to face climate litigation. Second, the study implements a placebo test by randomly assigning climate litigation status to a subset of firms and re-running the regressions to verify that our results are not driven by a mere coincidence. Third, the study performs a of subsample analyses to examine whether the effects are more pronounced in specific industries. Fourth, we test the sensitivity of our findings to alternative definitions of cash holdings variables. Finally, Chapter 4 account for the impact of non-climate-related litigation by including indicators for other types of litigation that the firm is facing at the same time.

Furthermore, to rigorously address potential endogeneity concerns such as time-varying unobservable, the study re-estimate the regression model by using the two-step System Generalized Method of Moments (System GMM) estimator proposed by Arellano & Bover (1995) and Blundell & Bond (1998). The validity of instruments is assessed through the Hansen J test of overidentifying restrictions. The diagnostic confirms that our instruments are valid and that the error terms do not suffer from serial correlation, further reinforcing the robustness of our findings. The results from the System GMM estimation are consistent with our baseline model.

Collectively, the battery of robustness tests supports the causal interpretation of our findings by reducing the likelihood that unobserved confounding factors influence the relationship between climate litigation and cash holdings.

1.3 Thesis contributions

This thesis contributes to the growing literature on climate finance by

systematically examining the role of climate governance investigated through the climate laws, policies, and climate litigation in shaping corporate financial behaviour.

Chapter 2 of this thesis contributes to the understanding of global climate governance by applying a machine learning-based LDA model to analyse a corpus of 3,229 CLPs description enacted across 198 countries between 1947 and 2023. To the best of our knowledge, this is the first study to use an unsupervised machine learning model to decode thematic structures from global climate laws and policies documents. This analytical approach not only captures the multidimensionality of climate laws and policies enacted across the world but also allows a more systematic understanding of global climate law and policy trends. Chapter 2 also provides an understanding of how the thematic evolution of climate laws and policies across time and geography, particularly in the wake of major climate conventions such as the Earth Summit, Kyoto Protocol, and Paris Agreement. By leveraging our findings, researchers can move beyond generalised interpretations and engage in more theme-specific investigations that account for climate law and policy heterogeneity. Moreover, this study offers researchers in accounting and finance new avenues to explore how development in climate laws and policies enactment influence the firm-level outcomes. For instance, Cormack et al. (2020) show that carbon reduction policies can negatively impact profitability and return on capital expenditure, while Seltzer et al. (2022) document adverse effects on bond ratings and credit spreads following the Paris Agreement. Additionally, the topic-modelling approach enables researchers to assess the financial implications of distinct climate laws and policies themes such as energy efficiency laws or carbon mitigation rules on firm-level investment, disclosure, or market valuation. As shown in Yang (2023), carbon emissions trading policies affect corporate environmental investments. By providing the thematic classification, the study offers a structured empirical basis for comparative and sector-specific analysis.

Chapter 3 of the thesis makes several important contributions. First, the work advances the nascent literature on climate law and policies and corporate finance by examining how implementation of CLPs influence firms' debt maturity decisions. While previous research has investigated the financial consequences of climate laws such as their effects on R&D spending (Brown et al., 2022), asset pricing (Bolton & Kacperczyk, 2023), innovation activities (Dai et al., 2020), and bank lending practices (Mueller & Sfrappini, 2022). However, the link between CLP and firms' debt structure has not been

thoroughly explored. Dang et al. (2022b) provide one of the few studies in this domain, showing that NO_x Budget Trading Program in the US prompted manufacturing firms to rely more heavily on short-term borrowing. However, this research focused on specific climate policy instruments and a US market-based context, which limits its broader applicability. By using firm-level panel data from 23 countries, this chapter offers cross-national evidence on how increasing CLPs enactment influences debt maturity choices, filling a significant gap in the existing literature.

Methodologically, Chapter 3 introduces a Climate Law Index measure to quantify the cumulative effect of CLPs enacted annually within each country. To construct an index the study closely follows the methodological framework of Simintzi et al. (2015). While Simintzi et al. 2015 construct an index based on employment protection reforms across 21 OECD countries from 1985 to 2007, our CLI is based on climate-related laws and policies changes across a comprehensive set of developed economies over a much longer time horizon i.e., 1997 to 2022.

Specifically, the CLI index is constructed to reflect the changes in CLPs, analogous to the employment protection reforms index in Simintzi et al., (2015) but applied to the domain of climate governance. Importantly, unlike event studies or single climate laws and policies analysis, the CLI enables a more nuanced and continuous evaluation of CLP changes over time. Additionally, in Chapter 2, we find the heterogeneity in the focus of CLPs; therefore, we conduct a sectoral analysis in Chapter 3. To do this, we manually classify each CLPs by its sectoral focus in Chapter 3 (e.g., Energy, Agriculture, Transport, Buildings and Cross-sectoral), allowing for deeper insights into how policy relevance across industries shapes firms' debt structuring preferences. This sectoral mapping is critical because the financial exposure and adjustment costs associated with CLPs vary substantially across industries. For instance, carbon-intensive sectors like manufacturing face higher compliance costs under emissions-focused policies (Sato et al., 2015), which in turn may influence their capital structure decisions differently than firms in low-carbon sectors.

This sectoral classification enables a more granular empirical analysis of how sector-relevant CLP shapes firm-level debt maturity decisions. Additionally, this sectoral classification allows us to conclude that not all CLPs have the same final impact on firms.

This study also contributes to capital structure literature by providing empirical support for the notion that change in climate laws and policies leads firms to reduce their

reliance on long-term debt. Previous studies suggest that climate policy uncertainty can affect borrowing costs and bond market perceptions (Seltzer et al., 2022), regulatory exposure reduces firms' debt capacity (Chen et al., 2012), and heightened climate risk is priced into bank loans (Delis et al., 2024). The findings in this chapter build on this work by showing that even in the absence of direct penalties, firms adjust their debt maturity structure to maintain flexibility in an uncertain regulatory environment. These arguments are also consistent with the institutional and real options theories.

Furthermore, Chapter 3 contributes to the literature on policy uncertainty and firm risk management, prior work has shown that economic policy uncertainty affects corporate investment (Gulen & Ion, 2016), risk-taking (Brogaard & Detzel, 2015), and M&A activities (Bonaime et al., 2018). In line with this literature, the chapter finds that climate law and policies introduce uncertainty, due to ongoing climate laws and policies enactments, leads firms to shorten debt maturity to preserve financial agility and minimize exposure to long-term contractual obligations. This aligns with the arguments advanced by Pastor & Veronesi (2013), Stiglitz et al. (2017), and Berger et al. (2005) that uncertainty acts as a constraint on corporate financing.

Chapter 4 of the thesis contributes to a very recent strand of literature that is climate litigation risk. While previous studies have primarily focused on short-term stock market reactions to climate litigation events (Sato et al., 2024; Dulak & Gnabo, 2024), this chapter takes a forward-looking approach by examining how exposure to climate litigation influences firms' internal liquidity management. This link has not been previously documented.

Recent prior work in this area conducted by Sato et al. (2024) and Dulak & Gnabo (2024), documents that climate litigation leads to declines in stock prices. For instance, Sato et al. (2024) report that unfavourable rulings reduce average abnormal returns by -0.41% , and up to -1.5% for heavy polluting industries. Dulak & Gnabo (2024) find that climate related case filings trigger stock price declines, but adverse judgments result in severe declines, particularly in high-profile cases. While insightful, these studies offer only a partial view of firms' strategic response to climate litigation.

By contrast, this chapter shifts the focus from market-based outcomes to managerial decision-making, providing evidence that climate litigation is associated with 23% increase in corporate cash holdings. Unlike stock prices, cash holding reflects managerial expectations of future liabilities and precautionary motivations. We find that

firms facing climate lawsuits increase cash holdings for the four consecutive years following climate litigation, consistent with a conservative financial strategy aimed at mitigating legal, operational, and reputational risks.

Chapter 4 further contributes to the literature on cash holdings and litigation risk. While past research has shown that litigation related to shareholder lawsuits or securities fraud can increase precautionary cash holdings (Arena & Julio, 2015; Nguyen et al., 2018; Malm & Kanuri, 2017; Liu, 2024), this study is the first to establish this relationship in the context of climate litigation. Climate litigation differs in that it is often initiated by NGOs, public entities, or citizen groups; targets systemic environmental harm rather than firm-specific fraud; and is grounded in evolving legal norms tied to international climate agreements (Setzer & Higham, 2022).

Finally, the study contributes to the climate risk literature by identifying climate litigation as a discrete and underexamined dimension of transition risk. While most studies categorize litigation under broader transition risks like regulatory shifts or carbon pricing (Dietz et al., 2016), we argue that climate litigation risk operates through distinct channels such as reputational damage, compliance failure, and legal uncertainty particularly visible in landmark cases like *Milieudefensie v. Shell* (2021) and *Urgenda Foundation v. Netherlands* (2019). Overall, this chapter calls for recognising litigation as an explicit climate risk category in corporate risk frameworks. The findings carry strong implications for regulators, investors, and firms alike, highlighting the financial consequences of non-compliance with the climate law and policies framework and adhering to international climate agreements.

Contributions from this thesis have several potential applications. For instance, researchers can exploit the insights from Chapter 2 to examine heterogeneity in climate regulatory exposure, firm adaptation strategies, and stock market reactions. For example, by using the thematic classification of CLPs researchers can construct firm-level exposure indices based on a firm's operating geography and the type of CLPs most prevalent in that jurisdiction. This allows for panel-based investigations of how different types of CLPs influence firm decisions such as investment in green technologies, capital structure adjustments, or changes in carbon disclosure practices.

Also, an empirical finance researcher could link firms' geographic exposure to jurisdictions with a strong presence of "carbon pricing" laws (as captured by our LDA themes) and test how that exposure affects firm leverage or cost of capital, extending

studies like Bolton & Kacperczyk (2021). Similarly, scholars could examine how exposure to “climate adaptation-focused” or “renewable energy scheme” CLPs affect firms in high-emissions sectors (e.g., energy, utilities, manufacturing) in terms of stock price volatility or ESG performance.

Chapter 2 has the immediate relevance for policymakers and practitioners. Policymakers may use the thematic classifications and their evolution to introduce new CLPs or refine existing ones, aiming to close policy gaps and enhance climate resilience. Lastly, the Chapter 2 also has direct implications for economic agents, including corporations, investors, and financial institutions. For instance, corporations can map their operational footprint against jurisdictions with emerging carbon pricing or emissions disclosure laws to anticipate future compliance costs and adjust capital expenditure plans (Ilhan et al., 2023). Similarly, financial institutions can incorporate the identified themes into their credit risk assessments, particularly in carbon-intensive industries, where future CLPs could increase default risks or reduce asset values (Laeven & Popov 2023). By revealing the thematic structure and country-specific focus of climate law frameworks, the study allows economic agents to systematically assess their exposure to regulatory risks, plan compliance strategies, and adjust investment portfolios accordingly. Our thematic structure allows various stakeholders to take into the account for the financing, risk management, and investment strategies in alignment with evolving climate laws and policies. For example, previous studies such as Bryant et al. (2019), Shen et al. (2023), Ilhan et al. (2023), and Laeven & Popov (2023) have demonstrated the shifts in regulatory compliance influence firm actions, stock price responses, institutional investor behaviour, and bank lending.

Similarly, the Chapter 3 offers practical implications for stakeholders. Policymakers can benefit from understanding the unintended consequences of changing in the climate law and policy environments such as firms reducing long-term borrowing which may undermine firm investment in long-term sustainability projects. For institutional investors and creditors, the findings highlight the importance of integrating climate law and policy exposure into risk models and credit assessments.

Taken together, the three main chapters in this thesis provide a comprehensive understanding of how various dimensions of climate governance that is enactment of climate law and policy, and climate litigation shape corporate financial decision-making. By integrating advanced machine learning methods, panel econometric models. The

thesis demonstrates that firms respond to changes in climate law and policy by strategically adjusting their debt maturity structures. Furthermore, non-compliance with these laws and policies can lead to climate litigation, which ultimately affects a firm's cash holdings in anticipation of potential legal consequences. These findings have important implications for researcher, policymakers, financial institutions, and managers navigating the evolving landscape of climate-related financial risk.

1.4 Thesis structure

This thesis consists of three interconnected studies, each utilising distinct sample-size, sample-period and different methodological approaches. Despite their independent empirical designs, all three studies are unified by the overarching objective of understanding how climate governance, measured through climate laws and policies, and climate litigations affects firm-level financial decision-making. The chapters are logically sequenced to reflect the progression from mapping the climate laws and policies to quantifying their financial impact and exploring how non-compliance with these laws and policies leads to climate litigation and thus reshapes corporate financial responses.

Chapter 2 investigates the global landscape of climate laws and policies using a global dataset of 3,229 climate-related laws and policies enacted in 198 countries between 1947 and 2023. This chapter, titled "*Decoding Global Climate Laws and Policies*," applies LDA to extract thematic patterns in climate laws and policies documents. The purpose of this chapter is to provide conceptual and empirical foundations for the quantitative study used in the subsequent analysis.

Drawing on the findings from Chapter 2, Chapter 3 construct a novel Climate Law Index to quantify changes in climate laws and policies over time and across jurisdictions. The chapter, titled as "*Climate Change Laws and Policies and Corporate Debt Maturity Decisions*," constructs a panel data for over 171,486 firm-year observations across 23 countries from 1997 to 2022. Using panel fixed effects models, it shows that increases in CLI are significantly associated with a decline in long-term debt and increase in short-term debt, indicating that firms adjust their borrowing decisions in response to change in climate laws and policies.

Finally, Chapter 4 shifts focus from formal regulation to legal enforcement. Chapter 4 titled as "*Climate Litigation and Corporate Cash Holdings*," this chapter investigates whether climate-related lawsuits lead to changes in corporate cash-holding behaviour. Drawing on a panel dataset of 2,046 firm-year observations for US listed

companies from 2004 to 2023. The chapter documents that firms facing climate litigation increase their cash holdings as a precautionary measure in response to climate litigations. The study performs a comprehensive set of robustness checks, including placebo tests, subsample analysis, controls for non-climate litigation, alternative variable definitions, and the two-step system GMM estimation to address endogeneity.

Chapter 5 concludes the thesis by synthesising findings across the three chapters, highlighting the implications for policymakers, investors, and managers, and outlining avenues for future research.

Chapter 2

Decoding Global Climate Laws and Policies

2.1 Introduction

“To reach 2°C, it’s probably a question of stronger laws, not more laws. What we have to do now is to strengthen those frameworks, implement stronger policies, have fewer exemptions, higher carbon prices, more focused support on energy efficiency, and better prohibitions on land use.” Professor Sam Fankhauser, University of Oxford, Ex-Director of Grantham Research Institute⁶

Climate change has emerged as one of the many challenges that the international community has to confront in the 21st century, with its far-reaching impacts on every country. Global environmental assessment bodies have indicated that critical issues such as sustainable development, climate change, anthropogenic greenhouse gas emissions (GHGs), extreme hunger and poverty, and the rate of biodiversity loss are not being adequately addressed (e.g., IPCC, 2007; UNEP, 2007; IAASTD, 2008; OECD, 2008). Despite these early reports, the first comprehensive United Nations assessment 2023 technical report of global efforts to combat global warming (global stocktake), the world is currently not on track to effectively combat climate change and is on course for a temperature increase of up to 2.6 degrees Celsius.⁷ The World Bank estimates that climate change has the potential to displace a staggering 216 million people within their own countries by 2050, with regions projected to experience significant internal migration as early as 2030 a trend that is expected to intensify in the coming years.⁸ Before the year 2000, global daily mean temperatures had never surpassed 1.5 degrees Celsius above pre industrial levels. However, by September 2023, there had already been 38 days with global average temperatures exceeding 1.5°C a record high, with further increases anticipated (Ripple et al., 2023).⁹

Researchers emphasize the necessity for a strong legal basis and comprehensive action from nations to effectively address climate change issues (Bogojević, 2023; Mohammed et al., 2013). Climate laws are shown to have a statistically significant impact on achieving emission reduction, with each new climate law reducing CO₂ emissions by 0.78% in the first three years, and by 1.79% in subsequent years (Dubash, 2020).

⁶ See <https://www.carbonbrief.org/mapped-climate-change-laws-around-world/> [Accessed 11 August 2023]

⁷ See <https://unfccc.int/documents/631600> [Accessed 9 September 2023]

⁸ See <https://www.worldbank.org/en/topic/climatechange/overview#2> [Accessed 9 September 2023]

⁹ A satellite data reveals that Antarctic Sea ice reached its lowest daily on July 7, 2023, falling 2.67 million square kilometres below the 1991–2023 average See <https://earthobservatory.nasa.gov/images/151692/exceptionally-low-antarctic-sea-ice> [Accessed 27 October 2023]

According to a recent survey conducted by the Pew Research Centre, public concern over climate change has been steadily increasing in recent years. The majority of survey participants believe that government regulations are necessary to address climate change issues.¹⁰ As countries confront the challenges posed by climate change, a key aspect of their response lies in the formulation and implementation of climate-related laws and policies. These laws also serve as essential tools for translating international commitments into actionable steps at the national level. Furthermore, the implementation of effective climate laws and policies (*hereafter CLP*) plays a pivotal role in navigating the complexities of climate change and fostering sustainable development. Studies recognize that achieving the objectives of the 2015 Paris Agreement demands the adoption of new, robust, and comprehensive approaches to climate governance (Bodansky, 2016; Falkner, 2016).

With growing global consensus on the necessity for stronger climate commitments, lawmakers worldwide are reassessing their strategies for dealing with climate change. In this context, scholars and policymakers recognize the importance of monitoring and evaluating the progress of CLP to assess a nation's commitment to achieving its climate objectives (Schoenefeld, 2021; Aldy, 2014). The 2009 Copenhagen Accord established the framework for implementing systems for measurement, reporting, and verification to oversee the efforts of developing nations in mitigating climate change. Further, the 2010 Cancun and 2011 Durban climate conferences proposed a framework for international consultations and analysis, ensuring clear prospects for the creation of a more comprehensive and robust mechanism for reviewing and reporting CLP on an international scale. Additionally, international climate agreements such as the Paris Climate agreement have set ambitious targets to limit the rise in global temperature, thus, aiming to mitigate the severe undesirable effects of climate change (United Nations, 2015). As a signatory to this landmark agreement, 196 countries have pledged to curb GHGs, and limit temperature rise to 1.5 degree Celsius.¹¹ However, it is essential to recognize that the success of these global climate agreements such as the 1997 Kyoto Protocol and the 2015 Paris Agreement relies on each country's ability to translate these commitments into concrete actions. In light of the increasing prevalence of climate change laws and policies and to assess the progress made in translating climate-related

¹⁰ See- <https://www.pewresearch.org/short-reads/2023/08/09/what-the-data-says-about-americans-views-of-climate-change/> [Accessed 21 August 2023]

¹¹ See <https://unfccc.int/process-and-meetings/the-paris-agreement> [Accessed on 29 July 2023]

commitments into actionable measures, this research conducts an in-depth examination of the promulgation of the global CLPs between 1947-2023 and primarily address three research questions:

1. *What are the key focus areas of climate laws and policies?*

[RQ1]

2. *How do climate laws and policies vary across different economies?*

[RQ2]

3. *Does the focus of climate laws and policies differ based on climate pledges?*

[RQ3]

The selection of the above three research questions in this study is informed by to provide a comprehensive understanding of how CLPs evolve across time and economies. The first question focuses on identifying thematic focus areas, which is essential for understanding the core themes of global climate governance. The second question addresses cross-country heterogeneity, particularly in relation to countries' institutional capacities and levels of economic development. The third question assesses how international agreements shape national policy trajectories, thus enabling a longitudinal view of global climate lawmaking.

To analyse the large corpus of CLP text, we utilize Latent Dirichlet Allocation (LDA), a prominent technique in Natural Language Processing (NLP) and text mining. LDA enables us to uncover predominant themes and trends within the CLP dataset, without relying on predefined categories (Blei et al., 2003; Jin et al., 2023). Additionally, the probabilistic inference approach of LDA helps identify word clusters and underlying topics within a document, as well as relevant topics across a collection of documents (Chen et al., 2009). Utilizing LDA, we generate precise and insightful topics and extract valuable insights from CLP data. From our analysis, we identify the following three topics of international CLP focus: (i) Energy Efficiency and Power Generation; (ii) Climate Change Adaptation Policies and Disaster Management Plans; and (iii) Reducing Emissions and Carbon Footprint.

Considering the widespread acknowledgment of the unique challenges posed by Sub-Saharan Africa, Developing and Emerging economies, and Advanced Economies in addressing the climate change issue, we conducted a comparative analysis of CLP within these three distinct economic groups.¹² Our analysis reveals that in Sub-Saharan African

¹²Sub-Saharan Africa bear the most severe consequences of climate change with an anticipated increase in

economies, CLP predominantly focus on resource management, disaster management, and adaptation strategies, with an emphasis on promoting the use of renewable energy for enhanced electricity efficiency. Whereas both Developing and Emerging economies and Advanced economies exhibit a concentration on laws aimed at reducing emissions through a targeted sectoral approach.

Further, we extend our analysis to investigate the evolution of CLPs post three major international climate conventions i.e., the 1992 Earth Summit, the 1997 Kyoto Protocol, and the 2015 Paris Agreement. The analyses reveal an evolving focus of international CLPs across all three climate conventions. Following the Earth Summit, CLP strongly focused on air pollution and environmental protection activities suggesting that the early phase of international CLP centred on comprehending and addressing the direct consequences of human activities on the environment. Furthering this goal, the CLPs post-Kyoto Protocol placed a heightened emphasis on protecting forests, managing disaster risks, and GHG reductions, signalling a shift towards ecosystem-based approach and climate change preparedness. The CLPs promulgated after the Paris Agreement further placed a strong emphasis on enhancing efficiency of non-fossil-based energy systems and implementing sectoral carbon control measures towards achieving net-zero goals by 2050. These shifts in focus of CLPs reflect the evolving understanding of policy makers and commitment towards climate change.

This study makes a several distinct contributions to understanding climate laws and policies. First, we use Machine learning (ML) approach to decode the underlying patterns and themes embedded within the vast corpus of enacted global climate laws and policies (i.e., 3229). To the best of our knowledge this is the first study to apply ML technique on the CLP documents and provide a comprehensive understanding of the diverse strategies and objectives adopted by countries in their effort to address the critically important issue of climate change (Cows et al., 2023).

Second, we provide an empirical setting for academic researchers to investigate the implications of CLP evolution within their research in the field of Accounting and

poverty, vulnerability in environmental systems, and a decline in GDP due to the impacts on agriculture and public health. Developing and Emerging Economies, despite their lesser contribution to climate change, are more susceptible, particularly those dependent on rain-fed agriculture or having exposure to coastal regions. While Advanced Economies are better equipped to manage the climate change effects, still face significant economic implications and prioritize the implementation of adaptation and mitigation strategies.

See <https://unfccc.int/news/climate-change-is-an-increasing-threat-to-africa> and <https://www.brookings.edu/articles/developing-countries-are-key-to-climate-action/>

Finance. For example, a study by Cormack et al. (2020) underscores that stringent carbon reduction policies negatively affect net profitability and return on capital expenditure. Researchers can use our thematic analysis to better understand the nuances of how specific aspects of CLPs, such as energy efficiency and power generation laws may impact financial outcomes. Similarly, Seltzer et al. (2022) examines the implementation of multiple policies in the US (i.e., Clean Water Act, Clean Air Act, and Resource Conservation and Recovery Act) and documents negative consequences on bond ratings and credit yield spread after the Paris Agreement.

Furthermore, the EU Emissions Trading Scheme (EU-ETS) Phase III, which introduced auctioned emission permits, increased financial distress risk among regulated firms relative to unregulated firms (Lambertides & Tsouknidis, 2023). Similarly, Hong et al. (2023) show that renewable portfolio standards in the US a form of climate regulation raised the cost of capital for affected firms. These findings align with earlier findings by Haq et al. (2001) that industries often perceive environmental regulations as constraints on profitability and competitiveness, although compliance costs are frequently overestimated while potential gains from technological innovation are underestimated. Also, CLPs have broader implications for corporate operations, including raw material costs, energy expenses, and consumer demand shifts (Lash & Wellington, 2007). In this regard, proactive companies that integrate due diligence processes and commit to binding greenhouse gas emission reduction targets can better manage risks and gain a competitive advantage in a carbon-constrained future (Iglesias Márquez, 2020; Lash & Wellington, 2007). However, Bartram et al. (2022) caution that financially constrained firms may respond to stringent CLPs by shifting emissions and plant ownership to jurisdictions with laxer regulations, undermining global mitigation efforts.

Recent research also highlights the capital structure and M&A implications of CLPs. Li et al. (2022) find that climate laws influence cross-border M&A activities, particularly in countries with strong legal enforcement, where stringent CLPs can deter acquisitions due to heightened compliance risks. In the U.S., implementation of the NOx Budget Trading Program has been shown to shorten corporate debt maturity structures, especially for electricity-intensive and financially constrained firms (Dang et al., 2023; Xu & Kim, 2022). The financial sector is similarly affected. Ghosh (2023) reports that climate laws in MENA countries reduce overall bank lending by 5%, with a stronger

effect on Islamic banks, highlighting potential credit supply contractions in regulated economies. At the same time, mandatory climate disclosure rules influenced by frameworks such as TCFD and ISSB have reduced greenwashing allegations in Canada and the U.S., indicating positive implications for accounting transparency and credibility (Gilliland et al., 2023).

Importantly, while CLPs may impose compliance costs, well-designed and effectively implemented policies can yield both environmental and economic benefits. For example, Ramzan & Ali (2025) find that CLPs enhance firm performance among US energy companies by improving reputation and stimulating innovation. In Europe, Kalantzis et al., (2024) documents that EU-ETS regulated firms increased investments in intangible assets during periods of high carbon prices, suggesting strategic repositioning towards low-carbon competitiveness. Brown et al. (2022) similarly report that sulphur oxides (SO_x) taxes in Europe prompted high-emission firms to increase R&D investments. At a macro level, Eskander & Fankhauser (2020) estimate that climate legislation reduces national CO₂ emissions by 0.78% within the first three years and 1.79% over the longer term. Further, Liu & Feng (2023) show that renewable energy promotion laws significantly accelerate solar and wind adoption, particularly in high- and upper-middle-income countries.

Moreover, our thematic climate convention analysis provides nuanced insights into the various dimensions of CLPs implemented after three major climate conventions. Researchers can exploit the identified LDA themes and correlate them with profitability, cost structures, or stock market performance. Focusing on emission reduction and carbon footprint reduction initiatives, Yang (2023) evidence that the carbon emission trading system negatively affects corporate environmental investment. By integrating our thematic analysis, researchers can extend their investigations to conduct cross-sectoral and cross-national comparative analyses. A comparative approach of how different industries and countries respond to CLP themes can enrich the financial and accounting research landscape. By leveraging our findings, scholars can move beyond broad generalisations and contribute to a more nuanced, heterogeneous, and actionable body of knowledge within the financial and accounting disciplines. In essence, scholars can use our study as a guide to identify gaps and focus on specific aspects that may have been overlooked or require deeper exploration to advance the understanding of the financial implications.

Third, this research offers a thematic, evidence-based mapping of CLPs, which can assist policymakers in identifying broad trends and focus areas across different economies and time periods. Additionally, our findings can provide foundational insights that may inform the development of more targeted CLP implementations. The thematic patterns derived from our study can also support international cooperation by highlighting areas of convergence and divergence in global climate governance. Policymakers may use these insights to reflect on their national CLP strategies, align them with emerging global priorities, and strengthen the regulatory environments that are responsive to evolving climate challenges.

This research has substantial implications for economic agents such as corporations, financial market participants and accounting firms. Our study provides insights into the evolving nature of regulatory compliance requirements across major economies, enabling a better assessment of its impact on economic agents' strategies and actions. By comprehending the evolving legal landscape, economic agents can proactively adjust their practices thereby ensuring legal/regulatory compliance, assess the opportunities and threats posed by the CLP, thus helping them to evolve actionable strategies of financing, investments, and risk management. For instance, Bryant et al. (2019); Shen et al. (2023); Iihan et al. (2023); Laeven & Popov (2023) demonstrate how changes in climate regulatory compliance can impact firms' beyond-compliance climate change actions, stock reaction, institutional investors perception, and bank lending, respectively.

By integrating our analysis, economic agents can leverage our findings to make informed decisions in compliance, investments, risk management, and financing, contributing to a more nuanced understanding of the relationship between regulatory dynamics and financial strategies.

For practitioners, the chapter provides a clear mapping of regulatory exposure across sectors, helping firms identify which areas (e.g., energy, transport, agriculture) are most affected by climate laws and therefore require strategic adaptation. For policymakers, the findings highlight sectoral imbalances and concentration of climate policies, providing insights into where regulatory efforts are most active and where further policy development may be required.

Above all, our work offers a structured overview of the thematic focus of global climate laws and policies, which may support climate activists and civil society

organizations in identifying key areas of policy concentration and thematic gaps. While the study does not assess the enforceability or compliance of specific CLPs, the findings can nonetheless inform broader advocacy strategies by illustrating where legislative attention has been most concentrated across regions and economic contexts. Additionally, the implications of our research extend to international collaboration by fostering a better understanding of shared policy priorities and framing opportunities for mutual learning. Lastly, by highlighting patterns and interdependencies in global CLP development, this research underscores the value of enhanced international cooperation, exchange of best practices, and capacity-building efforts aligned with the objectives of international climate agreements.

2.2 Data source

For this research, we collect the CLP data between 1947 to June 2023 from the Climate Change Laws of the World (CCLW) database provided jointly by the Grantham Research Institute and Climate Policy Radar.¹³ The CCLW database provides comprehensive information on climate change-related laws and policies from all countries that are parties to the United Nations Framework Convention on Climate Change (UNFCCC), totalling 198 countries in all, in addition to the European Union (EU). These also includes several territories that are not part of the UN or UNFCCC, such as Taiwan, Palestine, and Western Sahara. In Table 2.1 we list these countries with relative percentage of CLPs.

Table 2.1 Percent of climate law and policies distribution by country

Country Name	Count	Country Name	Count	Country Name	Count	Country Name	Count
Afghanistan	0.40%	Djibouti	0.25%	Lao PDR	0.37%	Romania	0.56%
Albania	0.62%	Dominica	0.31%	Latvia	0.22%	Russian Federation	0.59%
Algeria	0.43%	Dominican Republic	0.56%	Lebanon	0.19%	Rwanda	0.37%
Andorra	0.93%	Ecuador	0.50%	Lesotho	0.19%	Sao Tome and Principe	0.06%
Angola	0.71%	Egypt, Arab Rep.	0.43%	Liberia	0.28%	Saudi Arabia	0.22%
Antigua and Barbuda	0.28%	El Salvador	0.74%	Libya	0.06%	Senegal	0.62%
Argentina	0.93%	Equatorial Guinea	0.15%	Liechtenstein	0.34%	Slovak Republic	0.68%

¹³ See- <https://climate-laws.org> and <https://app.climatepolicyradar.org/search> [Accessed on 30 June 2023]

Armenia	0.37%	Eritrea	0.06%	Macedonia,	0.15%	Slovenia	0.34%
Australia	0.77%	Estonia	0.19%	Madagascar	0.31%	Solomon Islands	0.25%
Austria	0.62%	Eswatini	0.15%	Malawi	0.46%	Somalia	0.19%
Azerbaijan	0.12%	Ethiopia (excludes Eritrea)	0.53%	Malaysia	0.25%	South Africa	0.59%
Bahamas	0.25%	European Union	2.54%	Maldives	0.28%	South Sudan	0.09%
Bahrain	0.15%	Fiji	0.37%	Mali	0.96%	Spain	2.08%
Bangladesh	0.56%	Finland	0.53%	Malta	0.31%	Sri Lanka	0.53%
Barbados	0.28%	France	2.23%	Marshall Islands	0.15%	St. Kitts and Nevis	0.22%
Belarus	0.99%	Gabon	0.25%	Mauritania	0.22%	St. Lucia	0.19%
Belgium	0.43%	Gambia, The	0.25%	Mauritius	0.34%	St. Vincent and the Grenadines	0.12%
Belize	0.22%	Georgia	0.53%	Mexico	0.71%	Sudan	0.06%
Benin	0.15%	Germany	1.58%	Micronesia, Fed. Sts.	0.19%	Suriname	0.15%
Bhutan	0.62%	Ghana	0.46%	Moldova	0.37%	Sweden	1.24%
Bolivia	0.62%	Greece	0.68%	Monaco	0.06%	Switzerland	0.46%
Bosnia and Herzegovina	0.03%	Grenada	0.22%	Mongolia	0.50%	Syrian Arab Republic	0.12%
Botswana	0.15%	Guatemala	0.50%	Montenegro	0.28%	Taiwan	0.19%
Brazil	2.01%	Guinea	0.28%	Morocco	0.74%	Tajikistan	0.43%
Brunei	0.15%	Guinea-Bissau	0.15%	Mozambique	0.53%	Tanzania	0.46%
Bulgaria	0.53%	Guyana	0.12%	Myanmar	0.53%	Thailand	0.62%
Burkina Faso	0.37%	Haiti	0.06%	Namibia	0.37%	Timor-Leste	0.31%
Burundi	0.34%	Honduras	0.50%	Nauru	0.25%	Togo	0.59%
Cabo Verde	0.22%	Hong Kong, China	0.15%	Nepal	0.53%	Tonga	0.22%
Cambodia	0.81%	Hungary	0.56%	Netherlands	0.68%	Trinidad and Tobago	0.22%
Cameroon	0.28%	Iceland	0.25%	New Zealand	0.53%	Tunisia	0.25%
Canada	0.93%	India	1.27%	Nicaragua	0.40%	Turkey	0.84%
Central African Republic	0.09%	Indonesia	1.55%	Niger	0.31%	Turkmenistan	0.03%
Chad	0.31%	Iran, Islamic Rep.	0.40%	Nigeria	0.62%	Tuvalu	0.31%
Chile	1.05%	Iraq	0.03%	Niue	0.25%	Uganda	0.37%
China	1.02%	Ireland	0.87%	Norway	0.59%	Ukraine	0.68%
Colombia	1.27%	Israel	0.74%	Oman	0.22%	United Arab Emirates	0.43%

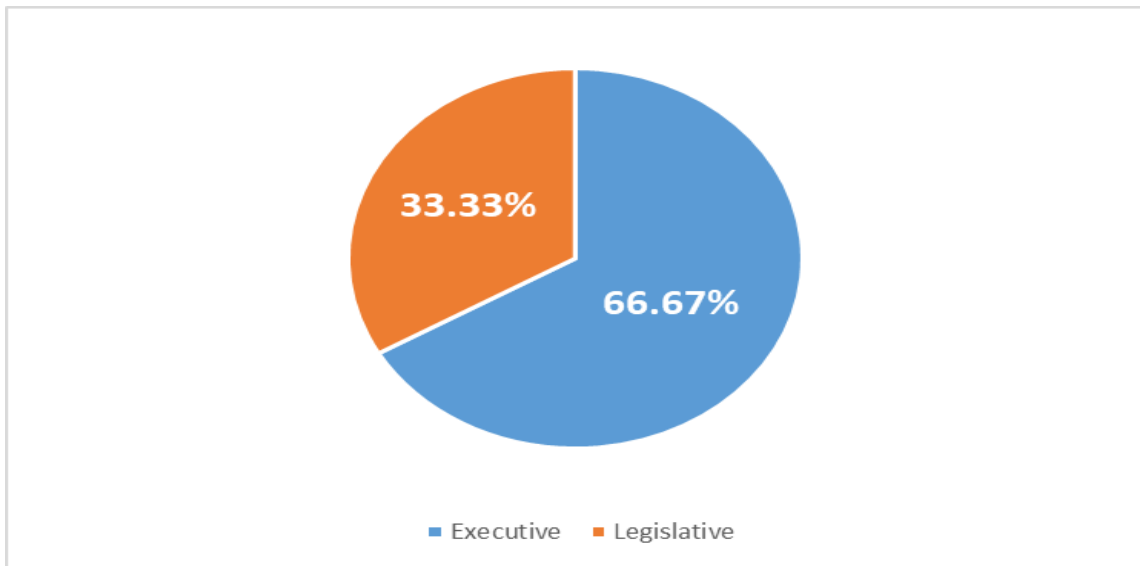
Comoros	0.12%	Italy	1.27%	Pakistan	0.71%	United Kingdom	2.04%
Congo, Rep.	0.28%	Jamaica	0.15%	Palau	0.25%	United States	2.26%
Cook Islands	0.12%	Japan	1.30%	Palestine	0.22%	Uruguay	1.12%
Costa Rica	0.87%	Jordan	0.40%	Panama	0.59%	Uzbekistan	0.28%
Cote d'Ivoire	0.56%	Kazakhstan	0.34%	Papua New Guinea	0.40%	Vanuatu	0.56%
Croatia	0.59%	Kenya	0.62%	Paraguay	0.59%	Venezuela	0.34%
Cuba	0.40%	Kiribati	0.37%	Peru	0.59%	Vietnam	1.83%
Cyprus	0.09%	Korea, Dem. Rep	0.15%	Philippines	1.02%	Yemen, Rep.	0.19%
Czech Republic	0.46%	Korea, Rep.	1.24%	Poland	0.68%	Zambia	0.62%
Democratic Republic of Congo	0.22%	Kuwait	0.09%	Portugal	1.08%	Zimbabwe	0.46%
Denmark	0.53%	Kyrgyz Republic	0.53%	Qatar	0.12%	Total	100.00 %

The table presents the distribution of CLP by country. The Count represents the percentage of CLP that each country contributes. The diverse distribution of CLP suggests that each country has its own approach to addressing climate change.

According to the CCLW database, there is no universally accepted definition for the term 'climate change framework law'. The database, therefore, identify CLPs based on specific shared characteristics, categorizing them as framework laws. The CCLW include all CLP that typically outline the strategic direction of a nation's climate change policy, either passed through the legislative process (33% of the CLP data) or through executive decision-making bodies (67% of the CLP data) (see figure 2.1).¹⁴

Figure 2.1 Distribution of worldwide climate laws and policies by category

¹⁴ Climate laws or policies enacted by the legislative branch of the government incorporate long-term or medium-term targets and pathways for climate action at the national level. It establishes a governance structure for climate-related matters that applies across multiple sectors and include provisions for transparency and accountability. Conversely, executive policies are interpreted more broadly, encompassing multi-sectoral action plans for specific aspects of climate action, such as a national low-carbon energy policy.



The figure illustrates the distribution of CLP by categories worldwide. The distribution underscores 67% of CLP are enacted by the legislative branch. In contrast 33% are attributed to the executive branch.

The database focuses exclusively on climate change-related laws and policies and provides detailed access to legal documents/information directly addressing areas pertinent to climate change mitigation, adaptation, loss and damage, disaster risk management or land, land use change and forestry (LULUCF). It is important to note that CCLW database includes only those CLPs that exhibit a clear commitment to addressing climate change concerns and cover various aspects of climate change action.¹⁵ Furthermore, the database covers only national and sectoral levels of legislation and policies. Sub-national government law and policy responses, international legislation and treaties are not included.¹⁶ The database captures major amendments to laws and updates document summary accordingly. However, laws that are outdated due to being repealed or replaced are not included.

Moreover, CCLW database curated by the Grantham Research Institute offers standardised English summaries and metadata for the climate laws and policies. This standardization helps ensure consistency and comparability across countries. However, we acknowledge that legal interpretation is embedded within national legal cultures and institutional contexts (Voigt, 2009), the use of broad thematic coding rather than relying

¹⁵ These aspects include energy efficiency, promoting low-carbon energy supply, restraining the development of fossil fuel-based infrastructure, supporting low-carbon building initiatives, implementing carbon pricing policies, curbing industrial emissions, combating deforestation, encouraging sustainable land use practices, investing in climate-related research and development, enhancing low-carbon transportation, and deploying natural disaster risk management measures.

¹⁶ While we do reference some sub-national examples such as California's Zero-Emission Vehicle Program or Florida's building codes, these are cited solely for illustrative purposes to contextualize certain policy trends or demonstrate real-world relevance of themes identified in the LDA analysis.

on literal legal translation enables us to focus on substantive content and policy intent.

2.3. Data Pre-processing

Data preprocessing is a crucial step in any topic modelling framework (Albalawi et al., 2020). In order to ensure the reliability of our topic modelling results, we implement a series of preprocessing steps outlined by Ali & Marisetty (2023), Aziz et al. (2022), and Kumar et al., (2023). We thoroughly review our CLP dataset, initially comprising 4085 rows, and manually inspect each description. During the inspection, we identified several special characters, symbols (e.g., @, #, %), bullet points, and URLs, which were subsequently removed from the dataset before proceeding with further processing. Additionally, we carefully drop duplicate rows that belong to the same country. This data refinement measures resulted in 3,229 rows of CLP description document. Following the initial cleaning, we import the data into KNIME tool for further data cleaning and preprocessing.¹⁷ This comprehensive preprocessing ensures that the data is prepared for accurate LDA analysis. Table 2.3 shows how a sample of each CLP description has undergone preprocessing, and the outcome achieved. At the same time, Figure 3.3 offers a comprehensive overview of all the steps undertaken in the data cleaning process.¹⁸

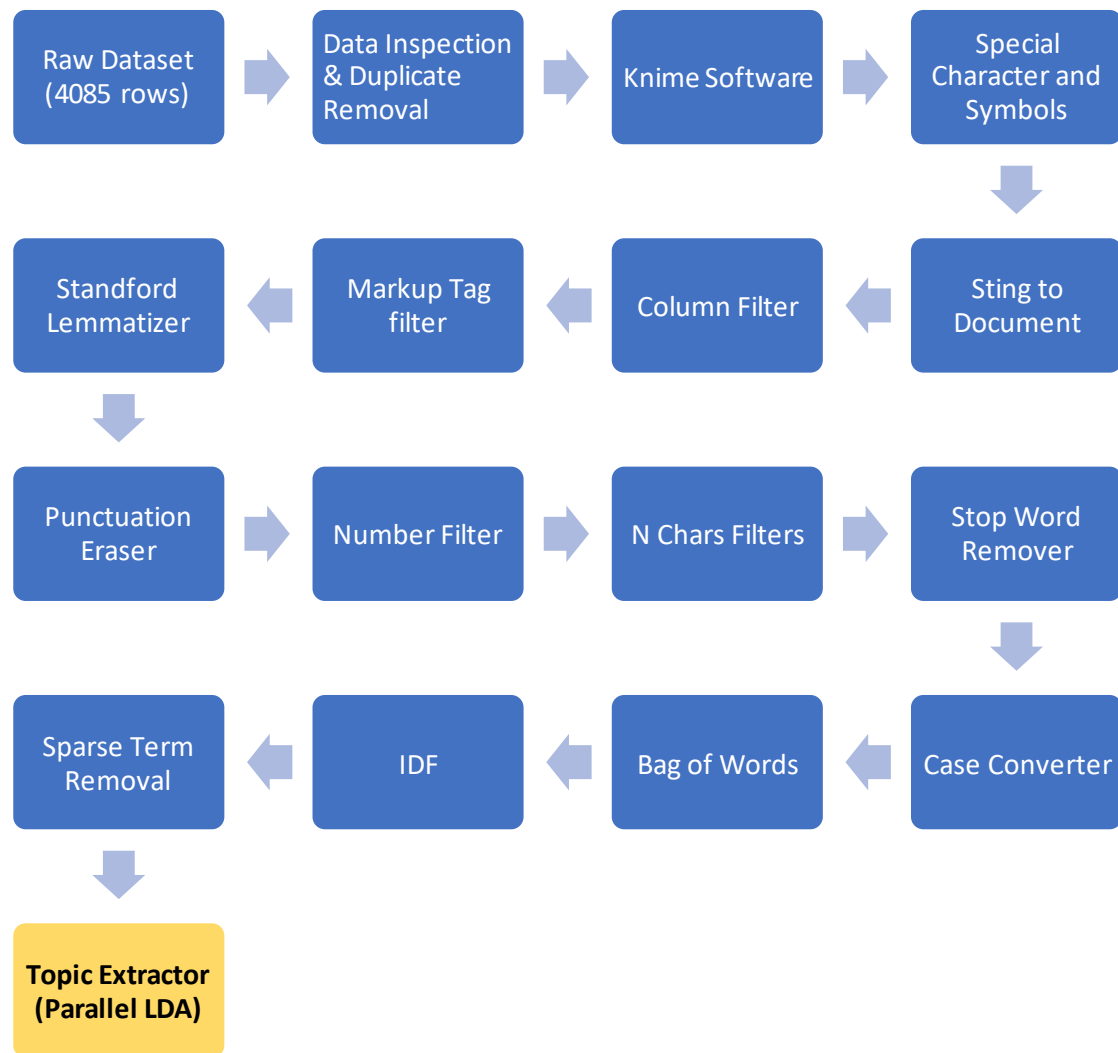
Table 2.2 LDA pre-processing outcome

Pre-processing Steps	Outcome
Law Description	“This policy aims at creating better social, economic and environmental conditions for people living in rural areas. This includes energy services, electric lighting, and energy efficiency. Renewable energy is notably promoted. The document further sets out legal and regulatory framework objectives and standards”.
Retained Words – After Stop Word Removal	‘policy’, ‘aim’, ‘create’, ‘better’ ‘social’, ‘economic’, ‘environment’, ‘condition’, ‘people’, ‘live’, ‘rural’, ‘area’, ‘includes’, ‘energy’, ‘service’, ‘electric’, ‘lighting’, ‘energy’, ‘efficiency’, ‘renewable’, ‘energy’, ‘notably’, ‘promoted’, ‘document’, ‘sets’, ‘legal’, ‘regulatory’, ‘framework’, ‘object’, ‘standard’
Lemmatize	‘policy’, ‘aim’, ‘create’, ‘good’, ‘social’, ‘economic’, ‘environment’, ‘condition’, ‘people’, ‘live’, ‘rural’, ‘area’ ‘include’, ‘energy’, ‘service’, ‘electric’, ‘lighting’, ‘energy’, ‘efficiency’, ‘notably’, ‘promote’, ‘document’, ‘set’, ‘legal’, ‘regulatory’, ‘framework’, ‘object’, ‘standard’

¹⁷ We prepare and clean the rows containing the CLP data file using various packages in the KNIME software, which we also use to conduct the LDA analysis. KNIME is a powerful data analysis tool that allows for easy integration of algorithms, data manipulation, and visualization methods through modules or nodes (Berthold et al., 2024). Drawing on learning theory which provides an understanding for how people learn and the choice of tools that contribute to effective learning outcomes (Krätzig & Arbuthnott, 2006). We use new alternative learning mode, KNIME, beyond traditional script-based coding like R, Visual Basic, or Python. KNIME follows a low-code approach, where users can build workflows using thousands of nodes that cover a wide range of functions. For more see <https://www.knime.com>

The table shows the climate laws and policies description transformation after applying the ML techniques.

Figure 2.2 Steps involved in data preprocessing



The figure provides a detail workflow of the data cleaning process and demonstrate the essential steps in preparing data for LDA analysis.

2.4. Methodology

We utilise ML algorithms that are specifically designed for analysing datasets, with a primary focus on tasks such as prediction, classification, and clustering, involving various forms of data processing (Agrawal et al., 2019). ML provides powerful tools for analysing collections of texts, including academic journal papers (Wanner et al., 2014). Moreover, the ML approach offers numerous advantages, including broader generalizability, increased objectivity, improved replicability, enhanced statistical power, and the ability to identify hidden linguistic features within the document (El-Haj et al., 2019).

In our analysis, we employ an LDA, a popular ML tool, which systematically

examines a corpus of text to identify latent topics within it (Black et al., 2022; Cai et al., 2019; Fligstein et al., 2017). LDA is widely used in research for topic identification as it goes beyond static word frequencies and allows exploration of latent relationships between terms and topics within a given sample (Blei et al. 2003). In LDA models, documents are represented as compositions of a fixed number of topics, which are probability distributions over a vocabulary. A unique advantage of LDA is that it does not require predetermined word dictionaries or topic categories but rather relies on the co-occurrence of words, which are likely to be semantically related. This process reduces researcher bias, as prior knowledge of document content does not impact the topic classification. By examining the most probable words within each topic, researchers can grasp the underlying meaning of words and generate suitable title with words. When applied to a set of texts, LDA generates a series of topics, each represented by a collection of words that frequently co-occur in the corpus. The algorithm clusters words based on their frequencies and co-occurrence within one or more documents (Treude & Wagner, 2019). Importantly, given the cross-country scope of the dataset and the long historical span (1947–2023), there is no universally accepted taxonomy that could be applied consistently across jurisdictions and time. Thus, LDA avoids this limitation by allowing themes to emerge inductively from the text.

Several studies have demonstrated LDA as a valuable tool for analysing both large and small corpus of text (e.g., Asmussen & Møller, 2019; El-Haj et al., 2019; Li, 2011). Moreover, the transparency of the LDA process allows other researchers to review most of the decisions made during the analysis. For example, Benites-Lazaro et al. (2018), Goloshchapova et al. (2019) and Jin et al. (2023) applied the LDA method to analyse the social actor discourses on climate change, energy, and food security, corporate social responsibility reports, and urban climate adaptation alignment with sustainable development, respectively, and justified their decision to use LDA due to its capacity to provide valuable insights into the contextual dynamics. In recent years, accounting and finance researchers have extensively used the LDA method. For instance, Brown et al. (2020) applied LDA to analyse 10-K filings, while Feuerriegel & Pröllochs (2021) employed LDA to examine 8-K reports. Additionally, Huang et al. (2018) and Garanina et al. (2022) utilised LDA to analyse analyst reports and review the literature on blockchain in accounting research.

The application of LDA method offers significant practical advantages as it

represents documents as a combination of multiple topics, with each topic comprising a mixture of related words. This aspect of LDA enables a more comprehensive analysis of the relationships and patterns within CLP dataset. The ability of LDA to represent documents as a combination of multiple topics proves particularly advantageous in the context of climate law studies, where documents often encompass overlapping themes. Through the application of LDA, we identify the most representative words associated with each topic and discern the focus of CLP within those topics.

Following the process developed by Blei et al. (2003), we use a predefined number of topics and retains the ones with the highest probability based on keywords. We initiate with k number of topics, α and β hyperparameters, where α controls the distribution of topics across documents and β influences the distribution of words across topics. A high value for α suggests that each document in the corpus is likely to have a distribution of most of the topics, while a low α implies that each document will contain only few of the topics in the corpus (Blei et al., 2003). Similarly, a high β value suggests that each topic is likely to have a distribution of most of the words, whereas a low β value indicates that each topic contains only a few of the words. We estimate the topic-word distribution ϕ using the following equation (2.1):

$$\phi_{d,v} = \frac{(nd_{d,k} + \alpha)}{(\sum_k (nd_{d,k} + \alpha))} \text{ ----- (2.1)}$$

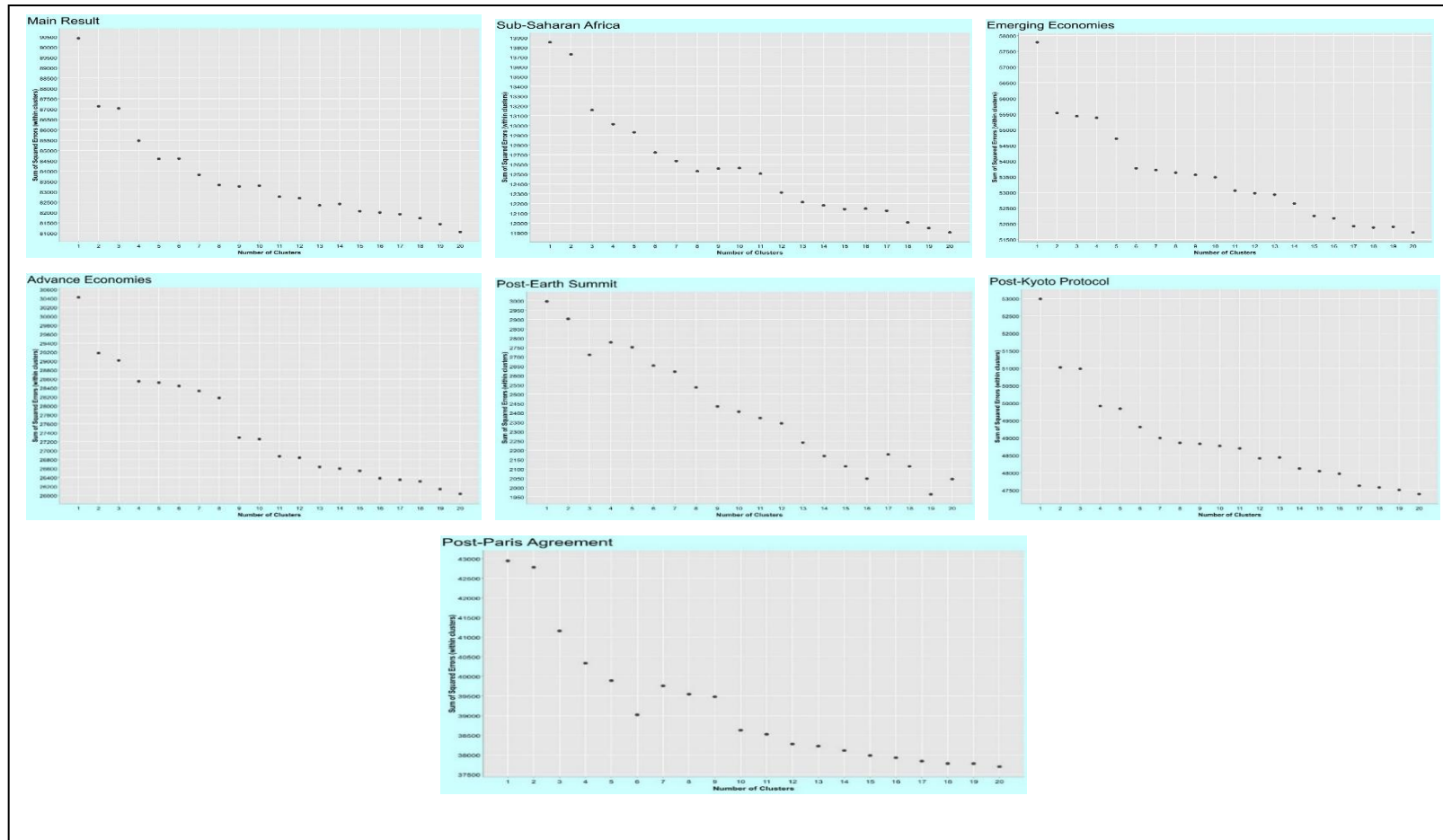
where, $\phi_{d,v}$ is the probability of word v in document d , $nd_{d,k}$ is the number of words in document d assigned to topic k , and α is the smoothing parameter, which helps prevent the model from assigning a probability of zero to a word in a topic. The denominator term, $\sum_k (nd_{d,k} + \alpha)$, sums the overall topics k for the given document d . Next, we iterate the algorithm with five various topic numbers (2, 4, 5, 10 and 20) and manually examine the interpretability of the resulting configurations.¹⁹ To assess the clarity of the resulting configurations, consistent with the literature, we considered the top 10 words associated with each topic, based on the highest probability measure and word's rank in terms of exclusivity and frequency (Roberts et al., 2016). Additionally, we use the widely applied K-means clustering technique, utilized in various domains such as e-commerce, healthcare, finance, technology, meteorology, and astronomy (Bethlendi et al., 2022; Racolte et al., 2022; Selcuk & Coban, 2023).

In the K-means clustering, we employ the Elbow method clustering technique to

¹⁹ We do this because LDA model begins with selection of k and finding optimal k is crucial for model fitting (AlSumait et al., 2009; Panichella et al., 2013).

identify the number of clusters in the given dataset. The Elbow method involves plotting the within-cluster sum of squares (WCSS) against the number of clusters (Cui, 2020; Kedia et al., 2018). At a certain point, adding more clusters does not significantly improve the quality of clustering, leading to an elbow point in the plot. This elbow point is an indicator of the appropriate number of clusters, allowing for a balance between capturing meaningful patterns in the dataset. The elbow point is the value of number of cluster (n) which the rate of the WCSS sharply changes. For example, in Figure 2.2 the “Main Result” plots n is equal to 2.

Figure 2.3 Optimal topic graph



The figure depicts the sum of squared values across 1 to 20 clusters. We utilise the elbow method to determine the optimal number of clusters and repeat the same process to answer all three research questions posed in the study.

According to Cao et al. (2024), harnessing machine learning (ML) computational power together with human art of interpretability can generate meaningful and accurate result. Also, extant literatures agrees that manual visualization can support and enhance the interpretability of results (Blei & Lafferty, 2009; Gardner et al., 2010; Gretarsson et al., 2012). Therefore, through visualizations, we manually refine the number of topics to 3 because three topics led to the emergence of more distinct, coherent, and interpretable topics with the CLP components of the dataset. The topics derived from the visualizations are more reflective of the nuanced content within the dataset, encompassing a detailed range of subject matters and yielding insights that were not adequately captured if we keep the number of topics to two (see Table 2.2 showcasing alternative topics with $n=2$, 4 and 5). Furthermore, the manual iteration not only enhanced the quality of the topics but also improved the overall meaningfulness and accuracy of representing the complex textual data.

Table 2.3 Topic derivation with different n value

Alternative Result with n= 5	Alternative Result with n= 4	Alternative Result with n= 3	Alternative Result with n= 2
Keywords: electricity, efficiency, law, source, power, production, act, consumption, fuel, generation Topic 1 Title: Energy Efficiency and Power Generation Laws	Keywords: electricity, efficiency, law source, power, production, act, development, consumption, generation Topic 1 Title: Energy Efficiency and Power Generation Laws	Keywords: electricity, efficiency, law, source, power, production, act, development, consumption, generation Topic 1 Title: Energy Efficiency and Power Generation Laws	Keywords: emission, efficiency, electricity, law, act, plan, gas, source, sector, carbon Topic 1 Title: Managing Carbon Emissions and Promoting Energy Efficiency
Keywords: change, adaptation, policy, disaster, plan, national, action, management, risk, development Topic 2 Title: Climate Change Adaptation Policies and Disaster Management Plans	Keywords: change, development, policy, adaptation, management, plan, strategy, national, disaster, Action Topic 2 Title: Climate Change Adaptation Policies and Disaster Management Plans	Keywords: change, development, policy, adaptation, management, plan, strategy, national, disaster, action Topic 2 Title: Climate Change Adaption Policies and Disaster Management Plans	Keywords: change, development, policy, management, adaptation, plan, national, strategy, action, disaster Topic 2 Title: Climate Change Adaptation Strategy and Disaster Management
Keywords: development, forest, resource, strategy, management, water, sector, policy, land, environment Topic 3 Title: Forest and Natural Resource Management Strategies	Keywords: emission, plan, carbon reduction, sector, transport, gas, efficiency, ghg, target Topic 3 Title: Reducing Emissions and Carbon Footprint in Various Sectors through Targeted Strategies	Keywords: emission, plan, carbon, reduction, sector, transport, gas, efficiency, ghg, target Topic 3 Title: Reducing Emissions and Carbon Footprints in Various Sectors	

Keywords: act, law, emission, environment, protection, article, change, government, fund, art	Keywords: act, law, change, emission, environment, protection, government, national, article, fund
Topic 4 Title: Environment Protection laws and Emission Control Measures	Topic 4 Title: Environment Protection and Emission Control
Keywords: emission, plan, carbon, reduction, gas, transport, sector, efficiency, ghg, save	
Topic 5 Title: Strategies for Emission Reduction from various sectors	

The table shows the LDA output based on different n values. LDA analysis results shows that using n=3 provides a more robust and logical choice as each topic is distinct and covers a broad area of climate law and policy. The topic derives with n=3, do not overlap and each represents a unique aspect of climate law and policy. As the number of topics increases (example n=4 or n=5), the topics start to overlap and become less distinct, making it harder to interpret the results. Therefore, n=3 seems to be the most logical choice based on the distinctiveness of topics, coherence of keywords, simplicity and interpretability, and relevance to climate law and policy.

2.5. Result

2.5.1 Key focus areas of climate laws and policies

We leverage LDA topic modelling to analyse the 10 most important keywords for each topic. We then manually refine topic titles based on the most representative words identified by LDA, resulting in three titles per theme: (i) Energy Efficiency and Power Generation; (ii) Climate Change Adaptation Policies and Disaster Management Plans; and (iii) Reducing Emissions and Carbon Footprint in Various Sectors. Details and keywords are presented in Table 2.4. To address RQ1, following prior research, we combine human and machine-based methods to infer topics and extract semantic meaning from the CLP documents (Kumar et al., 2023; Rabitz et al., 2021; Zander et al., 2023).

Table 2.2 The list of topics and associated keywords within each topic

Topics	Title	Keywords within the topics
Topic 0	Energy Efficiency and Power Generation	electricity, efficiency, law, source, power, production, act, development, consumption, generation

Topic 1	Climate Change Adaption Policies and Disaster Management Plans	change, development, policy, adaptation, management, plan, strategy, national, disaster, action
Topic 2	Reducing Emissions and Carbon Footprints	emission, plan, carbon, reduction, sector, transport, gas, efficiency, ghg, target

The table indicate the topic derived and keywords associated with each topic.

2.5.1.1 Energy Efficiency and Power Generation

The adverse impact due to climate change can be mitigated through fundamental changes in the current energy systems.²⁰ The role of renewable and sustainable energy in facilitating a just transition toward achieving the SDGs cannot be understated and represent distinct concepts within the global energy landscape. Kim et al., (2013) study the renewable energy plan of South Korea, find that households are willing to bear a significant portion of the increase in cost, supporting the sustainable shift towards renewable energy. Long-term renewable energy planning is crucial and often involve national-level strategies.

Our LDA reveals the first topic *Energy Efficiency and Power Generation* as identified by a set of key words (electricity, efficiency, law, source, power, production, act, development, consumption, generation) broadly focus on sustainable energy for climate action, aligning with Sustainable Development Goals (SDGs) 7 and 13, which prioritize affordable, clean, reliable, and sustainable energy. The topic's significance is underscored by various national instruments that include national renewable energy policies and legislation promoting clean energy and international agreements that play crucial roles in shaping global efforts toward a sustainable and renewable energy future (Hirschl, 2009). For instance, the European Union's Renewable Energy Directive, outlines binding renewable energy targets that significantly contribute to sustainable development (EU, 2018). Similarly, the World Bank underscore the crucial role of renewable energy in promoting universal access to electricity while supporting the goals of sustainable development (World Bank, 2020).

The energy sector faces two paramount challenges on the path to a sustainable future: (i) meeting the growing demand for electricity and (ii), securing the energy supply while simultaneously controlling for carbon emissions (Abbasi & Abbasi, 2010; Kaygusuz, 2012). Strategies for sustainable energy development typically revolve around three primary technological shifts: curbing energy demand, enhancing energy production efficiency, and substituting fossil fuels with diverse renewable energy sources. The 2022

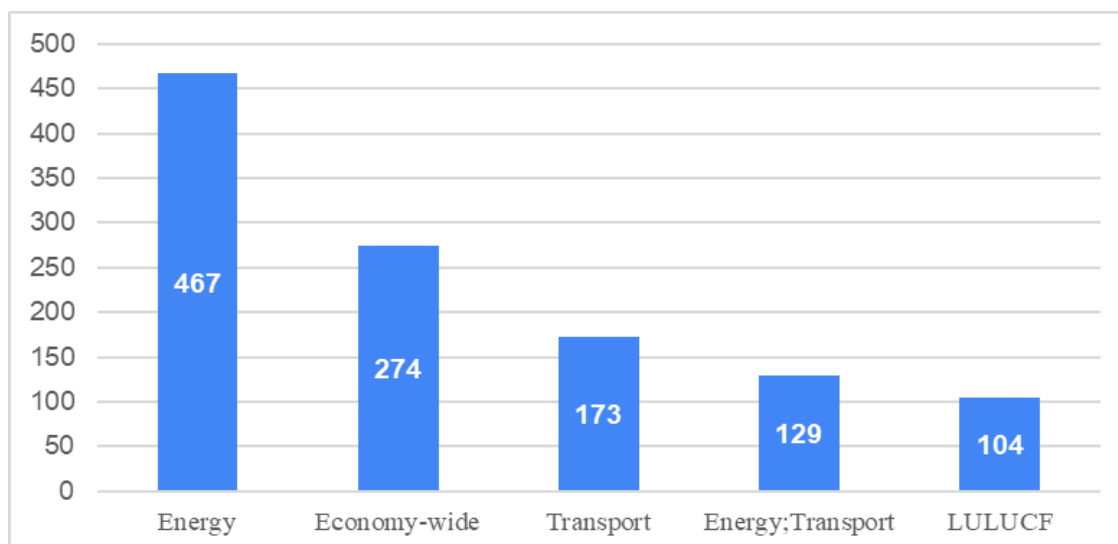
²⁰ See <https://www.epa.gov/climateimpacts/climate-change-impacts-energy> [Accessed on 29 August 2023]

World Energy Institute data highlights that approximately 82% of the world's energy is derived from conventional sources such as coal, oil, and gas.²¹ Whereas, the International Energy Agency (IEA) reports that renewables accounted for only 29% of global electricity generation in 2020, underscoring the urgent need for increased renewable energy integration to address climate change (IEA, 2021). According to the recent analysis, despite a decline in the usage of fossil fuels in the developed economies of the US and EU, CO₂ emissions from energy increased once again to a record high in 2023 (IEA, 2024). Transitioning to renewable energy sources including wind, hydropower, bioenergy, thermal, and solar, expeditiously and reducing reliance on fossil fuels, play a pivotal role in the transition towards cleaner energy to combat climate change (Edenhofer et al., 2011). These efforts are in line with the Paris Agreement, which urges countries to transition towards low-carbon economies (UNFCCC 2015).

Our Analysis indicate that worldwide, countries have implemented a diverse array of CLPs focused on sustainable energy adoption and generation to mitigate the impacts of climate change. Particularly, 40 countries have sustainable energy strategy which outline the nation's climate commitment to mitigate the climate change and its impact. Example: The US National Climate Change Policy of 2012 sets the vision for nation sustainable energy, whereas the Ireland Sustainable Energy framework sets out four objectives i.e., energy supply security, sustainable power generation, competitiveness of energy supply; and an integrated approach to energy policy. Additionally, we document that energy sector is by far a major focus within the CLP dataset (see Figure 2.4).

Figure 2.2 Top 5 sectors of climate laws and policies focus areas

²¹ See <https://ourworldindata.org/sources-global-energy#:~:text=In%202020%2C%20the%20global%20primary%20energy%20mix%20was,2.6%25%207%20Solar%3A%201.4%25%208%20Other%20renewables%3A%200.5%25> [Accessed on 29 August 2023]



The figure illustrates the top 5 sectoral focus in CLP. The figure underscores the predominant emphasis on the Energy sector with a substantial margin at 467 CLP, followed by Economy-wide at 274 CLP. The Transport and combined Energy-Transport sectors also receive considerable attention, reflecting the importance of sustainable transportation in policymakers' consideration. However, the relatively least focus is on Land Use, Land-Use Change, and Forestry (LULUCF) at 104, suggesting a potential area for further exploration and development in climate law and policy development.

Many countries have committed to increasing renewable energy capacities as part of their climate action plans in alignment with their Nationally Determined Contributions (NDCs). For instance, Germany's Renewable Energy Sources Act of 2014 provides a framework for promoting renewable energy through feed-in tariffs and incentives, while India's National Action Plan of 2008 outlines strategies for promoting renewable energy to achieve sustainable development goals. Costa Rica's achievement of nearly 100% renewable energy in electricity generation by 2020, primarily driven by a legal framework promoting hydropower, wind, geothermal, and solar energy sources, stands as a notable milestone in renewable energy adoption.²² Similarly, Denmark's remarkable achievement in transitioning to highest share of 54% wind energy in 2023 in its electricity mix highlights the instrumental role of supportive legal structures and incentives in fostering renewable energy adoption and sustainable development (IEA, 2023).

Furthermore, global efforts have led to the formulation of impactful renewable energy directives and policies. The Renewable Energy Directive 2018 (RED II) in the EU sets binding targets for renewable energy, aiming for 32% of energy consumption to come from renewables by 2030. Initiatives such as the United States' Clean Power Plan of 2015, India's Smart Cities Mission of 2015, Japan's Feed-in Tariff of 2012, Germany's

²² See <https://www.worldfuturecouncil.org/100-renewable-energy-costa-rica/> [Accessed 6 November 2023]

Renewable Energy Sources Act of 2014, also incentivize the use of wind and solar power through feed-in tariffs. Similarly, China's Renewable Energy Law 2006 aim to increase the share of renewable energy in its energy consumption, signals a commitment to decreasing dependence on non-renewable sources such as coal. As a result of these renewable energy regulations, the expansion of renewables, especially solar energy, has provided alternative power sources, thereby reducing reliance on fossil fuels and contributing to sustainable energy development (Østergaard et al., 2020). Further, developing countries have started off-grid rural electrification systems using renewable energy sources which is an alternative to costly grid extensions in remote areas of the world (Kanase-Patil et al., 2010).²³

Overall, the implementation of laws and policies on “*Energy Efficiency and power generation*” play a crucial role in the energy transition and have a significant impact on the economy. Current energy policies have proven effective in areas like automobiles, appliances, lighting, and renewable power (Daszkiewicz, 2020). However, the IEA (2021), has underscored three pivotal challenges in the energy transition. First, addressing cyberthreats is crucial, requiring improved climate resilience in energy infrastructure and strategic market interventions. Second, the escalating frequency of extreme weather events poses threats to energy security, demanding proactive governmental measures for risk anticipation and mitigation. Last, ensuring electricity infrastructure adaptability involves synchronized scaling of clean energy technologies, reducing fossil fuel reliance, optimizing energy efficiency, and establishing resilient clean energy supply chains. Moreover, successful progress depends on robust collaborations between states, local governments, and federal entities. Policymakers can tackle the challenges of implementing energy policies by enacting supportive measures, streamlining permitting processes, and providing clear guidelines to attract investments and promote the adoption of renewable energy sources, such as wind energy. Additionally, implementing budget-neutral policies, including gradually increasing GHD taxes to achieve emission reductions, combined with transfers to households, subsidies for low-emission technologies, and labour tax cuts, can be effective.²⁴ Gradual

²³ It is important to note that expanding renewables can also cause problems, especially if poorly planned. These challenges may include a reduction in biodiversity due to land-use changes, an increase in mining activities for rare earth materials, and increased GHG emissions resulting from land-use changes (Spillias et al., 2020).

²⁴ See <https://www.imf.org/en/Blogs/Articles/2022/10/05/further-delaying-climate-policies-will-hurt-economic-growth> [Accessed on 13 February 2024]

implementation of climate policies minimize short-term economic pain, prompting a smooth transition to a clean economy. While initial costs exist, long-term benefits outweigh them as clean energy investments create jobs, enhance security, and reduce overall costs.²⁵

2.5.1.2 Climate Change Adaptation Policies and Disaster Management Plans

The IPCC Third Assessment Report (IPCC III) 2001 highlights the importance of Climate change adaptation as a holistic and forward-looking approach that recognizes the urgency of addressing the adverse consequences of a changing climate while simultaneously striving to establish more sustainable and resilient systems for the future. highlights.²⁶ The 13th Conference of the Parties (COP 13) in 2007 led to the establishment of the Adaptation Fund Board, focusing on managing financial resources for adaptation projects in developing countries. Subsequently, COP-14, held in Poznan in 2008, marked significant progress in addressing adaptation issues within UNFCCC framework. Initiatives such as Reducing Emissions from Deforestation and Forest Degradation (REDD) exemplify the interconnectedness between climate adaptation and forest preservation (UN-REDD, 2013). Given these, the CLPs focus on adaptation is quite evident and our LDA analysis using the set of key words: change, development, policy, adaptation, management, plan, strategy, national, disaster, action reveals the second topic *Climate Change Adaptation Policies and Disaster Management Plans*.

The UN Development Adaptation Policy Framework emphasizes the crucial integration of adaptation policies into broader sustainable development plans and emphasizes the need for coordination and collaboration across sectors and levels of government (Lim & Spanger-Siegfried, 2004). Studies have underscored the urgent need for robust and transformative adaptation policies to promote sustainability in responses to climate change (Eriksen & O'Brien, 2007). The Copenhagen Consensus on Climate Change in 2009, where adaptation was formally acknowledged as one of the five major responses to climate change, underscores the role of adaptation alongside mitigation strategies in the global response to climate change and further highlights its significance in protecting communities and ecosystems from the impacts of a changing climate

²⁵ See <https://www.whitehouse.gov/briefing-room/blog/2023/12/19/building-a-thriving-clean-energy-economy-in-2023-and-beyond/> [Accessed on 13 February 2024]

²⁶ This report emphasized the necessity for proactive measures to adapt to the changing climate and its potential impacts. See <https://www.ipcc.ch/report/ar3/wg2/> [Accessed 6 November 2023]

(Bosello et al., 2009).²⁷

In recent years, several countries have incorporated the National Adaptation Plans (NAPs) as part of their climate law frameworks. NAPs serve as strategic blueprints outlining a country's approach to adapting to climate change, identifying priority sectors, necessary actions, and funding mechanisms. For example, Uganda's NAP provides a comprehensive roadmap for integrating climate adaptation into national development planning (UNDP, 2020). Similarly, the UK Climate Change Act of 2008 mandates the government to produce Adaptation Programmes every five years, assessing risks and opportunities and outlining sector-specific strategies for addressing climate change impacts (UK Climate Change Act, 2008). Developing countries' adaptation frameworks reveal the unique challenges they face, including limited financial resources, weak institutional capacity, and a lack of access to technology and information.

In the United States, some regions have their own climate laws and regulations. Florida, for instance, introduced building design codes to ensure the resilience of new infrastructure and buildings as an adaptation measure associated with rising sea levels and storm surges (Florida Building Code, 7th Edition, 2020). Similarly, the California Global Warming Solutions Act 2006 (AB 32) requires the state to develop comprehensive climate adaptation plans, with a focus on regional impacts (California Global Warming Solutions Act, 2006).

Globally, countries have witnessed a sharp rise in climate change-related disasters in recent decades.²⁸ Climatic events such as severe droughts, wildfires, rising sea levels, floods, and catastrophic storms have led to significant loss of life, destruction of homes, infrastructure, livelihoods, and financial damage, hindering development efforts. For instance, a post-disaster assessment of the 2022 Pakistan flood estimated a total economic

²⁷ The UNEP's Climate Change Adaptation Finance Gap Report 2016 reveals that developing countries requires USD 140-300 billion expenditure for adaptation annually by 2030. See <https://www.unepfi.org/climate-change/adaptation/> [Accessed 1 September 2023]

²⁸ Between 1970 to 2019, floods, storms and extreme temperature resulted in more than 2 million deaths, and with over USD 4 trillion in economic damages globally, with Asia suffering the most, mainly caused by Floods, storms, and extreme temperatures. Africa encountered 1,695 disasters, resulting in 731,747 lives lost and economic losses of USD 5 billion. In Asia, 3,454 disasters caused a staggering 975,622 deaths and USD 2 trillion in economic damages. South America experienced 34,854 fatalities and economic losses of USD 39.2 billion, primarily attributed to floods. North America, Central America, and the Caribbean collectively suffered 74,839 deaths and incurred USD 1.7 trillion in economic losses, with storms accounting for 54% of recorded disasters. The Southwest Pacific recorded 1,407 disasters leading to 65,391 deaths and USD 163.7 billion in economic losses, primarily from storms and floods. Europe saw 1,672 disasters, resulting in 159,438 deaths and economic losses of USD 476.5 billion, with extreme temperatures being the primary contributor. See [Climate and weather-related The acdisasters surge five-fold over 50 years, but early warnings save lives - WMO report | UN News](#) [Accessed 30 August 2023]

loss of approximately USD 15.2 billion, with the country needing USD 16.3 billion for resilient rehabilitation and reconstruction.²⁹ Similarly, the year 2023 witnessed an escalation of extreme weather events globally, including heatwaves, wildfires, heavy rainfall causing flooding, and an unprecedented hurricane season.³⁰ Despite global finance for climate action reaching USD 803 billion annually for 2019-20, it falls significantly short of the estimated USD 3 trillion annual investment required to limit temperature rises to 2 degrees Celsius or 1.5 degrees Celsius.³¹ Acknowledging this, at the recent 2022 COP27, world leaders established a dedicated fund for ‘Loss and Damage’ (Sarr, 2022).

The IPCC 2014 highlight the urgency of integrating disaster management into climate policies (IPCC, 2014). Efforts to reduce the catastrophic consequences of climate change have long been underway. The Sendai Framework for Disaster Risk Reduction, adopted in 2015 in Sendai, Japan, recognizes the interconnectedness between disaster risk reduction and climate change adaptation, underscoring the need for coordinated and ecosystem-based initiatives to minimize vulnerabilities (UNDRR, 2015). Globally, various approach and efforts are being introduced to enhance disaster preparedness, response, and recovery. For example, the United States Disaster Mitigation Act of 2000 establishes a framework and directives to reduce life and property loss from natural disasters.³² Similarly, Gambia’s 2007 National Disaster Management Policy outlines a comprehensive approach to disaster management, encompassing education, gender considerations, proactive measures, local knowledge integration, and early warning systems.³³ The European Union's Horizon 2020 research programme and the European Union Green Deal emphasize ecosystem-based approaches to support risk prevention and increase resilience to disasters (Quevauviller, 2022). Further, in Asia, the China Actions for Disaster Prevention and Reduction action outlines establishing a comprehensive disaster reduction working system, enhancing disaster monitoring and early warning capabilities, raising public awareness, and reducing human casualties and economic

²⁹See <https://www.worldbank.org/en/news/press-release/2022/10/28/pakistan-flood-damages-and-economic-losses-over-usd-30-billion-and-reconstruction-needs-over-usd-16-billion-new-assessme> [Accessed 30 August 2023]

³⁰ See <https://theweek.com/in-depth/1021278/2023-extreme-weather> [Accessed 30 October 2023]

³¹ See <https://www.un.org/en/climatechange/raising-ambition/climate-finance> [Accessed 30 October 2023]

³²See <https://www.fema.gov/emergency-managers/risk-management/hazard-mitigation-planning/regulations-guidance> [Accessed 31 August 2023]

³³ See https://www.preventionweb.net/files/10881_GambiaDisasterManagmntPolicyJul07.pdf [Accessed 31 August 2023]

losses caused by natural disasters in China.³⁴ The recent midterm review of Sendai Framework for Disaster Risk Reduction 2015-2030, countries around the world has enhanced disaster risk assessment and analysis capabilities at all levels. However, the report underscores the need for further strengthening of the 'Build Back Better' strategy and emphasizes the inadequacy of disaster reduction strategies at the local level.³⁵

Thus, our analysis of the CLPs under this theme indicates that in the face of global impact due to climate change, collective efforts at the national, regional, and community levels remain pivotal in building resilience and minimize the consequences of global warming. Recognizing the importance of financing adaptation efforts, the UNFCCC has established the Green Climate Fund (GCF), to provide financial support to the developing countries for climate adaptation and mitigation projects.

2.5.1.3 Reducing Emissions and Carbon Footprint

From the next set of key words i.e., emission, plan, carbon, reduction, sector, transport, gas, efficiency, ghg and target, as identified by the LDA, the final third topic *Reducing Emissions and Carbon Footprint* emerges. Since the Industrial Revolution a concerning increase in GHGs emissions has triggered a series of environmental changes, including an alarming rise in global surface temperatures, sea-levels, heatwaves, storms, and extreme rainfall events. In response, the UNFCCC initiated an international environmental treaty in 1992 that led to adoption of the Kyoto Protocol on December 11, 1997, and later the pledges under 2015 Paris convention. However, despite these global efforts to curb GHGs emissions, the volume of emissions has increased substantially with global energy-related carbon dioxide emissions increasing by 6% in 2021, with a further 0.9% increase in 2022 from industrial processes (IEA, 2023). Quantifying the repercussions of the global increase in emissions, scientists at the NASA have shown a significant increase in the average rate of global mean sea-level rise from 1993 to 2021 from approximately 2.5 mm (millimetres) to 3.4 mm.³⁶ According to the 2022 Global Sea Level Rise Technical Report, if the world fails to effectively reduce future emissions, there is a potential for an additional sea-level rise of 1.5 to 5 feet (0.5 to 1.5 meters),

³⁴ See <https://reliefweb.int/report/china/full-text-chinas-actions-disaster-prevention-and-reduction> [Accessed 31 August 2023]

³⁵ See https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf?_gl=1*799qy7*_ga*NTA4MzMyMjY3LjE2OTkyODY0Njk.*_ga_D8G5WXP6YM*MTY5OTI4NjQ5MC4xLjAuMTY5OTI4NjQ5MC4wLjAuMA [Accessed 31 August 2023]

³⁶ See <https://sea.level.nasa.gov/faq/8/is-the-rate-of-sea-level-rise-increasing/> [Accessed 1 September 2023]

ultimately resulting in a total rise of 3.5 to 7 feet (1.1 to 2.1 meters) by the end of this century (Sweet et al., 2022).

Countries, therefore, must continually update and strengthen their legal frameworks to meet their climate commitments and transition to a sustainable, low-carbon future. The Kyoto Protocol and the Paris Agreement, landmark international treaties, established the foundation for emission reduction obligations (UN 1998). Additionally, regulations like carbon pricing mechanisms and emissions trading systems have gained momentum in many countries as measures to cut down emission (Water Resource Institute 2021). The European Union's Emissions Trading System (EU-ETS) recognized as the world's first major carbon market, regulates emissions across various sectors and facilitates emission reductions through a cap-and-trade system (Ellerman & Buchner, 2007).

Countries and industries are implementing targeted strategies to minimize their environmental impact and transition to more sustainable practices. For instance, California's Zero-Emission Vehicle Program adopted in 1990 and the UK Road to Zero Strategy in 2018 promote the use of electric and hybrid cars, public transportation, and invest in cleaner fuel technologies. The International Maritime Organization's MARPOL Annex VI 2005 regulates air pollution from ships, encouraging the use of cleaner fuels and technologies in marine transportation.³⁷ The EU-ETS for Aviation introduced in 2012, imposes caps on carbon emissions from flights, prioritize fuel efficiency and investments in sustainable aviation technologies. In the agricultural sector, India's National Mission for Sustainable Agriculture 2010 emphasizes eco-friendly practices and soil health, while Germany's Action Program 2017 on Nitrate Reduction targets nitrogen pollution through sustainable farming methods (Kuhn et al., 2019).

Similarly, China, the world's largest emitter, has introduced a range of policies to curb emissions, including carbon intensity targets in 2005, emissions trading schemes in 2011, the Renewable Energy Law in 2013, and the Air Pollution Prevention and Control Action Plan in 2021. The European Green Deal of 2019 commits the EU to achieving climate-neutrality by 2050, establishing binding emissions reduction targets for various sectors (Wolf et al., 2021). Additionally, our analysis also shows that countries such as Canada, Australia, South Africa, Brazil, and South Korea have implemented various

³⁷ See <https://www.epa.gov/enforcement/marpol-annex-vi-and-act-prevent-pollution-ships-apps> [Accessed 2 November 2023]

measures, including carbon pricing, renewable energy programs, and forest preservation rules, underscoring the global commitment to addressing climate change and reducing emissions through diverse regulatory strategies.

It is important to note that each nation tailors its strategies to its unique circumstances and priorities. However, the effectiveness of these regulations depends on a variety of factors, including political will, economic conditions, and the specific challenges each country faces in its efforts to combat climate change.

2.5.2. Climate laws and policies across different economies: Comparative Analysis

World needs climate action on all fronts: everything, everywhere, and all at once. One of the most frequent debates around climate laws often centres on whether advanced countries should take a more proactive approach and implement stringent climate laws to double down on carbon emissions reductions and achieve net-zero climate goals. This is due to the fact that advanced economies, such as the United States, EU, Russia, and Japan have been major contributors to global emissions, accounting nearly 13,020 metric tonnes of GHG emissions.³⁸ In this context, UN secretary-general Antonio Guterres proposed a Climate Solidarity Pact and emphasizes that wealthier countries should enhance their commitments to achieving net-zero GHGs emissions targets.³⁹ He also emphasizes the urgency of striving to reach this goal as early as possible, ideally by 2040, rather than the previously targeted date of 2050. However, to set a more robust global path to net-zero emissions by 2050, the world needs to pay greater attention to the inclusion of Developing and Emerging Economies (D&E) as they currently contribute to over two-thirds of global CO₂ emissions, while emissions in advanced economies are steadily declining, despite an expected 4% rebound in 2021 (IEA, 2021). In this context, Paris Agreement focus shifts to D&E like China, India, and Brazil and highlight the growing role D&E in the global economy and the challenges they face in balancing economic growth with environmental sustainability. On the other hand, despite the low emissions, vulnerable countries like Sub-Saharan African region are experiencing the impact of climate change.⁴⁰ According to UNFCCC, the rising temperatures, changing precipitation patterns and intensified

³⁸ See <https://edition.cnn.com/interactive/2023/12/us/countries-climate-change-emissions-cop28/> [Accessed 15 February 2024]

³⁹ See <https://press.un.org/en/2023/sgsm21730.doc.htm> [Accessed 16 August 2023]

⁴⁰ Sub-Saharan Africa accounts for the smallest share of global greenhouse gas emissions, at just 3.8%. In contrast, China, the United States, and the European Union have much higher emissions percentages. See <https://www.cdp.net/en/research/global-reports/africa-report> [Accessed on 22 August 2023]

extreme weather events pose significant threats to human health and safety, as well as jeopardize food and water security and socio-economic progress in the African region.⁴¹ African region has started to implement CLP, but progress has been slow due to limited resources and competing priorities such as economic development, poverty alleviation, and infrastructure improvement (Zeufack et al., 2022).

According to Hope (2004), intricate and multifaceted issues particularly in the Sub-Saharan African and advanced economies are deeply rooted in poverty, insufficient service provision, and political instability, posing obstacles to overall development and human security. The challenges have been further intensified by the global financial crisis, especially in Sub-Saharan Africa, where reliance on foreign finance inflows and export growth based on commodities has exposed the region to vulnerabilities (Allen & Giovannetti, 2011). Also, African leader alleges African leaders assert that Western countries have been relying on coal and oil for decades. However, they criticize developed nations, private banks, and ESG investors for pressuring African countries to refrain from pursuing similar practices.⁴² However, the conflict between developing and advanced economies has intensified following the Glasgow climate conference in 2021.⁴³ At the conference, developed nations pledged to raise capital for developing and poorer nations to support their shift to renewable energy. Despite being endorsed as a landmark climate finance framework by world leaders to fund the green transition in poorer countries, it is currently facing challenges in mobilizing the required capital. Above noted conflict and challenges between these economies provides an important avenue for a comparative analysis of CLP between different groups of countries. Additionally, cross-contextual comparison can enhance our understanding of how global economies utilize CLP as tools to address climate change issues. Also, cross-contextual comparison can advance our knowledge on how global economies are using CLP as tools to address climate change issues. Given these economic distinctions, following the International Monetary fund (IMF) country composition classification⁴⁴ and by using the LDA analysis, we examine the CLP focus of Sub-Saharan Africa (SSA), and Advanced

⁴¹ See <https://unfccc.int/news/climate-change-is-an-increasing-threat-to-africa> [Accessed on 22 August 2023]

⁴² See- <https://www.ft.com/content/817a5868-872d-401a-802a-ce7ef3465e0c> [Accessed 16 February 2024]

⁴³ See- <https://www.ft.com/content/d49f8109-01ea-4ca3-ac0d-15df8cfdcf70> [Accessed 16 February 2024]

⁴⁴ See- <https://www.imf.org/en/Publications/WEO/weo-database/2023/April/groups-and-aggregates> [Accessed on 16 August 2023]

Economies, and Developing and Emerging Economies (D&E). Comparing these three distinct categories of economies unveil the topics and themes within these regions' CLPs. Table 2.5 reports the topic derived using LDA method.

Table 2.3 The list of defined topics in three distinct economies and associated keywords within each topic

Sub-Saharan African	Developing and Emerging Economies	Advanced Economies
Keywords: policy, strategy, disaster, management, plan, adaptation, risk, sector, capacity, country Topic 0 Title: Disaster Management Policy and Strategic for Sectoral Capacity Building and Adaption	Keywords: change, policy, management, adaptation, national, plan, strategy, disaster, action, forest Topic 0 Title: Disaster Management Policy for Climate Change Adaptation and Forest Preservation	Keywords: climate, change, adaptation, policy, plan action, government, development, risk, management Topic 0 Title: Climate Change Risk and Adaptation Strategies
Keywords: environment, management, act, forest, implementation, policy, action, council, redd, protection Topic 1 Title: Environment Management Act and Implementing Policies for Forest Protection and REDD Initiatives	Keywords: efficiency, law, electricity, emission, source, power, sector, production, policy, plan Topic 1 Title: Efficient Electricity Production, Emission Control, and Sectoral Policy Implementation	Keywords: plan, resilience, commission, recovery, investment, reform, EU, support, allocation, financing Topic 1 Title: EU Recovery, Resilience, Support, and Investment Reforms
Keywords: energy, sector, policy, production, source, electricity, efficiency, renewable, resource, power Topic 2 Title: Renewable Energy Sources for Efficient Electricity Production and Resource Management		Keywords: emission, act, gas, Reduction, carbon, transport, ghg, target, co2, government Topic 2 Title: Reducing Greenhouse Gases Emissions through Targeted Government Initiatives and Carbon Reduction Strategies
		Keywords: electricity, law, act, Source, power, efficiency, building, production, art, installation Topic 3 Title: Electricity Efficiency and Building Artistic Installation and Production

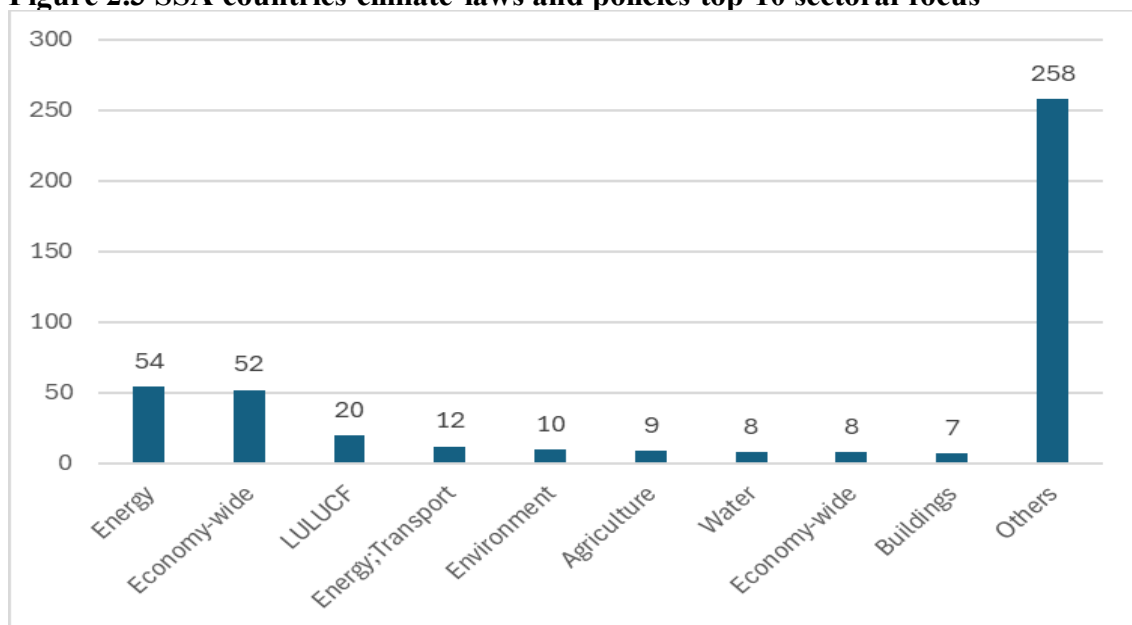
The table indicates the topic derived and keywords associated with each topic across the three distinct economies.

2.5.2.1 Sub-Saharan Africa (SSA)

Our study reveals that the CLP focus of SSA is on sustainable development goals, renewable energy, adaption, and resilience-building strategies to combat climate change. Particularly, the LDA analysis identifies three prominent themes shaping SSA's approach

to climate action.: (i) *Disaster Management Policy and Strategic for Sectoral Capacity Building and Adapation*, (ii) *Environment Management Act and Implementing Policies for Forest Protection and REDD Initiatives*, and (iii) *Renewable Energy Sources for Efficient Electricity Production and Resource Management*. CCWL provides data on 520 CLPs from 45 countries within the SSA region. Figure 2.5 shows the sectoral focus of the CLP in SSA. The most prominent sectoral focus is “Energy”, “Economy-wide”, and “LULUCF” with 54, 52, and 20 CLPs, respectively. The combination of “Energy and Transport”, and “Environment” accounts to total 22 CLP, and “Agriculture” alone with 9 CLP. In this section “Other” category aggregates a long tail of sectors, each with a small count, as well as multi-sectoral CLPs that do not fit neatly into a single sector. Due to this heterogeneity, we put them into the other categories.

Figure 2.3 SSA countries climate laws and policies top 10 sectoral focus



The figure illustrates the sectoral focus of CLP in SSA countries. Each bar represents a unique standalone or combination of sectors, with the length of the bars indicating the number of CLP focusing on those sectors. The figure provides a comprehensive overview of the CLP landscape in SSA, highlighting the key sectors of focus and offering insights to policymakers for potential areas of intervention and policy development.

According to International Rescue Committee report 2023, top 10 countries that are particularly vulnerable to climate change, despite having contributed little to its cause are Afghanistan, Central African Republic, Chad, Ethiopia, Nigeria, Somalia, Syria, The Democratic Republic of Congo, Yemen, and Sudan. SSA countries recognize the escalating impact of climate change on vulnerable populations via exacerbating issues such as food insecurity, population displacement, and putting severe pressure on water

accessibility, and health (Serdeczny et al., 2017).⁴⁵ These projected impacts are expected to escalate, even if global warming is restricted to 1.5°C. Further, the rise in temperature by 2°C can result in more frequent and severe heatwaves, while coastal areas may experience heavier rainfall within central Africa (Weber et al., 2018). In 2022, SSA regions have seen devastating floods, and now face the looming spectre of drought because of a La Niña event.⁴⁶

Disaster risk management (DRM) efforts in the SSA region are ongoing and evolving and over the past few years as Africa has encountered five of its deadliest weather disasters since record-keeping commenced in 1900.⁴⁷ Acting upon the severity of weather-related events, our SSA analysis indicates that several African countries have implemented DRM laws to address the growing threat of disasters. For instance, South Africa's 2002 Disaster Management Act sets out the country's approach to disaster management, creating the National Disaster Management Centre and outlining responsibilities across various government entities. While the Nigerian 2010 National Disaster Management Act formalizes the National Emergency Management Agency and disaster management strategies and Ethiopia's 2007 Disaster Risk Management Proclamation creates the Disaster Risk Management Commission and delineates responsibilities for disaster risk reduction, with an emphasis on coordination at various levels of government. Further, Uganda's Disaster Preparedness and Management Act of 2010 established the Uganda National Emergency Coordination and Operations Centre (NECOC) for DRR, response, and recovery. Similarly, Kenya introduced the Disaster Risk Management Act in 2012, establishing the National Disaster Operation Centre (NDOC) and providing a legal framework for risk assessment, early warning systems, and coordinated disaster management. These DRR laws within SSA region collectively aim to reduce risks, enhance resilience, and improve disaster response in the face of climate change through coordination, risk assessment, and early warning systems.

Further analysis reveals that the SSA countries has promulgated CLPs that address the complex relationship between climate change, sustainable agriculture, and forestry through a series of forward-looking policies and initiatives with an aim to enhance food security, reduce emissions, conserve biodiversity, and build resilience in

⁴⁵ See <https://www.rescue.org/article/10-countries-risk-climate-disaster> [Accessed 11 September 2023]

⁴⁶ See <https://nuruinternational.org/blog/nuru-views/effects-of-la-nina-in-east-west-africa/> [Accessed 5 September 2023]

⁴⁷ See <https://yaleclimateconnections.org/2023/05/five-of-africas-top-30-deadliest-weather-disasters-have-occurred-since-2022/> [Accessed 15 February 2023]

the face of a changing climate. Over the last decade, the African continent has developed the NAPs to adapt agriculture to climate change that often incorporate strategies such as drought-resistant crops and climate-smart agriculture practices (Akinagbe & Irohibe, 2014; Zougmore et al., 2018). Further, regional efforts, such as REDD+ initiatives and the African Forest Landscape Restoration Initiative, underscore the importance of forest protection and biodiversity conservation. Additionally, climate finance mechanisms such as the GCF and Payment for Ecosystem Services schemes have provided critical support. These efforts collectively represent a growing commitment to addressing climate change's impact on agriculture and forestry in SSA, with implementations spanning from the early 2000s to the present.⁴⁸

Given SSA's rich biodiversity and dependence on natural resources, environmental management and protection laws play a crucial role. Several African countries have enacted laws that address pollution control, waste management, and ecosystems safeguarding. For instance- Kenya enacted the Environmental Management and Coordination Act of 1999 and South Africa's National Environmental Management Act of 1998 provides the legal framework for environmental management, including environmental impact assessments and waste management. Similarly, Ghana's Environmental Protection Agency Act of 1994, Tanzania's Environmental Management Act of 2004 and Nigeria's National Environmental Standards and Regulations Enforcement Agency Act of 2007, created the environmental regulatory frameworks to regulate environmental protection and resource management by enforcing environmental standards and regulations. Further, to regulate fishing activities in territorial waters and to promote sustainable fisheries management and marine ecosystem, protection of endangered species, and prevention of illegal, unreported, and unregulated fishing practices, SSA regions also has the Kenya Fisheries Management and Development Act 2016 and South Africa Marine Living Act 1998 laws. Notably, being rich in forest, land and natural resources, several regulations related to the mining and extractive industries emphasize responsible resource extraction and community engagement.

With only half its population having access to electricity, SSA is the world's least electrified region. Despite relying heavily on conventional biomass for nearly half its energy needs, renewable sources like solar, wind, hydro, and geothermal hold significant

⁴⁸ For instance, Africa Agriculture Development Programme 'CAADP' in 2003, focus on sustainable agricultural growth.

potential for the region. (Mohammed et al., 2013). A review of some of the CLPs within the SSA region indicate laws and policies to reduce emissions and promote renewable energy. For instance, South Africa Renewable Energy Independent Power Producer Procurement Program 2011 aims to attract private investment in renewable energy projects, while Kenya's Feed-in Tariff, 2008 and Nigeria's National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015 is committed to sustainable energy by increasing power output and energy security. In similar line, Ghana has set ambitious targets in its Renewable Energy Master Plan in 2019 to increase the share of renewables in electricity generations mix.⁴⁹ Further, South Africa introduced a carbon tax in 2019 to disincentivise GHG emissions in industries. These initiatives among SSA countries reflect a growing recognition of the importance of sustainable energy in addressing climate change and fostering energy efficiency in the region. A report the International Renewable Energy Agency (IRENA) in partnership with the African Development Bank (AfDB) outlines a roadmap toward an energy system based on renewables. This transition is projected to yield significant economic growth, job creation, and improvements in human well-being across every region of the continent (IRENA and AfDB 2022).

Despite the imperative for climate action in SSA, the region faces substantial financial gaps. Michaelowa et al. (2021), highlight that SSA region actively engages in international cooperations and seek support from developed nations for finance support and implement climate initiatives. The IMF (2023) estimates that African continent would need USD 277 billion annually to implement its NDC and achieve climate goals by 2030, while current annual climate finance stands at only USD 30 billion. Further, regional initiatives, as emphasized by African Union's Agenda 2063 which underscore the importance of sustainable energy development and climate resilience in the region, is crucial to bridging this gap and supporting SSA in implementing effective climate initiatives.

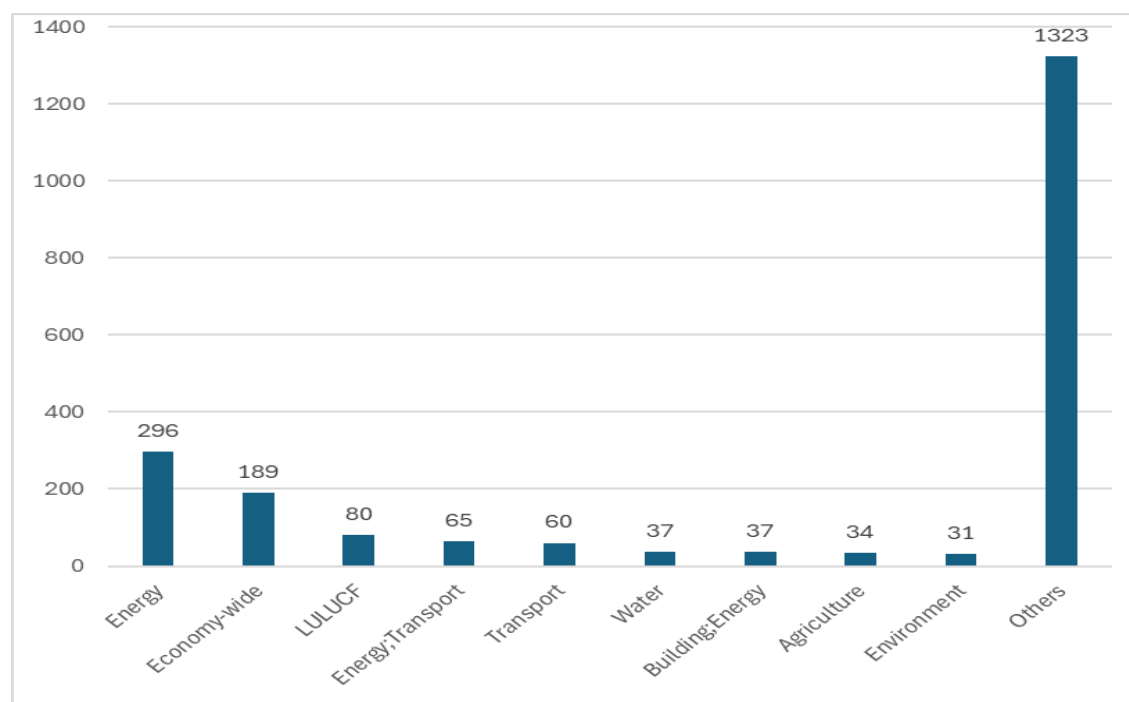
2.5.2.2 Developing and Emerging Economies (D&E)

CLP in D&E centres on comprehensive climate action while promoting sustainable development. Using LDA we derive two CLP topics within D&E economies: (i) *Disaster Management Policy for Climate Change Adaptation and Forest Preservation*, and (ii) *Efficient Electricity Production, Emission Control, and Sectoral*

⁴⁹ See https://climateactiontracker.org/documents/864/2021_08_CAT_Governance_Report_Ghana.pdf [Accessed 5 September 2023]

Policy Implementation. CCWL provides data on 2087 CLPs from 149 countries within the D&E region. Figure 2.6 shows the sectoral focus of the CLP in D&Es. We notice a strong emphasis on energy-related CLP, with 296 counts, followed by Economy-wide and LULUCF focuses with 189 and 80 counts, respectively.

Figure 2.4 Developing and emerging countries climate laws and policies top 10 sectoral focus



The figure represents the focus on CLP in emerging and developing countries. The horizontal bar represents a sector, and the length indicates the number of CLPs in that country.

D&Es are significantly more vulnerable to the effects of climate change compared to developed countries, as it may jeopardize countries' economic growth.⁵⁰ In many developing countries, the consequences of climate change are already apparent, manifesting as an increase in vector-borne diseases like malaria and dengue fever, increase in water levels, water scarcity in arid regions, decline in agriculture productivity, and on the ecosystem (Sem, 2009).

Between the years 1970 and 2019, more than 91% of the tragic fatalities over 11,000 natural disasters documented globally occurred in developing countries, with economic losses amounting to USD 3.64 trillion.⁵¹ This statistic underscores the

⁵⁰ See <https://www.un.org/en/chronicle/article/devastating-worlds-poor-climate-change-threatens-development-gains-already-achieved> [Accessed 6 September 2023]

⁵¹ See <https://news.un.org/en/story/2021/09/1098662> [Accessed 6 September 2023]

disproportionate impact of such events on vulnerable regions with limited resources and capacity to respond effectively (WMO, 2021). A report from the University of Notre Dame's Global Adaptation Index highlights that vulnerable countries have recognized climate change as a central concern in their national adaption development strategies.⁵²

Recognizing the vulnerability, D&E are proactively addressing the challenges posed by climate change through the implementation of CLPs focused on adaptation strategies. For example, Bangladesh's Climate Change Strategy and Action Plan, implemented in 2009, emphasizes disaster preparedness and resilient infrastructure. Ethiopia's Climate-Resilient Green Economy Strategy, introduced in 2011, integrates adaptation into development, focusing on sustainable land management. Costa Rica's National Climate Change Adaptation Policy from 2008 promotes ecosystem-based adaptation and water resource protection. India's National Action Plan on Climate Change since 2008 includes a mission for sustainable agriculture. Rwanda's 2011 National Climate Change Policy focuses on agriculture and disaster risk management. Vietnam's 2008 National Target Program to Respond to Climate Change prioritizes early warning systems and community-based disaster risk reduction. Similarly, Peru's 2012 National Strategy on Climate Change emphasizes water resource management and ecosystem-based adaptation strategies. These policies exemplify the D&E nations commitment to safeguard their populations and build resilience environments from the impacts of climate change.

Research indicates that D&E nations are vulnerable to natural disasters, and these disasters undermines the advancements achieved through the sustainable development efforts in these countries (Mirza, 2011; Rumpa et al., 2023). In response, developing countries are progressively incorporating disaster risk reduction strategies and resilience-building into their structural transformation to mitigate the impact of growing extreme weather events. For instance, the Philippines' Climate Change Act of 2009 established the Climate Change Commission to coordinate climate policies and DRM efforts. Similarly, Nepal's National Strategy for Disaster Risk Reduction guides its DRM endeavours by emphasizing governance, early warning systems, community preparedness, and climate integration. Bangladesh's Disaster Management Act of 2012 formalized its DRM framework, prioritizing community-based disaster preparedness.

⁵² The index uses two decades of data encompassing 45 different indicators to assess 181 countries. It takes into account both the vulnerability and preparedness of these countries to adapt effectively to various challenges. See <https://releases.gain.org/> [Accessed 6 September 2023]

Jamaica's Disaster Risk Management Act of 2015 set the stage for improved disaster risk reduction and climate adaptation measures. Similarly, Honduras National Policy on Comprehensive Risk Management and Disaster Response 2010, and India's Disaster Management Act, 2005 underscore disaster preparedness, risk reduction, early warning systems, and community-based approaches in their DRM strategies. Overall, the above CLP measures establish legal and institutional frameworks that are necessary to reduce vulnerability and protect communities, thus signifying a concerted effort to build resilience and mitigate climate-induced disasters.

According to Bhattacharya et al (2023), D&E economies are likely to emit more than half of the total global GHGs emission by 2030, necessitating strong policy commitments and substantial investments in green economies. On another note, D&E contribute significantly to global emissions, accounting for 63 percent of current global carbon emissions.⁵³ A recent report indicates that by 2030, GHG emissions from developing countries are projected to exceed those from developed nations, even when China is excluded from the calculation.⁵⁴ The reliance of developing countries on non-renewable energy, natural resources, and growing population pressures are contributing factors to carbon emissions (Hanif et al., 2019). Prior to the Paris Agreement, developing nations did not commit to binding emissions targets, often debating that wealthiest nations take the lead in emissions reduction efforts (Chandler et al., 2002). However, post Paris, D&E have started to implement various CLPs around increasing the use of renewable energy sources, improving energy efficiency in buildings and appliances, reducing deforestation, and promoting the use of public transportation to reduce emissions. For instance, China's 13th Five-Year Plan 2016 Chile Energy Efficiency Law 2016, Costa Rica and Law for the Promotion of Electric Transportation 2018, outlines emission reduction and environmental goals in various sectors.

Developed countries can play a pivotal role in assisting D&E by providing financial support, facilitating technology transfer and offering support in capacity building. More importantly, a collective and shared responsibility between developed and developing nations is crucial to effectively combat climate change and promote a sustainable global future.

⁵³ See <https://www.cgdev.org/media/developing-countries-are-responsible-63-percent-current-carbon-emissions> [Accessed 6 September 2023]

⁵⁴ See <https://www.brookings.edu/articles/developing-countries-are-key-to-climate-action/> [Accessed 6 September 2023]

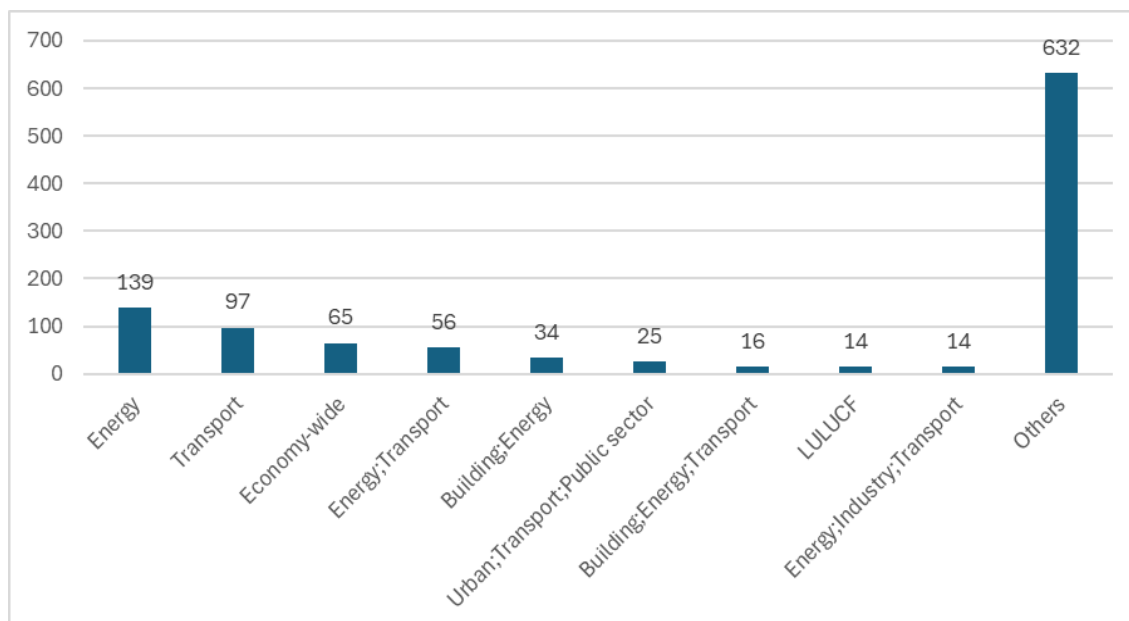
2.5.2.3 Advanced Economies

Over the years, advanced economies (developed nations) have adopted strategies that encompass promoting low-carbon technologies, energy efficiency, sustainable consumption behaviours and have enforced carbon pricing policies to lower their per capita CO₂ emissions (Mendelsohn et al., 2012). Although developed countries have initiated efforts to mitigate climate change, to achieve the climate commitments and avoid potential catastrophe a fundamental shift in worldviews and policy approaches is necessary (Leichenko & O'Brien, 2020; Redclift & Hinton, 2008). Further, at the COP 27 in 2021, delegates from developing countries stressed that developed countries should take a lead and deliver on their commitments to achieve the Paris Agreement.⁵⁵ Specifically, Indian delegates highlight the need that developed countries should take additional steps and commit to net-minus rather than net-zero emissions.

Using the LDA method on 986 CLPs obtained from CCWL data from 40 developed countries, we extract the following four thematic areas of CLPs in advanced economies: (i) *Climate Change Risk and Adaptation Strategies*, (ii) *EU Recovery, Resilience, Support and Investment Reforms*, (ii) *Reducing Greenhouse Gases Emissions through Targeted Government Initiatives and Carbon Reduction Strategies* (iv) *Electricity Efficiency and Building Artistic Installation and Production*. Figure 2.7 shows the sectoral focus of the CLP in Advanced Economies. We document a pronounced emphasis on energy-related CLP, with 139 counts, followed by transport and economy-wide focuses with 97 and 65 counts respectively.

Figure 2.5 Advanced countries climate laws and policies sectoral focus

⁵⁵See <https://press.un.org/en/2022/gaef3566.doc.htm> [Accessed 8 September 2023]



The figure shows the sectoral focus of CLP in advanced countries. Each category is represented by a horizontal bar, the length of which indicates the number of CLPs in that sector.

Energy security and a continuous energy supply are essential elements for promoting sustainable economic development (Blum, 2015). According to IEA (2021), to achieve climate goals of net zero without impeding economic advancement, countries must emphasize comprehensive and transformative energy efficiency strategies throughout their entire economies. IPCC (2022) special report on Global Warming of 1.5°C highlights that energy efficiency stands out as one of the primary methods by which the world can satisfy its growing demand for energy services while significantly lowering energy consumption. The EU actively advocates for the principle of 'energy efficiency' under the revised 2030 EU Climate and Energy Target that encompasses several key objectives such as a 40% reduction in GHG emissions compared to 1990 levels, a target of 27% energy consumption from renewable sources, and a matching 27% target for improved energy efficiency (Zhang et al., 2021).

At the country level, advanced economies have enacted several CLPs aimed at enhancing energy efficiency and reducing GHG emissions. For example, among the first nations, Japan enacted the Rational Use of Energy Act in 1979 to promote energy-efficient technologies and practices in industry and transportation. Almost two decades later, the Energy Efficiency Act 1997 in Sweden included the measures for energy audits and building standards. The German Renewable Energy Sources Act 2000 incentivizes renewable energy production by providing feed-in tariffs for renewable energy producers. While the United Kingdom's Climate Change Act 2008 and the French Energy Transition

for Green Growth Act 2015 set ambitious emissions and renewable energy targets and improve energy efficiency; Denmark's Energy Efficiency Obligation Scheme 2012 encourages energy savings in their customer base, promoting energy efficiency measures in residential and commercial buildings. These CLPs collectively underscore the commitment of advanced nations to a sustainable, low-carbon future by embracing cleaner energy sources, enhancing energy efficiency, and reducing emissions across various sectors. For instance, the United States National Energy Efficiency Standards 1987 for appliances and equipment have resulted in nearly USD 2 trillion in savings for American homes and businesses on their utility bills and is recognized as one of the nation's most effective energy policies.⁵⁶

The global shift towards clean energy is in progress, yet its speed and extent vary widely among nations and industries (Sun et al., 2020). In this context, United States Clean Power Plan (rescinded in 2019) sought to limit GHG emissions from power plants by promoting renewable energy and energy efficiency. Later in 2022 the US passed Inflation Reduction Act wherein the US government provides USD 369 billion for clean energy production, clean manufacturing, clean vehicle, and clean buildings. The energy sector is at the forefront of this transition in advanced economies when compared to D&E which encounter more obstacles due to their economic conditions and lack of fundings (Gosens, 2020). A global equitable clean energy transition can be accelerated by policy backing technological advancements, and greater financing and investment (Gingerich, 2018). Moreover, the net-zero emissions and the transition to clean energy should be achieved while maintaining the focus on the immediate needs of energy reliance and affordability (Pacthod et al., 2022).

According to the IEA (2021) report, despite the worldwide commitment to achieve net-zero, the current pledges by advanced economies fall short of what is needed to achieve global net-zero carbon dioxide emissions from energy by 2050. The report indicates that a clean, dynamic, and resilient energy economy should be primarily driven by renewable sources like solar and wind, replacing fossil fuels.

Furthermore, our analysis indicates that transportation, building, and agriculture sectors were the key focus sectoral focus of CLPs among the advanced economies. For instance, California's Zero-Emission Vehicle 1990 requires automakers to produce

⁵⁶ See <https://www.nrdc.org/resources/2-trillion-success-story-energy-efficiency-standards> [Accessed 11 September 2023]

electric cars, promoting clean transportation. Australia's National Construction Code 2022 sets energy efficiency standards for buildings, while Germany's Passive House Standard 1996 and Ireland's Building Regulation 2012 encourages ultra-energy-efficient construction. In agriculture, the French Ecophyto Plan 2008 seeks to reduce pesticide usage through sustainable practices, and Denmark's Organic Action Plan 2011 promotes organic farming. These initiatives exemplify the importance of tailored approaches to address climate challenges in different sectors, recognizing that a one-size-fits-all solution is not sufficient.

Climate related extreme weather events are on rise globally, including in advanced nations. In 2021, the US experienced Hurricane Ida and severe winter weather in the south and central regions, resulting in 542 fatalities and a cost of USD 121 billion to the US economy.⁵⁷ In Canada, British Columbia recorded an unprecedented temperature of 49.6°C on June 30, 2021.⁵⁸ The southwestern US endured multiple heatwaves, with Death Valley, California, reaching 54.4°C on July 9th, 2021, marking the highest temperatures ever recorded globally since the 1930s.⁵⁹ Additionally, 2021 witnessed numerous wildfires, including the Dixie fire in northern California, which started on July 13th and engulfing approximately 390,000 hectares of land by October 7th, making it the largest single fire in California's recorded history.⁶⁰

As intensifying extreme weather events are becoming more frequent, it becomes imperative for critical infrastructure facilities to reevaluate their construction standards and planning frameworks to endure these events. In this context, advanced nation integrates various climate adaptation into their legal frameworks and policy agendas. Notable examples include Germany's Adaptation Action Plan 2008, addressing climate risks and adaptation measures; the Netherlands' Delta Programme 2010 to tackle sea-level rise and flooding vulnerabilities; Australia's National Climate Resilience and Adaptation Strategy (2015), emphasizing sector-specific resilience, the US Executive Order 13653, 2013 requiring federal adaptation plans and the National Climate Assessment reports, and Canada's Pan-Canadian Framework on Clean Growth and

⁵⁷ See <https://yaleclimateconnections.org/2022/01/the-top-10-global-weather-and-climate-change-events-of-2021/> [Accessed 11 September 2023]

⁵⁸ See <https://earthobservatory.nasa.gov/images/148530/blazes-rage-in-british-columbia> [Accessed 11 September 2023]

⁵⁹ See <https://www.bbc.com/news/world-us-canada-53788018> [Accessed 11 September 2023]

⁶⁰ See <https://unfccc.int/news/state-of-climate-in-2021-extreme-events-and-major-impacts> [Accessed 11 September 2023]

Climate Change 2016, which prioritizes infrastructure resilience and Indigenous-led adaptation. Further, Norway's National Strategy for Adaptation to a Changing Climate 2013 to enhance climate resilience in agriculture, energy, and health sectors emphasise research and monitoring. Similarly, Denmark's Climate Change Adaptation Plan 2008 addresses adaptation in key sectors, such as agriculture, water resources, and urban planning. Furthermore, New Zealand's Climate Change Adaptation Technical Working Group formed in 2017 provides guidance on adaptation strategies, including sea-level rise planning, resilient infrastructure, and natural hazard management.

The Key elements of these policies include risk assessments, early warning systems, resilient infrastructure, and cross-sectoral coordination. The integration of climate adaptation into legal frameworks demonstrates the commitment of advanced economies to addressing climate change as a central aspect of their sustainable development agendas. In advanced economies, future CLPs must focus on enhancing climate resilience, fostering innovation, and integrating cross-sector collaboration. It is imperative that these efforts should include concerted efforts towards public education, global cooperation, and continuous risk assessment leading to climate resilient future.

Climate change remediation requires long-term sustainable growth and countries preventive action. In this context, the development of green finance holds significant importance because green finance offers the potential to the support the transition and development of critical infrastructure required to combat and mitigate the impact of climate by secure funds for eco-friendly projects, promoting innovation and developing renewable energy systems (Martin, 2023). The G20 Green Finance Comprehensive Report 2016 introduced the concept of green finance, defining it as an investment and financing activity aimed at producing environmental benefits and promoting sustainable development (Ouyang et al., 2023).⁶¹ According to United Nations Environment Programme, green finance can be promoted through regulatory frameworks and increased investment in clean and green technologies, increased use of green bonds and financing sustainable natural resource-based green economies and climate smart blue economies.⁶²

⁶¹ The roots of green finance can be traced back to the 1970s, when Germany established the world's first policy-based environmental bank to provide preferential loans for environmental projects (Xue et al., 2023).

⁶² See <https://www.unep.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/green-financing#:~:text=Green%20financing%20could%20be%20promoted%20through%20changes%20in,incrase%20use%20of%20green%20bonds%2C%20and%20so%20on.> [Accessed 11 September 2023]

Several advanced economies have introduced CLPs to encourage green finance and establish legal frameworks that facilitate sustainable, low-carbon investments. For example, UK Green Finance Strategy 2019, and endorsement of the Task Force on Climate-related Financial Disclosures recommendations 2017, aims to encourage investments in green projects and sets the stage for sustainable finance initiatives and requires organizations to disclose climate-related financial risks and opportunities, promoting transparency. Similarly, Germany's Sustainable Finance Strategy 2019, aims at encouraging sustainable investments and responsible banking practices. Canada established the Sustainable Finance Action Council in 2019 to increase green finance, while Japan's financial industry embraced the Principles for Financial Action towards a Sustainable Society in 2019, emphasizing sustainability and climate action. Overall, our analysis suggests that the current set of CLPs in advanced economies emphasize transparency, provide guidance on environmentally responsible activities, and incentivize sustainable financial practices. However, it is recommended that advanced economies promote international collaboration, offer financial incentives for green investments, enhance reporting and disclosure requirements, raise awareness about green finance, support innovation, and prioritize long-term climate planning to expedite the transition towards a sustainable, low-carbon future.

Finally, Table 2.6 summarise the difference in CLP themes in three distinct economies discussed in this section. Despite the unique challenges each economy face in addressing climate change, all three share a common recognition of taking action to tackle climate change.

Table 2.4 Difference in climate laws and policies themes in three distinct economies

Sub-Saharan African	Emerging and Developing Economies	Advanced Economies
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Disaster Management and Adaptation: Focus: Prioritising disaster management strategies and adaptation measures. Challenges: Limited resources and infrastructure hinder effective disaster response. Policy Approach: Emphasis on community-based resilience and early warning systems. Forest Protection and REDD Initiatives: Focus: Policies aim to preserve forests and combat deforestation. Challenges: Illegal logging and land-use conflicts. Policy Measures: Implementing forest protection laws, promoting sustainable practices, and engaging local communities. Climate Risk Assessment: Focus: Rigorous assessment of climate risks. Challenges: Data gaps and capacity limitations. Policy Measures: Developing risk maps, vulnerability assessments, and climate adaptation plans.	Renewable Energy Sources: Focus: Transitioning to cleaner energy. Challenges: Balancing economic growth with environmental concerns. Policy Measures: Incentives for renewable energy adoption, grid integration, and capacity building. Resource Management: Focus: Sustainable use of natural resources. Challenges: Population growth and resource depletion. Policy Measures: Land-use planning, water management, and conservation regulations. Disaster Action Plans: Focus: Preparedness and response. Challenges: Limited infrastructure and funding. Policy Measures: Early warning systems, community training, and disaster recovery plans.	Emission Control and Efficiency: Focus: Reducing greenhouse gas emissions. Challenges: Balancing economic growth and environmental impact. Policy Measures: Stringent emission standards, carbon pricing, and clean technology adoption. Sector-Specific Policies: Focus: Tailored policies for different sectors. Challenges: Industry resistance and regulatory complexity. Policy Measures: Sector-specific targets (e.g., transportation, industry, agriculture). Government-Led Initiatives: Focus: Government plays a central role. Challenges: Political dynamics and public support. Policy Measures: Research funding, innovation hubs, and public-private partnerships. Green Recovery and Resilience: Focus: Post-pandemic recovery with sustainability. Challenges: Economic stability and job creation. Policy Measures: Investment in green infrastructure, circular economy, and climate resilience.
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The table highlights the differences in CLPs themes based on the topics derived within the specified

economies.

Overall, the research question 2 examines whether the thematic composition of CLPs across countries and economies, with particular emphasis on sectoral similarities and differences. The findings indicate that while there is a core set of sectors that consistently appear across economies, however the emphasis and policy framing of these sectors differs systematically by economic structure and development level.

For instance, across countries, a high degree of sectoral similarity is observed in areas such as energy, emissions mitigation, and adaptation-related infrastructure. These themes emerge consistently across advanced, emerging, and developing economies, indicating the global convergence of climate governance priorities driven by international agreements such as the Kyoto Protocol and the Paris Agreement (Averchenkova et al., 2017; Eskander & Fankhauser, 2020). Additionally, the observed themes suggests that CLPs globally share a common baseline, particularly in sectors directly linked to greenhouse gas mitigation and climate risk management.

However, research question 2 also reveals pronounced sectoral differences in CLPs emphasis. For example, advanced economies exhibit a stronger concentration of CLPs in sectors related to energy transition, industrial decarbonisation, carbon pricing, and technological innovation. This reflects both higher institutional capacity and the availability of financial and technological resources required to implement market-based and innovation-driven climate policies (Newell et al., 2014; Popp et al., 2020). In contrast, emerging and developing economies reveal a greater emphasis on adaptation, agriculture, water resources, and disaster risk management. These differences are consistent with higher climate vulnerability, greater dependence on climate-sensitive sectors, and more immediate exposure to physical climate risks (Fankhauser & McDermott, 2014; Kahn et al., 2021). Notably, the themes do not indicate weaker climate commitment rather it shows a sectoral pattern which reflects differentiated policy priorities shaped by economic structure and exposure to climate risk.

Importantly, the sectoral variation occurs primarily in relative intensity rather than in sectoral presence. Most countries legislate across similar sectoral domains, but allocate legislative attention differently depending on development stage, fiscal capacity, and climate risk exposure. For instance, the energy sector in India and Germany, while both countries legislate extensively on renewable energy and emissions, Germany's Renewable Energy Sources Act enforces aggressive decarbonisation targets under the

Energiewende, whereas India's Energy Conservation Act and National Solar Mission reflect a more gradual, development-oriented transition demonstrating that variation lies in legislative intensity rather than sectoral coverage. This finding supports the principle of common but differentiated responsibilities in climate governance, whereby countries pursue climate objectives through sectoral pathways aligned with domestic economic and institutional conditions (Keohane & Victor, 2016; Tobin et al., 2018). Overall, the nuanced pattern highlights that cross-country differences in climate legislation are not random, but systematically linked to economic structure, development level, and exposure to climate risk.

2.5.3 Climate Pledges and Evolution of Climate Law and Policies

Leaders from 178 nations attended The Earth Summit 1992 that established the United Nations Framework Convention on Climate Change (UNFCCC) in part as an international environmental treaty to combat climate change by limiting average global temperature increases.⁶³ The Earth Summit is recognized as first binding treaty that address several key climate issues (replace the use of fossil fuels, vehicle emission, protect endangered species, water uses and supply, ocean protection, and polluter pay principle).⁶⁴ This conference result in the adoption of Agenda 21, a comprehensive plan for sustainable development, which was adopted by United Nation later in 2015.

Following the Earth Summit, the 1997 Kyoto Protocol and the 2015 Paris Agreement, were major climate conferences that introduced a legally binding emission reduction target, paving the way for more structured approach to climate commitments.⁶⁵ Specifically, Kyoto Protocol called for reducing the emission of six GHGs by 5.2 percent below 1990 levels in developed countries and established a system to monitor the countries' progress.⁶⁶ The treaty, however, did not compel developing countries, including major carbon emitters China and India, to take action. This gap was filled in the 2015 Paris agreement which requires all countries to set emissions-reduction targets,

⁶³ A total of 154 states signed this treaty at the United Nations Conference on Environment and Development (UNCED).

⁶⁴ See <https://www.un.org/en/conferences/environment/rio1992> [Accessed 22 August 2023]

⁶⁵ See <https://www.cfr.org/backgrounder/paris-global-climate-change-agreements> [Accessed 23 August 2023]

⁶⁶ Britannica, T. Editors of Encyclopaedia (2023, May 23). Kyoto Protocol. Encyclopedia Britannica. <https://www.britannica.com/event/Kyoto-Protocol>, Six GHGs are Methane, Nitrous Oxide, Carbon Dioxide, Chlorofluoro carbon, Carbon monoxide, Sulphur dioxide.

with most countries having agreed to a common goal of holding global average temperature increase to well below 2°C of pre-industrial levels and pursue efforts to limit temperature rise to 1.5°C (UNFCCC, 2015). Unlike other climate pledges, Paris agreement applies bottom-up and top-down approach, allowing nations to set their own NDCs (King & Van Den Bergh, 2019).

Despite this, adequacy of aggregated pledges in limiting global temperature rise to well below 2°C, a central aim of the Paris Agreement, has been questioned. Despite the Paris agreement net-zero target, there are only 14 countries and the European Union that has net-zero related climate laws.⁶⁷ Recently, the Copernicus Climate Change Service in Brussels has disclosed that the mean global temperature between February 2023 and January 2024 set a new record, reaching at 15.02°C, that is 1.52°C higher than the pre-industrial period of 1850-1900.⁶⁸

The international climate pledges encourage national governments to align their policies with global climate goals. Since 2015, dozens of countries have submitted stronger pledges to align to the goals of the Paris Agreement.⁶⁹ In our analysis, we observe that many countries implemented CLPs after the Kyoto Protocol and the Paris agreement, signalling countries' commitment to climate goals. For example- EU-ETS implemented in 2005, which is the world's largest carbon market, sets a cap on GHG emissions for approximately 10000 industrial sites. Similarly, the European Climate Law in 2021 aims to ensure that the EU achieves net-zero GHG by 2050 and establishes an interim target of at least a 55% reduction in emissions by 2030 compared to 1990 levels. Thus, the Earth summit, Kyoto and Paris climate conventions gives us an interesting setting to further investigate the evolving international CLP regulatory landscape following these events. Given the importance of three major climate agreements and the progress in implementing CLPs, we investigate our third research question: *Does the focus of climate laws and policies differ based on climate pledges?* To best of our knowledge, this is the first study that delves into the underlying theme of climate laws and policies that has evolved post these three climate agreements.

We group our post climate agreement CLP sample based on the year it came into the force due to two main reasons. First, the year of climate agreements is the starting

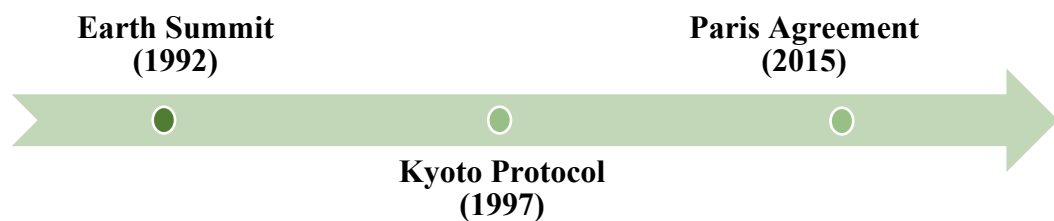
⁶⁷ See <https://www.wri.org/insights/net-zero-ghg-emissions-questions-answered> [Accessed 22 August 2023]

⁶⁸ See <https://climate.copernicus.eu/global-climate-highlights-2023> [Accessed 22 February 2024]

⁶⁹ See <https://climateactiontracker.org/climate-target-update-tracker-2035/> [Accessed 02 August 2025]

point for crafting the legal language, commitments, and discussion on developing CLPs. Second, the ratification of climate agreements occurred at different times for different countries, so ratified countries can implement or start working towards drafting climate legislation immediately after countries signed the climate agreement. For example, Canada, Germany and Japan ratified the Kyoto Protocol in year 2002 that is before the Kyoto Protocol (February 2005) officially came into force for all the countries. Following the ratification Japan implement first Strategic Energy Plan in June 2002, which sets out provision for resilient and environmentally friendly supply of energy. Similarly, Canada Implemented Canadian Environmental Protection Act (CEPA) 1999 that aims to protect the environment and human health in Canada by preventing pollution and promoting sustainable development. Further, under the section 46 of CEPA, Canada launched a program in December 2004 to collect information on greenhouse gas emissions from industrial facilities in Canada. Figure 2.8 illustrate the timeline of three major global climate agreements. We analyse the important keywords identified by LDA and generate the most appropriate titles for all the three climate agreements (see table 2.7).

Figure 2.6 Three major international climate agreements timeframe



The figure presents the timelines of three pivotal international climate agreements that we have used in our study.

Table 2.5 The list of defined topics on climate conventions and associated keywords within each topic

Post-Earth Summit	Post- Kyoto Protocol	Post-Paris Agreement
keywords: law, air, emission, environmental, protection impact, environment, act activity, assessment	keywords: forest, environment, management, law, national protection, act, fund, ministry, change	keywords: plan, efficiency emission, carbon, electricity, sector, support, transport investment, eu
Topic 0: Air Emission Impact Assessment and Environmental Protection Activities	Topic 0: Forest Protection Law and Fund for change	Topic 0: Electricity Efficiency planning, Carbon control in the Transport Sector, and EU Support
keywords: electricity, source, power tariff, law, market, plant, purchase	keywords: change, policy, adaptation plan, strategy, disaster, management	keywords: law, emission, act, article, art, gas, government, greenhouse, carbon, regulation

amendment, green	sector, risk, action	Topic 1: Law and Regulation for Greenhouse Gas and Carbon Emission Control
Topic 1: Tariff Law Amendment for Sustainable Power Plant Sources	Topic 1: Disaster Risk Management and Adaptation Plan	
keywords: forest, law, conservation programme, change, fund, sector tax, protection, climate	keywords: emission, carbon ghg, reduction, act, gas, change greenhouse, plan, sector Topic 2: Greenhouse Gas Emission and Carbon Reduction Plan	keywords: change, policy, development, adaptation, management, strategy, plan, national, action, sector Topic 2: Policy and Strategy for Climate Change Adaptation and Management
Topic 2: Forest Conservation Programme and Sector Fund Allocation for Climate Change and Protection		
	keywords: electricity, efficiency, source, law, production, power, act, consumption, building, sector Topic 3: Electricity Efficiency and Source of Power Production	

Table 8 indicates the topic derived and keywords associated with each topic across the three different climate conventions.

2.5.3.1 Post Earth Summit

The June 1992 Earth Summit in Rio de Janeiro laid the groundwork for global climate governance. This event marked the largest assembly of global leaders with participation from 117 heads of state and representatives from 178 countries. At the Earth Summit, world leaders and representative from countries agreed on 27 nonbinding principles for environmentally sustainable development, while Agenda 21 outlined global strategies for environmental preservation and sustainable development.⁷⁰ Additionally, the Statement of Principles on Forests aimed to safeguard tropical rainforests by advising nations to monitor and protect their forest resources was agreed.⁷¹

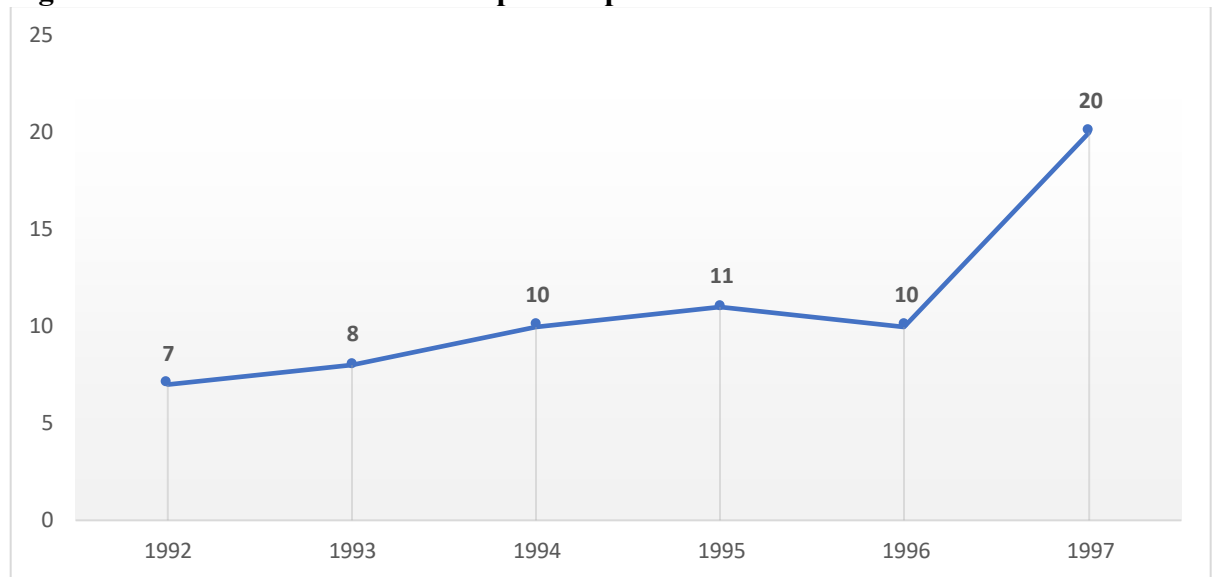
Between 1992 and 1997 (post-Earth Summit period), 51 countries passed a total of 66 climate-related laws. Among these countries, Cuba with 7.58 percent of all CLPs accounts for the highest number of climate laws. Using LDA, we derive the following 3 topics of CLPs for post-Earth Summit period: (i) *Air Emission Impact Assessment and Environmental Protection Activities*, (ii) *Tariff Law Amendment for Sustainable Power Plant Sources*, and (iii) *Forest Conservation Programme and Sector Fund Allocation for Climate Change and Protection*. Figure 2.9 indicates a total number of CLPs each year.

⁷⁰See <https://www.britannica.com/topic/member-states-of-the-United-Nations-UN-2226365> [Accessed 15 September 2023]

⁷¹ See <https://www.un.org/en/conferences/environment/rio1992> [Accessed 15 September 2023]

We find a noticeable increase in CLP, from 7 in 1992 to around 10 in 1994 to 1996, and then a significant increase in 1997, reaching 20 CLP.

Figure 2.7 Count of climate laws & policies post-Earth summit



The figure illustrates trends and patterns in the implementation of CLP post-Earth Summit from 1992 to 1997.

The Vienna convention 1985 and Montreal Protocol 1987 highlighted the issues of Ozone layer depletion and actions needed to control it. Several nations enacted various law and policies to regulate emissions and improve air quality. In the context of Air Emission Impact Assessment and Environmental Protection Activities, European Community Eco-Management and Audit Scheme (EMAS) Regulation in 1993, promoted environmental management and performance improvements, and Japan's Action Plan for the Control of Global Warming in 1994, outlined strategies to control GHG emissions. Similarly, Australia's National Greenhouse Response Strategy in 1992 and the National Environment Policy in India in 2006 emphasized emission control and air quality management.

Notably, countries implemented several CLPs on the 'Green Power Purchase and Tariff Law Amendment for Sustainable Power Plant Sources'. For instance, United States introduced the Renewable Energy Production Incentive (REPI) program in 1997 under the Energy Policy Act of 1992, while Germany established the Electricity Feed-In Act called as Stromeinspeisungsgesetz (SEG) to encourage renewable energy production that was later replaced by Renewable Energy Source Act 2000 (Böhringer et al., 2017). The REPI program provides a payment of 1.2 cents per kilowatt-hour for electricity produced from eligible renewable energy sources and promote the utilization of renewable energy

sources.⁷² Further the European Union's the SAVE Program launched in 1992 focused on enhancing energy efficiency in buildings and appliances and similarly, the United Kingdom's Energy Efficiency Commitment in 1995, encouraged energy suppliers to implement energy-saving initiatives in homes and businesses. In the United States, Environmental Protection Agency's Energy Star program in 1992 implemented the energy labels that required to provide information on the energy consumption of products and devices using different standardized methods in homes, commercial buildings, and industrial plants. In addition, the Australian National Greenhouse Response Strategy, established in 1992, outlined comprehensive measures to reduce GHG emissions, including a significant emphasis on energy efficiency and conservation.

In the years leading up to the Kyoto Protocol, only few countries initiated foundational forest conservation programs, recognizing the interplay between forests and climate change mitigation. In 1996, Costa Rica established a framework for sustainable forest management, emphasizing reforestation and the creation of protected areas. Also, in late 1990s, Costa Rica started a Forestry Law and Payment for Environmental Services program, aimed at allocating funds to landowners for maintaining forest cover. Further, Sweden with its rich forest resources implemented Forest Act of 1993, exemplified early commitment to sustainable forestry practices. These early initiatives laid the foundation for more comprehensive efforts to align forest conservation with climate change mitigation and protection objectives, setting the stage for more comprehensive international efforts in subsequent years.

2.5.3.2 Post Kyoto Protocol

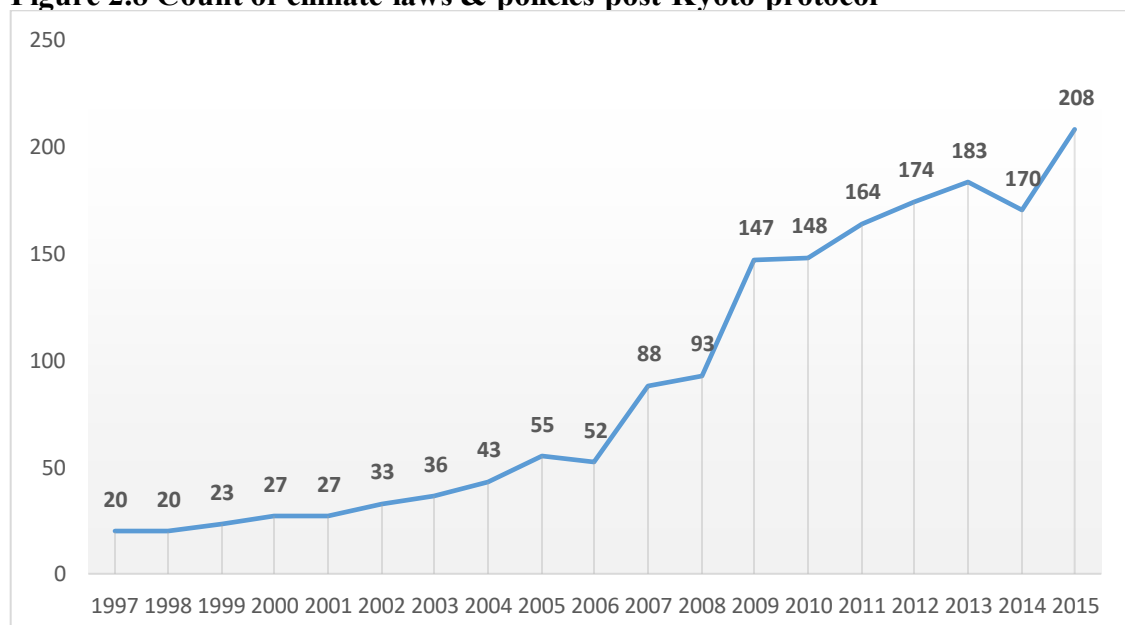
The Kyoto Protocol on December 11, 1997 (that came into force on 16 February 2005), marked a turning point in international climate legislations, introducing legally binding emission reduction targets from developed nation. The Kyoto Protocol operationalizes the UNFCCC by requiring developed countries and transitioning economies to limit and reduce GHGs emissions in line with NDC targets. The Protocol mandates binding emission targets for the first commitment period (2008-2012) to achieve a five percent reduction from 1990 levels (Jakeman et al., 2002). In the second commitment period (2013-2020), countries pledged to cut emissions by at least 18 percent below 1990 levels. An essential aspect of the Kyoto Protocol is the introduction

⁷² See <https://archive.epa.gov/epawaste/hazard/wastemin/web/html/rpsinc.html> [Accessed 15 September 2023]

of flexible market mechanisms, allowing emissions permit trading (Mckibbin & Wilcoxon, 1999). It also establishes rigorous monitoring, review, and verification processes and a compliance system for transparency and accountability. The Protocol additionally supports countries in adapting to the adverse impacts of climate change and encourages technology development for enhanced resilience. Furthermore, the Kyoto Protocol established the Adaptation Fund, which finances adaptation projects and programs in developing countries that are signatories to the Protocol.⁷³

We derive the following four themes of CLP for the post Kyoto Protocol Summit i.e, between 1997 to 2015: (i) *Forest Protection Law and Fund for change*, (ii) *Disaster Risk Management and Adaptation Plan*, (iii) *Greenhouse Gas Emission and Carbon Reduction Plan*, and (iv) *Electricity Efficiency and Source of Power Production*. These topics reflect global efforts to combat climate change directly aligned with the Kyoto Protocol guidelines. It is important to note that there has been a significant increase in CLPs post-Kyoto Protocol, resulting in the implementation of 1711 CLPs across 195 countries. Brazil leads in the number of CLP enacted, contributing 2.16 percent of the total CLP implemented between 1997 to 2015. Figure 2.10 indicates a total number of CLPs each year. The substantial increase after 2008 indicates the commitment of countries to address climate change issues, reaching 208 CLP by 2015.

Figure 2.8 Count of climate laws & policies post-Kyoto protocol



The figure illustrates the evolution of CLP post the Kyoto Protocol, spanning from 1997 to 2015.

⁷³See https://unfccc.int/kyoto_protocol [Accessed 16 September 2023]

In our analysis, we notice numerous CLPs were enacted across the four distinct themes. For example, in the realm of Forest Protection Law and Fund for change, Norway's Forestry Act 2005 aims to combat deforestation and promote sustainable management of forest resources. Norway's annual commitment of USD 440 million surpasses the USD 100 million pledged by the United States under the Tropical Forest Conservation Act (TFCA).⁷⁴ Similarly, Indonesia's Moratorium on Forest Conversions 2011 and Brazil's Forest Code revised in 2012 outlines stringent regulations for landowners, focusing on protection of forest ecosystem, restoration, and responsible land use practices. Importantly, Indonesia paused the conversion of primary forests and peatlands into agricultural land, acknowledging the ecological significance of these areas (Sloan, 2014).

In the context of the Disaster Risk Management and Adaptation Plan, the Kyoto Protocol established the Adaption fund in 2001 to support the adaptation programmes and projects in developing countries.⁷⁵ We notice several countries implemented disaster risk management and adaptation plan related laws and initiatives to address the challenges posed by climate change and natural disasters. Japan introduced Act on Promotion of Global Warming Countermeasures 1998 which was further revised in 2002 and 2005. The act promotes the development of adaptation plans and strategies to manage the risks posed by climate-related disasters. Similarly, various other countries disaster management CLPs includes Namibia's National Disaster Plan 1998, Panama Decree No. 156 on the National Civil Protection Plan 2002, and South Korea Framework Act on the Management of Disasters and Safety 2004. These laws underscore the global recognition of the need for robust disaster risk management and adaptation plans to build resilience and mitigate the impacts of climate-related disasters.

Further, we document countries enacted laws and policies on 'Greenhouse Gas Emission and Carbon Reduction Plan', as mandated under the Kyoto Protocol for emission reduction targets. For Instance, UK's Climate Change Act 2008 introduced binding emissions targets for various sectors, and California's Global Warming Solutions Act (AB 32) 2006 set ambitious emissions reduction goals. Similarly, Netherland's Environmental Management Act 2004, Italy's National Plan for Biofuels and Biomass 2000, and Austria's Climate Strategy 2002 aims to cut the emissions from various sectors

⁷⁴See <https://news.mongabay.com/2009/03/norway-emerges-as-champion-of-rainforest-conservation/> [Accessed 04 November 2023]

⁷⁵ See <https://unfccc.int/Adaptation-Fund> [Accessed 4 November 2011]

and promote the deployment and adoptions of sustainable sources.

Finally, countries worldwide implemented various CLPs aimed at improving electricity efficiency and transitioning to sustainable sources of power production. For example, Germany's Renewable Energy Sources Act (2000) set the stage for a renewable energy revolution, while Japan's Feed-In Tariff System in 2012 encourage the use of renewables following the Fukushima disaster (Wen et al., 2021). Furthermore, EU introduced the Ecolabel Regulation in 2010, which promotes the eco-friendly products and responsible consumption. Other CLPs such as Denmark's Electricity Supply Act 1999, India's Electricity Act 2003 introduced the provision for integration of renewable energy sources into the national grid and off-grid renewable power projects across the country. The above efforts are mainly driven by a growing awareness of the environmental impacts of conventional energy sources. However, specific measures varied across different countries, the overall trend emphasize the promotion of renewable energy and the adoption of energy-efficient technologies for more sustainable and low-carbon future.

2.5.3.3 Post Paris Agreement

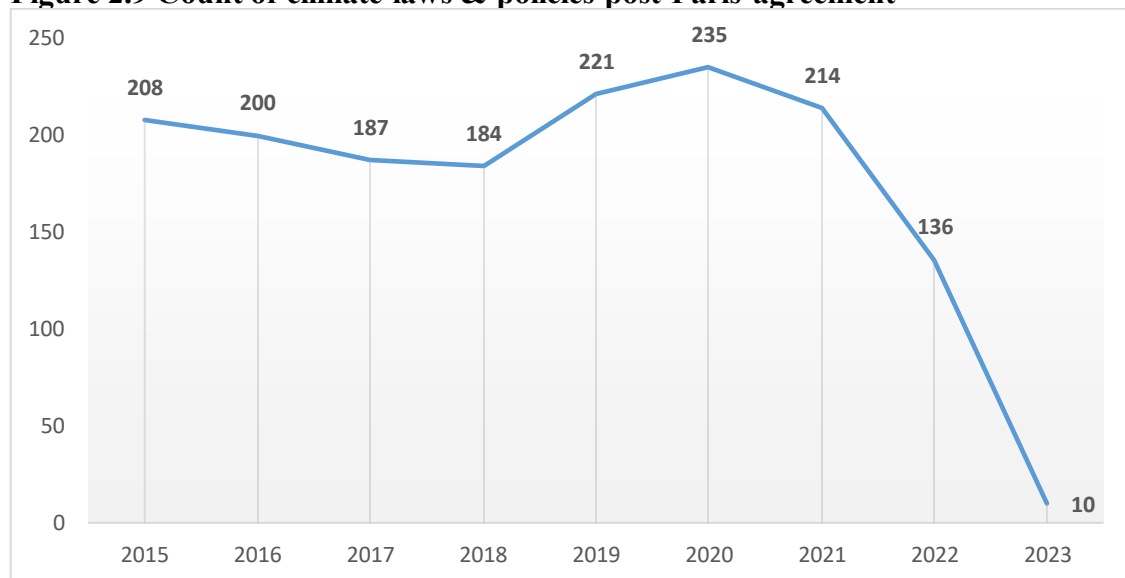
The 2015 Paris Agreement constitutes a legally binding international treaty on climate change. The primary objective of the Paris Agreement is to strengthen the global response to climate change by aiming to maintain the global temperature rise well below 2 degrees Celsius, with an additional effort to limit the increase to 1.5 degrees Celsius. The agreement comprises 16 introductory paragraphs and 29 articles and mandated participating countries to submit a plan outlining their actions to reduce GHG emissions, termed as their NDCs.⁷⁶ These NDC plans undergo regular review and update every five years, in the hope that global ambition can be increased through a process of 'naming and shaming' (Falkner, 2016). The agreement also establishes a monitoring and reporting system to track progress toward achieving its objectives, including regular emissions reports and assessments of NDC compliance (Burleson, 2016). Furthermore, the Paris Agreement requires developed nations to provide financial support to developing countries, facilitating their transition to low-carbon economies and adaptation to climate change impacts. It also sets a global goal for enhancing adaptation measures, building resilience, and reducing vulnerability to climate change effects. Schleussner et al. (2016) note that several countries' mitigation targets for the period between 2020- 2030 fall short

⁷⁶See <https://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf> [Accessed 17 September 2023]

of what is needed to attain the temperature goal.⁷⁷

An LDA analysis on the post-Paris agreement period, reveals three distinct themes: (i) *Electricity Efficiency planning, Carbon control in Transport Sector, and EU Support*, (ii) *Law and Regulation for Greenhouse Gas and Carbon Emission Control*, and (iii) *Policy and Strategy for Climate Change Adaptation and Management*. These topics shows essential aspects of global endeavours to address climate change, with some directly aligning with the Paris Agreement's directives i.e. GHG emission control. Notably, there has been a considerable rise in CLPs following the Paris Agreement, leading to the introduction of 1595 climate-related laws and policies across 187 countries. France stands out with the highest number of CLPs implemented, accounting for 4.08 percent of the total laws and policies enacted from 2015 to June 2023. Interestingly, there is an initial decline in CLP implementation, decreasing from 208 in 2015 to 184 in 2018. Subsequently, peaking at 235 CLP in 2020. However, there is a sharp decline in the years following Covid-19 pandemic, plummeting significantly to just 10 climate laws and policies by June 2023. Figure 2.11 indicates a total number of CLPs each year.

Figure 2.9 Count of climate laws & policies post-Paris agreement



The figure illustrates the evolution of CLP post the Paris Agreement, spanning from 2015 to 2023.

The post-2015 era following the Paris Agreement, nations worldwide have enacted various CLP on the above noted three distinct topics. The United States recently passed the Inflation Reduction Act in 2022, showcasing a commitment to renewable energy through tax incentives for solar and wind projects, energy storage, and

⁷⁷ Climate action tracker website provide country wise interpretation of country efforts to meet the Paris agreement. See <https://climateactiontracker.org/countries/> [Accessed 17 September 2023]

manufacturing. Similarly, the European Green Deal, introduced in 2019, is a comprehensive EU initiative supporting sustainable practices, renewable energy, and carbon reduction. France's Ecological Transition for Climate (TEC) Law in 2019 focuses specifically on carbon control in the transport sector promoting the usage of electric vehicles and investments in public transportation. Also, France's TEC Law serves as an example of targeted legislation addressing carbon control in the transport sector. Further, Canada's Pan-Canadian Framework on Clean Growth and Climate Change, initiated in 2016, includes the Greenhouse Gas Pollution Pricing Act enacted in 2018, establishing a national carbon pricing system. China, through its 13th Five-Year Plan (2016) and the Law on Combating Air Pollution, implemented a national carbon market in 2017.

The revised Renewable Energy Directive (2018/2001/EU) set a new binding target of at least 32% of energy from renewable sources by 2030, with a possibility of raising this target to 45% if certain conditions (e.g. scaling up renewable energy in power generation, industry, buildings, and transport) are met.⁷⁸ These laws align with various EU directives that aims to promote energy efficiency and sustainable transportation. These initiatives underscore a global commitment to addressing climate change across diverse sectors, reflecting the evolving landscape of climate governance in the post-Paris Agreement era.

2.6 Conclusion

In this study we present a comprehensive overview of global CLPs through LDA analysis, identifying key themes and patterns from 1947 to 2023. Our analysis reveals three distinct themes like Energy Efficiency and Power Generation Laws, Climate Change Adaptation Policies, and Reducing Emissions and Carbon Footprints that underscore the multifaceted approach of CLP to address climate change and the affirmative actions taken by various countries.

Despite collaborative efforts and commitments, agreements like the Paris Agreement are non-binding, allowing leaders to choose non-adherence. The COP-26 conference in 2021 saw 193 parties agreeing to revise climate plans, but only 24 followed through, questioning the consistency of commitments.⁷⁹ Mitigating climate change requires a coordinated strategy, addressing disparities in global climate efforts, the lack

⁷⁸ See <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A32018L2001> [Accessed 24 February 2024]

⁷⁹ See <https://unfccc.int/NDCREG> [Accessed 26 October 2023]

of enforcement mechanisms, and divergent socioeconomic priorities.

Despite all these CLPs, the UN Production Gap surprisingly reveals that governments globally intended to extract significantly more fossil fuels than align with their commitments under the Paris Agreement.⁸⁰ Since the COVID-19 pandemic, the G-20 has allocated roughly USD 300 billion as new funds for fossil fuel operations which is far more than the resources directed towards clean energy generations. While the G-20 countries have established NDCs, only a few countries have adopted net-zero objectives.⁸¹ This raises questions about the consistency of countries' climate commitments and whether the CLPs implemented so far suffice alignment with the objectives of the Paris Agreement.

To establish effective global climate governance, countries must prioritise collective action and a shared commitment to combat climate change. The effectiveness of global climate governance is compromised by three key issues. By addressing these key issues, countries can establish a stronger foundation for effective global climate governance.

In addition, countries must set a deadline to phase out fossil fuels and exponentially increase the renewable energy capacity and carbon free power sources to meet the total energy needs. Furthermore, significant investments in decarbonization technologies are crucial to achieve deep emissions cuts. It is important to note that decarbonization technologies such as carbon-capture and sequestration technologies (CCST) will require strong cooperations between state and central governments and through monitoring and verification to avoid greenwashing by companies (Salvi & Jindal, 2019). Countries should adopt diverse approaches, like higher carbon taxes, promoting research, and developing alternative fuels like Ethanol and Biofuel for sectors like shipping and aviation.⁸²

Post the Paris agreement, transition to renewable energy systems has seen a vast heterogeneity in the adoption of renewable energy practices across countries. For example, Iceland ranks number one globally, accounting for 88.87% of renewable energy

⁸⁰ By 2030, the production plans and projections of governments are anticipated to result in approximately 240% more coal, 57% more oil, and 71% more gas than is compatible with efforts to limit global warming to 1.5°C. See <https://productiongap.org/> [Accessed 26 October 2023]

⁸¹ See <https://www.imf.org/external/np/g20/pdf/2021/062221.pdf> [Accessed 26 October 2023]

⁸² It is projected that by 2050, global aviation and shipping combined will contribute to nearly 40% of global carbon dioxide emissions. See <https://www.eea.europa.eu/articles/aviation-and-shipping-emissions-in-focus> [Accessed 26 October 2023]

generation, while high-polluting countries such as the US, Russia, and India only generate 10.66%, 6.22%, and 9.31% of renewable energy, respectively. Countries must prioritize infrastructure development to harness renewable energy potential, fostering a stable economy, job growth, and a robust energy infrastructure. A strategic combination of renewable and natural resources, along with targeted policies, can significantly reduce emissions. Transition to renewable energy sources not only reduces emissions but also fosters a stable economy, stimulates job growth, and establishes a dependable and robust energy infrastructure (Ram et al. 2021).

As the frequency and severity of extreme climate events continue to rise, there is an urgent requirement for increased funding to assist developing nations in coping with climate-related losses and damages. According to latest assessment, developing countries will require approximately USD 5.5 trillion annually by 2030 for climate related expenditure.⁸³ The newly established United Nations global fund for loss and damage, initiated during COP27 holds promise, but its effectiveness will depend on substantial backing and contributions from affluent countries. In future, nation within the three distinct economies identified in this research would require stronger partnerships and global climate funds to support capacity-building efforts and technology transfer programs.

For emerging economies, clean energy adoption and technology transfer initiatives should be the key priority. Whereas, in advanced economies, the focus should be on developing innovative climate technologies and integrating climate considerations into corporate governance and reporting standards to encourage businesses to adopt sustainable practices and transparency in environmental impact disclosure. Additionally, strengthening international collaboration agreements and climate diplomacy initiatives is also crucial for advanced economies, as this enables global cooperation on climate action. In the context of Sub-Saharan Africa, future CLPs should prioritize several key areas. First, building resilience against climate shocks to mitigate the adverse impacts of climate change. Second, there should be an emphasis on expanding renewable and clean energy technologies to reduce carbon emissions. Third, mobilizing private sector financing is essential for promoting climate and green growth.

Large number of studies evidence the impact of CLPs on firm and financial markets. For instance, studies indicate the impact of CLPs on asset pricing (Bolton &

⁸³ See <https://unctad.org/sdg-costing/climate-change> [Accessed 26 February 2024]

Kacperczyk, 2023) and shareholders' investment decisions (Krueger et al., 2020), R&D expenditures (Brown et al., 2022), corporate capital structure (Dang et al., 2022), and bank lending decisions (Fard et al., 2020). This research can provide novel empirical setup for future research in the areas of accounting and finance to investigation on impact of the evolving CLPs across the three focus areas, three distinct economies and the three key climate conventions. California Governor recently signs Climate Disclosure Bills which require companies with over USD 1 billion in revenue to report all emissions annually from all scope starting in 2026. Similarly, the Securities and Exchange Commission of Brazil require a mandatory sustainability reporting issued by the IFRS Foundation's International Sustainability Standards Board (ISSB) from 2026 for public companies. Moreover, large companies in California require to disclose companies' financial risks related to global warming and the GHG emissions from their operations and supply chains. The Securities and Exchange Commission (SEC) announced a guideline for companies' climate disclosures.

Recently, the EU introduced the Carbon Border Adjustment Mechanism (CBAM) as a regulatory measure designed to impose a fair carbon price on the emissions associated with the production of carbon-intensive goods entering the EU market. The CBAM transitional period that began in October 2023 and will last until 2025 requiring companies to report emissions without financial obligations. Starting from 1 January 2026, only registered declarants will be permitted to import CBAM goods, with customs authorities obligated to monitor imports and deny those from non-registered declarants. This new cross border trade regulation will have a direct consequence on the international trade opening up new areas for academic research. Importers subject to registration can apply for authorization starting from 1 January 2025.⁸⁴ Importers will need to purchase certificates covering these CO₂ emissions, thus placing foreign producers on a par with EU industries. EU lawmakers have also recently announced a provisional agreement on a new law intended to safeguard consumers from deceptive sustainability claims and greenwashing practices.⁸⁵ In US, the SEC passed the much-anticipated climate-related disclosure rule on March 6, 2024, requiring US public corporations to reveal information about the risks associated with climate change, their strategy to mitigate those risks, and

⁸⁴ See https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en [Accessed 27 October 2023]

⁸⁵ See <https://www.esgtoday.com/eu-lawmakers-ban-generic-and-emissions-offsetting-based-green-product-claims/> [Accessed 27 October 2023]

the financial effects of extreme weather episodes.⁸⁶

In the future, corporations will exert more pressure from stakeholder for sustainable and environmentally conscious practices. While certain industries like high carbon emissions firms might face immediate financial implications, low emissions businesses will have less severe implications. We suggest businesses to invest in green technologies and adhere to climate governance to ensure long-term sustainability and enhance their reputation and competitiveness globally. Additionally, integrating sustainable practices into business models can help companies cultivate a positive brand image and market standing by leveraging consumer goodwill and loyalty. Also, corporations will be required to adhere to more stringent environmental regulations, potentially leading to increased investment in green technologies and sustainable practices and adopt circular economy practices, innovations in product design, recycling technologies, and waste management systems. According to Markus et al. (2024), public firms in the US spend around USD 300,000 a year on lobbying against climate change while receiving higher returns. According to the author, businesses that engage in climate advocacy likely have carbon-intensive business models. Corporations in these regions must proactively embrace sustainability and should assess and manage climate risks, such as rising sea levels, increased drought risk, and shifting rainfall patterns, to ensure the resilience of their operations and supply chains. Furthermore, companies must align nation's climate commitments into their business strategies.

As noted above, there might be initial costs associated with the transition to sustainable practices, but it can create significant opportunities for economic growth and job creation in the renewable energy sector and other green industries. Additionally, reduced health care costs due to improved air and water quality could contribute positively to the overall economy.

The growing number of CLPs presents significant implications for accounting, corporate finance, and capital markets. Climate-related regulations influence firm behaviour by altering the cost of capital, investment decision, and disclosure obligations (Ho et al., 2024). For instance, Cormier et al. (2005) find that firms exposed to environmental regulations tend to enhance their environmental disclosures. Similarly, Ghosh (2023) show that implementation of CLPs reduces the lending by 5 percent in

⁸⁶ See <https://www.esgtoday.com/sec-approves-scaled-back-climate-disclosure-rules/> [Accessed 6 March 2024]

MENA region. Additionally, CLPs affects firm behaviour by influencing beliefs about future regulation, abatement plans, and emissions mitigation (Ramadorai & Zeni, 2024). In this context, our thematic analysis of CLPs offers researchers a structured basis for exploring the differential economic and accounting consequences of climate regulation across jurisdictions and time.

Moreover, research by Grewal et al. (2019) and Christensen et al. (2021) indicates that voluntary and mandatory climate disclosure policies influence firm valuation, and institutional investor behaviour. Researchers have also emphasized that the introduction of CLPs negatively influences environmental liabilities, operating costs, earnings, and cash flows, and it may be led to an increased probability of losses (Huang et al., 2018; Nguyen, 2018; Seltzer et al., 2022; Luo & Tang, 2014).

Our analysis reveals a dominant theme such as emissions control, renewable energy deployment, and adaptation financing offers new variables and contextual benchmarks for future empirical research. For example, the presence of climate mitigation policies affects firms' cost of debt, credit ratings, and green bond issuance (Flammer, 2021; Seltzer et al., 2022). Researchers can build on our findings to test how CLPs implementation affects the corporate borrowing decisions and the maturity structure of the borrowing.

Our study lends guidance to the various international environmental bodies/organisations to do climate action progress checks and enhance compliance with international agreements. So, it is imperative for lawmakers, policymakers, and civil society to continue working together to strengthen existing climate laws and policies, enact new ones where needed, and ensure their robust implementation.

Chapter 3

Climate Change Laws and Policies and Corporate Debt Maturity Structure

3.1 Introduction

“Climate change laws and the policies created to address climate change have significant implications for businesses – it will fundamentally change many products, services, and operating models. Successful companies need to measure and manage these risks and actively seek the opportunities a clean economy creates. We need to invest for the future not the past.”

- Ignacio S. Galan, Chairman and Chief Executive Officer, Iberdrola⁸⁷

Does climate law and policies impose financial burdens on firms? Since the signing of the Kyoto Protocol in 1997 and the Paris Agreement in 2015, many countries have committed to reducing emissions and developing roadmaps for achieving a "zero-carbon society" with "net zero emissions" (Delafield et al., 2021). In response, lawmakers worldwide are reassessing their climate strategies, recognizing the need for stronger, more comprehensive governance frameworks aligned with the Paris Agreement's objectives (Bodansky, 2016; Falkner, 2016). To effectively combat climate change, governments have introduced a broad array of climate laws and policies aimed at fostering a sustainable and resilient future. While these climate laws and policies are essential for addressing global climate change issues, it often impose significant compliance costs on firms, requiring them to meet environmental standards, invest in cleaner technologies, modify operational practices and create regulatory uncertainty for firms.⁸⁸ Such requirements can result in substantial capital expenditures, necessitating financial restructuring that may affect a firm's capital structure decisions (Kovacs et al., 2025; Dang et al., 2022b). As a result, these change in climate laws and policies shifts are increasingly influencing corporate financial decisions, compelling firms to reassess their capital structures, investment strategies, and risk management frameworks.

Despite widespread recognition of the necessity of climate laws and policies, their implementation presents significant challenges for stakeholders, including lenders,

⁸⁷ See- <https://caneurope.org/hundreds-of-cities-states-and-regions-businesses-investors-and-civil-society-are-moving-to-implement-the-paris-agreement-ahead-of-g20-meeting-in-hamburg/> [Accessed 08 February 2025]

⁸⁸ In 2015, FirstEnergy Corporation announced the retirement of six coal-fired power plants in Ohio, citing the state's Renewable Portfolio Standards Act of 2008 as a key factor. Since the implementation of the Clean Air Act in 1970, FirstEnergy has invested USD10 billion in environmental protection efforts. Additionally, adaptation measures such as the United States Flood Insurance Reform Act of 1973 and the Bangladesh Disaster Management Act of 2012 require companies to prepare for and respond to natural disasters. This increases the cost of preparedness and poses challenges for firms operating in those regions. Similarly, mitigation measures like Italy's Green Certificates System (2002) and India's Energy Conservation Building Code (2017) mandate that companies adhere to specific energy-efficient standards, raising compliance costs for businesses that produce or use energy-intensive products. See <https://www.prnewswire.com/news-releases/firstenergy-citing-impact-of-environmental-regulations-will-retire-six-coal-fired-power-plants-138115263.html> [Accessed 10 May 2024]

investors, policymakers, and corporations (Krueger et al., 2020; Stroebe & Wurgler, 2021). Implementation increase the regulatory risks that stem primarily from the imposition of stricter climate-related rules, which can adversely impact the financial performance and capital access for the firms. Lenders, for instance, factor in these risks when assessing creditworthiness, often resulting in higher borrowing costs for firms. Delis et al. (2024) document a 16-basis point increase in the cost of credit for fossil fuel companies, and document that banks tend to charge higher interest rates. Similarly, Ivanov et al. (2022) find that polluting firms face reduced access to long-term bank financing, shortened debt maturities, and increased interest rates. Regulatory risks also extend to public debt markets. For example, Seltzer et al. (2022) report that credit ratings for polluting firms in jurisdictions with stricter environmental enforcement declined following the rise in climate regulatory pressure. Duan et al. (2020) likewise find that firms with a high-emissions firms experience worsening debt conditions under increase in climate law and policies. Collectively, this growing body of literature highlights the importance of understanding the financial implications, both intended and unintended of climate laws and policies on corporate finances (Li et al., 2022; Brown et al., 2022; Dang et al., 2022b; Mueller & Sfrappini, 2022).

A growing body of literature highlights the substantial financial impact of climate laws and policies. For instance, sulphur dioxide emissions reduction laws have been found to decrease firm productivity due to increased power generation costs (Gray & Shadbegian, 2000). Similarly, an analysis of US state-level environmental legislation reveals that firms with poor environmental profiles face higher yield spreads and lower bond ratings (Seltzer et al., 2022). Beyond direct compliance costs, non-compliance can lead to significant financial penalties and reputational damage, ultimately impacting cash flows (Bauer & Hann, 2010). Furthermore, a study by Dechezleprêtre & Sato (2017) suggests that stringent environmental regulations adversely affect trade, employment, and productivity in energy-intensive sectors. These findings collectively highlight the intricate relationship between CLP and corporate financial stability. Studies reveal that when firm experience increase in operational and friction in financial stability, firms reconfigure their debt structures. However, such adjustments can lead to higher borrowing costs (Morris & Shin, 2004), tighter contractual terms in future debt agreements (Lou & Otto, 2019), diminished expected returns (Vatta, 2016), and adverse shifts in managerial incentive alignment (Castro et al., 2020).

While a considerable amount of research has explored the broader implications

of CLP on corporate capital structure, particularly in relation to landmark agreements like the Kyoto Protocol and the Paris Agreement, the cumulative impact of these CLPs on corporate debt maturity structure remains underexplored. This gap is particularly notable given that debt maturity decisions are pivotal for a firm's financial stability and long-term survival (Schiantarelli & Sembenelli, 1997; Aivazian et al., 2005). The discussion on debt maturity has gained prominence since the global financial crisis, as the overreliance on short-term debt was a key factor during the crisis (Brunnermeier, 2009). Furthermore, debt maturity choices directly influence a firm's exposure to refinancing risks, liquidity constraints, and interest rate volatility affecting not only profitability but also future access to financing and overall corporate resilience.

More importantly, even the anticipation of future CLP can materially impact firms' financial conditions. For instance, research indicates that rising climate regulatory risk increases corporate bond spreads and lowers credit ratings, underscoring that uncertainty about future regulation itself imposes costs on firms and investors (Seltzer et al., 2022). Despite the evident link between CLP enactment and financial markets, we lack clarity on how firms adjust their debt maturity structures in response to CLP implementation. Understanding this is crucial, as firms must decide the appropriate mix of short-term and long-term debt, a decision that is particularly sensitive to change in CLP. On one hand, committing to long-term debt under a changing CLP regime may lock firms into obligations that become costly if new regulations raise compliance costs or constrain operations. On the other hand, excessive reliance on short-term debt increases exposure to refinancing risks, making firms more vulnerable to financial distress.

While a growing body of literature has examined policy uncertainty⁸⁹ and pricing of climate-related risks, far less attention has been paid to firm-level balance sheet responses, particularly in terms of debt maturity structuring. However, no study to date has directly examined the cumulative impact of CLP on corporate debt maturity. Given that firms' financing and operational activities are shaped by CLP enactment, this study seeks to address the research gaps by answering two key questions: *Does CLP materially*

⁸⁹ However, while the role of general policy uncertainty has been increasingly recognized, climate-related law and policies uncertainty represents a distinct and exogenous risk source. CLP introduces a unique blend of long-term horizon uncertainty (e.g., carbon pricing, emission caps, renewable mandates) designed for long-term structural shifts, often spanning decades. However, their implementation timelines (e.g., phase-out dates for fossil fuels and carbon tax increase) are frequently ambiguous or subject to political negotiation. Firms must navigate evolving lender expectations, collateral risks, and regulatory timelines, often resorting to innovative instruments (green bonds, sustainability-linked loans) or adjusted maturity profiles.

influence a firm's choice between short-term and long-term debt? and (2) Does the magnitude or direction of this effect vary depending on the firm's sector-specific exposure to climate regulations?

Emerging literature underscores how market and general policy uncertainty influence corporate debt maturity preferences. For example, Datta et al. (2019) and Tran & Phan (2022) find that firms facing heightened policy uncertainty shorten their debt maturities due to increased information risk, despite the associated refinancing costs. Similarly, Hasan et al. (2022) observe that firms exposed to oil prices related uncertainty prefer short-term debt for its financial flexibility, even though it elevates refinancing risk. Building on this literature, we argue that CLP exerts both direct financial pressures⁹⁰ and indirect pressures via heightened regulatory uncertainty.⁹¹ As a result, firm must balance their need for additional financial resources with the flexibility required to navigate evolving CLP environments.

Prior corporate finance research suggests that in times of uncertainty, firms issue less debt and seasoned equity due to their reluctance to seek external funding (Zhang et al., 2015; Gungoraydinoglu et al., 2017). Companies are also less willing to raise capital through initial public offerings (Colak et al., 2017), and when they do seek financing, they face higher costs associated with both debt (Francis et al., 2014; Waisman et al., 2015) and equity (Brogaard & Detzel, 2015; Colak et al., 2017). This is because heightened uncertainty increases the risk premium required by investors. Additionally, financial intermediaries may become more reluctant to lend due to deteriorating market conditions and a heightened risk of default and repayment delays by borrowers (Baum et al., 2021; Bordo et al., 2016; Hodula et al., 2023).⁹² While debt financing offers distinct advantages such as preserving ownership concentration and managerial autonomy (Baker et al., 2018; Stulz, 1990). It also provides tax benefits through interest deductibility, reducing tax liabilities and potentially increasing returns on investment via leverage (Myers, 1984). However, adjustments in financial leverage ratios often necessitate

⁹⁰ When a government enacts a carbon tax or introduces a cap-and-trade system (e.g., the EU Emissions Trading System), firms must pay for their carbon output or purchase emissions allowances.

⁹¹ Even before a climate law is enacted or fully implemented, the anticipation of stricter future CLP can lead investors and creditors to re-evaluate risk exposure.

⁹² In addition, financial institutions consider compliance requirements in their lending strategies, affecting the amount they lend and debt composition (short-term vs long-term) (Nieto 2019). For instance, the introduction of the 2017 Internal Capital Adequacy Assessment (ICAAP) led to a lending reallocation by large banks exposed to climate risk. Using Brazilian firm data, Miguel et al. (2022) find that, following the ICAAP reform, there was a substantial increase in the proportion of short-term loans to sectors vulnerable to climate change, contributing to changes in large banks' credit allocation.

corresponding changes to a firm's debt maturity structure.

In the context of CLP, the financial pressures faced by firms may be further intensified by the need for substantial investments in sustainable infrastructure, technological upgrades, operational restructuring, and increased tax and compliance burdens. These adjustments are not merely economic choices but are also shaped by institutional forces. Institutional theory posits that organizations must conform to prevailing societal expectations, regulatory norms, and institutional pressures to maintain legitimacy, secure resources, and avoid penalties (Hickson et al., 1971). Within the CLP framework, firms are increasingly expected to demonstrate environmental responsibility and alignment with regulatory norms. Non-compliance or delayed adaptation can result in reputational damage, regulatory penalties, and a loss of investor confidence. Thus, institutional pressures serve as a powerful channel through which CLP affects firm behaviour, compelling companies to reshape their financing strategies, including debt maturity choices, in order to navigate both market-based and legitimacy-based constraints.

We assert that there are two primary reasons why CLP may affect corporate debt maturity decisions. The first reason is related to the CLP implication and related uncertainty associated with it. As discussed above CLP aimed at addressing environmental challenges requires firms to take adaption, mitigation, or transitional measures often involve significant upfront costs and uncertainties related to technology adoption, infrastructure upgrades, purchasing emission permits and operational changes. Recent studies have emphasized the significant investment needed to address the increased regulatory compliance costs for the power sector (Martin et al., 2016) and an increase in manufacturers' energy costs (Sijm et al., 2006). These financial burdens expose businesses to climate-regulatory risk, a crucial aspect of climate-related transition risk (Krueger et al., 2020), which has significant consequences for both companies and their stakeholders. Studies in this context suggest that when the adverse selection cost is enormous, firms cannot obtain long-term debt financing because lenders are unwilling to take on the risk of providing finance without sufficient information to assess the borrower's ability to repay the debt (Buch & Lusinyan, 2003; Datta et al., 2019; Hasan et al., 2022).

Second, firm access to finance in wake of CLP enactment. Notably, a study by Wang & Shao (2019) examining the effect of green credit policy suggest that China's green credit policy limits the non-environmentally friendly firms' ability to obtain debt

from banks. Fard et al. (2020) shows that firms subject to stricter environmental regulations face higher interest rates from financial institutions due to over increased environmental liabilities resulting from these regulations.⁹³ These firms also experience reduced participation in loan syndicates, as lenders avoid lending to firms due to concerns about potential increases in environmental liabilities or future cash flows.⁹⁴ Consequently, borrowing firms have to pay higher spreads on their loans and face other contractual adjustments, such as higher upfront fees and shorter maturities. Thus, this disagreement between the borrowers and lenders lead borrowers (firms) to prefer short-term debt over long-term.

Additionally, by undertaking short-term debt companies avoid conflicts between shareholders and manager because firms do not have to commit to a long-term repayment schedule (Wu et al. 2022). This rational is consistent with agency theory, which support that short-term debt is a mechanism to discipline managers and reduce agency conflicts between shareholders and managers (Custódio et al., 2013). Uncertainties surrounding the long-term financial implications of CLP can lead to conservative debt maturity decisions, leading firms to opt for shorter maturities to maintain financial flexibility in adapting to potential future changes in CLP. Additionally, the change in CLP and the uncertainty surrounding its enforcement and implications make it difficult for firms to fully assess the associated risks and opportunities. Real option theory supports that firms value flexibility when making investment and financing decisions under uncertain conditions (Dixit & Pindyck, 1994). As noted above, CLP introduce regulatory uncertainty, making it difficult for firms to forecast compliance costs, disclosure requirements, future environmental obligations, or potential carbon taxes. Thereby relying on short-term debt, firms retain the option to adjust their capital structure more frequently in response to evolving climate policies.

To test this conjecture, in this study, we examine the effects of CLP on firms' debt maturity choices by quantifying the CLP enactment from 23 countries from 1997 to 2022. To do this, following Simintzi et al., (2015) we construct a Climate law index which capture the cumulative count of CLP enacted in a country. We employ OLS fixed effect model to examine the cumulative impact of CLP on corporate debt maturity structure.

⁹³ The increase in the interest rate lasts for up to two years for the non-US firms and three years when US firms are included.

⁹⁴ This is because strict environmental policies can create binding obligations and lead to significant financial drains for firms. Also, non-compliance may result in downgraded bond ratings and potential legal actions or bankruptcy.

Our findings reveal that a one-unit increase in the Climate Law Index is associated with a 1.74% (106 basis point) decrease in the share of long-term debt. This effect is highly statistically significant at 1% significance level and remains robust across different model specifications. In other words, firms operating in jurisdictions with more CLP tend to allocate a smaller portion of their debt to long-term instruments, shifting toward shorter maturities. Correspondingly, the share of short-term debt increases by a similar magnitude, indicating a clear rebalancing strategy. Moreover, our results suggest a moderate increase in total debt levels in response to change in CLP enactment, however we observe a greater increase in net debt compared to total debt indicating that firms are simultaneously reducing their cash holdings to meet with the regulatory compliance. Overall, our finding indicates that firms primarily manage CLP risk by shortening debt maturities.

These findings are broadly consistent with prior research on policy uncertainty and corporate debt structure. We, however, look at the uncertainty from the climate regulatory uncertainty dimension. Notably, our results align with and reinforce emerging evidence on climate risk and debt maturity decisions. For instance, Dang et al. (2022a) find that following the enactment of air pollution regulations in the U.S., affected firms significantly shortened their debt maturity structures, and effect is particularly pronounced in energy-intensive and manufacturing industries. It is important to note that this study focused on manufacturing industries using the NOx budget trading program in the US. Similarly, Goodell et al. (2025) report that firms with greater exposure to climate risks tend to issue less long-term debt and shift toward shorter maturities, corroborating the negative relationship between climate risk⁹⁵ and long-term debt. Importantly, our results remain robust even after controlling for key macroeconomic factors (e.g., inflation, country size) and firm-specific characteristics (e.g., size, tangibility, growth, and return on assets).

To deepen our analysis, we incorporate sector-specific characteristics of CLP. To this end, we manually reviewed 921 climate laws and policies description and categorized them according to UNEP's sectoral framework.⁹⁶ Our sectoral analysis reveals that firms operating in the Energy and Transport sectors experience the strongest decline in long-

⁹⁵ Leveraging the firm-level climate risk exposure data provided by Sautner et al. (2023) where the author employs a machine learning method to analyse earnings call transcripts. The focus is on the extent of discussion regarding a company's vulnerabilities to climate change, specifically in relation to regulatory, physical, and opportunity shocks.

⁹⁶ See <https://wetr-climate.unepgrid.ch/climate/responses/which-sectors-have-major-impact>

term debt, indicating that regulatory pressures in these industries lead to more conservative debt financing strategies. However, the observed effect is less pronounced in other industries i.e., Building, Cross-sectoral, and Agricultural. Additionally, we observe that legal origin, national governance structures, macroeconomic conditions, and financially constraints factors moderate the relationship between CLI and long-term debt. Notably, we observe a non-linear pattern between CLI and long-term debt, suggesting that as the cumulative count of CLP increases, the debt maturity-shortening effect accelerates. We employ the Instrumental variable analysis and lagged model to address the endogeneity concerns. Our results are robust to sub-sample analysis, alternative measure of debt maturity, and adding additional control variable analysis.

First, we extend the growing body of research on the financial implications of climate laws and policies by examining their effect on corporate debt maturity structure. While existing studies have explored the impact of climate laws on R&D expenditure (Brown et al., 2022), asset pricing (Bolton & Kacperczyk, 2023), innovation (Dai et al., 2020), bank lending (Mueller & Sfrappini, 2022), institutional investor decisions (Krueger et al., 2020), and firm valuation (Krueger, 2015), the relationship between climate law and corporate debt maturity remains underexplored. Moreover, much of the existing literature focuses on specific regulatory events or single-country settings, limiting generalisability. By providing the first cross-country firm-level evidence, this study offers a broader and more systematic perspective on how changes in CLPs influence corporate financing structure.

Second, we make a methodological contribution by constructing a Climate Law Index (CLI) that captures the cumulative count of climate-related laws and policies enactment across countries and over time. Rather than focusing on individual regulatory events, the CLI measures the accumulation of climate-related laws and policies, allowing us to examine long-term regulatory exposure faced by firms. In addition, we manually classify CLPs into sectoral categories which help us examine how sector-specific CLP focused affect corporate debt maturity. Sectoral analysis shows that firms in capital-intensive industries such as energy tend to rely more on long-term debt, whereas firms in sectors characterised by technological uncertainty, such as transport, prefer shorter maturities. This sectoral evidence complements recent work on climate policy heterogeneity and firm behaviour but adds a financing dimension that has been largely absent from prior studies (Martinsson et al., 2024; Kim & Bae, 2022; Le & Azhgaliyeva, 2023). This sectoral disaggregation allows us to uncover heterogeneous effects across

industries, highlighting that climate regulation does not operate uniformly across sectors.

Third, we contribute to the capital structure literature by demonstrating how changes in CLPs influence firms' debt structuring decisions, particularly their choice between short-term and long-term financing. Prior studies document that environmental regulation affects financing costs and leverage for example, Kyoto Protocol ratification in Australia reduced corporate leverage (Nguyen & Phan, 2020), and US firms with lower environmental performance experienced higher bond yield spreads following the Paris Agreement (Seltzer et al., 2022). Similarly, Chen et al. (2012) show that regulatory risk affects firms' ability to meet debt obligations, while Delis et al. (2024) find that climate policy risk shortens loan maturities in carbon-intensive industries. Extending this literature, we provide evidence that firms respond to the accumulation of CLPs by adjusting the maturity structure of debt, reflecting a trade-off between long-term investment needs and financial flexibility under regulatory pressure.

Fourth, we extend the literature on examining the policy uncertainty and firm risk management. Prior literature studying the regulatory uncertainty has been shown to influence systematic risk, asset pricing, and corporate decisions (Pastor & Veronesi, 2013; Brogaard & Detzel, 2015; Kaviani et al., 2020), as well as investment, mergers, and financing choices (Gulen & Ion, 2016; Jens, 2017; Bonaime et al., 2018). Consistent with this literature, we show that the accumulation of CLPs introduces regulatory uncertainty that shapes firms' debt maturity decisions. Importantly, our results suggest that firms respond to this uncertainty by adjusting financing horizons, reinforcing the argument that evolving regulatory environments can affect corporate stability and financial market outcomes (Stiglitz et al., 2017; Berger et al., 2005).

Fifth, and importantly, we document that the relationship between CLI and corporate debt maturity is non-linear. At the low levels of CLI, the effect on debt maturity is slightly positive. However, as CLI increases we find a decline in long-term debt to preserve the refinancing flexibility amidst heightened compliance uncertainty. Finally, beyond its academic contributions, this study has important practical implications. For policymakers, the findings highlight the importance of designing climate laws and policies that minimise unintended financial consequences (*for instance, by clearly communicating policy trajectories or providing transition support*), by reducing regulatory uncertainty and supporting long-term financing where needed. Our study is also useful for the financial institutions. This is because our results provide insights into how climate related laws and policies enactment affects firms' debt profiles, which is

critical for assessing credit risk and portfolio exposure. For corporate managers, the study underscores the need to carefully balance financing flexibility and long-term investment commitments when responding to evolving climate regulatory exposure.

Finally, our study is also relevant for practitioners, particularly corporate managers and financial decision-makers, the findings provide insights into how firms respond to climate regulation by balancing long-term investment needs with the desire for financial flexibility, especially under uncertainty and during crisis periods. For policymakers, the results highlight that CLPs can have unintended financial consequences by influencing firms' financing structures, and that these effects vary across sectors and economic environments. This suggests the need for more stable, predictable, and sector-sensitive policy frameworks to ensure that climate objectives are achieved without distorting corporate financing behaviour.

3.2 Literature review & hypothesis

3.2.1 CLP and its effect on firm

As noted above climate change presents a multifaceted challenge that demands government interventions, typically through the enactment of various CLPs. Despite these efforts, many countries are still lagging in the implementation of CLP (Monasterolo et al., 2022). Extant literature shows that CLPs implementation influences institutional environments and corporate decision-making. For example, Commins et al. (2011) reveals that stringent climate policies lead to increased adoption of cleaner technologies and reductions in carbon emissions by companies. In another study, Bartram et al. (2022), evidence that California cap-and-trade (CAT) affect the financial constraints firms and firm shift their operation to other states. This shift is mainly attributed to the regulatory costs associated with CAT making it less profitable for these firms to continue emitting in California. A study by Greenstone et al., (2012) reveals that US air quality regulation leads to decline in total productivity for the heavily polluting industries. While many CLPs to mitigate climate change increase the costs for the firms, these costs vary across firms even within industry. Importantly, CLP impact firms differently within industries, with some industries such as energy, manufacturing, and supply chains being more vulnerable to climate change policies and associated operational costs (Owusu & Asumadu-Sarkodie 2016).

We posit that in response to climate regulatory shocks, firms tend to pursue three objectives: reduce, avoid, and adapt strategies. Proposed by Meyer & Rowan (1997),

Institutional theory suggest that organizations must adopt structures and practices primarily for legitimacy and acceptance within their institutional environments rather than solely for efficiency. Using the Institutional theory lenses, we assert that firms with a CLP implementation face three interrelated forces. These include coercive pressures from binding regulations, normative expectations from professional and investor communities, and mimetic imitation of industry leaders (DiMaggio & Powell, 1983). Therefore, to maintain legitimacy and avoid penalties, firms must adapt their structures, practices, and strategies to align with prevailing CLP rules and norms. By responding to the CLP implementations firms not only avoid the negative consequences but also maintain legitimacy in the eyes of stakeholders and regulatory authorities (Hickson et al. 1971). Also, firms exposed to CLPs enactment often face challenges regarding their future operations, compelling managers to act rationally and allocate resources towards developing the necessary infrastructure, technologies, disclosures and undertake necessary financial decisions to adapt to the CLP rules and norms.

Moreover, when a CLP is implemented, firms must consider the associated risks and take timely financial decisions to mitigate the regulatory non-compliance risks and to maintain a positive image, avoid legal consequences, and broadly meet the stakeholder expectations. Failure to conform can lead to higher borrowing costs, bond-rating downgrades and reputational damage, which directly affects access to capital (Delis et al., 2024). Managers therefore adjust financial policy in ways that keep both legitimacy and flexibility, preserving the option to refinance once the cost of carbon or future compliance requirements become clearer (Bolton & Kacperczyk, 2023). A recent study suggest that firms adopt more conservative capital structures in response to climate policy regulations like the NOx Budget Trading Program (Dang et al., 2022b). We assert that in response to enactment of CLPs, managers may seek additional finances (i.e., debt) to support regulatory compliance, manage transition risks, align business with stakeholder expectations, and ensure long-term business sustainability (Lash & Wellington, 2007).

3.2.2 CLP and financial choice

A common notion in the literature is that firms exposed to climate policies face increased uncertainty, which can significantly influence their financial leverage decisions (Zhou & Wu, 2023; Seltzer et al., 2022; Ginglinger & Moreau, 2023; Nguyen & Phan, 2020). This literature argues that CLPs impose new forms of regulatory risks and uncertainties, prompting firms to reconsider their financing structures to manage these

emerging risks. Within corporate financial literature, borrowing decisions have been identified as a critical element of corporate financing strategies, since they directly affect profitability, capital costs, and financial flexibility (Ross, 2005; Hovakimian et al., 2001; Myers et al., 1997). In the context of our research, we assert that the implementation of CLPs has a profound influence on a firm's financing decisions due to increase in compliance cost and heightened uncertainty.⁹⁷

When firms are mandated by CLP enactment to invest in environmentally friendly technologies such as reduce emissions, several important consequences emerge. Firstly, market dynamics may shift as environmentally conscious consumers increasingly prefer eco-friendly products, thus directly affecting the firm's demand, revenue, and profitability (Flammer, 2021). Secondly, CLP often introduce additional taxes, levies, or penalties, directly increasing firms' operational and compliance costs and further diminishing profit margins (Ginglinger & Moreau, 2023). Clarkson et al. (2008) highlight that firms' environmental actions signal critical information to creditors regarding future operating performance and credit risks, thereby directly influencing firms' debt-financing capacities. Specifically, heightened regulatory intensity translates into higher compliance expenditures, thereby eroding profitability and raising the perceived risk of loan repayment among lenders (Zhou & Wu, 2023).

Basing on above literature, we posit that CLPs amplify uncertainty, elevate compliance costs, and adversely affect profitability and overall business operations. As a result, firms face significant challenges in managing their financial positions. To navigate these financial pressures, firms strategically adjust their financing decisions in alignment with pecking order theory (Myers & Majluf, 1984). Pecking order theory posits that firms prioritize internal financing (retained earnings) first, then debt, and finally equity issuance as a last resort, primarily to minimize information asymmetry costs associated with external financing. In scenarios where increased regulatory pressures erode profitability, internal cash flow often becomes insufficient to fund required investments in eco-friendly technologies and compliance initiatives. Consequently, firms are likely to rely more heavily on debt financing to bridge the funding gap without immediately diluting

⁹⁷ Firms face uncertainty regarding the precise implications of new CLPs, including potential future modifications, enforcement strictness, penalties for non-compliance, and the associated costs required to achieve compliance (Ilhan et al., 2023; Krueger et al., 2020). Also, CLP can have a far-reaching effect on employment, trade, and investment. The extent to which these effects will be felt, and the degree to which they can be mitigated, is uncertain and can create uncertainty among stakeholders including investors and lenders.

ownership through equity issuance. Debt thus emerges as a preferred external financing source, allowing firms to maintain operational flexibility, respond efficiently to regulatory demands, and preserve their strategic positioning in an uncertain policy environment (Nguyen & Phan, 2020).

Research indicates that climate law significantly impacts firms' capital structure decisions. For example, the ratification of the Kyoto Protocol is associated with lower leverage, particularly in developed economies and market-based financial systems (Chen & Wang, 2012). Similarly, Ginglinger & Moreau (2023) document that heightened physical climate risks since 2015 result in decreased leverage by negatively influencing both debt demand and supply. Nguyen & Phan (2020) reinforce these findings by demonstrating that increased carbon risks driven by climate regulations encourage financially constrained firms to reduce their financial leverage. Additionally, Dang et al. (2022b) provide evidence that firms adopt more conservative capital structures following the NOx Budget Trading Program. Similarly, Seltzer et al. (2022) examines how climate regulatory risks affect corporate bond markets, revealing that firms facing stringent environmental regulations or having poor environmental performance are penalized through higher bond yield spreads and lower credit ratings, affecting firms' borrowing decisions and leverage ratios. However, sector-specific variations exist; Rao & Moyer (1994) highlight that in the electric utility sector, unfavourable regulatory environments may occasionally encourage increased leverage as a mitigating strategy, although this option remains limited due to higher bankruptcy risks. Collectively, these studies underscore that climate-related regulatory factors are critical determinants of corporate financial leverage decisions.

3.2.3 CLP and corporate debt maturity

Nevertheless, existing literature has examined how CLPs influence corporate borrowing decisions; however, a critical gap remains in understanding how cumulative changes in CLPs specifically influence debt maturity structures. Also, prior studies predominantly focus on single CLP events (*e.g., Kyoto Protocol ratification, carbon tax implementation, NOx Budget Trading Program, climate mitigation policies*) and in a single-country contexts, neglecting the dynamic, cumulative nature of CLP. The choice between short- and long-term debts determines firms' liquidity risk, refinancing costs, and capacity to invest in long-term sustainability projects. Understanding debt maturity choices becomes crucial because long-term debt commitments might exacerbate financial

inflexibility and regulatory risk, whereas short-term debt could impose frequent refinancing pressures (Chen et al., 2021; Barclay & Smith, 1995). Also, relying on short-term debt leaves firms vulnerable to rollover risks and increased credit risks due to the necessity of regular refinancing (Della- Seta, 2020). Prudent management of these risks is crucial, as debt maturity can jeopardize a firm's capacity to fulfill its obligations, especially in times of economic downturns or market volatility.

Debt maturity decisions represent a critical trade-off between the refinancing risks inherent in short-term debt and the mispricing risks associated with long-term debt (Diamond, 1991, 1993; Barclay & Smith, 1995; Myers, 1977; Flannery, 1986; Datta et al., 2005). Firms incur refinancing risks due to volatile market conditions, capital market imperfections (Froot et al., 1993), and adverse shifts in firm prospects, which may force refinancing at prohibitively high rates (Diamond, 1991). Additionally, lenders may undervalue a firm's long-term viability, precipitating inefficient liquidation (Sharpe, 1991; Diamond, 1991, 1993) or distressed asset sales (Brunnermeier & Yogo, 2009; Choi et al., 2017). Short-term debt amplifies credit risk (Gopalan et al., 2014) and exacerbates underinvestment issues, as frequent rollover demands constrain capital allocation to growth opportunities (Almeida et al., 2011).

The choice between short and long-term debts is critical for firms. According to Stiglitz & Weiss (1981), businesses cannot secure long-term debt financing when there is a significant information asymmetry and a substantial risk of default. CLP generally requires firms to take adaptation, mitigation, transitional measures, and sets the rules and regulation for firms to comply with. Failure to comply with climate law and policies increases the climate litigation risk and lead to decrease in firm value by 0.41 % (Sato et al., 2024). As such, we argue that CLP often spurs severe information asymmetry between firms and external stakeholders (e.g., creditors, investors). This is mainly due the regulatory uncertainty regarding the future amendments, stringency of CLP, complexity of CLP requirement, reliance on scientific expertise for clear understanding and adherence, the influence of lobbying and special interests, and challenges in implementation and monitoring. Using US firm data, Custódio et al. (2013) document that firms with higher information asymmetry subject to short-debt maturity during the 2008 Global financial crisis. This argument is also in line with Flannery (1986) and Diamond (1991) models, which explain that in the presence of asymmetric information, a firm undertake a short-term debt commitment. By relying less on long-term debt, firms signal their financial strength and liquidity to invest in climate-friendly initiatives

promptly, demonstrating its commitment to meeting regulatory requirements. Stulz (2000) substantiates this finding by revealing that firms choose short-term debt to signal the stakeholder about the firms' financial stability. Further, Ben-Nasr et al. (2015) find that firms undertaking short-term debt commitments are prepared to expose themselves to more frequent monitoring, and therefore short-term debt is taken as a signal to the market indicating the financial solvency of the firm.

We utilize the agency theory as an additional theory to understand firms' incentive to reduce reliance on long-term debt under the CLP implementation. Agency theory, which examines conflicts of interest between managers (agents) and stakeholders (principals) (Jensen & Meckling, 1976), focuses on mitigating these conflicts by designing mechanisms such as monitoring systems, and contractual agreements to align the interests of agents with those of principals and reduce climate regulatory risk. According to agency theory, debt contracts exacerbate conflicts between managers and shareholders, particularly when firms face heightened regulatory uncertainty leading to agency conflicts. As noted earlier, firms exposed to CLPs encounter significant increases in compliance obligations, monitoring requirements, and potential penalties. Under such circumstances, short-term debt acts as a disciplinary mechanism by limiting managerial discretion over free cash flows, reducing the risk of overinvestment in speculative climate projects or misallocation of transition funds (Jensen, 1986; Wu & Xu, 2024). This aligns with agency theory's premise that frequent refinancing forces managers to undergo market scrutiny, curbing opportunistic behaviour and aligning actions with shareholder interests (Myers, 1977). Research suggests that short-term debt can serve as a monitoring mechanism, reducing agency conflicts between managers and shareholders by exposing firms to more frequent market scrutiny (Anginer et al., 2022).

Also, from the creditor-manager dimension, it can be argued that CLP exacerbate information asymmetry as managers possess private knowledge about compliance costs and stranded asset risks while creditors lack this information. Creditors likely to wait for complete information about CLP implications providing shorter maturities to mitigate the greater default risks when firm exposed to climate regulatory risk. This increase in perceived risk, driven by agency conflicts, forces creditors to provide shorter debt maturities, enabling them to regularly reassess managerial actions, financial conditions, and the evolving CLP landscape. A study by Diamond (2004, p.1464) provides evidence in support and reveals that when cost of enforcement is high, borrower tend to rely more on short-term debt. This is consistent with the risk management perspective that firms

intend to prefer short-term debt due to creditor's concerns about potential default. In such cases, lenders may demand higher interest rates or impose stricter terms to compensate for the increased risk associated with the borrower (Diamond, 1991; Chen et al., 2021).

Beyond geopolitical instability and political uncertainties, research studies identified climate change risk has emerged as a pivotal source of uncertainty shaping corporate debt maturity. In particular, climate regulatory risks, such as abrupt policy shifts (e.g., carbon taxes, emissions caps), technological disruptions (e.g., renewable energy mandates), and litigation risks (e.g., lawsuits over climate inaction) create significant financial uncertainty for firms. CLP changes can lead to stranded assets (e.g., fossil fuel infrastructure rendered obsolete) and sudden increases in compliance costs, particularly for carbon-intensive industries (Battiston et al., 2017; Delis et al., 2024). For example, firms in sectors like energy and manufacturing face heightened exposure to regulatory penalties, reduced asset valuations, and reputational damage, which elevate credit risk metrics such as default probabilities and loss given default (Capasso et al., 2020; Jung et al., 2018). Also, firms with significant climate regulatory exposure experience elevated credit risk for lenders, decline in firm value, cash flow volatility (Miguel et al., 2024; Ongsakul et al., 2023; Tran & Phan, 2022). Consequently, lenders perceive these firms as riskier, imposing stricter borrowing terms, higher interest rates, and costlier long-term debt (Berger et al., 2005; Custódio et al., 2013). For instance, banks increasingly price climate risks into loan terms, charging carbon-intensive firms up to 150 basis points more than low-emission peers (Delis et al., 2024). This creates a feedback loop where firms facing change in CLPs risks are pushed toward shorter debt maturities to avoid locking in unfavourable long-term financing costs (Custódio et al., 2013).

Furthermore, the Real Options Theory (ROT) provides a better understanding why firms exposed to change in CLPs prefer short-term debt. ROT posits that firms facing uncertainty should retain flexibility to defer, adapt, or abandon investments as new information emerges (Myers, 1977; Trigeorgis, 1996). In the context of CLP implementation, the option to wait allows firms to delay irreversible commitments, such as long-term debt covenants, until CLP trajectories stabilize (Myers, 1977; Della Seta et al., 2020). This is critical as climate regulatory timelines, like net-zero targets, remain unpredictable.⁹⁸ Simultaneously, the option to abandon enables firms to exit high-carbon

⁹⁸ Countries are continuously adjusting their climate targets and strategies. For instance, the UK has set

projects⁹⁹ if climate laws render them unviable, minimizing exit costs compared to rigid long-term debt obligations (Trigeorgis, 1996; Battiston et al., 2017). The option to adapt, facilitated by frequent refinancing cycles, permits firms to renegotiate financing terms as new CLP risks emerge, such as stricter emissions standards, ensuring alignment with evolving risk assessments (Custódio et al., 2013; Della Seta et al., 2020). Empirical evidence corroborates this behaviour, for example Bradley & Roberts (2015) demonstrated that firms facing climate policy uncertainty shorten debt maturities to preserve renegotiation flexibility, while Della Seta et al. (2020) reveals that climate-sensitive firms strategically employ short-term debt as a hedge against regulatory shocks, effectively treating short-term debt as a real option. According to Busch & Hoffmann (2007), climate regulations increase the uncertainty surrounding long-term environmental investments, creating the risk of stranded assets-investments that become prematurely obsolete due to unexpected regulatory shifts. Consequently, firms operating in change in CLP environments strategically adopt shorter-term debt financing to preserve flexibility and adapt quickly as regulatory frameworks evolve (Flammer, 2021; Ginglinger & Moreau, 2019). Empirical evidence from Krueger et al. (2020) further underscores that firms under high climate-policy uncertainty deliberately reduce long-term leverage and instead prefer financing strategies that preserve managerial discretion and investment optionality. By integrating these mechanisms, ROT underscores how short-term debt serves as a dynamic tool for firms to manage CLP risks while retaining financial and operational agility. Based on above given argument this study hypothesizes the following relationship:

H1: Certis Paribus, the implementation of the CLP leads firms to prefer short-term debt over long-term debt.

3.3 Data

To conduct this study, we use multiple data sources. First, we obtain the climate change laws and policies data from the Climate Change Laws of the World (CCLW) database maintained by the Grantham Research Institute on Climate change and the

interim carbon budgets with a 78% reduction target by 2037. See <https://commonslibrary.parliament.uk/research-briefings/cbp-9888/>

⁹⁹ Danish energy company DONG Energy (now Ørsted) successfully transitioned from 85% coal-generated power to 86% renewables by 2019, achieving its goal 21 years early. Additionally, Shell has announced a 1-2% annual decline in oil production after peaking in 2019, while BP promised a 40% reduction in oil and gas production by 2030 compared to 2019 levels. See <https://gijn.org/resource/guide-investigating-fossil-fuels-climate-pledges-private-companies/>

environment at London School of Economics and the Sabin Centre at Columbia Law School.¹⁰⁰

Second, our firm-related datasets are obtained from the Standard & Poor's Compustat Global database between 1997 and 2022.¹⁰¹ Following the D'Mello & Miranda (2010) we exclude annual observations from our analysis if a firm's long-term and short-term debt surpasses its total assets. Additionally, we exclude observations with missing data on total assets and sales. We discard firm-year observations where the long-term and short-term debt over total debt is less than 0 or more than 100 percent. Given that financial firm level data are often subject to heavy tails and skewness, we winsorized all the continuous variables at 1st and 99th percentiles to reduce the impact of extreme outlier observations on our results (Nguyen & Qiu, 2022). This approach helps enhance the robustness of our empirical findings by reducing the impact of extreme values without distorting the overall data distribution.

Third, we obtain country-level control variables data from the World Bank's World Development Indicators (WDI) database to control for macroeconomic conditions. Following the literature, we exclude the financial (*SIC codes 6000 to 6999*) and utilities (*SIC codes 4900 to 4999*) sectors from our sample as these firms adopt different financial choices compared to others (Nguyen & Phan, 2020; Chen & Wang, 2012) and are heavily regulated and operate differently than other industries (Opler et al. 1999).

To construct our sample, we merge CLP data¹⁰², Standard & Poor's CompStat Global, and WDI database leaving us with 171548 firm level observation from 23 developed countries. We focus on developed countries as these nations generally possess

¹⁰⁰ More detailed information about the climate changes law database used for this study can be found here: <https://climate-laws.org/>. We obtain the data from the Climate Policy Radar Database on 3rd May 2023.

¹⁰¹ We selected 1997 as the starting point for our analysis to ensure dataset consistency, as we observe a marked increase in CLP from this year onward. Prior to 1997, CLP was low (e.g., 1–4 laws per year only in some countries), providing insufficient data for meaningful analysis. From 1997, there is a noticeable incremental increase in the number of CLP passed annually in every country in our sample. The sample period concludes in 2022 to ensure data completeness and to align with the observed incremental increase in CLP enactment. This timeframe allows for a robust analysis of the impact of CLP on firm corporate debt maturity decisions.

¹⁰² We initiated the data cleaning process by designating 'Main' as the document role, ensuring we focused exclusively on main law and police documents. Subsequently, we filtered these documents by type, selecting categories such as ACT, DECREE, DECREE LAW, Directive, Executive Order, Law, Law and Plan, Order, Ordinance, Regulation, Royal Decree, and Rules. These classifications are all significant legal instruments with substantial implications, which was essential for curating a dataset of meaningful and impactful climate laws and policies. We further refined the dataset to include only documents that had been passed and approved by relevant authorities, ensuring that it contained only those laws recognized and accepted by the country. To prevent any bias or skewness from repetition, we also removed duplicate laws and policies from the same country. After completing these steps, we arrived at a dataset comprising 921 unique, relevant, and officially sanctioned laws.

stronger, more well-defined, and effective climate laws and policies compared to the developing countries (Farzaneh & Banimostafaarab, 2025). Also, developed countries hold a predominant position in global Climate Governance, contributing a substantial 60.3% share, while developing nations account for 39.7% (Wang & Fang, 2024). Moreover, companies in developed countries exhibit significantly higher levels of climate change governance (Dilling et al., 2024), making them ideal sample-set for examining the impact of climate laws on corporate behaviour. We report a summary of the sample distribution across countries in the Appendix A.

3.4 Empirical Strategy: Climate law and debt maturity structure

To examine the effect of climate laws and policies on long-term borrowing, we use firm-level data and employ a fixed effect ordinary least square model. To do this, we construct a climate law index (CLI) to estimate the dynamic effects of CLPs on corporate debt maturity decisions.

3.4.1 Dependent variable

Prior studies have employed various measures to calculate long-term borrowing. Consistent with Antoniou et al. (2006), Aivazian et al. (2005), Zheng et al. (2012), Ben-Nasr et al. (2015), and Díaz-Díaz et al. (2016), we define firm debt maturity as the ratio of long-term debt to total debt (*where long term debt includes debt due in less than 4 years*), which represents the proportion of long-term obligations in a firm's overall debt structure.

However, due to data constraints in our multi-country analysis, we are unable to obtain the detailed debt maturity breakdowns provided in Keefe & Yaghoubi (2016) and Datta et al. (2019).¹⁰³ Additionally, following Titman & Wessels (1988) we measure short-term leverage as the ratio of short-term debt to total debt. The debt measures used in this study are derived from Compustat balance-sheet data and therefore capture aggregate debt obligations reported by firms, including both bank loans and publicly issued debt instruments.

For robustness checks, we employ alternative measures of long-term debt. Specifically, in line with prior research, we define an additional measure as the ratio of long-term debt to total liabilities (Awartani et al., 2016), same as scaling long-term debt

¹⁰³ Huang et al. (2016) emphasize that no single proxy for debt maturity is universally superior, reinforcing the validity of our approach.

to total assets. This allows us to verify the consistency of our findings across different definitions of debt maturity.

3.4.2 Independent variable

Our primary explanatory variable is the Climate Law Index (CLI), which captures the change in the implementation of CLP at the country-year level.¹⁰⁴ Following Simintzi et al. (2015), we construct CLI using the following equation:

$$CLI_{c,t} = CLI_{c,t-1} + R_{c,t} \text{ -----(3.1)}$$

In the specification (1) $R_{c,t}$ is an indicator variable that takes the value of 1, if CLP was introduced in a country c in the year t and the value 0 if there was no CLP in the country c in the year t . The CLI we construct varies at the country year level and ranges between 0 and 16 and captures the variation in the CLP between 1997 – 2022. The specification (1) construct ensures that the CLI evolves over time for each country based on the number of CLPs promulgated each year in that country. Thus, CLI captures the cumulative effects of CLP changes, with higher values indicating a greater number of CLP implementation in the country.

The CLI index construction can be understand as follows: Suppose $t = 0$ is the starting period in our sample, and we have three countries: A, B, and C, introducing CLPs over two consecutive years, 1997 and 1998. In the year 1997, Country A and C introduce climate laws, while Country B does not. So, for 1997, the CLI for Country A and C will be 1 ($0 + 1 = 1$), whereas for Country B, it will be 0 ($0 + 0 = 0$). In the year 1998, Country A and B introduce CLP, while Country C does not implement any new CLP in the year. So, for the year 1998, the CLI for Country A and B will be 2 (i.e. $1 + 1 = 2$), and 1 (i.e. $0 + 1 = 1$) respectively. However, for Country C, the index will not change as no CLP was introduced in that particular year (i.e. $1 + 0$).

3.4.3 Control variables

To ensure a robust analysis of the relationship between CLP and long-term debt, we incorporate several firm-level and country-level control variables, each theoretically and empirically justified. At the firm level, we control for firm size (Size), measured as the natural logarithm of total assets, which we expected to have a positive relationship with debt maturity, as larger firms typically face lower information asymmetry and have

¹⁰⁴ Importantly, CLI should not be interpreted as a measure of the stringency or regulatory intensity of CLPs. Instead, it is the total number of climate laws and policies enacted within a country over the sample years.

better access to long-term debt due to their greater collateral capacity and investment opportunities (Barclay & Smith, 1995; Stohs & Mauer, 1996). Next, we control for firm quality, defined as net income plus depreciation divided by net debt (Antoniou et al., 2006), is also expected to be positively related to long-term debt since higher-quality firms experience lower borrowing costs and better credit access (Diamond, 1991). Similarly, Property, Plant, and Equipment (PPE), measured as net PPE divided by total assets (Goodell et al., 2025), is anticipated to have a positive association with long-term debt, as tangible assets provide collateral, improving creditor confidence (Myers & Rajan, 1998). Sales growth, defined as the percentage change in sales from the previous year, is expected to positively association with long-term debt, as firms with higher growth potential are more likely to secure long-term financing to support expansion (Flannery, 1986). Also, high-growth firms prefer long-maturity debt to mitigate overinvestment risks, as it restricts their ability to divert cash to future projects. Additionally, asset maturity, measured as gross PPE divided by depreciation (Guedes & Opler, 1996), is anticipated to have a positive relationship with long-term debt in line with the maturity-matching principle (Myers, 1977), which suggests that firms with long-lived assets prefer long-term financing to align debt obligations with asset lifespans. Leverage, defined as total debt divided by total equity, is expected to be positively related to long-term debt, as highly leveraged firms tend to issue long-term debt to avoid frequent refinancing risks (Johnson, 2003). Return on Assets (ROA), calculated as EBITDA divided by total assets, is also expected to have a positive relationship with long-term debt, given that more profitable firms generate stronger cash flows, making them better positioned to obtain long-term financing (Diamond, 1991). Conversely, liquidity, measured as current assets divided by total assets, is expected to have a negative impact on debt maturity, as firms with higher liquidity tend to rely more on internal financing or short-term borrowing instead of long-term debt (Stohs & Mauer, 1996). At the country level, we control for country size, measured as log of Gross Domestic Product (GDP), which is anticipated to have a negative association with debt maturity. Larger economies tend to have more developed financial markets, providing firms with greater access to diverse financing options, which leads them to prefer shorter-term debt (Fan et al., 2012). By incorporating these firm-specific and macroeconomic controls, we ensure the robustness of our analysis, allowing us to effectively isolate the impact of CLP on corporate debt maturity. Table 3.1 presents the definitions of all variables used in this study. Some control variables were excluded (e.g., corporate governance related

variables) from the main regression models primarily due to data constraints. Additionally, including them would significantly reduce the available sample because of missing observations.

Table 3.1 Variable definitions

Variables	Calculation	Source
Dependent Variables		
Long term debt/TD (Debt maturity)	Total book value of long-term debt/Total Book value of Debt	Compustat Global
Short term debt/TD	Total book value of debt in current liabilities/ Total Book value of Debt	Compustat Global
Long term debt/TL (Debt maturity)	Total book value of long-term debt/Total Liabilities	Compustat Global
Total debt/Equity (TA/Equity)	The book value of debt/ the sum of the book value of debt and equity.	Compustat Global
Net Debt/Assets	Total book value of debt minus cash/ Total Book value of Assets	Compustat Global
Independent Variables		
Climate Law index (CLI)	constructed as: $CLI_{c,t} = CLI_{c,t-1} + R_{c,t}$ where $R_{c,t}$ takes the value of one if country c introduces climate legislations in year t and 0 otherwise. This indicator is designed to capture the long-run effects of changes in climate regulation.	
Moderating variables [National Governance]		
Rule of Law (RL)	The RL captures the perceptions of the extent to which agents have confidence in and abide by the rules of society, including the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. It typically ranges from approximately -2.5 to +2.5 with a higher RL score indicates stronger RL.	WDI database from World Bank
Regulatory Quality (RQ)	The RQ captures the perceptions of the government's ability to formulate and implement sound policies and regulations that permit and promote private sector development. It typically ranges from approximately -2.5 to +2.5 with a higher RQ score indicates better regulatory quality.	WDI database from World Bank
Control of Corruption (CC)	The CC reflects the perceptions of the extent to which public power is exercised for private gain. It typically ranges from approximately -2.5 to +2.5 with a higher CC score means better control of corruption.	WDI database from World Bank
Principal Component Analysis (PCA)	The PCA is a composite governance measure using the above three governance variables i.e., RL, RQ, and CC.	Author's own construction
Legal Origin Common	Dummy variable that takes the value of 1 if a firm is domiciled in country with common law legal origin, 0 otherwise.	

Legal French Civil	Dummy variable that takes the value of 1 if a firm in domiciled in country with French civil law legal origin, 0 otherwise.	
Legal German Civil	Dummy variable that takes the value of 1 if a firm in domiciled in country with German civil law legal origin, 0 otherwise.	
Legal Scandinavian Civil	Dummy variable that takes the value of 1 if a firm in domiciled in country with Scandinavian civil law legal origin, 0 otherwise.	
KZ Index	$-1.002 * (\text{Cashflow (Net income plus Depreciation and Amortization / PPE}_{t-1})) + 0.283 * (\text{Tobin's Q}) + 3.139 * (\text{Leverage (total debt to Total book value of assets)}) - 39.368 * (\text{Dividend / Total asset}_{t-1}) - 1.315 * (\text{Cash equivalent / PPE}_{t-1})$	Kaplan & Zingales, (1997)
Global Crisis Period	Dummy variable equal to 1 if the firm-year observation falls in the Global Financial Crisis (2008–2009) and the COVID-19 pandemic period (2020–2021); 0 otherwise.	
Country Controls		
Country size	The natural log transformation of GDP in USD	World Bank WDI database
Inflation	The annual growth rate of the GDP implicit deflator	World Bank WDI database
Firm Controls		
Firm-size	$\ln(\text{Book-value of Total Assets})$	Compustat Global
Firm quality	$\text{Net income plus depreciation/Net Debt}$	
PPE	$\text{Net PPE/ Total Assets}$	Compustat Global
ROA	$\text{EBITDA/Total Assets}$	Compustat Global
Asset Maturity	$\text{Gross PPE/Depreciation}$	Compustat Global
Leverage	$\text{Total debt/Total Equity}$	Compustat Global
Sales growth	$\left[\frac{\text{Total sales}_t - \text{Total sales}_{t-1}}{\text{Total sales}_t} \right]$	Compustat Global
Liquidity	$\text{Current Assets/ Total Assets}$	Compustat Global

This table shows the construction and the definitions of all the variables in the text.

3.5 Empirical Results

3.5.1 Descriptive statistics

Table 3.2 shows an industry distribution based on the Fama-French 48-industry classification, covering 23 developed countries from 1997 to 2022. The Business Services sector leads with 15.98% of the total observations, followed by electronic equipment (5.63%), Computer (5.63%). Additionally, capital-intensive industries like Steel (5.25%) and Machinery (5.10%) are moderately represented. Healthcare sectors, such as medical equipment (2.66%), Healthcare (1.53%), and pharmaceuticals (drugs) (4.37%) also have a notable presence. In contrast, industries like Tobacco Products (0.17%), Defense (0.12%), and Shipbuilding (0.32%) are minimally represented in our sample set.

Table 3.2 Industry distribution

	Freq.	Percent	Cum.
(1) Agriculture	1667	0.95	0.95
(2) Food Products	4183	2.39	3.34
(3) Candy & Soda	1031	0.59	3.92
(4) Beer & Liquor	1534	0.87	4.80
(5) Tobacco Products	294	0.17	4.97
(6) Toys	1466	0.84	5.80
(7) Recreation	3199	1.82	7.63
(8) Printing & Publishing	909	0.52	8.15
(9) Household Products	3754	2.14	10.29
(10) Clothing	1996	1.14	11.43
(11) Healthcare	2676	1.53	12.95
(12) Medical Equipment	4668	2.66	15.61
(13) Pharmaceuticals (Drugs)	7662	4.37	19.98
(14) Chemical	5604	3.20	23.18
(15) Rubber & Plastic	1801	1.03	24.21
(16) Textiles	1243	0.71	24.92
(17) Building Materials	5588	3.19	28.10
(18) Construction	6298	3.59	31.70
(19) Steel	3890	2.22	33.92
(20) Fabricated Products	757	0.43	34.35
(21) Machinery	8940	5.10	39.45
(22) Electrical Equipment	2647	1.51	40.96
(23) Automobiles & Trucks	4907	2.80	43.75
(24) Aircraft	1052	0.60	44.35
(25) ShipBuilding, Railroad	563	0.32	44.68
(26) Defense	204	0.12	44.79
(27) Precious Metals (Gold, Silver)	2298	1.31	46.10
(28) Non-Metallic & Industrial Metal Mining	2665	1.52	47.62
(29) Coal	691	0.39	48.02
(30) Petroleum & Natural Gas	6757	3.85	51.87
(32) Telecommunication	5332	3.04	54.91
(33) Personal Services	2079	1.19	56.10
(34) Business Services	28017	15.98	72.08
(35) Computers	4533	2.59	74.66
(36) Electronic Components	9874	5.63	80.30
(37) Laboratory Equipment	2726	1.55	81.85
(38) Paper & Paper Products	2440	1.39	83.24
(39) Containers & Packaging	824	0.47	83.71
(40) Transportation	6539	3.73	87.44
(41) Wholesale	8474	4.83	92.27
(42) Retail	9210	5.25	97.53
(43) Restaurants, Hotels, Motels	4335	2.47	100.00
Total	175327	100.00	

This table shows the list of industry we use to construct sample of the firms based on Fama-French 48 industry classification from 23 countries over 1997-2022. A frequency column presents the number of firm observations in each industry "Percent" indicates the proportion of the total sample, and "Cum." reflects cumulative percentages. Financial industries (SIC 6000–6999) and utilities (SIC 4900–4999) are excluded.

Table 3.3 presents the descriptive statistics of the key variables used in our analysis. The sample consists of 171486 firm-year observations. The mean value of Debt Maturity (*long-term debt/Total debt*) is 0.607, suggesting on average, firms rely more heavily on long-term debt. We observe there is considerable variation ($SD = 0.342$), with

some firms having no long-term debt (min = 0) and others relying entirely on it (max = 1). The CLI has a mean of 6.155 (on a 0 - 16 scale), suggesting a moderate degree of CLP presence across the sample countries, with a widespread (SD = 4.367), highlighting heterogeneity in CLP implementation.

Firm-specific characteristics also vary considerably. Firm size, measured as the natural logarithm of total assets (standardized)¹⁰⁵, has a mean of -0.35, suggesting that the sample includes a substantial proportion of smaller firms.¹⁰⁶ Firm quality, an indicator of financial health, has a mean of 0.115 and a standard deviation of 3.568, with values ranges between -19.984 to 19.022, reflecting variation in market perceptions of firm fundamentals.

The average proportion of property, plant, and equipment (PPE) to total assets is 0.284, indicating a moderately asset-intensive sample. Sales growth is positive on average (0.222), but shows high skewness, suggesting a few firms experience exceptionally high growth. Notably, the asset maturity shows considerable dispersion, with a mean of 13.682 and a standard deviation of 34.079, showcasing a significant variation in the lifespan of firms' assets. This observed dispersion is due to the presence of a capital-intensive sectors such as manufacturing and utilities which tend to have longer-lived assets, whereas technology and service firms typically rely on shorter-lived intangible assets (Antoniou et al., 2006; Renato Soares Terra, 2011). Overall, this suggests that firms in the sample operate across diverse industries, some with short-lived assets (e.g., services), and others with long-term physical capital (e.g., utilities, manufacturing).

Leverage, measured as total debt relative to total equity, has a mean of 0.827 and a wide standard deviation of 1.987. The presence of extreme values (ranging from -6.662 to 13.673) points to large differences in capital structure choices, with some firms being highly leveraged while others are over-capitalized. Return on Assets (ROA) has a mean of -0.492 and an exceptionally high standard deviation of 19.514, with values ranging from -119.069 to 32.718. This highlights substantial variability in firm profitability, with some firms experiencing significant losses in our sample set. Liquidity, defined as

¹⁰⁵ Normalized around the sample mean. This transformation helps us improves comparability across firms and reduces skewness in the distribution.

¹⁰⁶ In dollar terms, the mean total assets in the sample are approximately USD 242 billion. However, this value is influenced by a small number of very large firms indicating that the distribution of firm size is highly skewed. Therefore, the negative standardized mean reflects the presence of a substantial proportion of smaller firms relative to these large firms in the sample.

current assets relative to total assets, has a mean of 0.476 and ranges from 0.033 to 0.977, indicating that most firms maintain a reasonable level of liquid assets. Higher liquidity may enable firms to better absorb the transitional costs associated with CLP, potentially reducing their reliance on short-term borrowing. Finally, country size, a macroeconomic control variable, has a mean near zero (0.066) but displays considerable variation (standard deviation 1.40). This suggests differences in the scale of national economies across the sample, which may affect institutional quality and financial market development.

Additionally, Table 3.3, panel B provides the summary statistics of additional debt structure and firm-level financial variables. The ratio of short-term debt to total debt has a mean of 0.393 and a standard deviation of 0.342, suggesting that, on average, firms rely less on short-term borrowing than long-term debt. The total debt-to-equity (TD/Equity) ratio has a mean of 0.365, indicating that, on average, debt constitutes roughly 36% of a firm's total equity. The relatively moderate average, combined with a standard deviation of 0.277, suggests that while many firms operate with conservative leverage, some firm has significantly higher debt. The net total debt-to-assets ratio shows a mean of 0.098, suggesting that cash holdings offset a substantial portion of gross debt for many firms. The minimum value of -0.774 indicates that some firms have cash exceeding total debt, while the positive skew in the distribution reflects the presence of more leveraged firms. This variable particularly helps in distinguishing between firms that are genuinely debt-reliant and those that maintain financial flexibility through large cash reserves. Finally, we use the ratio of long-term debt to total liabilities as an alternative definition and observe a mean of 0.287 and a standard deviation of 0.237, further confirming that long-term debt accounts for a smaller share of total liabilities across the sample. This could reflect structural preferences for short-term debt or constraints in accessing long-term financing.

These statistics suggest that firms exhibit considerable heterogeneity in their financial policies and debt structures. The variation in leverage, debt maturity, and asset characteristics underscores the importance of controlling for firm-specific and macroeconomic factors in our empirical analysis. The average debt maturity structure of our sample firms closely aligns with the findings presented by Antoniou et al. (2006).

Table 3.3 Descriptive statistics

Panel A	N	Mean	SD	p25	Median	p75	Min	Max
Debt maturity (LT/TD)	175745	0.607	0.342	0.33	0.698	0.919	0	1

CLI	175745	6.155	4.367	2	6	10	0	16
Size	175745	-0.35	3.229	-2.729	-0.757	1.699	-10.797	12.385
Firm quality	175745	0.115	3.568	-0.293	0.153	0.519	-19.984	19.022
PPE	175745	0.284	0.232	0.093	.228	0.42	0.002	0.928
Sales growth	175745	0.222	0.855	-0.037	.062	0.202	-0.811	6.527
Asset maturity	175745	13.682	34.079	4.31	7.244	11.773	0.871	353.545
Leverage	175745	0.827	1.987	0.145	0.46	0.987	-6.662	13.673
ROA	175745	-0.492	19.514	-1.046	3.959	7.891	-119.069	32.718
Liquidity	175745	0.476	0.230	0.3	0.473	0.645	0.033	0.977
Country size	175745	0.066	1.399	-0.767	-0.063	1.493	-4.738	2.235

Descriptive statistics of additional variables

Panel B	N	Mean	SD	p25	Median	p75	Min	Max
Short-term debt/TD	175745	0.393	0.342	0.81	0.302	0.670	0	1
Total Debt/Equity	175743	.365	0.277	.146	.334	.522	0	1.386
Net-Total Debt/TA	175683	0.098	0.284	-0.063	0.121	0.284	-0.774	0.757
Long-term debt/TL	175745	0.287	0.237	0.067	0.254	0.461	0	1

This table reports the descriptive statistics for the variables used in our analysis to analyse the impact of CLP on the corporate debt maturity. It covers the period from 1997-2022 of 175745 firm-year observations from 23 countries. Financial industries (SIC codes 6000–6999) and utilities (SIC codes 4900–4999) are omitted. Continuous variables in our sample are winsorized at the 1st and 99th percentiles.

Table 3.4 presents the pairwise Pearson correlation coefficients among all the key variables in the study. The results indicate that long-term debt is negatively correlated with the CLI, suggesting that firms in countries with CLP tend to have less long-term debt. Findings support our hypothesis that firms operating in countries with CLP are likely to have negative association with longer debt maturities.

PPE is positively correlated with long-term debt, supporting the fact that firms with higher tangible assets can secure long-term debt more easily due to collateralization. Leverage and ROA also show positive correlations with long-term debt, suggesting that more leveraged and profitable firms rely more on long-term debt. In contrast, liquidity exhibits the strongest negative correlation with long-term debt, indicating that firms with higher liquidity are less reliant on long-term debt. The CLI is positively correlated with country size, suggesting that larger economies tend to have more climate policies Overall, our correlations results are broadly consistent with previous literature (Datta et al., 2019; Choi, 2024).

Table 3.4 Pairwise panel correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)Debt maturity (LT/TD)	1.000										
(2) CLI	-0.016***	1.000									
(3) Size	-0.051***	0.312***	1.000								
(4) Firm quality	0.027***	-0.011***	0.005**	1.000							
(5) PPE	0.120***	-0.045***	0.108***	0.007***	1.000						
(6) Sales growth	0.005**	-0.041***	-0.152***	0.003	-0.024***	1.000					
(7) Asset maturity	-0.042***	0.023***	-0.041***	-0.015***	0.325***	0.055***	1.000				
(8) Leverage	0.047***	-0.022***	0.075***	-0.001	0.082***	-0.017***	-0.010***	1.000			
(9) ROA	0.079***	-0.017***	0.313***	-0.011***	0.060***	-0.137***	-0.062***	0.011***	1.000		
(10) Liquidity	-0.264***	-0.013***	-0.067***	0.009***	-0.621***	-0.014***	-0.204***	-0.091***	-0.040***	1.000	
(11) Country size	0.123***	0.106***	0.029***	-0.001	-0.069***	-0.016***	-0.060***	0.012***	-0.077***	0.029***	1.000

This table reports Pearson correlation coefficients between the key variables used in the analysis. All pairwise correlations are below the threshold (0.8), alleviating a concern of multicollinearity issues. Asterisks denote statistical significance at the 1%***, 5%** , and 10%* levels.

Table 3.5 reports the VIF values. The mean VIF is 1.61, well below the common threshold of 10, indicating that multicollinearity is not a major concern in the analysis.

Table 3.5 Variance inflation factor (VIF)

Variables	VIF	1/VIF
CLI	3.20	0.312019
Size	1.39	0.720904
Firm quality	1.00	0.998206
PPE	2.03	0.492026
Sales growth	1.09	0.915706
Asset maturity	1.28	0.778648
Leverage	1.17	0.858361
ROA	1.13	0.885864
Liquidity	2.69	0.371724
Country size	1.07	0.937140
Mean VIF	1.61	

This table presents the VIF values for the independent variables used in the regression analysis. The results confirm that the no VIF value is above 10.

3.5.2 Baseline results

In this section, we present our empirical analyses. First, we estimate baseline ordinary least squares (OLS) estimations using our Climate Law Index (CLI) measures to predict the term to maturity relationship. We incorporate a battery of firm-level and country-level control variables that may influence corporate debt maturity decisions. For all our model we use a lag specification for our explanatory variable because it reduces endogeneity concerns and improve the inferences.¹⁰⁷

Specifically, we use lagged values by one period of all independent and control variables, ensuring that CLI precedes observed changes in corporate debt maturity. This approach primarily addresses key econometric challenges i.e., reverse causality which can otherwise distort estimates and undermine causal interpretation (Goodwell et al., 2025). A major concern in analysing the CLP and long-term debt relationship is reverse causality as firms with greater access to debt financing may proactively allocate resources to mitigate climate regulatory risk, potentially shaping regulatory responses rather than being influenced by it. Additionally, capital structure adjustments take time (Whited & Roberts, 2013), further justifying the use of lagged explanatory variables.

By lagging CLI and control variables, we ensure that CLI precedes long-term debt

¹⁰⁷ Incorporating lagged variables in panel data analysis aligns with best practices in econometric modelling and is supported by extensive literature in corporate finance research (see., Hossain et al., 2021; Delis et al., 2024; Wooldridge (2010)). Also, lagged variables helps in addressing issues of endogeneity, dynamic adjustment, and temporal causality. Firm decisions, such as those related to capital structure, debt maturity, or investment are often influenced by past performance, historical financial constraints, or previous regulatory exposure.

adjustments, thereby isolating the direction of causality from climate regulatory pressures to financing decisions. Our methodological choices align with best practices in climate finance research. Notably, Goodwell et al. (2025) advocate for temporal separation between predictors and outcomes to disentangle bidirectional relationships and improve estimation accuracy.

Furthermore, we examine the heterogeneous effects of climate laws and policies on long-term debt decisions. To enhance the reliability of our findings, we test our results with an alternative measure of long-term debt and conduct sub-sample analyses. We also add control variables to mitigate omitted variable bias. These checks ensure that our conclusions about the impact of CLP on long-term debt are robust, minimizing the chances of measurement errors and biases. We then extend our analysis by exploring the impact of CLI with legal origin, national governance, non-linear relationships, and their impact on financially constrained firms, alongside macroeconomic shocks. Acknowledging the endogenous nature of our primary explanatory variable (CLI), we subsequently address endogeneity concerns by employing instrumental variables in a 2SLS setting.

We use the following form as a baseline regression equation to estimate the relationship

$$Debt\ maturity_{it} = \beta_0 + \beta_1 CLI_{c,t-1} + X_{i,t-1} + firm_i + ind_j * time_t + \varepsilon_{it} \text{ -----(3.2)}$$

Where $Debt\ maturity_{it}$ is the long-term debt by firm i in year t . We present the estimates of the baseline OLS equation in Table 6. $CLI_{c,t-1}$ is the Climate law index a main explanatory variable. $X_{i,t-1}$ is the vector of all the control variables named, size, firm quality, PPE, sales growth, asset maturity, leverage, ROA, liquidity, and country size. Additionally, the equation incorporates $firm_i$ and $ind_j * time_t$ fixed effect respectively. e_{it} is the error term. For all the regression equation, we cluster the standard errors at the firm level to account for the issues of heteroscedasticity and autocorrelation.¹⁰⁸

To begin with, this study employs a step-by-step fixed effects modelling approach to control for unobserved heterogeneity and improve the robustness of the estimates. Table 3.6, column 1 uses OLS regression with no fixed effect, which provides initial

¹⁰⁸ The primary reason for clustering at the firm level is to account for intra-firm correlation in the error terms. Also, clustering at the firm level ensures that these firm-specific shocks do not bias the standard error estimates. Our results remain fundamentally the same even when standard errors are grouped by country.

insights but is susceptible to the omitted variable bias as it does not account for firm, industry, or year-level heterogeneity. To address firm-specific unobserved heterogeneity, column 2 includes firm and year fixed effects, significantly improving model fit. This aligns with prior studies emphasizing the importance of firm and year-level controls in corporate financing decisions (Lemmon et al., 2008).¹⁰⁹

However, given that firms operate in distinct industry environments in column 3 we include industry-year fixed effects to control for industry-year variations, ensuring that industry-wise shock in each year do not bias the results (Graham et al., 2015). However, it does not control for unobserved firm-level heterogeneity. Column 4 includes country fixed effects, thereby controlling for time-invariant unobserved heterogeneity across countries such as legal origins, institutional quality, or baseline market development. However, it does not control for unobserved firm-level heterogeneity or time-varying industry and year shocks, potentially biasing estimates.

Given that our primary research question is about within-firm responses to CLI changes over time. Therefore, in column 5 we incorporate firm and industry-year fixed effects to net out all time-invariant differences across firms, while industry-year controls for sector-level shocks that vary over time.¹¹⁰ All the regression result included in this study has firm and industry-year fixed effect.¹¹¹ The coefficient of the CLI remains negative and statistically across all the models, confirming that CLI is negatively associated with *long-term debt* even after controlling for firm, and industry-year level characterises.

The coefficient of interest in column 5 is β_1 which captures the firms' debt maturity association with CLI. The estimated coefficient on CLI is -0.0106 at 1 percent significance, suggesting that a one-unit increase in the CLI score is associated with a 106 basis point reduction in the proportion of long-term debt relative to total debt.¹¹² For more

¹⁰⁹ A common approach in corporate finance that accounts for time-invariant firm heterogeneity and global time shocks.

¹¹⁰ This helps us control for unobserved heterogeneity at both the firm and industry-year levels. These dual fixed effects model effectively accounts for time-invariant characteristics specific to each firm and captures temporal shocks or trends unique to each industry within a given year.

¹¹¹ Given the cross-country nature of the dataset and the potential heterogeneity across firms, year and industries, including all three fixed effects is the most robust choice as it provides robust estimates of the relationship between CLP and debt maturity (see Petersen, 2009; Wooldridge, 2010; Gormley and Matsa (2014)).

¹¹² The coefficient of -0.0106 on CLI suggests that a one-unit increase in the CLI is associated with a 1.06 percentage point decrease in debt maturity (long-term debt). Converting this into basis points, we multiply the coefficient by 100, as 1 percentage point equals 100 basis points. This results in a 106-basis point reduction in debt maturity (long-term debt), aligning with the interpretation used in Simintzi et al., (2015).

intuitive understanding we estimate the CLI coefficient as a one-unit increase in CLI is associated with a 1.74% decrease in long-term debt.¹¹³ Our finding aligns with the existing literature that underscores the detrimental effects of regulatory risk on long-term debt financing (Datta et al., 2019; Dang et al., 2022b; Choi, 2024;), our findings corroborate this by revealing firms exposed to CLP enactment led to a decline in long-term debt borrowing.

Further, in line with our assertion that CLP heightens the firm risk by exposing firms to regulatory uncertainty like risk of stranded assets, forced upgrades, disrupted operation, high operation costs, penalties in future and increase in insurance premium costs (Campiglio et al. 2022). The negative effect of the CLI on long-term debt is consistent with the stated hypotheses and theoretical underpinning. According to Meckling & Jensen (1976) and Myers (1977), firms facing higher uncertainty and risk tend to shorten their debt maturity to maintain financial flexibility and avoid long-term commitments as that could become costly or unsustainable under changing regulatory conditions. As noted above, CLP enactment may force firms to adapt to new business models, invest in green technologies, additional regulatory compliance or divest from carbon-intensive assets. These transitions require financial flexibility, which is better supported by reliance on short-term debt. In this line Diamond (1991) and Flannery (1986) reveal that firms prefer short-term debt when they anticipate future changes in investment opportunities or need to adjust their capital structure in response to external shocks.

All our control variable relationship is in line with an expectation discussed in section 5.3. Firm size has a positive and significant relationship with debt maturity, indicating that larger firms tend to have a higher proportion of long-term debt. This is likely due to their diversified operations and stable cash flows, making them appealing to long-term lenders. This aligns with previous research, which shows that larger firms face reduced information asymmetry and lower default risk (Barclay & Smith, 1995).

We see that firm quality and ROA also positively impact debt maturity, supporting that financially stable and profitable firms are more likely to secure long-term debt (Stohs & Mauer, 1996). PPE and asset maturity support the asset-matching hypothesis, as firms with more tangible assets and longer asset lives rely more on long-

¹¹³The coefficient of CLI is -0.0106 (from Table 6) and the mean value of debt maturity is 0.607 (from Table 3). So, we calculate the average is equal to $-0.0106 / 0.607 * 100 = -1.74$ percent.

term debt (Myers, 1977). Leverage is positively related to debt maturity, aligning with the view that highly leveraged firms seek long-term financing to mitigate rollover risk (Johnson, 2003). Conversely, liquidity is negatively associated with debt maturity, suggesting that firms with higher liquidity prefer short-term financing (Diamond, 1991). At the macro level, country size negatively affects debt maturity, indicating that firms in larger economies have better access to short-term financing (Demirgüç-Kunt & Maksimovic, 1999). These findings highlight the interplay between firm characteristics, financial constraints, and macroeconomic conditions in shaping corporate debt maturity structures.

Overall, firms' debt maturity decisions appear to be influenced by factors such as firm size, asset tangibility, liquidity, profitability, and country economic conditions.

Table 3.6 Baseline: CLI and debt maturity relationship

	(1) Debt maturity (LT/TD)	(2) Debt maturity (LT/TD)	(3) Debt maturity (LT/TD)	(4) Debt maturity (LT/TD)	(5) Debt maturity (LT/TD)
CLI (t-1)	-0.0062*** (0.0000)	-0.0101*** (0.0000)	-0.0333*** (0.0000)	0.0085*** (0.0000)	-0.0106*** (0.0000)
Size (t-1)	-0.0032*** (0.0000)	0.0276*** (0.0000)	0.0046*** (0.0000)	0.0353*** (0.0000)	0.0273*** (0.0000)
Firm quality (t-1)	0.0024*** (0.0000)	0.0007*** (0.0021)	0.0022*** (0.0000)	0.0014*** (0.0000)	0.0006*** (0.0031)
PPE (t-1)	-0.0481*** (0.0000)	0.0478*** (0.0002)	-0.0440*** (0.0000)	0.0317*** (0.0000)	0.0533*** (0.0000)
Sales growth (t-1)	-0.0037*** (0.0010)	0.0056*** (0.0000)	-0.0014 (0.1961)	0.0022** (0.0417)	0.0051*** (0.0000)
Asset maturity (t-1)	-0.0006*** (0.0000)	0.0001* (0.0694)	-0.0006*** (0.0000)	-0.0003*** (0.0000)	0.0001 (0.1264)
Leverage (t-1)	0.0066*** (0.0000)	0.0019*** (0.0000)	0.0059*** (0.0000)	0.0044*** (0.0000)	0.0019*** (0.0000)
ROA (t-1)	0.0018*** (0.0000)	0.0003*** (0.0001)	0.0017*** (0.0000)	0.0008*** (0.0000)	0.0003*** (0.0005)
Liquidity (t-1)	-0.4487*** (0.0000)	-0.1403*** (0.0000)	-0.3921*** (0.0000)	-0.2470*** (0.0000)	-0.1366*** (0.0000)
Country size (t-1)	0.0484*** (0.0000)	-0.0808*** (0.0000)	0.0557*** (0.0000)	-0.0253*** (0.0000)	-0.0831*** (0.0000)
Adjusted R Square	0.14	0.54	0.18	0.27	0.54
Firm FE	No	Yes	No	No	Yes

Year FE	No	Yes	No	No	No
Industry FE	No	No	No	No	No
Country FE	No	No	No	Yes	No
Industry*year FE	No	No	Yes	No	Yes
N	175745.00	171634.00	175664.00	175745.00	171548.00

This table displays the regression results for the sample period from 1997 to 2022. The dependent variable in this analysis is Debt Maturity (long term debt relative to total book value of debt. Columns (1)– (5) incrementally add firm, year, and industry-year fixed effects (FE). Significance levels: *** (1%), ** (5%), * (10%).

3.5.3 Additional insights: Impact of CLI on Total debt and Short-term debt

In the previous section, we document a significant negative impact of change in climate laws and policies on long-term debt financing, raising an important question: what happens to short-term borrowing in response to these regulatory changes? To address this, we extend our analysis by examining how change in climate laws and policies influences firms' debt maturity structure (*i.e.*, *long-term versus short-term*), as well as their overall leverage decisions. We estimate the following fixed-effects panel regression model:

$$Debt\ structure_{i,t} = \beta_0 + \beta_1 CLI_{c,t-1} + X_{i,t-1} + firm_i + ind_j * time_t + \varepsilon_{it} \text{-----}(3.3)$$

Where, $Debt\ structure_{i,t}$ refers to four different dependent variables as specified in Table 3.7. These four variables are defined as follows: Debt Maturity which is defined as long-term debt to total debt ratio (LT/TD), Short-term Debt Ratio defined as short-term debt to total debt ratio (ST/TD) which is obligations due within one year (*i.e.*, debt in current liabilities), Total Debt Ratio defined as total debt to total equity (TD/Equity)¹¹⁴, and Net Debt Ratio defined as total debt minus cash holdings to total assets (TD-Cash/TA), respectively.

Drawing on existing literature, we hypothesize that firms adjust their leverage in response to policy shocks (*e.g.*, climate laws and policies) to maintain financial flexibility and manage regulatory uncertainty (Simintzi et al., 2015; Vega-Gutierrez et al., 2025; Dang et al., 2022b). As noted above in the previous section, compliance with CLP necessitates additional borrowing for investments in clean technology, carbon reduction initiatives, regulatory compliance measures or navigate through the CLP uncertainty. In this line, we also examine whether firms adjust their total debt and net-total debt levels

¹¹⁴ We use it as the primary leverage measure of leverage in this study because it is the theoretically most appropriate measure of the capital structure decision (Modigliani & Miller, 1958, Jensen & Meckling, 1976). Moreover, the definition captures the permanent capital structure split and is widely used in empirical studies including Rajan & Zingales (1995), Flannery & Rangan (2006), and Lemmon et al., (2008).

following the enactment of climate laws and policies. The results of this analysis are presented in Table 3.7.

The findings from Table 3.7, as reported in Column (1), reveal that firms reduce their reliance on long-term debt in response to the enactment of climate laws, while simultaneously increasing their short-term borrowing (see Column 2). This further confirms our assertion that CLP leads to an increase in short-term debt. This is also in line with the real options theory, which argues that firms facing uncertainty, such as that created by enactment of climate law and policies, prefer to retain financial flexibility, enabling them to adapt their investment and financing decisions as regulatory landscapes change. CLPs introduce significant uncertainty, as firms are often unsure about future compliance costs, potential penalties, or shifts in enforcement mechanisms. To navigate this uncertainty, firms eschew long-term debt, which locks them into fixed obligations, and instead rely on short-term debt, which allows them to periodically reassess their financing needs as CLIs evolve.

Additional analysis reported in (Columns 3 & 4) helps us understand the leverage dynamics in the wake of CLP enactment. Not surprisingly, firms moderately increase their total debt levels i.e., 0.034% (see column 3). Usually, CLPs' enactment imposes direct and indirect costs on firms, such as carbon taxes, emissions trading systems, or penalties for non-compliance. These costs create a financial burden that firms must address, often through increased borrowing to adjust their financial structures. This finding is in line with the view from the existing literature. For instance, Flammer (2021) identifies that firms increase their debt level to finance strategic shifts, such as transitioning to low-carbon business models. The author further reveals that companies adopt to this strategic shift to improve their environmental performance leading to higher environmental ratings and lower CO₂ emissions. Similarly, Bolton & Kacperczyk (2021) find that firms exposed to climate risks tend to increase their leverage to finance adaptation and mitigation strategies. We apply a theoretical framework to clarify this relationship. First, through the lens of Institutional theory, we argue that companies adapt to regulatory pressures in order to maintain legitimacy and avoid penalties. This adaptation may include borrowing funds to align their business practices with changes in the regulatory environment. CLP presents a regulatory force that compels firms to conform to new environmental standards. To comply with CLP, firms may require investing in clean technologies, carbon reduction measures, and other sustainability initiatives. These investments often require significant financial resources, which firms may obtain through

debt financing.

Second, provided by Myers & Majluf, (1984) pecking order theory explains the mechanism through which firms increase their borrowing. As noted above, CLPs create a need for additional amount that cannot be fully funded through internal sources (e.g., cash and liquid assets), forcing firms to rely on external debt. When companies need external financing, they tend to choose debt over equity because debt involves lower information costs. Together, these theories provide a strong understanding why firms increase their total debt levels in the face of climate laws.

Additional insight from Column 4 (Net Debt/TA) suggest that climate laws are influencing corporate leverage, with a stronger effect on net leverage. Specifically, a one-unit increase in CLI is associated a 0.0025 increase in Net Debt/TA (a 2.55% increase relative to the mean). The larger effect on Net Debt/TA suggests that firms are not only taking on more debt but also potentially reducing their cash holdings in response to climate regulations. Acharya et al. (2011) argue that firms with lower cash holdings are more exposed to external shocks. Climate laws and policies enactment leads to decrease in cash reserves and could increase firms' vulnerability to climate-related financial risks.

Overall, the CLP is not only influencing leverage but also the term structure of debt. However, the modest economic magnitude on leverage suggests that firms are cautiously adapting rather than making drastic changes in the leverage.

Table 3.7 The Impact of CLI on debt maturity relationship

	(1) Debt maturity (LT/TD)	(2) Short-term debt/TD	(3) TD/Equity	(4) Total debt- net/TA
CLI (t-1)	-0.0106*** (0.0000)	0.0106*** (0.0000)	0.0034*** (0.0013)	0.0025*** (0.0055)
Size (t-1)	0.0273*** (0.0000)	-0.0273*** (0.0000)	0.0242*** (0.0000)	0.0352*** (0.0000)
Firm quality (t-1)	0.0006*** (0.0031)	-0.0006*** (0.0031)	-0.0005*** (0.0025)	-0.0003** (0.0177)
PPE (t-1)	0.0533*** (0.0000)	-0.0533*** (0.0000)	0.1124*** (0.0000)	0.0947*** (0.0000)
Sales growth (t-1)	0.0051*** (0.0000)	-0.0051*** (0.0000)	-0.0009 (0.3104)	-0.0009 (0.2539)
Asset maturity (t-1)	0.0001 (0.1264)	-0.0001 (0.1264)	-0.0001*** (0.0015)	-0.0001** (0.0315)
Leverage (t-1)	0.0019***	-0.0019***	0.0138***	0.0104***

	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ROA (t-1)	0.0003*** (0.0005)	-0.0003*** (0.0005)	-0.0018*** (0.0000)	-0.0008*** (0.0000)
Liquidity (t-1)	-0.1366*** (0.0000)	0.1366*** (0.0000)	-0.0933*** (0.0000)	-0.3774*** (0.0000)
Country size (t-1)	-0.0831*** (0.0000)	0.0831*** (0.0000)	-0.0116 (0.1483)	-0.0160** (0.0185)
Adjusted R-square	0.54	0.54	0.61	0.73
Firm FE	Yes	Yes	Yes	Yes
Industry*year FE	Yes	Yes	Yes	Yes
N	171548.00	171548.00	171546.00	171486.00

This table presents the regression results examining the relationship between the CLI and different measures of corporate debt structure. Column (1) represents long-term debt as a proportion of total debt (Debt Maturity), Column (2) represents short-term debt as a proportion of total debt, Column (3) represents total debt as a proportion of total assets, and Column (4) represents total debt less cash holdings as a proportion of total assets. All independent variables are lagged by one period (t-1). The model incorporates firm fixed effects (FE) and industry-year fixed effects (FE). Statistical significance is denoted as follows: *** p<0.01, ** p<0.05, * p<0.10.

3.5.4 Sectoral characteristics of CLP and corporate debt maturity relationships

To deepen our understanding of how different types of CLPs influence corporate debt maturity, we extend our analysis by incorporating sector-specific characteristics based on the UNEP's classification.¹¹⁵ To do this, we manually reviewed 921 CLPs and categorized the descriptions categories. According to the UNEP, five key sectors have the highest potential to reduce global GHGs and are thus central to climate policy interventions: Energy, Agriculture, Transport, Buildings and Cross-sectoral.

According to Berry & Rondinelli (1998) and Fan et al., (2019) firms in the energy and industry sectors face stringent regulatory pressures to adopt to proactive environmental management strategies. We assert that energy focused CLPs may lead firms to prefer shorter debt maturities to maintain financial flexibility in an evolving regulatory landscape. Whereas agriculture sector usually encounters CLPs focusing more on sustainable practices and resource management rather than direct emissions reductions (Henderson et al., 2021). Firms exposed agricultural focused CLPs might not have an immediate compliance pressures but could be influenced by long-term sustainability targets.

However, firms operating in transport firms, particularly those in aviation and shipping, face increasing regulatory scrutiny regarding carbon emissions (Bows-Larkin, 2015; Cullinane & Cullinane, 2013), potentially leading to a shift towards shorter debt

¹¹⁵ See <https://wesr-climate.unepgrid.ch/climate/responses/which-sectors-have-major-impact> [Accessed on 2 January 2025].

maturities. Similarly, firms involved in urban development and construction may face regulations related to energy efficiency and sustainable building practices, influencing their financing structures depending on the pace of regulatory changes.

Further, we incorporate a cross-sectoral perspective to better understand how climate laws and policies influence corporate debt maturity. Climate change responses often extend beyond individual sectors, creating interconnected regulatory pressures that affect multiple industries simultaneously. For instance, energy efficiency standards, carbon pricing mechanisms, and emission trading schemes impact not only the energy sector but also transport, and buildings sectors. We estimate a series of sectoral analysis based on the following specification:

$$\text{Debt maturity}_{it} = \beta_0 + \beta_1 \text{CLI}_{c,t-1} + \beta_2 \text{CLI}_{c,t-1} * \text{sectoral laws}_{c,t-1} + \beta_3 \text{sectoral laws}_{c,t-1} + X_{i,t-1} + \text{firm}_i + \text{ind}_j * \text{time}_t + \varepsilon_{it} \text{-----} (3.4)$$

Table 8 explores whether the enactment of sectoral climate laws moderates the relationship between CLI and debt maturity decisions of firms. In Table 3.8, sectoral law dummy variables (*Energy law*, *Transport law*, *Building law*, *Agricultural law*, *Cross-sectoral law*) are defined as equal to 1 if a CLP targeting that sector was enacted in a given country-year, and 0 otherwise.

The finding reveals significant sectoral heterogeneity in how firms adjust their debt maturity structures in response to CLI, with the effects varying based on the specific regulatory focus of the laws. Firms exposed to energy laws increase their reliance on long-term debt, as indicated by the positive and statistically significant interaction term $\text{CLI} \times \text{Energy Law}$ (0.00127, $p < 0.01$). This suggests that energy laws, which often mandate large-scale investments in renewable energy and carbon reduction technologies, compel firms to finance these capital-intensive projects through long-term debt. For instance, a one-unit increase in the cumulative effect of CLI is associated with a 0.127 percentage point increase in the proportion of long-term debt for firms exposed to energy laws. This aligns with the trade-off theory of capital structure, which posits that firms balance the benefits of long-term debt (e.g., stable financing for large investments) against its costs (e.g., reduced flexibility) (Myers, 1977; Flammer, 2021). In contrast, firms exposed to transport laws reduce their reliance on long-term debt, as evidenced by the negative and statistically significant interaction term $\text{CLI} \times \text{Transport Law}$ (-0.00172, $p < 0.10$). This reflects the high uncertainty and rapid technological changes in the transport sector, where firms prefer short-term debt to maintain financial flexibility, consistent with real options theory (Dixit & Pindyck, 1994; Hsu et al., 2023). Firms

exposed to building laws and cross-sectoral laws show no significant changes in debt maturity, likely because these laws require smaller, incremental investments that can be funded through internal resources. Similarly, firms exposed to agricultural laws exhibit a weak and non-significant response, possibly due to the sector's reliance on government subsidies and smaller-scale investments.

As shown in Table 3.8, the findings demonstrate that the impact of CLPs on debt maturity is not uniform across sectors but depends critically on the nature of climate-related regulatory exposure and investment requirements. For instance, the results indicate that energy-related CLPs are associated with an increase in long-term debt usage, which reflect the capital-intensive nature of energy transition investments (Wilson et al., 2025). In contrast, transport-related climate laws are associated with a shift towards shorter debt maturities, suggesting that firms in this sector prioritize financial flexibility in response to technological uncertainty and evolving regulatory standards (Engau et al., 2011). Notably, the absence of significant effects in building, agricultural, and cross-sectoral CLPs further highlights that not all CLPs impose the same financial constraints or investment needs for firms.

Furthermore, the findings indicate that the relationship between CLPs and debt maturity is determined by the relative importance of long-term investment requirements versus the need for financial flexibility under uncertainty. In sectors such as energy, where compliance with CLP requires large, irreversible capital investments, firms increase their reliance on long-term debt to secure stable financing. In contrast, in sectors such as transport, where technological uncertainty and regulatory changes are more pronounced, firms reduce long-term debt and rely more on short-term financing to retain flexibility. This pattern provides empirical support for both trade-off theory and real options theory, suggesting that firms actively adjust debt maturity by balancing the benefits of long-term financing against the costs of reduced flexibility in uncertain regulatory environments.

Overall, the above analysis helps us conclude that climate regulation affects corporate debt maturity decisions through sector-specific CLPs, rather than as a uniform climate-related regulatory shock. These findings underscore the importance of considering CLPs sectoral focus when analysing the financial impacts of climate laws and policies. Importantly, our finding also serves a guide for a policymaker to tailor climate regulations to the specific needs and challenges of different sectors while

ensuring that firms have the financial flexibility to comply without compromising their long-term stability.

Table 3.8 Sectoral characteristics of CLI and debt maturity relationship

	(1) Debt maturity (LT/TD)	(2) Debt maturity (LT/TD)	(3) Debt maturity (LT/TD)	(4) Debt maturity (LT/TD)	(5) Debt maturity (LT/TD)
CLI (t-1)	-0.0108*** (-8.76)	-0.0106*** (-8.65)	-0.0104*** (-8.49)	-0.0108*** (-8.64)	-0.0108*** (-8.73)
CLI * Energy law (t-1)	0.00127** (3.06)				
Energy law (t-1)	-0.00905** (-2.72)				
CLI * Building law (t-1)		0.000759 (0.52)			
Building law (t-1)		-0.00433 (-0.43)			
CLI * Transport law (t-1)			-0.00172* (-2.50)		
Transport law (t-1)			0.0163* (2.33)		
CLI * Cross- sectoral law (t-1)				-0.0000676 (-0.16)	
Cross-sectoral law (t-1)				-0.00409 (-1.17)	
CLI * Agricultural law (t-1)					0.00108 (1.46)
Agricultural law (t-1)					-0.0101 (-1.76)
Size (t-1)	0.0273*** (12.33)	0.0273*** (12.32)	0.0273*** (12.31)	0.0273*** (12.32)	0.0273*** (12.31)
Firm quality (t-1)	0.000640** (2.96)	0.000638** (2.95)	0.000638** (2.96)	0.000638** (2.96)	0.000639** (2.96)
PPE (t-1)	0.0534*** (4.16)	0.0533*** (4.16)	0.0528*** (4.12)	0.0536*** (4.18)	0.0534*** (4.16)
Sales growth (t-1)	0.00514*** (4.76)	0.00514*** (4.76)	0.00517*** (4.79)	0.00514*** (4.76)	0.00514*** (4.76)
Asset maturity (t-1)	0.0000667	0.0000662	0.0000665	0.0000662	0.0000665

	(1.54)	(1.53)	(1.53)	(1.53)	(1.53)
Leverage (t-1)	0.00195*** (5.11)	0.00195*** (5.12)	0.00194*** (5.11)	0.00194*** (5.11)	0.00194*** (5.11)
ROA (t-1)	0.000261*** (3.49)	0.000261*** (3.48)	0.000260*** (3.48)	0.000262*** (3.51)	0.000260*** (3.48)
Liquidity (t-1)	-0.137*** (-12.67)	-0.137*** (-12.66)	-0.137*** (-12.67)	-0.137*** (-12.67)	-0.137*** (-12.67)
Country size (t-1)	-0.0829*** (-8.78)	-0.0830*** (-8.81)	-0.0825*** (-8.73)	-0.0841*** (-8.91)	-0.0829*** (-8.79)
Adjusted R square	0.53	0.53	0.53	0.53	0.53
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry*Year FE	Yes	Yes	Yes	Yes	Yes
N	171548	171548	171548	171548	171548

This table presents the regression results examining the relationship between the CLI and corporate debt maturity, incorporating interactions with different sectoral CLPs. Column (1) – (5) introduce interactions with specific legal frameworks, including energy laws, building laws, transport laws, cross-sectoral laws, and agricultural laws. All independent variables are lagged by one period (t-1). Statistical significance is denoted as follows: *** p<0.01, ** p<0.05, * p<0.10.

3.6 Robustness Checks

3.6.1. Sub-sample analysis

To validate the robustness of our baseline results, we first conduct a sub-sample analysis focusing on two different sample restrictions. Table 3.9 presents the outcomes of the sub-sample robustness checks, which further supports the consistency of our findings.

In Column (1), we conduct a sub-sample analysis by restricting the sample to countries where average CLI scores exceed the sample-wide median. To do this, we compute the mean value of CLI across country in sample set and then calculate the median of these country-level means. By focusing our regression analyses on this 'high-climate-law' subsample, we test whether the negative relationship between CLI and debt maturity persists in environments with higher CLP. Similarly, in Column (2), we re-estimate our regression model by focusing on sample below the median CLI score. Both the approach ensures that our baseline results (*see table 6 column 5*) are not driven by countries with high or low CLI, confirming that the observed relationship between CLI and debt maturity is robust across varying CLP in country. In Column (3), we run one more regression with the whole sample with defining above median CLI dummy variable

=1 if the CLP is above median and 0 if CLP is below median.¹¹⁶

In Column (4), we examine the impact of CLP on corporate debt maturity after excluding countries with the large number of observations in our sample.¹¹⁷ This ensures that our results are not disproportionately influenced by a few large economies, which could skew the baseline findings due to their dominant representation in the dataset. By excluding these countries, we assess whether the negative relationship between CLI and debt maturity holds across a more balanced cross-country sample. The coefficient on the CLI remains negative and statistically significant, indicating that the relationship between CLI and debt maturity persists even after excluding large economies.

Further, in Column (5), we examine the impact of CLP on corporate debt maturity just on US observations. Not to our surprise, the sub-sample analysis restricted to US observations reveals findings consistent with both our expectations and the broader literature i.e., decline in the long-term debt. For instance, Abotula et al., (2024) demonstrate, using US firm data, that increases in regulatory compliance costs lead firms to shorten their debt maturity, with the effect amplified for financially constrained firms. Corroborating this, Saba (2025) finds that US firms exposed to higher climate and environmental regulatory risk systematically issue shorter-maturity debt, particularly among highly leveraged. Similarly, Seltzer et al. (2022) using the Paris Agreement as an exogenous regulatory shock, confirm that climate regulatory risk raises bond yield spreads and asset volatility for US public firms. More broadly, Goodell et al. (2025) document a negative relationship between climate change risk and long-term debt issuance across a multi-country sample. Taken together, our US sub-sample results documenting a decrease in long-term debt under the CLP implementations are consistent with the prior studies, reinforcing the conclusion that regulatory-induced uncertainty and increased financing costs incentivise US public firms to shorten their debt maturity structure. Overall, the result of the sub-sample analysis suggests that the effect is not driven solely by the regulatory environments of dominant economies but is a more general phenomenon across developed countries.

Table 3.9 Robustness: Sub-sample analysis

(1)	(2)	(3)	(4)	(5)
Debt maturity (LT/TD)	Debt maturity (LT/TD)	Debt maturity (LT/TD)	Debt maturity (LT/TD)	Debt maturity (LT/TD)

¹¹⁶ We find that the above median CLI are not significantly different from below median CLI.

¹¹⁷ We exclude the United States, Japan, South Korea, the United Kingdom, and Canada to check whether these high observation countries dominate our findings.

CLI (t-1)	-0.0072*** (0.0019)	-0.0050** (0.0224)		-0.0045*** (0.0067)	-0.0077*** (0.0067)
CLI median dummy			-0.0045 (0.2686)		
Size (t-1)	0.0256*** (0.0000)	0.0239*** (0.0000)	0.0264*** (0.0000)	0.0239*** (0.0000)	0.0440*** (0.0000)
Firm quality (t-1)	0.0008** (0.0264)	0.0008** (0.0226)	0.0006*** (0.0033)	0.0007** (0.0298)	0.0010** (0.0164)
PPE (t-1)	0.0797*** (0.0003)	0.0348* (0.0951)	0.0487*** (0.0002)	0.0619*** (0.0023)	0.0785*** (0.0000)
Sales growth (t-1)	0.0036* (0.0778)	0.0053*** (0.0012)	0.0052*** (0.0000)	0.0053*** (0.0013)	-0.0022 (0.2331)
Asset maturity (t-1)	0.0000 (0.3643)	0.0001 (0.3849)	0.0001* (0.0919)	0.0001 (0.4643)	-0.0005*** (0.0000)
Leverage (t-1)	0.0011 (0.2094)	0.0021*** (0.0048)	0.0019*** (0.0000)	0.0020** (0.0158)	0.0041*** (0.0000)
ROA (t-1)	0.0003** (0.0480)	0.0001 (0.2958)	0.0003*** (0.0004)	0.0002 (0.2371)	0.0008*** (0.0000)
Liquidity (t-1)	-0.1012*** (0.0000)	-0.1716*** (0.0000)	-0.1376*** (0.0000)	-0.1557*** (0.0000)	-0.2102*** (0.0000)
Country size (t-1)	-0.1169*** (0.0000)	-0.0584*** (0.0005)	-0.0628*** (0.0000)	-0.0398** (0.0149)	-0.0289 (0.2773)
Adjusted R Square	0.54	0.48	0.54	0.47	0.21
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry*Year FE	Yes	Yes	Yes	Yes	Yes
N	63,094.00	59,794.00	171,548	63,955.00	50,162.00

This table examines the robustness of the relationship between CLI and debt maturity using sub-sample analysis. Column (1) and (2) focuses on countries with above and below median CLI scores respectively. Column (4) excludes countries with the largest sample representation to check if the findings are disproportionately influenced by dominant economies. Column (5) restrict to US observations only. Statistical significance is denoted as follows: *** p<0.01, ** p<0.05, * p<0.10.

3.6.2. Alternative measure of debt maturity

To further validate the robustness of our baseline findings, we employ the alternative measures of debt maturity following established definition in the literature. This ensures that the relationship between CLI and corporate debt maturity is not sensitive to the specific definition of debt maturity. Table 3.10 presents the results of the alternative measure of debt maturity.

Following, Awartani et al. (2016) and Canbaloglu et al., (2022), we measure the debt maturity as ratio of long-term debt to total liabilities. The coefficient on CLI remains

negative and significant, further lend support to our baseline findings. Overall, the consistency of the CLI coefficient across alternative definition of debt maturity underscores the robustness of our baseline conclusion that CLP enactment drive firms toward shorter debt maturities.

Table 3.10 Robustness: Alternative definition

	(1) Long-term debt/TL
CLI (t-1)	-0.0030*** (0.0002)
Size (t-1)	0.0331*** (0.0000)
Firm quality (t-1)	0.0002 (0.1904)
PPE (t-1)	0.0451*** (0.0000)
Sales growth (t-1)	0.0017** (0.0186)
Asset maturity (t-1)	0.0000 (0.1396)
Leverage (t-1)	0.0055*** (0.0000)
ROA (t-1)	-0.0001 (0.2492)
Liquidity (t-1)	-0.1828*** (0.0000)
Country size (t-1)	-0.0353*** (0.0000)
Adjusted R Square	0.64
Firm FE	Yes
Industry*Year FE	Yes
N	171548.00

This table presents the robustness check results using an alternative definition of debt maturity, measured as long-term debt relative to total liabilities (Long-term debt/TL). The CLI and other firm-level characteristics are lagged by one period (t-1). Statistical significance is denoted as follows: *** p<0.01, ** p<0.05, * p<0.10.

3.6.3. Additional control variables

As an additional robustness test, we incorporate five additional control variables namely inflation (*using the annual growth rate of the GDP implicit deflator*), a dividend payer dummy, R&D (*R&D expenses scaled by total assets*), unemployment rate (*measured as total share of the labour force that is without work*), and trade openness (*measured as the sum of exports and imports as a percentage of GDP*) to ensure that our

findings remain valid even after including the additional control variables. Our choice of incorporating these additional control variables is consistent with previous literature. Numerous studies employ this control to capture macroeconomic and firm-specific factors that can influence both the capital structure and debt maturity decisions. For example, Fan et al. (2019) assert that inflation is associated with debt maturity decision. Inflation volatility creates economic uncertainty, which can amplify the perceived risks of CLP. So, firms facing both regulatory and inflationary uncertainty may shorten debt maturity to retain flexibility. Baker & Wurgler (2002) reveals that managers choose the debt maturity structure to maximize the firm's value in alignment with leverage, liquidity, and dividend policies. Moreover, Bharath et al. (2008) argue that firms with high R&D expenditure face greater information asymmetry because the value of R&D investments is difficult to assess and verify. This increases the cost of long-term debt, as lenders demand higher premiums to compensate for the uncertainty. As a result, firms with high R&D expenditure may prefer shorter debt maturities to reduce the cost of borrowing.

Additionally, unemployment and trade openness capture broader macroeconomic conditions. Higher unemployment may reflect weak economic fundamentals, which can influence firms' ability to secure long-term borrowing decision and increase the credit risk (Bai, 2021). Meanwhile, firms operating in trade openness economies are more exposed to international climate regulations (e.g., EU-CBAM, EU-ETS) and global investor pressure which can shape the firm access to the debt market in the presence of CLPs (Dang et al., 2025).

We present the results with the additional control variables in Table 3.11. Notably, the coefficient on CLI remains negative and significant, indicating that CLI is associated with decline in long-term debt even after controlling for firms' dividend policies, research and development activities, and macroeconomic variables such as inflation, unemployment and trade openness. Overall, the battery of robustness checks provided further confidence that our results are robust.

Table 3.11 Robustness: Additional control variables

	(1) Debt maturity (LT/TD)
CLI (t-1)	-0.0039*** (0.0000)
Size (t-1)	0.0327*** (0.0000)

Firm quality (t-1)	0.0002 (0.1817)
PPE (t-1)	0.0463*** (0.0000)
Sales growth (t-1)	0.0015** (0.0303)
Asset maturity (t-1)	0.0000 (0.1477)
Leverage (t-1)	0.0055*** (0.0000)
ROA (t-1)	-0.0001 (0.1251)
Liquidity (t-1)	-0.1811*** (0.0000)
Country size (t-1)	-0.0422*** (0.0000)
R&D (t-1)	-0.0458* (0.0789)
Dividend dummy (t-1)	0.0070** (0.0221)
Inflation (t-1)	-0.0002 (0.6480)
Unemployment (t-1)	-0.0040*** (0.0000)
Trade (t-1)	0.0001 (0.1688)
Adjusted R square	0.64
Firm FE	Yes
Industry*Year FE	Yes
N	171548.00

This table presents the robustness check results by incorporating additional control variables. The CLI and firm-level characteristics are lagged by one period (t-1). Additional controls include R&D, dividend, inflation, unemployment, and trade. Statistical significance is denoted as follows: *** p<0.01, ** p<0.05, * p<0.10.

3.7 Additional analysis

3.7.1 Legal origin analysis

Research indicate that legal system of a country plays a crucial role in shaping its financial structure with profound implications for corporate law, financial development, and economic growth (La Porta et al., 1997). Countries with a common law system generally provide stronger investor protection and more effective legal enforcement

compared to those with a civil law framework (La Porta et al., 1997, 1998).¹¹⁸ From a political perspective, civil law countries often prioritize the rights of the state over private property rights, which can impact economic growth (Beck et al., 2003). These differences in legal origins i.e., common law versus civil law give rise to distinct approaches to rulemaking and enforcement, leading to variations in investor protection, corporate governance practices, and stakeholder obligations (La Porta et al., 1999). For instance, common law jurisdictions typically grant courts broader interpretive powers, allowing for a more flexible, case-by-case evolution of regulations. In contrast, civil law systems (e.g., French, German, Scandinavian) rely on detailed codification and legislation, often emphasizing stakeholder welfare over shareholder interests (Becchetti et al., 2020).

Extant literature suggests a systematic differences among legal origins to protect between creditors and debtors, which can influence the debt maturity decisions (La Porta et al., 1997,1998; Djankov et al., 2007). In civil law countries, rigidity and weaker investor protections may force firms to adopt shorter debt maturities in response to regulatory changes (Djankov et al., 2007). Whereas the regulatory flexibility and stronger investor protections in common law countries enable firms to maintain longer debt maturities, even in the face of regulatory uncertainty (Demirgüç-Kunt & Maksimovic, 1999). Legal origin also shapes corporate governance practices, which can influence how firms respond to environmental regulations. For example, in Scandinavian civil law countries firms may face greater pressure to align their financing strategies with sustainability goals (Jackson & Apostolakou, 2010).

To investigate how legal origin moderates the relationship between CLI and corporate debt maturity, we follow the classification framework established by La Porta et al. (1999). English Common Law, French Civil Law, German Civil Law, and Scandinavian Civil Law. This classification is used as a dummy variable to empirically test our baseline model.¹¹⁹ The results of this analysis are presented in Table 3.12. We use the following specification to examine whether legal origin moderates the relationship between CLI and corporate debt maturity:

¹¹⁸ In common law systems, parties have more flexibility to negotiate the terms of their agreement, whereas in civil law systems, many provisions are automatically implied into a contract by law, and parties cannot contract out of certain provisions.

¹¹⁹ We use dummy variable to clarify which takes a value of 1 if the country's following into the particular legal system (i.e., English Common Law, French Civil Law, German Civil Law, and Scandinavian Civil Law) 0 otherwise. Using the World Factbook database, which provides the description of a country's legal system, a brief statement on the origins and major features of each legal system. See- <https://www.cia.gov/the-world-factbook/field/legal-system/> [Accessed on 20 December 2024]

$$Debt\ maturity_{it} = \beta_0 + \beta_1 CLI_{c,t-1} + \beta_2 Legal\ origin_i + \beta_3 CLI_{c,t-1} * Legal\ origin_i + X_{it-1} + firm_i + ind * time_t + \varepsilon_{it} \text{-----} (3.5)$$

In common law countries, the interaction term CLI*Common Law is positive and statistically significant, indicating that the negative impact of climate laws on debt maturity is mitigated. This suggests that firms operating in Common law jurisdictions are less likely to shorten their debt maturities in response to climate laws compared to the other legal origin countries. Finding aligns with the literature showing that common law countries provide a more adaptable legal environment and stronger investor protections providing firms to navigate regulatory changes without drastic adjustments to their financing strategies (La Porta et al., 1998; Djankov et al., 2008). Interestingly, the interaction term CLI*French Civil Law is also positive and significant, suggesting that firms in French civil law countries unlikely to prefer shorter debt maturity in response to climate laws relative to the other legal origin countries. This finding can be attributed to the more emphasis on stakeholder welfare in French civil law systems which may encourage firms to adopt more stable financing strategies (Becchetti et al., 2020).

Conversely, the interaction term of German Civil Law and Scandinavian Civil Law is negative, indicating that the reduction in debt maturity in response to CLPs is stronger in these legal origin systems than in the others. This finding aligns with the literature on the conservative nature of German civil law systems, which emphasize a strict enforcement of regulations in German civil law countries (La Porta et al., 1997). The rigidity and weaker investor protections in civil law countries may force firms to adopt shorter debt maturities to mitigate regulatory and financial risks (Fan et al., 2012). The negative interaction term CLI*Scandinavian Civil Law lend support that Scandinavian civil law systems are known for their emphasis on stakeholder welfare, sustainability and characterized by rigid regulatory frameworks. This rigidity may amplify the risks associated with long-term financing under CLP, forcing firms to adopt more conservative financing strategies (Djankov et al., 2008).

Table 3.12 Legal Origin: CLI and corporate debt maturity relationship

	(1) Debt maturity (LT/TD)	(2) Debt maturity (LT/TD)	(3) Debt maturity (LT/TD)	(4) Debt maturity (LT/TD)
CLI (t-1)	-0.0107*** (0.0000)	-0.0112*** (0.0000)	-0.0081*** (0.0000)	-0.0102*** (0.0000)
CLI * Common law (t-1)	0.0023***			

	(0.0041)			
CLI * French Civil law (t-1)		0.0052*** (0.0000)		
CLI * German Civil law (t-1)			-0.0033*** (0.0001)	
CLI * Scandinavian Civil law (t-1)				-0.0077*** (0.0000)
Size (t-1)	0.0269*** (0.0000)	0.0277*** (0.0000)	0.0271*** (0.0000)	0.0271*** (0.0000)
Firm quality (t-1)	0.0006*** (0.0031)	0.0006*** (0.0032)	0.0006*** (0.0032)	0.0006*** (0.0029)
PPE (t-1)	0.0530*** (0.0000)	0.0534*** (0.0000)	0.0533*** (0.0000)	0.0524*** (0.0000)
Sales growth (t-1)	0.0052*** (0.0000)	0.0051*** (0.0000)	0.0052*** (0.0000)	0.0052*** (0.0000)
Asset maturity (t-1)	0.0001 (0.1263)	0.0001 (0.1278)	0.0001 (0.1284)	0.0001 (0.1237)
Leverage (t-1)	0.0019*** (0.0000)	0.0020*** (0.0000)	0.0019*** (0.0000)	0.0019*** (0.0000)
ROA (t-1)	0.0003*** (0.0006)	0.0003*** (0.0005)	0.0003*** (0.0006)	0.0003*** (0.0004)
Liquidity (t-1)	-0.1376*** (0.0000)	-0.1343*** (0.0000)	-0.1360*** (0.0000)	-0.1381*** (0.0000)
Country size (t-1)	-0.0818*** (0.0000)	-0.0750*** (0.0000)	-0.0751*** (0.0000)	-0.0856*** (0.0000)
Adjusted R square	0.54	0.54	0.54	0.54
Firm FE	Yes	Yes	Yes	Yes
Industry*Year FE	Yes	Yes	Yes	Yes
N	171548.00	171548.00	171548.00	171548.00

This table presents the regression results examining the relationship between the CLI and firm debt maturity, incorporating the legal origin. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.

3.7.2 National Governance

Scholars from different disciplines draw an attention of policymakers in an attempt to analyse the quality of governance in countries. A sound governance is crucial in countries to effectively implement and formulate policies (Han et al., 2014). Empirical evidence further confirms that weak governance exacerbates climate-related financing

constraints, leading firms to shorten debt maturity in anticipation of regulatory unpredictability. On the other hand, strong institutions enable firms to confidently undertake long-term climate investments (Acharya et al., 2011).

In our analysis, we focused on three specific governance indicators from the Worldwide Governance Indicators¹²⁰ framework i.e., RQ, RL, and CC. To examine whether national governance quality moderates the relationship between CLI and corporate debt maturity, we estimate the following model:

$$\text{Debt maturity}_{it} = \beta_0 + \beta_1 \text{CLI}_{c,t-1} + \beta_2 \text{Governance indicator}_i + \beta_3 \text{CLI}_{c,t-1} * \text{Governance indicator}_i + X_{it-1} + \text{firm}_i + \text{ind} * \text{time}_t + \varepsilon_{it} \text{-----} (3.6)$$

These indicators were selected due to their direct relevance to corporate financial decision-making and the enforcement of climate-related policies. Strong regulatory quality ensures predictable and stable policies, reducing uncertainty in financial decision-making and facilitating long-term debt issuance (Fan et al., 2012). Similarly, a robust RL enhances creditor confidence by ensuring contract enforcement and legal protections, thereby enabling firms to secure long-term financing (Demirgüç-Kunt & Maksimovic, 1999). Meanwhile, CC plays a crucial role in corporate governance, as corruption weakens investor trust, increases borrowing costs, and distorts firms' debt maturity structure by making short-term financing more attractive (Djankov et al., 2007). In context of CLP, these governance indicators shape firms' responses to regulatory frameworks. For instance, high RQ promotes compliance and green investments, strong RL ensures legal enforcement of CLP, and strong CC prevents regulatory weakness and evasion of environmental standards (Porta et al., 1998).

To comprehensively assess governance quality, we utilized the PCA Index¹²¹, which measures governance quality at the country-year level and is defined as the first principal component of these three governance indicators. The results presented in Table 3.13 highlight the significant role of national governance quality in moderating the relationship between CLP and corporate debt maturity.

Across all models (Column 1 to 4), the coefficient on CLI remains consistent with our baseline result. However, we document the notable differences when interacting CLI

¹²⁰ The worldwide governance indicators define the RQ as a measure of the effectiveness of government regulations in promoting enterprises. RL measures the extent to which the government and individuals are bound by law and have equal access to justice. CC measures the extent to which corruption is controlled by the government and the degree to which it permeates society. See this for more details <https://info.worldbank.org/governance/wgi/>

¹²¹ This approach allows us to capture a composite measure of governance that reflects the combined influence of world governance indicator on corporate financial decisions.

with governance the governance indicator. For instance, the interaction terms for RQ in Column (2) and CC Column (3) are both positive and 1% significance. This suggests that firms operating in countries with strong regulatory frameworks and low levels of corruption experience a reduction of the negative impact that CLP have on shorter debt maturity. The positive interaction signs indicate that better governance mitigates the negative effect of climate laws on debt maturity. In other words, in countries with higher regulatory quality or lower corruption, the CLI's impact on shortening debt maturity is less severe. Similarly, the coefficient of the interaction term CLI*PCA is 0.0013 and significant at the 5% level. We infer that strong governance likely creates a more predictable and secure environment for lenders and firms, allowing companies to maintain longer debt maturities even with CLP enactment. These findings resonate with prior cross-country evidence that institutional quality affects debt structure. Fan et al. (2012) document that firms in countries with weaker legal systems or higher corruption rely more on short-term debt, whereas strong investor protections facilitate longer debt maturities.

Conversely, coefficient of the interaction term CLI*RL in Column (1) is not statistically significant, suggesting that RL does not significantly alter the way firms adjust their debt maturities in response to CLP implementation. One possible reason for this that RL may imply general legal effectiveness and it is too broad an index in context of our study. Also, RL broad regulatory rigor affects all policies, not just climate laws and policies. All other governance indicators show negative standalone coefficients. This means that high governance imposes stricter compliance requirements (*e.g., transparent reporting, anti-corruption measures*), increasing short-term liquidity needs. Our argument is in line with Fan et al., (2012) and Anginer et al., (2022), which support that firms in countries with weaker governance and more corruption tend to use more short-term debt as a strategy.

Table 3.13 National Governance: CLI and debt maturity relationship

	(1) Debt maturity (LT/TD)	(2) Debt maturity (LT/TD)	(3) Debt maturity (LT/TD)	(4) Debt maturity (LT/TD)
CLI (t-1)	-0.0120*** (0.0000)	-0.0133*** (0.0000)	-0.0123*** (0.0000)	-0.0107*** (0.0000)
CLI * RL (t-1)	0.0011 (0.3645)			
RL (t-1)	-0.0397*** (0.0049)			

CLI * RQ (t-1)		0.0027** (0.0201)		
RQ (t-1)		-0.0385*** (0.0000)		
CLI * CC (t-1)			0.0025*** (0.0009)	
CC (t-1)			-0.0407*** (0.0000)	
CLI * PCA (t-1)				0.0012** (0.0234)
PCA (t-1)				-0.0322*** (0.0000)
Size (t-1)	0.0278*** (0.0000)	0.0277*** (0.0000)	0.0278*** (0.0000)	0.0276*** (0.0000)
Firm quality (t-1)	0.0006** (0.0117)	0.0006** (0.0111)	0.0006** (0.0110)	0.0006** (0.0112)
PPE (t-1)	0.0515*** (0.0001)	0.0528*** (0.0001)	0.0521*** (0.0001)	0.0521*** (0.0001)
Sales growth (t-1)	0.0052*** (0.0000)	0.0052*** (0.0000)	0.0052*** (0.0000)	0.0053*** (0.0000)
Asset maturity (t-1)	0.0001 (0.2149)	0.0001 (0.2061)	0.0001 (0.2050)	0.0001 (0.2124)
Leverage (t-1)	0.0018*** (0.0000)	0.0018*** (0.0000)	0.0018*** (0.0000)	0.0018*** (0.0000)
ROA (t-1)	0.0002*** (0.0070)	0.0002*** (0.0067)	0.0002*** (0.0072)	0.0002*** (0.0076)
Liquidity (t-1)	-0.1357*** (0.0000)	-0.1361*** (0.0000)	-0.1362*** (0.0000)	-0.1362*** (0.0000)
Country size (t-1)	-0.0731*** (0.0000)	-0.0650*** (0.0000)	-0.0617*** (0.0000)	-0.0608*** (0.0000)
Adjusted R square	0.54	0.54	0.54	0.54
Firm FE	Yes	Yes	Yes	Yes
Industry*Year FE	Yes	Yes	Yes	Yes
N	157670.00	157670.00	157670.00	157670.00

This table presents the regression results examining the relationship between the CLI and firm debt maturity, incorporating the national governance. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.

3.7.3 Examining the non-linear relationship of CLI

Climate literature indicates that the relationship between responses to climate risks and its effects is non-linear. For example, Burke et al. (2015) demonstrate that economic productivity exhibits a non-linear response to temperature changes, peaking at

an optimal point before declining sharply at higher temperatures. Similarly, Liu et al. (2023) find that climate risk influences insurance demand in a non-linear fashion, with significant shifts occurring only after certain exposure levels are crossed. Also, Goodwell et al., (2025) acknowledges a non-linearity in how climate change risks affect debt maturity.

Given the discussion above, we also examine whether relationship between CLI and corporate debt maturity is linear or non-linear. As reported in Table 3.6 column (5) we observe a significant negative relationship between CLI and debt maturity. However, when we test a non-linear effect, the results reveal a more nuanced dynamic. To examine potential non-linear effects of CLI on corporate debt maturity, we estimate the following model:

$$Debt\ maturity_{it} = \beta_0 + \beta_1 CLI_{c,t-1} + \beta_2 CLI^2_{c,t-1} + X_{it-1} + firm_i + ind * time_t + \varepsilon_{it} \text{-----} (3.7)$$

We present this result in Table 3.14 and interestingly find that introduction of a quadratic term renders the linear coefficient insignificant (0.0009), while the squared term remains significant and negative (-0.0006) at 1%. This indicates an inverted U-shaped relationship negative and significant coefficient of the quadratic term of CLI square which means that the relationship between CLPs enactment and debt maturity is non-linear. This means that at low levels of CLI, the effect on debt maturity is slightly positive. However, as CLI increases, the negative squared term dominates, leading to a decline in long-term debt to preserve the refinancing flexibility amidst heightened compliance uncertainty.

To add to this relationship further the non-linear behaviour suggests that firms may initially perceive moderate climate policies as manageable or temporary, but as climate laws and policies number intensify, the perceived risks and compliance burdens prompt firms for adjustments in debt maturity composition. This finding resonates with the work of Wang & Shao (2019), who argue that market based environmental policy stringency exert non-linear effects on green growth. The study reveals that positive impact on green growth becomes significant only at higher levels of regulation. This suggests that there is a threshold effect, where low to moderate levels of regulations may not be sufficient to drive green growth.

The non-linear relationship between CLI and debt maturity can be best understood through the lens of Real options theory. We argue that with more CLP numbers, firms face increasing uncertainty about future costs and risk associated with climate law and

policies implementation. In this scenario, shortening debt maturities provides firms with a real option to reallocate resources and adapt to evolving regulatory landscapes, thus mitigating the risks in an uncertain environment (Dixit & Pindyck, 1994). Also, as CLI increase, firms become more dependent on regulators and stakeholders (e.g., ESG investors), because it creates a volatile regulatory environment. Consequently, firms strategically choose to shorten debt maturity to combat adverse selection while showcasing their confidence in meeting upcoming CLP. This proactive approach not only strengthens firm position but also discourages lenders from levying excessive risk premiums (Flannery, 1986). Overall, we assert that the relationship between CLP enactment and corporate debt maturity decisions appears to be more complex than a straightforward linear association.

Table 3.14 Non-linear: CLI and debt maturity relationship

	(1) Debt maturity (LT/TD)
CLI (t-1)	0.0007 (0.7705)
CLI'Sqr (t-1)	-0.0006*** (0.0000)
Size (t-1)	0.0272*** (0.0000)
Firm quality (t-1)	0.0006*** (0.0030)
PPE (t-1)	0.0521*** (0.0000)
Sales growth (t-1)	0.0052*** (0.0000)
Asset maturity (t-1)	0.0001 (0.1260)
Leverage (t-1)	0.0019*** (0.0000)
ROA (t-1)	0.0003*** (0.0005)
Liquidity (t-1)	-0.1368*** (0.0000)
Country size (t-1)	-0.0662*** (0.0000)
Adjusted R square	0.54
Firm FE	Yes
Industry*Year FE	Yes
N	171548.00

This table examines the non-linear relationship between the CLI and corporate debt maturity by including

a squared CLI term (CLI²). Statistical significance is denoted as follows: *** p<0.01, ** p<0.05, * p<0.10.

3.7.4 Examining the financially constrained firms

The results in Table 3.15 we further explore how financial constraints, measured by the Kaplan-Zingales (KZ) Index¹²², moderate the relationship between CLI and corporate debt maturity. The KZ Index is widely used to capture firm-level financial constraints, with higher values indicating more constrained firms (Kaplan & Zingales, 1997). Financial constraints play a crucial role in shaping firms' access to capital markets and their ability to navigate regulatory pressures. A study by Dang et al., (2022a) further suggest that mandatory pollution abatement regulation affects financially constrained firms more. As a result, firms reduce their R&D investment and capital expenditure, resulting in lower long-term profits. Because financial constraints lack the flexibility to absorb the costs associated with CLPs. This limitation can significantly affect how these firms manage their debt maturity, particularly in response to CLPs enactment. To examine whether financial constraints moderate the relationship between CLI and corporate debt maturity, we estimate the following model:

$$Debt\ maturity_{it} = \beta_0 + \beta_1 CLI_{c,t-1} + \beta_2 Financial\ constrained_{it-1} + \beta_3 CLI_{c,t-1} * Financial\ constrained_{it-1} + X_{it-1} + firm_i + ind * time_t + \varepsilon_{it} \text{ ----- (3.8)}$$

In the above equation, financial constrained is a dummy variable, equal to 1 if the firm is classified as financially constrained, and 0 otherwise. Whereas CLI * Financial constrained is the interaction term capturing whether the effect of CLP enactment on debt maturity is moderated by financial constraints. Table 3.15 explores whether financially constrained firms respond differently to CLPs. The coefficient on CLI remains negative (−0.0084), reaffirming our baseline finding that CLP leads to shorter debt maturities. Not surprising, interaction term CLI*KZ Index is negative and highly significant (−0.0011) suggesting that financially constrained firms are even more sensitive to CLP implementation. This means that firms with higher KZ Index scores (*financial*

¹²² The KZ Index is calculated as: KZ Index = -1.002 * (cashflow / ppe_t-1) + 0.283 * (T.Q.) + 3.139 * (Lev) - 39.368 * (dividend / asset_t-1) - 1.315 * (cash balance / ppe_t-1), where cashflow / ppe_t-1 is the ratio of cash flow to one-period lagged net property, plant, and equipment, cash balance / ppe_t-1 represents the ratio of cash balances to one-period lagged property, plant, and equipment, and div / asset_t-1 is the ratio of cash dividends to one-period lagged book value of total assets. Leverage (Lev) is defined as total debt divided by the book value of total assets. Tobin's Q (T.Q.) is measured as the sum of the book value of total assets and the market value of equity minus common equity, divided by the total book value of assets. To mitigate the influence of extreme values, we winsorize all components of the KZ Index at the 1st and 99th percentiles, thereby reducing the impact of outliers on our results. We then construct a binary indicator for financial constraints takes a value of one if the firm-year observation has a KZ Index above the sample median and zero otherwise.

constraints) reduce their debt maturities even more aggressively in response to CLI compared to financially unconstrained firms. Empirical studies Barclay & Smith (1995) and Johnson (2003) confirm that riskier or smaller firms (often those without strong credit ratings) rely more on short-term debt. Financially constrained firms typically have limited access to capital and face higher costs of borrowing, due to high default risk. During CLP shock these firms may fear that future compliance costs or regulatory shocks could worsen their credit risk. Also, lenders, in turn, may be less willing to offer long-term financing to high-risk or cash-strapped firms. As a result, constrained firms likely resort to shorter-term debt to remain flexible, even though this exposes them to refinancing risk.

This behaviour is consistent with the findings of Datta et al., (2019) and Choi (2024) suggesting that firms with limited financial flexibility adjust their debt structures more conservatively when exposed to policy related uncertainty. However, the KZ index main effect in the regression is near zero and statistically insignificant, indicating that the CLI*KZ interaction remains significant (*while KZ alone is not*) underscores that financial constraints per se don't deterministically drive maturity choices. In other words, a stable environment, simply being financially constrained (high KZ index) does not necessitate a different debt maturity strategy. In normal scenario (no regulatory pressure), a constrained firm can secure debt financing with similar maturities to an unconstrained firm by leaning on relationships or by paying a slightly higher price on loan (Wilner, 2000).

Table 3.15 Financial constraints and CLI debt maturity relationship

	(1) Debt maturity (LT/TD)
CLI	-0.0091*** (0.0000)
CLI*Kz index (t-1)	-0.0010*** (0.0000)
Kz index (t-1)	0.0001 (0.3309)
Size (t-1)	0.0292*** (0.0000)
Firm quality (t-1)	0.0007*** (0.0024)
PPE (t-1)	0.0486*** (0.0004)
Sales growth (t-1)	0.0055***

	(0.0000)
Asset maturity (t-1)	0.0001 (0.2829)
Leverage (t-1)	0.0021*** (0.0000)
ROA (t-1)	0.0002*** (0.0080)
Liquidity (t-1)	-0.1487*** (0.0000)
Country size (t-1)	-0.0752*** (0.0000)
Adjusted R square	0.56
Firm FE	Yes
Industry*Year FE	Yes
N	152020.00

This table examines the moderating effect of financial constraints, measured by the Kaplan-Zingales (KZ) index, on the relationship between the CLI and corporate debt maturity. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.

3.7.5 Analysis for the Covid-19 and Global financial crisis (GFC) period

In this section, we conduct an additional test to understand whether the Global Financial Crisis (GFC) and the Covid19 period amplify the relationship between CLI and corporate debt maturity structure. In Table 3.16, the full-sample interaction models (Columns 1 and 2) CLI reflects the effect during non-crisis periods, whereas in Columns (3) and (4), the estimates are obtained from restricted, non-overlapping subsamples. This further enhance our understanding on whether firms' debt maturity choices, are sensitive to climate law and policies during the periods of macroeconomic shock years.

González (2015) highlights that the financial crisis led to a reduction in corporate debt maturity through two primary mechanisms. Firstly, lenders tightened their borrowing conditions, resulting in higher borrowing costs and a shift towards shorter-term debt. Secondly, banks grappling with solvency challenges replaced long-term debt with short-term alternatives to mitigate their financial risks. To test for differential effects of CLI on debt maturity during the GFC and COVID-19, we estimate the following models:

$$Debt\ maturity_{it} = \beta_0 + \beta_1 CLI_{c,t-1} + \beta_2 CLI_{c,t-1} * GFC_t + X_{it-1} + firm_i + ind * time_t + \varepsilon_{it} \quad (3.9)$$

$$Debt\ maturity_{it} = \beta_0 + \beta_1 CLI_{c,t-1} + \beta_2 CLI_{c,t-1} * COVID - 19_t + X_{it-1} + firm_i + ind * time_t + \varepsilon_{it} \quad (3.10)$$

In equation 3.9, the *GFC* is a dummy variable which is defined as equal to 1 if the

year is 2006-2010, and 0 otherwise, capturing the pandemic period. However, in equation 3.10, the *COVID* – 19 is also a dummy variable that is defined as equal to 1 if the year is 2018-2022, and 0 otherwise, indicating the GFC period. The interaction terms ($CLI \times GFC$ and $CLI \times COVID-19$) measure whether the relationship between CLI and debt maturity differs specifically during pandemic and GFC period.

The findings reveal several important insights. The results reported in Table 3.16 indicate that the relationship between CLI and debt maturity differs across macroeconomic shocks.

During the GFC period (Column 1), the baseline coefficient on CLI is positive ($\beta = 0.0040$), while the interaction term is negative ($\beta = -0.0012$, $p < 0.05$). This implies that although the effect of CLI is weakened during the GFC crisis. However, the overall relationship remains positive. Several explanations may account for why long-term debt appears to increase in the GFC period. First, the GFC was primarily a banking sector crisis, where banks reduced lending and refinancing became difficult. During the financial crisis period, firms face significant rollover risk, as short-term debt cannot be easily refinanced. In this context, Kalemli-Özcan et al. (2022) documented that European firms with higher short-term debt reduced investment more severely during the crisis, with rollover risk identified as a key transmission channel. Similarly, He et al. (2017) reveal that during financial crises, firms face increased default risk and credit spreads due to fluctuating margin requirements, especially affecting short-term debt refinancing. Consequently, firms respond by increasing reliance on long-term debt to secure funding and avoid refinancing risk. When combined with climate law's enactment which further increase the uncertainty therefore this leads to a negative relationship between CLI and long-term debt.

In Contrast, during the COVID-19 period (Column 2), the coefficient on CLI is negative and statistically significant ($\beta = -0.0093$), and the interaction term is also negative ($\beta = -0.0020$, $p < 0.05$), indicating a stronger shift toward shorter debt maturity during the pandemic. This is consistent with the main finding of the chapter and suggests that firms respond to climate regulation by shortening debt maturity to preserve financial flexibility under regulatory uncertainty. The tendency to favour shorter-term debt amid global financial crises aligns with the dual pressures of economic instability and regulatory ambiguity, reinforcing González's (2015), Demirgüç-Kunt et al. (2020) and Massa et al. (2013), findings.

Furthermore, the results from the restricted, non-overlapping samples (Columns

3 and 4) show negative coefficients for CLI, reinforcing that when crisis and stable periods are cleanly separated, firms tend to shorten debt maturity in response to climate laws and policies enactment. Our finding is consistent with real options theory, which predicts that firms avoid long-term commitments under uncertainty (Dixit & Pindyck, 1994).

These results were not entirely expected ex ante because prior literature lends the support to our finding. Overall, the analysis demonstrates that the impact of CLI on corporate debt maturity is not constant over time but depends critically on macroeconomic conditions. When credit constraints dominate (e.g. GFC), firms increase debt maturity to mitigate refinancing risk. When uncertainty dominates (e.g. COVID), firms shorten debt maturity to preserve flexibility.

Table 3.16 Macroeconomic shocks and CLI debt maturity across no-overlapping crisis and stable period

	(1) Debt maturity (LT/TD)	(2) Debt maturity (LT/TD)	(3) Debt maturity (LT/TD) (GFC)	(4) Debt maturity (LT/TD) (COVID)
CLI (t-1)	0.0040*** (0.0000)	-0.0093*** (0.0000)	-0.0122*** (0.0000)	-0.0053*** (0.0068)
CLI*GFC (2006-10)	-0.0012** (0.0157)			
CLI*Covid19 (2018-22)		-0.0020** (0.0154)		
Size (t-1)	0.0302*** (0.0000)	0.0273*** (0.0000)	0.0162*** (0.0001)	0.0178*** (0.0000)
Firm quality (t-1)	0.0007*** (0.0025)	0.0006*** (0.0032)	0.0005 (0.1678)	0.0003 (0.2990)
PPE (t-1)	0.0490*** (0.0001)	0.0529*** (0.0000)	0.0331 (0.1130)	0.0678*** (0.0007)
Sales growth (t-1)	0.0049*** (0.0000)	0.0052*** (0.0000)	0.0052*** (0.0034)	0.0014 (0.4168)
Asset maturity (t-1)	0.0001* (0.0671)	0.0001 (0.1218)	0.0001** (0.0461)	0.0000 (0.5869)
Leverage (t-1)	0.0019*** (0.0000)	0.0019*** (0.0000)	0.0034*** (0.0000)	0.0001 (0.8758)
ROA (t-1)	0.0003*** (0.0002)	0.0003*** (0.0005)	0.0002 (0.1043)	0.0001 (0.2068)

Liquidity (t-1)	-0.1417*** (0.0000)	-0.1365*** (0.0000)	-0.1211*** (0.0000)	-0.0725*** (0.0000)
Country size (t-1)	-0.0094 (0.1282)	-0.0808*** (0.0000)	-0.0256 (0.1602)	-0.0447** (0.0210)
Adjusted R square	0.54	0.54	0.57	0.63
Firm FE	Yes	Yes	Yes	Yes
Industry*Year FE	Yes	Yes	Yes	Yes
N	171634.00	171548.00	59,987.00	72,309.00

This table presents the regression results examining the relationship between the CLI and firm debt maturity, incorporating macroeconomic shocks such as the Global Financial Crisis (GFC) (2008–09) and the COVID-19 pandemic (2020–21). Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

3.8 Endogeneity test

3.8.1 Instrumental Variable

We assert that our analysis on the effect of CLP on corporate debt maturity is that our CLP variables may not be exogenous. Despite controlling for time, industry-level, and firm level fixed effects in all models, omitted variables might still affect the CLI and debt maturity relationship. In fact, CLP may be determined by unobserved variables that also affect corporate debt maturity which can lead to biased estimates (e.g., corporate governance characteristics or ESG scores). To address this concern, we re-estimate our model utilizing an instrumental variable. The empirical model is specified as follows:

First stage:

$$CLI_{c,t-1} = \beta_0 + \beta_1 GHG_{c,t-1} + X_{it-1} + firm_i + ind * time_t + \varepsilon_{it} \text{ ----- (3.10)}$$

Second stage:

$$Debt\ maturity_{it} = \beta_0 + \beta_1 \widehat{CLI}_{it-1} + firm_i + ind * time_t + \varepsilon_{it} \text{ ----- (3.11)}$$

In the above equations, $CLI_{c,t-1}$ is the Climate Law Index in country c , instrumented using GHG emissions. $GHG_{c,t-1}$ are total country-level greenhouse gas emissions, serving as an instrument. $Debt\ maturity_{it}$ is the long-term debt to total debt ratio for firm i in year. $X_{i,t-1}$ is the vector of all the control variables. Additionally, the equation incorporates $firm_i$ and $ind_j * time_t$ fixed effect respectively. e_{it} is the error term. The results from 2SLS estimations are shown in Table 3.17, where Column 1 shows the first stage results for CLI and the instrumental variable (i.e. GHG), while column 2 show the second-stage results for CLI and debt maturity.

We use GHG emissions as an instrument because it is closely tied to an enactment of CLP. This is because country-level GHG emissions are a plausible instrument for the CLI because it reflects the environmental pressures and policy needs of a country.

Intuitively, countries with higher GHG emissions face greater domestic or international pressure to enact climate legislation, leading to a higher CLI. Conversely, CLP tend to reduce emissions over time, creating a strong inverse relationship (Eskander, & Fankhauser, 2020). Also, global evidence shows that the adoption of climate change laws has significantly lowered emissions (e.g. climate policies since 1999 cut global CO₂ by 38 Gt) (Eskander, & Fankhauser, 2020). This suggests GHG emission levels are a relevant predictor of a country's CLI satisfying the IV relevance condition. In Table 3.17 first-stage regression, the coefficient of GHG emissions is highly significant ($t = -88.46$), confirming that countries' emissions are linked to CLI.

It is also plausible to argue that one would not expect the country's emissions to systematically influence how firms choose short vs. long-term debt. In other words, GHG emissions are plausibly exogenous to firm financing decisions, affecting them only by inducing regulatory changes captured by CLI. The use of country-level environmental variables as instruments has precedent in the literature. For example, studies have instrumented policy indices or risk measures with higher-level environmental or economic variables that are exogenous to firm behaviour. Bonaime et al. (2018) use country-level policy uncertainty shocks to identify effects on corporate investment, under the assumption that macro uncertainty affects firms only via the business environment. Similarly, Julio and Yook (2012) show that uncertainty around national elections leads firms to cut investment by 4.8%, demonstrating that exogenous country-level political factors can causally impact corporate decisions. Our use of GHG emissions to instrument CLI follows this philosophy leveraging a country-level environmental factor to isolate the exogenous component of CLP enactment.

The first-stage results show GHG emissions are a powerful and valid instrument (highly correlated with CLI and passing all IV diagnostics).¹²³ The second-stage regression estimates the effect of CLI (instrumented) on corporate debt maturity (LT/TD ratio). The coefficient on CLI instrumented is -0.0203 . This implies that a 1-unit increase

¹²³The Kleibergen–Paap rk Wald F statistic is 7824.42, which is well above the common critical threshold of 10 (Staiger & Stock, 1997). The Cragg–Donald Wald F statistic is 47249.07, further supporting the strong instrument relevance. The Anderson canonical correlations LM test statistic is 4730.56 with p -value = 0.00, rejecting the null hypothesis of under identification and confirming instrument relevance. Also, the Hansen J statistic (p -value = 0.51) and Sargan J statistic (p -value = 0.48) are both insignificant, indicating that the instrument is valid and uncorrelated with the error term in the second stage. Finally, the Hausman exogeneity test yields a statistic of 9.26 (p -value = 0.00), indicating that CLI is endogenous and justifying exogeneity condition and indicating a no direct channel through which GHG affects debt maturity except via CLI enactment.

in CLI (as predicted by GHG emissions) leads to a 2.03 percentage point decrease in the proportion of long-term debt to total debt. Importantly, the effect is stronger than the result we document in Table 3.6 (column 5), highlighting the importance of accounting for endogeneity. The findings make economic sense: CLPs introduce new risks and constraints, to which firms respond by making adjustment in their debt maturity structure.

Overall, the reanalysis of Table 3.17 confirms that using GHG emissions as an instrument addresses bias in the CLI and debt maturity relationship and provides strong evidence that CLP exerts a causal influence on corporate debt maturity.

Table 3.17 Instrumental variable analysis

	Stage One (DV =CLI)	Stage Two (DV =Debt Maturity)
CLI (t-1) (instrumented)		-0.0203*** (-20.85)
GHG (t-1)	-1.09e-09*** (-88.46)	
Size (t-1)	0.5179*** (87.39)	0.0065*** (7.72)
Firm quality (t-1)	-0.0122*** (-5.64)	0.0020*** (7.90)
PPE (t-1)	-0.5845*** (-5.95)	-0.0357*** (-4.44)
Sales growth (t-1)	-0.1744*** (-21.30)	-0.0076*** (-7.10)
Asset maturity (t-1)	0.0012*** (3.89)	-0.0005*** (-12.19)
Leverage (t-1)	-0.0457*** (-7.83)	0.0057*** (11.65)
ROA (t-1)	-0.0152*** (-24.47)	0.0017*** (23.60)
Liquidity (t-1)	0.2701*** (2.99)	-0.4292*** (-51.66)
Country size (t-1)	2.0416*** (82.69)	0.0495*** (40.04)
Observations	171548	171548
R-squared	0.4625	0.1267
Industry*Year FE	Yes	Yes
Firm FE	Yes	Yes
Clustering	Firm	Firm
Anderson canon. corr. LM statistic	4730.56	
Anderson canon. corr. LM statistic p-value	0.00	
Kleibergen-Paap rk LM statistic	4730.56	
Kleibergen-Paap rk LM statistic p-value	0.00	
Cragg-Donald Wald F statistic	47249.07	
Kleibergen-Paap rk Wald F statistic	7824.42	
Hansen j-stat	0.00	
Hansen j-stat p-value	0.51	
Sargan j-stat	0.00	
Sargan j-stat p-value	0.48	
Hausman exogeneity test stat	9.26	
Hausman exogeneity test p-value	0.00	

This table presents the results for our 2SLS analysis. The dependent variable in Stage One is CLI, and in Stage two, it is debt maturity. The instrument used is GHG. Robust t-statistics using firm-level clustering of standard errors are presented in parentheses. The ***, **, and * indicate statistical significance at the

1%, 5%, and 10% levels, respectively.

3.9 Conclusion

Globally, climate change issue has prompted a wave of implementation of climate laws and policies. This study examines how global change in climate law and policies affects the corporate debt. For this purpose, we first time construct the climate law index to capture the long run effects of changes in climate law and policies. Our results indicate that a one-unit increase in CLI leads 1.74% reduction in long-term debt. As CLP increases, firms tend to favour financial flexibility over long-term commitments. We attribute this as a future climate law and policies impose uncertainty, unanticipated costs or compliance obligations to firms. We also find that Energy and Transport sector law leads to a more pronounced reductions in long-term debt. These nuanced findings highlight that climate law and polices is not uniform, reinforcing the need for sector-specific financial risk assessments when analysing the impact of CLP.

Our legal origin findings suggest that firms in Common Law and French Civil Law countries tend to rely more on long-term debt, likely due to stronger creditor rights and institutional support for long-term financing, respectively. In contrast, firms in German and Scandinavian Civil Law countries exhibit a preference for shorter maturities, reflecting conservative financial practices and a reliance on internal funding or short-term credit. We also find the national governance factors such as rule of law, regulation quality, and control for corruption moderate the relationship. We find that the interaction of national governance with CLI encourages the use of long-term debt. Furthermore, our finding suggest that financially constrained firms have limited capacity in adjusting their debt maturity structures. Importantly, our results indicate that the relationship between climate CLI and long-term debt is non-linear. This reflects the idea that moderate levels of CLI have a limited to no impact on a long-term borrowing. We assert that firms may initially perceive CLP as manageable, but as CLP number increases, the perceived risks and compliance burdens prompt firms for adjustments in debt maturity composition. Additionally, the effect of change in CLP on debt maturity varies with macroeconomic conditions, indicating that broader economic cycles may amplify or moderate firms' financial responses to CLP shifts. Our study is robust to a myriad of robustness checks.

We conduct a several endogeneity tests and alternative model specifications, confirming the causal impact of CLI on long-term borrowing. The results emphasize that CLP is no longer merely an environmental compliance concern but a fundamental determinant of corporate financial strategy. By shortening debt maturities, firms seek to

enhance financial flexibility, mitigate refinancing risk, and navigate evolving climate risk.

In addition, this study can benefit policymakers in framing new climate laws and policies in future because legislation have consequences on corporate sectors. The result suggest that CLP introduce uncertainty can bring unintended financial consequences, particularly by increasing firms' reliance on short-term financing mechanisms. If widespread, this shift could elevate corporate refinancing risks, leading to potential financial stability concerns in the face of economic downturns or monetary tightening cycles. Policymakers should therefore ensure that climate regulations are structured to minimize financial uncertainty, balancing regulatory effectiveness with corporate financing stability. Additionally, our findings indicate that sector-specific laws are stronger than having a general CLP targeting all the sectors. Moreover, regulatory initiatives promoting climate-adjusted lending mechanisms—such as sustainability-linked loans, transition bonds, and green credit facilities—could support firms in managing long-term financial stability amid climate transition risks.

Also, our study has a crucial implication for firms and investors. From a risk management perspective, firms should consider integrating climate law uncertainty into their capital structure decisions, recognizing that CLP shifts can significantly alter long-term financing costs and access to capital. Given the non-linear effect observed in our study, firms must assess their exposure to moderate versus extreme climate regulation scenarios and adapt their financing strategies accordingly.

We provide a foundational framework for future research at the intersection of sustainability, policy uncertainty, and corporate finance. Future research could further explore how firms' responses to CLP evolve over time, particularly as climate disclosure frameworks and regulatory enforcement mechanisms become more standardized. Additionally, future studies could investigate how financial institutions adjust credit terms, interest rates, and debt covenants in response to corporate CLP exposure, further clarifying the link between policy-induced uncertainty and corporate financial constraints. Finally, future research could assess whether the observed reduction in debt maturity is associated with long-term financial performance or investment efficiency, providing deeper insights into the trade-offs between financial flexibility and sustainability transition planning.

Chapter 4

Climate Litigation Risk and Corporate Cash Holdings

4.1 Introduction

“Climate litigation is offering citizens and activist groups a real opportunity to hold governments to account on climate-action obligations”¹²⁴

Climate litigation against corporations has emerged as a critical mechanism to enforce corporate accountability, with lawsuits targeting misleading disclosures, carbon emissions, and failures to adapt to climate risks (Setzer & Higham, 2023; Peel & Osofsky, 2020). Globally, climate change litigation¹²⁵ is on the rise. Between June 2022 to May 2023, the number of climate change litigation cases increased to 2341 cases, out of which 190 were filed in last 12 months.¹²⁶ Climate activists around the world are increasingly turning to litigation to compel governments and firms to take more robust and immediate climate action (Setzer & Byrnes, 2020). Especially, climate lawsuits against companies have increased globally, with around 230 lawsuits filed since 2015.¹²⁷ Notably, two-thirds of these cases were filed after 2020.

The increasing frequency of these climate litigations underscores their growing societal and economic importance, extending their influence beyond direct court outcomes. Importantly, lawsuits and court rulings related to climate change can ignite public debates in the media. In this context, a study by Peel & Osofsky (2013) suggests that even climate litigation cases that do not succeed in court can indirectly affect public discourse and national media narratives about climate change. Liu (2020) states that when a company is involved in litigation, whether as a plaintiff or a defendant, it can attract public and media scrutiny. It is therefore plausible that companies faced with climate lawsuits may experience immediate direct and indirect negative impacts. In this context, a study by Sato et al. (2024) reveals that the defendant firms facing climate lawsuits experience a 0.41 per cent decline in stock returns.

For example, in *Milieudefensie v. Shell* (2021), a Dutch court ordered Shell to reduce its global carbon emissions by 45 percent by 2030.¹²⁸ Compliance with this ruling

¹²⁴ See <https://www.lawsociety.ie/gazette/in-depth/climate-justice> [Accessed on 30th August 2024]

¹²⁵ Solana (2020) describes climate change litigation as any legal case where climate change is a central issue presented before a regulatory or judicial body with the power to issue binding decisions.

¹²⁶ See <https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2024/06/Global-trends-in-climate-change-litigation-2024-summary-brief.pdf>

[Accessed on 30th August 2024] Almost 90 percent of the cases filed since June 2022 are from outside the United States. In the year 2023, cases from seven new countries like Bulgaria, China, Finland, Romania, Russia, Thailand, and Turkey were reported.

¹²⁷ See <https://www.lse.ac.uk/granthaminstitute/news/climate-litigation-against-companies-is-on-the-rise-report-finds/> [Accessed on 30th August 2024]

¹²⁸ See <https://climatecasechart.com/non-us-case/milieudefensie-et-al-v-royal-dutch-shell-plc/> [Accessed on 05th April 2025] BP wrote down \$17.5 billion in oil and gas assets in 2020 after the *Milieudefensie* vs

forced Shell to direct investments in renewable energy and divest from fossil fuels. As demonstrated by Shell's case, immediate restructuring obligations and compliance costs arising from litigation compel investors and financial institutions to reevaluate firms' risk profiles, influencing broader market behaviours such as investment decisions and asset valuation.¹²⁹ Furthermore, financial institutions, due to its central role in economic development, face idiosyncratic risks from climate litigation because it may cause reputational damage even when not directly involved in such cases.¹³⁰ Investors and financial institutions, therefore, increasingly incorporate climate litigation into their financial decisions making (Solana, 2021).¹³¹ Firms facing climate litigation risk can also face exclusion from ESG funds and experience higher borrowing costs and divestment campaigns.¹³² For instance, BlackRock's 2023 report identified climate litigation as a top driver of "stranded asset" risks, directly linking lawsuits to firm valuation decline.¹³³

Other than the negative reputational and value impacts, climate litigation risks potential large penalties, compliance and legal expenses that can impose substantial drain on financial resources. Corporate cash holdings are a key component of a firm's financial flexibility. Prior literature has shown that firms accumulate cash for precautionary reasons in response to uncertainty, investment needs, and financing frictions (Opler et al., 1999; Almeida et al., 2004; Bates et al., 2009). Litigation risk, particularly from shareholder lawsuits or securities class actions, significantly influences companies' cash and liquidity policies (Arena & Julio, 2015; Malm & Kanuri, 2016). Arena and Julio (2015) find that firms involved in securities class action lawsuits significantly increase their cash holdings while cutting back on capital investment, suggesting a precautionary response to heightened financial uncertainty. Similarly, Malm & Kanuri (2016) show that

Shell verdict.

¹²⁹ For instance, in 2022, Shell invested approximately \$2.9 billion in wind and solar energy, accounting for about 8% of its total capital expenditures. Furthermore, Shell announced plans to invest between \$10 and \$15 billion from 2023 to 2025 in low-carbon energy solutions, including electric vehicle charging, biofuels, renewable power, hydrogen, and carbon capture and storage. See

<https://www.stocktitan.net/news/SHEL/shell-welcomes-dutch-court-of-appeal-6swsf61vq2so.html?> & <https://en.milieudefensie.nl/news/the-monitor-assessing-shells-progress-in-meeting-the-climate-case-verdict>

¹³⁰ Regulatory authorities, including the European Central Bank, have warned that banks might face heightened litigation risks if their lending activities are not aligned with climate goals. See <https://e-axes.org/research/the-impact-of-climate-litigation-on-banks/> [Accessed on 05th April 2025].

¹³¹ See <https://sustainability.slaughterandmay.com/post/102igvq/climate-litigation-risk-informing-investor-decisions> [Accessed on 05th April 2025].

¹³² See <https://corpgov.law.harvard.edu/2022/04/25/litigation-risks-posed-by-greenwashing-claims-for-esg-funds/> [Accessed on 05th April 2025].

¹³³ See <https://www.environmental-finance.com/content/news/blackrock-warns-on-stranded-assets.html> [Accessed on 05th April 2025]

firms in high-litigation-risk industries hold more cash to buffer against potential legal costs, with the effect being stronger for firms facing financing constraints. However, existing studies on litigation and corporate cash holdings predominantly focus on securities class action lawsuits, financial misreporting, or managerial misconduct, risks that are largely idiosyncratic and internal to the firm. While there is some empirical evidence on the effects of climate lawsuits and financial market impact, there are no studies focusing on the impact of climate litigations on corporate cash holdings (McCormick et al., 2018; Setzer & Vanhala, 2019; Solana, 2020; Sato et al., 2024; Dulak & Gnabo, 2024). Understanding firms' strategic responses to climate litigation necessitates an examination of firms' cash management policies. This is particularly important because corporate cash holdings play a central role in mitigating financial distress and maintaining operational flexibility during the period of climate litigation (Chang, & Yang, 2022; Chung et al., 2023; Duong et al., 2020).

We assert that unlike traditional litigation, climate litigation differs in nature, scope, and intensity.¹³⁴ Climate change litigation refers to any legal proceedings- whether federal, state, tribal, or local where the filings made by parties or the decisions rendered by the courts specifically address issues pertaining to the facts or legal frameworks surrounding the causes and effects of climate change. Climate litigations are often initiated by state attorneys general, municipalities, or environmental NGOs, and target firms not merely for wrongdoing, but for their long-term contribution to greenhouse gas emissions, misleading climate disclosures, or failure to align with the domestic and global climate goals (Setzer & Vanhala, 2019; Ruhl, 2021). This is further exacerbated by the fact that climate-related litigation is relatively new and evolving, making it harder for firms to predict and mitigate potential costs, which can include not just fines but also business operation overhaul, reputational, and regulatory costs (Haslem et al., 2017).¹³⁵ The climate litigation has led numerous companies to reassess and amend their sustainability policies in response to the legal challenges and societal pressures they face. For instance, the case of Greenpeace Italy v. Eni S.p.A. In 2023, Greenpeace Italy, along

¹³⁴ See <https://www2.deloitte.com/ch/en/pages/risk/articles/climate-litigation.html> [Accessed on 30th August 2024]

¹³⁵ Successful climate litigation cases present financial and legal challenges for corporations, impacting not only individual firms but also the broader financial system. These challenges are likely to catalyze stricter regulatory frameworks, necessitate changes in risk assessment models, increase insurance premiums, and potentially reduce coverage for companies with heightened exposure to climate-related legal risks. See <https://www.thomsonreuters.com/en-us/posts/esg/climate-washing-litigation/> [Available on 29th October 2024]

with the advocacy group ReCommon and twelve Italian citizens, filed a lawsuit against the Italian energy giant Eni. This case marked the first climate lawsuit against a privately owned company in Italy and was modelled after the landmark Dutch case against Shell. The lawsuit sought a court order compelling Eni to reduce its greenhouse gas emissions by 45% by 2030 compared to 2020 levels, aligning with the goals of the Paris Agreement. Although the case is still pending, it has already prompted increased scrutiny of Eni's environmental practices and has pressured the company to reassess its sustainability strategies.¹³⁶ In the another landmark, Client Earth vs. BP (UK High Court, 2024) ruling, BP was fined with 4.2 million pound for overstating renewable-energy investments while expanding oil production, signalling regulators' willingness to sanction exaggerated transition claims.¹³⁷ We posit that such litigation judgement will require change in firms forward-looking behavioural mandates, forcing firms to restructure operations, invest in decarbonization, and reallocate capital toward low-carbon alternatives. Recent empirical evidence underscores the material financial consequences of climate litigation for firms. According to Sato et al. (2024), the average economic cost of an adverse court ruling in climate-related cases is approximately USD 360 million, reflecting both direct liabilities and the broader financial repercussions of reputational damage, operational restructuring, and impact on company's balance sheet. Even in cases that do not result in adverse judgments, firms incur an average of USD 3 million in legal defence costs, revealing the substantial burden of simply being involved in climate litigation. Importantly, the study finds that investors actively price in these risks, anticipating lower future cash flows from operations and greater uncertainty (Malm et al., 2023; Malm & Sah, 2019). Given these differences, it is unclear whether prior findings on litigation risk and cash holdings generalize to climate litigation (Arena & Julio, 2015; Malm & Kanuri, 2016; Liu, 2024).

Under the precautionary cash motive theory, firms hold cash to hedge against future uncertainty and financing constraints (Schumpeter, 1936). Empirical work by Opler et al. (1999) find that firms with high cash flow volatility and poor access to capital markets hold significantly more cash. As noted above, climate litigation may impose business restructuring, compliance mandates and future financial burdens, thus increase in the uncertainty in cash flows and access to capital, thus amplifying firms' need to

¹³⁶ See <https://climatecasechart.com/non-us-case/greenpeace-italy-et-al-v-eni-spa-the-italian-ministry-of-economy-and-finance-and-cassa-depositi-e-prestiti-spa/> [Accessed on 30th October 2024]

¹³⁷ See <https://ifamagazine.com/why-investors-need-to-be-aware-about-the-rise-in-climate-litigation/> [Accessed on 10th April 2025]

enhance precautionary cash reserves (Javadi et al., 2023; Gounopoulos, & Zhang, 2024). We conduct an empirical investigation on how firms respond to climate litigation risks through their cash management strategies. To do this, we manually construct a dataset of climate litigation involving publicly listed US companies by reviewing all the climate case records. Our findings indicate that firms targeted by climate litigation tend to hold significantly more cash compared to their non-litigated peers. This suggests that facing climate litigation acts as a financial shock, prompting these firms to adopt precautionary liquidity behaviours.

This study provides new empirical evidence on whether climate litigation affects corporate liquidity policies, specifically cash holdings, and whether this response differs in magnitude, persistence, or mechanism from traditional litigation contexts. We analyse climate-related lawsuits filed in US jurisdictions against companies from 2004 to 2023, specifically identifying those involving publicly listed firms headquartered in the US.¹³⁸ Our baseline regression results show that firms involved in climate-related litigation significantly increase their cash holdings relative to non-litigated firms. The effect is economically meaningful, representing an increase of 23 percent more cash relative to the sample mean.¹³⁹ This finding is consistent with Arena & Julio (2015), who document a 1.1 percentage point increase in cash holdings following a securities class action lawsuit. Similarly, Malm & Kanuri (2016) report that firms in high-litigation-risk industries hold 5.6 percentage points more cash. Importantly, we observe a statistically significant increase in cash holdings is not a one-time adjustment. Rather, our analysis reveals that the increase in cash holdings persists for up to 4 years after the litigation event.

Additionally, we also examine the persistence effect of climate litigation using dynamic regression models, each introducing a dummy variable for a specific year relative to the litigation filing year. We find a continuous increase in cash holding persists and remains economically meaningful for up to four years after the climate litigation filing year. Next, we test whether firms experiencing a concluded litigation outcome (e.g., judgment, settlement) show differential behaviour in their cash holdings. Our

¹³⁸ The US record for the most climate litigation cases, totalling 1,745, with 129 new cases filed in 2023. It is followed by the UK, which has 24 cases, Brazil with 10, and Germany with 7. Among these countries, the UK has the highest cumulative count at 139 cases, while Brazil and Germany have recorded 82 and 60 cases, respectively. See https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2024/06/Global-trends-in-climate-change-litigation-2024_summary-brief.pdf

¹³⁹ Mean cash holdings is equal to 0.078 and coefficient on Litigation Dummy is 0.0179. So, $0.0179/0.078 = 0.2294$, which is approximately 23 %. However, this change is not annual, as the climate dummy remains for a three-year period.

investigation reveals that a litigation outcome is associated with a decline in cash holding. One possible reason for this decline is the diminishing uncertainty of litigation outcomes. Consequently, firms no longer need to maintain high cash holdings, leading them to deploy previously accumulated cash reserves towards strategic investments, debt repayment, or dividend distributions.

To ensure that these empirical findings are reliable and robust, it is critical to conduct robustness tests and address potential endogeneity concerns, including reverse causality and omitted variable bias. We perform a battery of robustness tests, to ensure that our results are robust and not driven by temporal trends or industry-specific factors. Our results are robust to alternative definition, placebo tests, sub-sample analysis, and controls for other litigation types. Importantly, our findings also hold even when factoring in other types of litigation besides climate. To address potential endogeneity concerns, including reverse causality and omitted variable bias, we adopt two complementary identification strategies. First, we estimate a lagged model in which all key explanatory variables are lagged by one year. This approach ensures that any observed increase in cash holdings is due to climate litigation, thereby mitigating simultaneity bias. Our results remain robust and statistically significant in this specification, providing preliminary support for a causal interpretation. Second, to further strengthen our identification, we employ a System Generalized Method of Moments (System GMM) estimator (Arellano & Bover, 1995; Blundell & Bond, 1998). This dynamic panel approach allows us to control for unobserved firm-specific heterogeneity, autocorrelation, and potential endogeneity of both the climate litigation variable and time-varying controls by using appropriate internal instruments. The consistency of our findings across both the lagged model and the GMM estimation enhances the credibility of our conclusion that climate litigation influences corporate cash holding behaviour.

This study makes significant contributions to the academic literature on climate risk and corporate finance by providing novel empirical evidence on how climate litigation influences corporate cash holdings. It advances three distinct strands of literature. First, this research offers first-hand insights into the financial implications of climate litigation risk, moving beyond the traditional focus on market-based reactions, such as stock price declines following climate lawsuit filings or adverse rulings, as documented in studies like Sato et al. (2024) and Dulak & Gnabo (2024). Unlike prior research that examines short-term market responses, this study is the first to investigate how climate litigation shapes firms' forward-looking cash management strategies. Our

empirical analysis reveals that firms involved in climate-related litigation significantly increase their cash holdings by 1.79 percentage points, representing a 23% rise relative to the sample mean, with this effect persisting for up to four years post-litigation. Similarly, Dulak & Gnabo (2024) report that while filings alone rarely trigger immediate market drops, adverse court decisions result in modest but significant declines, averaging around -0.22%, with limited spillover effects across industries. Their analysis of litigation events focuses on a tight event window of $[-1, +1]$ days, revealing that most climate litigation filings do not elicit a statistically significant market response, except in certain "highly visible" cases or when courts issue negative rulings. In this study, we demonstrate how climate litigation, distinct in its scope, public interest dimension, and regulatory implications, directly shapes corporate cash holding decisions. Notably, this finding underscores the long-term strategic adjustments firms make to mitigate the uncertainties and potential costs associated with climate litigation

Second, this study enriches the corporate cash holdings literature by identifying climate litigation as an additional and distinct determinant of cash holding decisions. Previous research has explored how litigation risks, such as securities fraud or shareholder lawsuits, influence cash holdings as a precautionary response to legal uncertainty and potential settlement costs (Malm & Kanuri, 2017; Arena & Julio, 2015; Nguyen et al., 2018). However, basing our argument that climate litigation differs due to its public interest nature, regulatory implications, and potential for significant reputational damage, as evidenced by landmark cases like *Milieudefensie v. Shell* (2021) and *Urgenda Foundation v. Netherlands* (2019). Our findings demonstrate that firms exposed to climate litigation significantly increase their cash holding. Importantly, the robustness checks confirming that this effect is specific to climate litigation, as non-climate litigation does not yield similar increases (see section 4.5.4). This effect is consistent across variety of robustness test. By introducing climate litigation as a new factor influencing corporate cash holding decision, this study adds to the cash holding literature (Opler et al., 1999; Aftab et al., 2018). Moreover, we demonstrate how firms dynamically adjust cash holdings in response to climate litigation risk over time. This dynamic evidence strengthens the interpretation that firms respond to climate litigation through a precautionary cash holdings channel, rather than through one-off accounting adjustments. By explicitly documenting the temporal pattern of adjustment, the revised table contributes to the literature on litigation risk and corporate cash holdings by introducing a dynamic perspective that has been largely absent in prior climate-finance

studies.

Third, this research advances the climate risk literature by recognizing climate litigation as a new and underexplored dimension of firm-level climate exposure, thereby broadening the understanding of climate risk beyond the traditional categories of physical, regulatory, and transition risks (BIS, 2021; Sautner et al., 2023). While physical risks (e.g., natural disasters), transition risks (e.g., carbon pricing, technological shifts), and regulatory risk (CABM, EU-ETS, Carbon policies) have been extensively studied (Li et al., 2020; Seltzer et al., 2022). However, climate litigation operates through unique legal, policy, and reputational mechanisms, as illustrated by high-profile cases that have set precedents for corporate accountability (Setzer & Higham, 2022). Our study provides empirical evidence that firms actively manage this emerging risk by increasing their cash holdings, suggesting that litigation risk should be explicitly included in comprehensive climate risk frameworks. This insight is particularly relevant given the rising frequency of climate-related lawsuits, especially against firms in high-carbon industries, which Sato et al. (2024) estimate can lead to economic costs of approximately USD 360 million per adverse ruling. By linking climate litigation to corporate financial strategies, this research complements recent studies that highlight the financial materiality of climate risks (Guizani et al., 2024; Zhang et al., 2024; Dang et al., 2022b; Sautner et al., 2023; Krueger et al., 2022) and provides actionable insights for policymakers aiming to enhance financial market regulation and corporate governance in the context of climate change.

Overall, these contributions are not only theoretically significant but also carry practical implications for practitioners and policymakers. For practitioners, including corporate managers and investors, the results highlight the importance of incorporating litigation risk into cash management planning and financial strategy, particularly in environments with increasing climate-related legal exposure. For policymakers, the findings suggest that climate litigation functions as an indirect enforcement mechanism that influences firm behaviour but may also lead to unintended financial consequences such as excess cash accumulation. This underscores the need to consider the broader financial implications of litigation-driven climate governance. Also, policymakers should treat climate litigation as a distinct risk dimension which can guide the development of more robust climate risk disclosure requirements and regulatory frameworks.

4.2 Literature Review

The intensifying climate crisis, marked by frequent severe weather events and

economic instability, has led to a surge in legal actions by various stakeholders, including individuals, environmental groups, and communities.¹⁴⁰ Climate litigation has emerged as a critical risk for businesses, particularly in sectors with high carbon emissions and environmental footprints. Climate litigation has increased globally in both frequency and scope over the past decade. As of mid-2023, more than 2,300 climate-related cases have been filed around the world, with nearly 200 new cases in the prior year alone.¹⁴¹ Roughly 70 percent of all known climate litigation cases were initiated after the Paris Agreement in 2015.¹⁴² Importantly, the scope of climate litigation has broadened in recent years. Although early climate litigation primarily sought to compel governments to implement stronger climate mitigation policies, recently, companies now comprise climate litigation cases, rising from about 9 % of annual filings pre-2015 to nearly 30 % in 2022 (Setzer & Vanhala, 2019).¹⁴³

Furthermore, climate litigation now spans multiple domains, for example, environmental law, human rights law, consumer protection and corporate law, reflecting the multifaceted avenues through which firms can be sued (Merner et al., 2024). Climate change litigation has emerged as a significant force in shaping environmental law and policy, compelling companies to align their operations with evolving legal frameworks (Kuo & Means, 2024). It is also reshaping the corporate behaviour by increase in forward-looking environmental disclosures in response to perceived litigation risk from peers' environmental disclosure lawsuits (Robinson et al., 2023). A prominent strand of these climate litigation often based on climate-related disinformation and greenwashing, compelling companies to re-evaluate their public communications and environmental policies.¹⁴⁴ Over 140 climate-washing cases had been filed globally by 2023, with court's ruling against companies in 54 of 77 decided cases.¹⁴⁵ These suits allege misleading

¹⁴⁰ See <https://earth.org/the-most-important-climate-litigation-cases-of-2024-and-why-they-matter/> [Accessed on 30th October 2024]

¹⁴¹ See <https://www.theguardian.com/environment/2023/jul/27/lawsuits-are-key-tool-in-delivering-climate-justice-says-un-body#:~:text=There%20have%20been%20%2C365%20lawsuits.related%20damages> [Accessed on 10th April 2025]

¹⁴² See <https://www.lse.ac.uk/granthaminstitute/news/climate-litigation-against-companies-is-on-the-rise-report-finds/#:~:text=The%20analysis%20for%20the%20report,cases%20were%20filed%20in%202023> [Accessed on 10th April 2025]

¹⁴³ See <https://www.theguardian.com/environment/article/2024/jun/27/sharp-rise-in-number-of-climate-lawsuits-against-companies-report-says#:~:text=for%20about%208,cases> [Accessed on 10th April 2025]

¹⁴⁴ See <https://blogs.lse.ac.uk/businessreview/2021/10/04/climate-change-litigation-is-growing-and-targeting-companies-in-different-sectors/> [Accessed on 30th October 2024]

¹⁴⁵ See <https://www.lse.ac.uk/granthaminstitute/news/climate-litigation-against-companies-is-on-the-rise-report-finds/> [Accessed on 10th April 2025]

environmental claims in advertising, ESG reports, and net-zero pledges. As a result, climate litigation has led to greater scrutiny of corporate sustainability reports and the authenticity of 'green' claims made by companies, thereby influencing them to implement more robust and verifiable environmental measures.¹⁴⁶ Since 2017, more than 30 US states have filed lawsuits seeking to hold fossil fuel firms financially responsible for climate change costs. These plaintiffs, which include New York City, San Francisco, Minnesota, Rhode Island, and most recently, the state of California, typically claim that oil and gas giants, for example, ExxonMobil, Chevron, BP, and Shell, knowingly contributed to climate change and deceived the public about it, resulting in damages such as sea-level rise adaptation expenses.¹⁴⁷

As noted above climate litigation is on the rise, and the climate lawsuit has significant enough to cause substantial adverse shocks to a company's expected cash flows.¹⁴⁸ In this context a study by Sato et al. (2024) reveals that the average economic cost of an adverse court ruling in climate-related cases is approximately USD \$360 million. In the United States, a growing climate litigation suits illustrates the scale of potential exposure. Notable cases include New York City v. ExxonMobil et al. (2021)¹⁴⁹, where major fossil fuel companies were sued for misleading investors about climate risks, and City of Oakland v. BP p.l.c. (2017)¹⁵⁰, where cities sought damages for rising sea levels, although the case was eventually dismissed. Other major lawsuits, such as

¹⁴⁶ Deutsche Umwelthilfe, an association focused on environmental and consumer protection in Germany, has initiated legal actions against both BMW and Mercedes-Benz. DUH argues that by not making a clear and irreversible commitment to stop selling internal combustion engine vehicles by 2030, BMW and Mercedes-Benz are infringing on the fundamental right to climate protection and jeopardizing the rights and freedoms of future generations. Additionally, three youth activists linked to Greenpeace and Fridays for Future Germany have filed a similar case against Volkswagen. See <https://www.lse.ac.uk/granthaminstitute/news/taking-companies-to-court-over-climate-change-who-is-being-targeted/> [Accessed on 30th October 2024]

¹⁴⁷ See <https://coveringclimatenow.org/from-us-story/how-climate-lawsuits-seek-to-hold-big-oil-accountable/#:~:text=up%20profits%20made%20while%20deceiving> [Accessed on 10th April 2025]. Many of these cases invoke tort law (e.g. public nuisance and product liability) or consumer protection statutes, framing climate change as a harm caused by the defendants' products and misinformation campaigns. At the same time, most of these lawsuits remain ongoing.

¹⁴⁸ See <https://news.climate.columbia.edu/2023/08/09/climate-lawsuits-are-on-the-rise-this-is-what-theyre-based-on/> and <https://www.bu.edu/articles/2024/high-level-lawsuits-disrupting-climate-change-policies/> [Accessed on 21 September 2024].

¹⁴⁹ See <https://climatecasechart.com/case/city-of-new-york-v-exxon-mobil-corp/> [Accessed on 10th April 2025]. The New York Supreme Court dismisses claims against fossil fuel companies, ruling that these companies do not violate the City's Consumer Protection Law. The New York City accuses them of misleading consumers about the climate change risks associated with their products and their commitments to renewable and alternative energy sources.

¹⁵⁰ See <https://climatecasechart.com/case/people-state-california-v-bp-plc-oakland/> [Accessed on 10th April 2025].

Minnesota State vs. American Petroleum Institute et al. (2020)¹⁵¹ and County of Multnomah v. Exxon Mobil Corp (2023)¹⁵², accused oil companies of deceptive practices about the environmental impacts of fossil fuels. In both the above lawsuits, the court rejected arguments and affirmed state courts' jurisdiction over claims based on deceptive trade practices and public nuisance laws. The Keystone XL Pipeline litigation saw TC Energy seeking USD \$15 billion in lost profits after the US government cancelled the project.¹⁵³ The Keystone XL Pipeline litigation began after the US government cancelled the pipeline project permit in 2021 due to environmental concerns. In response, TC Energy filed a USD 15 billion claim under the North American Free Trade Agreement, arguing that the cancellation was unfair. The largest climate-related settlement in the US occurred in 2024 when US Steel agreed to pay USD 42 million- USD 5 million in penalties and USD 37 million for environmental upgrades, following Clean Air Act violations after a fire at Clairton Coke Works. The USD 42 million settlement represents approximately 4.7% of net income and constitutes roughly 1.4% of impact on cash and cash equivalents. These cases illustrate how climate litigation can result in significant financial penalties, potentially causing large disruptions to a company's cash holdings and cash flow. In this context, research shows that companies involved in climate lawsuits, particularly the "Carbon Majors industries" (energy, utilities, and materials), experience stock price decline by 0.57% and 1.50% following filings and unfavourable decisions, respectively (Sato et al., 2024). Taken together, the magnitude, uncertainty, and climate-litigation costs heighten cash risk, strengthening managerial incentives to accumulate larger precautionary cash reserves

Prior research establishes that industry securities class action litigation incentivizes firms to accumulate cash as a buffer against potential liabilities (Arena & Julio, 2015). Firms that are subject to securities litigation either directly or through exposure to peer litigations face uncertainties that shape their cash holding decisions, often reflecting a precautionary motive aimed at mitigating potential future financial

¹⁵¹ See <https://climatecasechart.com/case/state-v-american-petroleum-institute/> [Accessed on 10th April 2025].

¹⁵² See <https://climatecasechart.com/case/county-of-multnomah-v-exxon-mobil-corp/> [Accessed on 10th April 2025].

¹⁵³ The first application for a Presidential Permit was submitted in 2008 but was denied in 2012. A second application was subsequently rejected during the Obama administration. However, After the Trump administration approves the permit in 2017, the parties terminate the arbitration and agree to waive any future claims related to previous events. In 2019, the permit gets reissued, but once President Biden takes office in January 2021, it was revoked. See <https://climatecasechart.com/non-us-case/tc-energy-corporation-and-transcanada-pipelines-limited-v-united-states-of-america-ii/>

shocks (Nguyen et al., 2018; Malm & Kanuri, 2017). In another study, Arena (2018) finds that corporate lawsuits filed with the Securities and Exchange Commission in the US tend to receive lower credit ratings, pay higher yields on loans, and are hesitant to rely on debt financing. As noted above litigation and corporate misconducts introduces uncertainty because of the prospect of large legal liabilities, compliance costs, or operational disruptions which can strengthens firms' precautionary savings motive. In such situation holding more cash, firms aim to reduce the need for external financing, which may be difficult to secure during periods of litigation induced uncertainty as a result firm can experience a higher cost of capital.

Although, previous studies have demonstrated a link between the risk of securities litigation in the industry and the levels of cash held by companies (Arena & Julio, 2015; Malm & Kanuri, 2016; Liu, 2024). However, we argue that climate litigation differs markedly from more traditional forms of corporate litigation such as securities fraud suits, antitrust cases, or consumer product lawsuits in its motivations, stakeholders, and potential impacts. Climate litigation is distinctive in the complexity of evidence and causation it brings into the courtroom. To establish liability for climate harms, these cases are usually based on extensive scientific data on climate change for example, carbon emissions, attribution science linking emissions to specific damages, and forward-looking climate scenarios like temperature rise. Judges are asked to consider climate models and long-term climate risk projections, which is far more complex and forward-looking than, evaluating a misstatement in a financial report, patent lawsuits, antitrust claims or security class action. Thus, climate litigation cases often require climate scientists, economists, and other experts to demonstrate a future associated risks and cause effect on climate change (Marner et al., 2024).

Thus, climate litigation differs fundamentally in scope, intent, and uncertainty, often involving forward-looking claims, non-shareholder stakeholders, and systemic accountability for environmental harm. However, despite the exponential rise in climate lawsuits and their profound implications on firm value, disclosure practices, and long-term strategy, no empirical study to date has investigated whether climate litigation impact firms' cash holding. This study fills an important gap by examining the link between climate litigation and corporate cash holdings.

4.2.1 Litigation Risk and precautionary cash holdings

Corporate litigation in finance is of great interest and worthy of investigation

largely because its cost-benefit trade-off for the firm stakeholders is unclear (Arena & Ferris, 2017). A large accounting and finance literature dating back to Skinnners (1994) explores how litigation risk affects corporate decision making. In this context, research studies on litigation risk indicate that litigation incurs not only direct legal costs but also has a negative impact on a firm's operations. It reduces operational efficiency and increases the time required to convert business activities into cash. This, in turn, directly affects the firm's cash flow and overall profitability (Malm & Sah, 2019). Additionally, firms involved in lawsuits are less likely to pay dividends, arguing that sued firms often face higher interest rates and stricter monitoring from financial institutions, making external financing more costly. To avoid the higher costs, firms retain earnings instead of paying dividends (Malm & Kanuri, 2020). According to He & Shi (2023), litigation risk leads to decline in ROA for Chinese non-financial listed companies. This finding indicates that litigation risk adversely affects ROA through the company's ability to avail debt financing. Taken together, these studies underscore the financial and operational burdens of litigation risk, which often extend beyond the courtroom and into strategic corporate policy. Prior research studies indicate firms with higher litigation risk experience external financing constraints (Autore et al., 2014), lower operating performance measured by return on assets and return on equity (Malm et al., 2023), and increase in cash holdings (Arena & Julio, 2015).

We argue that firms adjust their cash-holding strategies in the wake of climate litigation for various reasons. According to Opler et al., (1999) cash holdings by firms serves as an internal means of capital to circumvent the various immediate purpose. For example, operational needs, financial stability, liquidity management, investment, cover the legal cost and dividend decisions. Our argument is based on Schumpeter (1936), precautionary saving motive theory which suggest that climate litigated firms will hold more cash due to uncertain legal outcome and future cost associated with settlements. Also, the decision to hold higher cash holding by climate litigated firms aligns with the dynamic model of investment, financing, and risk management proposed by Bolton et al. (2011). This model suggests that when firm speculate high legal costs in future or change in financial conditions firms tend to rely more on increasing cash holdings while reducing investments as a means of risk management. Using a sample of securities litigation firms from the US, a study by Hutton et al. (2014) documents that litigated firms are less likely to opt for external debt and equity issuance leading to higher perceived risk among investors and lenders. This often results in higher interest rates on loans and a higher cost

of equity.

Based on the above argument we contend that firms vulnerable to climate litigation should maintain larger cash reserves. Cash acts as a buffer, allowing these firms to absorb the costs associated with ongoing legal proceedings and to sustain business stability amid heightened stakeholder scrutiny and rising external costs of capital. We also argue that the costs associated with climate litigation are often complex and multifaceted. This is because firms involved in climate litigation often face extended litigation timelines and increased uncertainty, making firms future financial planning difficult (UNEP 2021).

One primary reason climate litigation risk drives higher cash holding is due to the legal uncertainty. Legal representation fees in climate litigation can be significant, with plaintiffs often represented by specialized environmental law firms that work on a contingent basis, increasing the financial burden for firms (Pain & Pepper, 2019). Climate lawsuits can take years to resolve and firms facing such open-ended liability may choose to hold extra cash rather than commit it to illiquid investments. Cash provides flexibility because it can be used to pay a settlement cost or to invest in new technology (for instance, cleaner processes) to pre-empt further climate lawsuits. By holding more cash, companies also signal to investors and creditors that they can absorb climate litigation shocks and mitigate the increased cost of capital (Arena et al., 2012; Nguyen et al., 2018; Oliviero et al., 2024). In fact, corporate debt research shows that litigation risk itself makes financing more costly. Firms with litigation risk are associated with lower credit ratings and higher loan spreads on average (Arena, 2018; Ni & Yin, 2018). Firms tend to rely less on external debt financing, likely because potential legal liabilities deter lenders (Yuan & Zhang, 2015). This financing friction reinforces the incentive to maintain higher cash reserves. Maintaining higher cash holdings becomes more important when a lawsuit materializes and leads to a big penalty or settlement cost; a firm with ample cash can pay it without needing to seek costly external finance or not accessible for the firm. Empirical evidence confirms this dynamic: Companies that faced litigation payouts and lacked sufficient cash have their credit ratings downgraded, and borrowing costs spike at litigation outcomes (Arena, 2018). Therefore, climate litigated firms pre-empt this problem by hoarding cash as insurance against litigation outcomes or to cover the legal expense cost.

Another driver is the reputational and operational risk that climate litigation brings, which can indirectly affect cash policy. Being sued over climate issues can

significantly affect company's reputation and erode stakeholder trust, especially given the high public profile of many climate cases. For example, a lawsuit accusing a firm of greenwashing or of causing environmental harm may lead to consumer boycotts or stricter regulatory scrutiny, which in turn could affect revenues or increase expenses (Kim & Kim, 2024; McDonnell & King, 2013). Usually, this type of risk is hard to quantify but makes future cash flows more volatile. Firms respond to such volatility by increasing cash holdings as a cushion against the future cash flow volatility. Moreover, climate litigation is often accompanied by negative stock market reactions: a study by Sato et al. (2024) reveals that when a climate-related lawsuit is filed or an unfavourable judgment is announced, the defendant firm's stock price drops on average by about 0.4%, and by even more (up to 1.5% loss) for big emitters in novel types of cases. We argue that the managers cognizant of this risk must retain extra cash to stabilize the firm's financial position. This is because managers particularly those operating under heightened litigation and reputational risk may choose to accumulate cash reserves as a buffer against deteriorating external financing conditions. Holding more cash becomes a strategic response to absorb shocks and maintain operational flexibility when capital markets may react unfavourably to climate litigation news. This aligns with the precautionary motive for cash holdings (Almeida et al., 2004; Bates et al., 2009), where firms facing greater uncertainty and risk of financing constraints retain higher cash.

In addition, we assert that managers may also respond to the reputational and career risks associated with climate lawsuits by favouring conservative financial strategies that emphasize liquidity over investment.¹⁵⁴ Concerns about potential reputation loss or job loss, managers become conservative in their approach and hold higher cash balances to ensure financial stability and flexibility during uncertain times (Dittmar & Duchin, 2012; Nam et al., 2008).

Overall, the intersection of climate litigation and corporate finance is a nascent but important area of research. Based on both theoretical and empirical evidence, it is reasonable to conclude that firms facing climate litigation hold higher cash reserves as a precaution against potential future legal expenses, settlements, and operational

¹⁵⁴ In a 2022 case, directors and executives of a California utility company agreed to a \$117 million settlement after being sued for negligence related to inadequate safety measures prior to major wildfires. The lawsuit, brought by a trust established by wildfire victims, directly targeted the managers for their roles in the company's climate-related risk management. See <https://www.reuters.com/markets/commodities/pge-officials-reach-117-million-settlement-over-california-wildfires-2022-09-29/> [Accessed on 10th April 2025].

disruptions. This cash holding serves multiple purposes as it provides a reserve for potential legal payouts, ensures liquidity if the firm's reputation or operations suffer, and offsets the greater difficulty climate litigated firms may face in raising capital externally. Based on the above rationale and precautionary motive theory we hypothesize that *the Climate litigated firms are associated with an increase in cash holdings*

4.3 Data selection, variables, and empirical strategy

We systematically gather data on climate litigations filed in the United States (US) using the climate litigation databases maintained by the Sabin Centre for Climate Change Law. The data was obtained on May 23, 2023. As of May 2023, the US Sabin Centre's databases capture over 1621 litigations, involving judicial and quasi-judicial bodies that focus on significant aspects of climate change science, policy, or law.¹⁵⁵ Database do not include any litigations where climate change is merely incidental.¹⁵⁶

From the universe of climate litigations involving publicly listed companies in the US we have manually identified 295 climate litigation observations involving publicly listed US companies. This number results from our thorough reading of 1621 climate litigations court cases filed in the US region. Next, we consider only those companies with headquarters in the US region resulting in a final reported sample of 205 climate litigations observations. These litigated firms were then matched with the Compustat database using CUSIP identifiers and year, producing a final set of 205 climate litigation observations.¹⁵⁷ To avoid over-representation and to maintain consistency in firm-year level analysis, we consolidate multiple climate litigation against the same firm within a calendar year into a single firm-year observation. This approach is consistent with prior literature in corporate litigation studies (Arena and Julio, 2015; Hutton et al., 2014). This result in final 124 observations of climate litigation firms.

To construct our sample, we compile US firm-level data from Compustat and initially obtained 202,213 firm-year observations. We next apply a series of filters to ensure data quality and relevance. First, following Dittmar et al., (2003), we remove firms with missing information on key variables such as cash and cash equivalent, cash and short-term investment and total assets, leaving us with 137,160 firm-year observations. Second, we exclude financial firms (Standard Industry Classification (SIC) 6000 - 6999))

¹⁵⁵ See <https://climatecasechart.com/>

¹⁵⁶ The database includes only those litigations where climate change is a substantial component of the claim.

¹⁵⁷ We provide the list of all the companies involved in climate litigation in the online Appendix C.

as they are highly regulated and inventories of their marketable securities are included in cash (Opler et al., 1999). This sample filtration procedure yielded 118,137 firm-year observations. Next, we restrict our sample to the period between 2004 to 2023 and drop observations outside this range resulting in 90,897 firm-year observations before applying matching technique.¹⁵⁸

4.3.1 Matching procedure of climate litigated firm with non-climate litigated firm

As noted above that only 124 out of 90,897 firm-year observations pertain to companies involved in climate litigation, the large imbalance between the firms with and with no climate litigation raises concerns about potential skewed sample related estimation bias.

To mitigate this concern, we employ a criteria-based nearest-match procedure grounded in prior literature. To begin the matching, we first define a binary litigation indicator $litigation_i$ where $litigation = 1$ for firm involved in litigation in the year t and zero otherwise. Next, consistent with prior empirical corporate finance studies examining litigation risk and firm cash holding responses, we first restrict the control pool to firms (*not involved in climate litigation*) within the same 2-digit SIC industry classification as each litigated firm (Arena & Julio, 2015).¹⁵⁹ Industry matching is particularly important in the context of climate litigation because legal exposure is structurally concentrated in emissions-intensive sectors; failing to control for industry would therefore confound treatment effects with sectoral risk characteristics (Bolton & Kacperczyk, 2021). This led us to 59,842 firm-year observation.

Furthermore, within this industry-restricted sample, we match firms using three financial characteristics measured prior to litigation: return on assets (ROA), change in ROA (ΔROA), and market-to-book ratio (MB). These variables were selected because they capture complete dimensions of firm comparability. For instance, ROA and ΔROA dynamics proxy for operating performance and managerial efficiency, while market-to-book ratio reflects growth opportunities and market expectations. Prior literature shows that these characteristics jointly influence corporate financial policy, litigation exposure, and investor scrutiny (Opler et al., 1999; Bates et al., 2009; Kim et al., 2011; Arena &

¹⁵⁸ The first climate-related litigations in our sample occurred in 2004. As a result, any firm-year observations prior to 2004 have been excluded since they do not contain any litigation events and are not relevant for our identification strategy. Additionally, observations beyond 2023 have been excluded due to the conclusion of the climate-related litigation period.

¹⁵⁹ Climate litigated firm belongs to the following 2 digit SIC classification 12, 13, 15, 20, 28, 29, 30, 32, 33, 36, 37, 45, 49, 50, 51, 53, 55, 59, 73, 99.

Julio, 2015). Additionally, matching on these variables therefore ensures that treated (*firms involved in climate litigation*) and control firms are comparable in terms of financial condition, performance trajectory, and valuation, thereby satisfying the conditional comparability requirement for observational causal inference (Rosenbaum & Rubin, 1983).

To strengthen match quality, we implement a two-stage tolerance rule. We first apply strict matching thresholds (± 20 percent), ensuring close similarity across all matching dimensions. When no suitable control firm is found, we relax the criteria slightly and consider control firms that fall within ± 0.01 for return on assets and change in return on assets, or ± 0.01 for the market-to-book ratio. The control firm with the smallest cumulative distance is selected as the closest match.

Additionally, we impose a forward-looking data availability requirement to ensure that the selected control firm has at least ten years of data after the match year. This condition ensures that both treated and control firms can be analysed over a comparable horizon. Following equation explains the distance metrics procedure we applied to select the similar set of non-litigated firms:

$$|ROA_L - ROA_T| + |\Delta ROA_L - \Delta ROA_T| + |MB_L - MB_T| \quad \text{-----} \quad (4.1)$$

In the above equation, ROA_L and ROA_T represent the return on assets of the litigated and non-litigated firm, respectively, in the year preceding the litigation. ΔROA_L and ΔROA_T denote the change in ROA from year -2 to year -1 for the litigated and non-litigated firm, and MB_L and MB_T refer to the market-to-book ratios of the litigated and non-litigated firm in year -1 . After applying the above mentioned all the matching procedure we construct a control group of non-litigated firms that closely resemble the financial characteristics of the climate litigated firms. The final sample includes 2,046 firm-year observations of 152 unique firms.¹⁶⁰ Panel A Table 4.1 shows the distribution of the firm-year sample over the years, and Panel B shows distribution of climate litigation across the industries.

As a robustness check, we re-estimate our baseline regression using a weighted sample constructed using the entropy balancing method. This is because criteria-based matching ensures economically meaningful comparability between litigated and non-litigated firms, however such approaches may still be sensitive to researcher-defined thresholds or distance rules. Therefore, to minimise potential bias arising from

¹⁶⁰ This consist of 65 climate litigated and 87 non-climate litigated firm.

discretionary matching choices, we complement our baseline design with entropy balancing, a data-driven reweighting method widely used in prior empirical literature (Hou et al., 2024; Esqueda & Ngo, 2024; Hossain & Masum, 2022). Entropy balancing reweights the control group so that its covariate distribution exactly matches that of the treated group on specified moments, thereby eliminating observable imbalance without defined criteria-based matching (Hainmueller, 2012). Importantly, the consistency of results across both the matched sample and entropy-balanced sample indicates that our findings are not sensitive to matching design (see Appendix B).

**Table 4.1 Sample distribution
(Panel A)**

Year	Freq	Percent	Cum. Freq
2004	96	4.55	4.55
2005	101	4.94	9.48
2006	104	5.08	14.57
2007	106	5.18	19.75
2008	104	5.08	24.83
2009	105	5.13	29.96
2010	101	4.94	34.90
2011	105	5.13	40.03
2012	108	5.28	45.31
2013	109	5.33	50.64
2014	108	5.28	55.91
2015	111	5.43	61.34
2016	105	5.13	66.47
2017	114	5.08	71.55
2018	101	4.94	76.49
2019	102	4.99	81.48
2020	100	4.89	86.36
2021	98	4.79	91.15
2022	90	4.40	95.55
2023	91	4.45	100.00

Panel A of Table 4.1 outlines the sample distribution of the firm-year observations of the sample from 2004 to 2023.

Distribution of climate litigations cases across industries (Panel B)

Industry	Number of Lawsuits
Agriculture and mining	24
Food	4
Chemicals	2
Oil and gas	28
Manufacturing	12
Electronics & Computers	1
Transportation	5
Utilities	38
Wholesale Trade	3
General Merchandise/Retail	5
Business Services	2

Total	124
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Panel B of Table 4.1 outlines the distributions of climate litigations across the industry from 2004 to 2023.

4.3.2 *Dependent variables*

Following the definitions of Nguyen et al. (2018), we measure the cash holdings as total cash and short-term investments divided by the total book value of assets. For robustness, as an alternative measure, following Dittmar & Mahrt-Smith (2007), we also use total cash divided by the total book value of assets to measure cash holdings. These two definitions focus solely on gross cash holdings and do not consider any short-term debt obligations a firm may have, which can immediately limit the usability of cash. Therefore, we perform an additional robustness check and construct an alternative definition of cash holdings following Opler et al. (1999), where we calculate net cash as total cash and short-term investments minus short-term debt divided by the total book value of assets. This net cash definition highlights the portion of cash available after fulfilling short-term liabilities. By factoring in the short-term debt, we ensure that our net cash measure reflects the actual cash available to managers for navigating climate litigation risks.

Following Bates et al. (2009), we incorporate one additional measure of cash holdings to ensure robustness. This is because all the definitions above are scaled by total assets, therefore we complement them by employing cash-to-net-assets, which offer alternative scaling approaches to capture cash relative to non-cash assets.

4.3.3 *Independent variables*

To investigate the impact of climate litigation on corporate cash holdings, we use indicator variables as *litigation* dummy coded as 1 if the firm is involved in litigation during a given year and 0 otherwise. To better capture the ongoing effects of climate litigation exposure, we extend the litigation dummy to remain equal to 1 for three consecutive years following the initial filing. This coding choice reflects the typical legal timeline associated with climate litigation proceedings, where the resolution (settlement or judgment) is not immediate but takes over multiple fiscal years. A review of climate litigation case durations in our sample shows that, on average, climate lawsuits take three years from filing to settlement.

Our litigation dummy choice is also guided by the Arena and Julio (2015), who document that the average time between security class action litigation filing, and settlement is approximately two years. However, this study investigates the effects of securities class action lawsuits similarly treats litigation as a multi-year event to capture

the impact on firm's cash holdings. Importantly, because repeated filings are relatively infrequent in our sample, therefore we do not account for an intensity of climate litigations (*see Appendix C*). Moreover, we acknowledge that litigation intensity and case severity are conceptually relevant dimensions in our study. Unfortunately, consistent cross-firm data on damages claimed, settlement values, or case complexity are not systematically reported for the majority of climate cases in available databases. As a result, constructing a reliable continuous litigation severity measure is not feasible.

4.3.4 Control variables

Following Opler et al. (1999) and Dittmar & Mahrt-Smith (2007), we incorporate a comprehensive set of firm-specific and industry-level variables that may influence a firm's cash holdings. These control variables include firm size, measured as the natural logarithm of total assets which is expected to have a negative association with cash holdings, as larger firms generally have better access to capital markets, which can reduce their need for holding large cash reserves (Liu, 2024). The market-to-book ratio is a proxy for growth opportunities with a positive expected sign. Companies with more growth opportunities are expected to hold more cash to finance future projects without incurring costly external financing (Opler et al., 1999).

We also consider the Tangibility, measured as the ratio of property, plant, and equipment to total assets, is expected to be negatively associated with cash holdings, as tangible assets provide collateral for external financing, reducing the need for liquid reserves (Almeida & Campello, 2007). Next, we control for dividend payments as an indicator variable intended to capture its negative impact on cash holdings. Dividend-paying firms are typically more mature and distribute excess cash; hence, they are expected to hold less cash (Chen et al., 2012; Harford et al., 2008). R&D expenditure, defined as the ratio of R&D expenditures to sales, is anticipated to positively affect cash holdings, as high R&D spending implies a greater need for cash to support innovation (Subramaniam et al., 2011). Financial leverage, calculated as the ratio of total debt to total assets, is also anticipated to have a negative effect, as highly leveraged firms may prioritize debt servicing over accumulating cash reserves (Subramaniam et al., 2011; Bates et al., 2009). Furthermore, we control for Acquisition measured as acquisition expenditure scaled by total assets, to capture investment behaviour, which may instantly increase the demand for cash. Therefore, we anticipate a negative association with cash holdings (Nguyen et al., 2018). Loss is an indicator variable equal to 1 if the firm reports

a net loss for two consecutive years and 0 otherwise, capturing financial distress that typically correlates with increase in cash (Almeida et al., 2004).

We also include equity issuance and debt issuance, which captures net external financing and is computed as sale minus purchase of common and preferred stock and net debt issuance (issuance minus reduction), scaled by total assets, respectively. This variable helps identify whether cash accumulation is associated with new financing (Frank & Goyal, 2009; Bates et al., 2009). Thus, we expect a positive relationship of these two variables with cash holdings. Industry average cash flow volatility is calculated as the standard deviation of cash flow-to-assets over the prior 10 years within each 2-digit SIC industry, reflecting the broader volatility environment in which the firm operates (Nguyen et al., 2018; Dittmar & Mahrt-Smith, 2007). We also control for a net working capital which is defined as total working capital, less cash and short-term investments, divided by total assets, as firms with high working capital may rely less on cash reserves due to liquidity substitutes (Chen et al., 2012). Finally, we include cash flow measured as earnings after interest, dividends, and taxes, and before depreciation, scaled by total assets. This is because high cash flow enables firms to build cash reserves, suggesting a positive relationship with cash holding (Bates et al., 2009). Definitions of all the variables are reported in Table 4.2.

Table 4.2 Variable definitions

Variables	Definitions
Cash	Total cash and short-term investment / Total book value of asset. Nguyen et al. (2018).
Cash1	Total cash/ Total book value of asset. Dittmar & Mahrt-Smith, (2007).
Net Cash	Total cash and short-term investment minus short-term debt / Total book value of Asset (Opler et al., 1999).
Cash2	Total cash and short-term investment/ net assets. Where we define Net assets as total assets minus cash. Bates et al., (2009).
Independent variables	
Litigation Dummy	An indicator variable coded as 1 if the firm is involved in litigation during a given year and 0 otherwise. The dummy maintains the same value for the 3 years following the litigation.
Control variables	
Size	The natural logarithm of the book value of total assets in year t divided by 1000.
Market to book ratio	Market-to-Book ratio is calculated as the sum of the market value of equity (closing share price multiplied by the number of common shares outstanding) and the book value of debt (total assets minus common equity), divided by total assets.
Tangibility	Net total property, plant and equipment divided by total assets in year t.
Dividend dummy	A dummy variable equals to 1 if firm paid dividend in year t, 0 otherwise.

R&D	Ratio of R&D expenditures to sales, set to 0 if missing.
Financial leverage	Total debt (long-term debt + short-term debt) divided by total assets in year t.
Acquisition	Acquisition expenditure divided by total book value of assets in year t.
Loss	Indicator variable equal to one if the firm posts a loss for the 2 years, and zero otherwise
Net debt issuance	Issuance of long-term debt less reduction in long-term debt divided by total assets.
New equity issuance	Sale of equity shares less purchase of equity shares divided by total assets.
Industry average cash flow volatility	The two-digit SIC industry average standard deviation of cash flow over assets in the previous 10 years (with at least 3 non-missing observations)
Net working capital	Total working capital less cash and short-term investment divided by total assets in year t.
Cash flow	Earnings after interest, dividends, and taxes, and before depreciation, Scaled by total assets.
Return on assets	Total net income divided by total assets in year t.

The table presents the list of variables used in this study and their definitions.

4.3.5 Empirical Strategy

To examine the effect of climate litigation on corporate cash holdings, we estimate the following OLS fixed effect regression model:

$$Cash_{i,t} = \beta_0 + \beta_1 litigation_{i,t} + \delta Controls_{i,t} + Industry\ fixed\ effect_j + Year\ fixed\ effect_t + \epsilon_{i,t} \text{-----}(4.2)$$

Our choice of empirical model is motivated by both the nature of the research question and the structure of the dataset, which comprises repeated firm-year observations spanning 20-year period (2004-2023). This specification closely mirrors influential prior studies in corporate finance that examine the effects of legal, regulatory, or macroeconomic shocks on firm behaviour. For instance, Malm & Kanuri (2016) show that security class litigation risk is associated with higher cash holdings, using fixed effects models to account for unobserved heterogeneity across firms and industries. Similarly, Arena & Julio (2015) and Arena (2018) utilize firm-year data and fixed-effects regression models to investigate the impact of security class litigation on corporate cash holdings and debt strategies. Additionally, Javadi et al. (2023) analyse the influence of climate change on cash holdings and applied fixed-effects panel regressions to differentiate long-term firm behaviours from sector and time specific shocks.

In equation 2, $Cash_{i,t}$ denotes the level of cash and cash equivalents held by firm i in year t , scaled by total assets. $Litigation_{i,t}$ is a binary variable equal to 1 if the firm is involved in a climate-related lawsuit in year t , and 0 otherwise. We maintain the same dummy value for the firms involved in climate lawsuits for 3 years following, as we note

on average, climate lawsuit filing to settlement is close to 3 years in our sample set.¹⁶¹ $Controls_{i,t}$ represents a vector of firm-specific financial control variables, including firm size (*Size*), market to book ratio (*MB ratio*), property plant and equipment (*Tangibility*), indicators for dividend payout (*Dividend*), research and development expenditure (*R&D*), financial leverage (*Leverage*), acquisition expenditure (*Acquisition*), two-year firm loss (*Loss*), equity issuance (*Equity issuance*), debt issuance (*Debt issuance*), industry average cash flow volatility (*Industry cash flow*), net working capital (*Working Capital*), and cash flow (*Cash flow*). These variables are selected based on prior literature on the determinants of cash holdings (Opler et al., 1999; Bates et al., 2009).

To mitigate omitted variable bias, based on prior literature the regression models include an extensive set of firm-level financial controls, industry and year fixed effects, and robustness checks using alternative specifications (see section 4.5). These controls absorb time-invariant firm characteristics, macroeconomic shocks, and sector-specific trends that might otherwise confound the estimated relationship. We acknowledge that remaining unobserved heterogeneity (*like corporate governance variables, ESG factors*) may still exist but is unlikely to systematically bias the observed relationship.

In equation (2), we include the industry fixed effects as it is essential to control for time-invariant industry characteristics that might influence cash holdings. Our choice for industry fixed effects in our empirical model stems from the inherently industry-specific nature of climate litigation risk. Climate lawsuits are not randomly distributed across the firm rather we find that it tends to cluster in sectors with high environmental footprints, such as energy, utilities, manufacturing, and mining, which are more directly responsible for greenhouse gas emissions and climate-related externalities. Controlling for these industry effects ensures that the estimated effect of litigation is not confounded by industry-specific factors.

We also include year fixed effects to absorb macroeconomic shocks and temporal trends that could affect all firms each year, such as changes in interest rates, economic cycles, policy reforms, or shifts in investor sentiment about ESG and climate change. Year fixed effects help isolate the effect of climate litigation from these broad-based time effects that might otherwise bias the results. The combined use of industry and year fixed effects is consistent with best practices in the literature (e.g., Petersen, 2009; Gormley &

¹⁶¹ Arena & Julio, (2015) following Klausner & Hegland (2010), finds that the average time from securities class action lawsuit filing to settlement takes nearly two years.

Matsa, 2014) and enhances the model's ability to control for omitted variable bias and unobserved heterogeneity. Although firm fixed effects are commonly used in panel data models, we rely on a matched sample to pair climate-litigated firms with observationally similar non-climate litigated firms. Using firm fixed effects would absorb litigation status for many firms (due to single litigation years for many firms), reducing variation in the treatment variable. Instead, in line with Nguyen et al. (2018) and Dittmar et al. (2003), we use robust standard errors clustered at the firm level to address potential heteroscedasticity and intra-firm error correlation. Clustering at the firm level accounts for the likelihood that observations within the same firm may be correlated due to unobserved firm-specific characteristics, thus enhancing the accuracy of standard error estimates. Additionally, to ensure the robustness of our findings and address concerns regarding the correlation of residuals within industries and over time, we re-estimate our baseline regression model using alternative clustering techniques. We report the result of this analysis in Appendix D. Based on the above justification; we have used industry and year-fixed effect as our main baseline model.

4.4 Empirical Results and Discussion

In this section we present the empirical findings from our analysis of the relationship between climate litigation and corporate cash holdings. We begin by estimating baseline fixed effects regression models. We then explore the persistent effects of litigation over time using several year-specific litigation dummy variables. Further, we also assess whether the outcome of litigation cases materially affects firm cash decisions. Overall, in line with our hypothesis we find that climate litigation is positively and significantly associated with increase in cash holdings which is consistent with the precautionary cash motive theory. The effect is economically meaningful and persistent across multiple post-litigation years, suggesting that firms view climate litigation as a source of ongoing financial and legal uncertainty. Further, we conduct a battery of robustness checks to validate the consistency of our findings and address potential endogeneity concerns. These include alternative measures of cash holdings, placebo test, alternative sampling, controlling for non-climate litigations, lag-model specifications, and System GMM analysis to control for endogeneity concerns.

4.4.1 Pairwise correlation and multicollinearity test

Table 4.3 presents the Pearson correlation coefficients among the independent variables, allowing us to assess potential multicollinearity concerns. The consistently low

coefficients suggest that multicollinearity is unlikely to significantly affect our regression analyses. According to guidelines established by Gujarati (2004) and the literature, correlation coefficients exceeding 0.8 may indicate serious multicollinearity issues. In our dataset, all pairwise correlations are below this threshold, alleviating multicollinearity concerns (Grewal et al., 2004; Malik & Kashiramka, 2025).

To further verify the multicollinearity concerns, we also compute the variance inflation factors (VIFs) for each explanatory variable in our model. VIFs quantify the degree to which the variance of an estimated regression coefficient is increased due to multicollinearity. A VIF value above 10 is typically considered indicative of severe multicollinearity (Gujarati, 2004). In our analysis, the VIFs range from 1.14 to 7.58, well within acceptable limits. Table 4.4 reports the VIF values for the independent variables included in the baseline regression model.

Overall, both the low Pearson correlation coefficients and the acceptable VIF values confirm that multicollinearity does not pose a significant problem in our model. This enhances the robustness and reliability of our empirical findings.

Table 4.3 Pairwise correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Cash	1.000														
(2) Litigation	-0.048**	1.000													
(3) Size	-0.418***	0.207***	1.000												
(4) MB ratio	0.289***	-0.055***	-0.102***	1.000											
(5) Tangibility	-0.489***	0.081***	0.336***	-0.296***	1.000										
(6) Dividend	-0.319***	0.029	0.373***	-0.146***	0.212***	1.000									
(7) R&D	0.216***	-0.008	-0.145***	0.379***	-0.168***	-0.170***	1.000								
(8) Leverage	-0.341***	0.046**	0.213***	-0.019	0.214***	-0.029	-0.015	1.000							
(9) Acquisition	-0.064***	-0.042**	-0.046**	0.027	-0.133***	0.027	0.001	0.096***	1.000						
(10) Loss	0.258***	-0.001	-0.266***	0.027	-0.079***	-0.384***	0.132***	0.066***	-0.060***	1.000					
(11) Debt issuance	-0.057***	-0.012	0.009	0.071***	0.015	0.024	0.086***	0.252***	0.473***	-0.027	1.000				
(12) Equity issuance	0.050**	-0.018	-0.182***	0.019	0.054***	-0.127***	0.092***	0.032*	0.152***	0.182***	0.087***	1.000			
(13) Industry cash flow	0.321***	-0.063***	-0.256***	0.255***	-0.302***	-0.171***	0.198***	-0.216***	0.070***	0.187***	0.011	-0.013	1.000		
(14) Working capital	-0.024	-0.039**	-0.070***	-0.078***	-0.242***	0.067***	-0.129***	-0.417***	0.077***	-0.175***	-0.011	-0.031	0.085***	1.000	
(15) Cash flow	-0.001	-0.039*	0.117***	-0.017	0.012	0.074***	-0.272***	-0.288***	0.021	-0.299***	-0.121***	-0.208***	0.041**	0.224***	1.000

The table presents the Pearson correlation coefficients for the primary variables. Significance levels are indicated by *, **, and *** for the 10 percent, 5 percent, and 1 percent thresholds, respectively.

Table 4.4 Variance inflation factor (VIF)

Variables	VIF	1/VIF
Litigation	1.22	0.816742
Size	2.38	0.411388
MB Ratio	3.61	0.278957
Tangibility	6.50	0.154035
Dividend	5.20	0.207703
R&D	1.51	0.662572
Leverage	4.67	0.231631
Acquisition	1.70	0.822417
Loss	1.49	0.669458
Debt issuance	1.60	0.626208
Equity issuance	1.14	0.874865
Industry cash flow	7.58	0.132009
Working Capital	1.30	0.769698
Cash flow	1.63	0.613293
Mean VIF	2.98	

The table presents the VIF values for the independent variables included in the baseline regression model. VIF quantifies the severity of multicollinearity in the model.

4.4.2 Summary statistics

In Table 4.5, we report the descriptive statistics for the dependent and control variables used in the empirical analyses. On average, firms in our sample hold approximately 7.8 percent of their total assets in cash (mean value = 0.078), with a standard deviation of 11.5 percent, suggesting significant variation in cash holdings across the firms in our sample set. In our sample, the median is 3.2 percent, and the interquartile range (0.7%-10.4%) reflects the skewed nature of the cash holding, with a few firms holding large cash holdings. An alternative measure of cash holding (Cash1), shows a slightly lower mean of 5.9 percent, and median 2.8 percent. We also compute net cash holdings, defined as cash and short-term investment minus short-term debt, scaled by total assets (Opler et al., 1999). This captures net cash available after accounting for immediate short-term liabilities. The mean net cash ratio is 4 percent, but the minimum value is -30.3 percent, indicating some firms are more reliant on short-term debt than cash assets. This indicate that some firms may be financially constrained or adopting more aggressive capital structures. Notably, all our definitions of cash holdings are scaled by total assets. To address concerns regarding the scaling of the cash holding variable, we will re-run the results by introducing a new definition i.e., total cash and short-term investments divided by net assets. Here, we define net assets as total assets minus cash (Bates et al., 2009). The alternative measure of cash holding (Cash2), shows a mean of 96 percent, and median of 33 percent.

The main independent variable, *litigation*, captures whether a firm was involved

in a climate-related lawsuit in a given year, including the three years following the litigation to reflect the typical duration of legal proceedings and uncertainty. Approximately 13.4 percent of the sample years are associated with climate litigation, indicating a growing presence of climate litigation risk in the firm.

For our control variables, the average firm size is 1.67, and a median of 2.08. The minimum value of -7.086 suggests the presence of small firms in the sample. The market-to-book ratio, a proxy for growth opportunities, has a mean of 1.59 and the maximum value of 18.08 suggests some high-growth firms in our sample. In our sample, firms hold a substantial portion of their assets in physical capital, with tangibility averaging 52.1 percent. The dividend dummy shows that 78 percent of firms pay dividends, indicating a mature and financially stable sample overall.

In contrast, R&D expenditure is low across the sample (mean = 0.011, median = 0), indicating the presence of many non-innovative or mature firms. The financial leverage averages 31.1 percent, suggesting some firms are highly leveraged. Acquisition expenditures are relatively small (i.e., 1.7 percent). The loss dummy indicates that 10.5 percent of firms report losses for two consecutive years, signalling a presence of financial distress firms within the sample. We also control for external financing activities, separating net debt issuance and net equity issuance. Both variables exhibit negative values in the lower tail, reflecting net repayments or share buybacks. On average, firms issue debt equivalent to 1.7 percent of assets and equity equivalent to 0.4 percent of assets. The industry average cash flow volatility calculated using a rolling 10-year standard deviation of cash flows over assets for each 2-digit SIC industry, averages 15.1%, reflecting heterogeneity in earnings stability across industry. This variable captures the long-term risk environment in which firms operate and varies modestly across industries.

Net working capital has a mean close to zero (0.006) and a standard deviation of 0.188. The extreme minimum (-4.15) suggests a few firms with negative working capital. Lastly, cash flow, defined as earnings after interest, taxes, and dividends but before depreciation, scaled by total assets, has a mean of 6% and a wide range, with a minimum of -192%, indicating substantial variation in firms' internal cash generation capacity.¹⁶²

¹⁶² Negative values for the cash flow-to-assets ratio are particularly plausible in the context of the fossil fuel sector. In recent years, tightening global and domestic regulatory regimes around emissions, climate disclosures, and decarbonization targets have introduced policy uncertainty and stranded asset risk, especially for US based oil and gas majors. In response, many firms in the fossil fuel industry have adopted a strategy of accelerated extraction and capital-intensive investment in short- to medium-term projects before regulatory windows close or taxation rises. This strategy, often referred to as carbon-intensive frontloading can lead to short-term negative cash flows due to high capital expenditure (Merrill, 2018).

Next, we run the multivariate analysis to examine the relationship between climate litigation and firm cash holdings.

Table 4.5 Full sample summary statistics

	N	Mean	SD	p25	Median	p75	Min	Max
Cash	2046	0.078	0.115	0.007	0.032	0.104	0	0.725
Cash1	2046	0.059	0.082	0.006	0.028	0.081	0	0.646
Net cash	2046	0.04	0.135	-0.027	0.01	0.08	-0.303	0.658
Cash2	2046	0.96	0.169	0.007	0.33	0.116	0	1.298
Litigation	2046	0.134	0.341	0	0	0	0	1
Size	2046	1.672	2.035	0.571	2.08	3.352	-7.086	4.021
MB ratio	2046	1.591	1.068	1.122	1.285	1.627	0.513	18.084
Tangibility	2046	0.521	0.237	0.338	0.571	0.716	0.008	0.922
Dividend	2046	0.78	0.414	1	1	1	0	1
R&D	2046	0.01	0.039	0	0	0	0	0.387
Leverage	2046	0.316	0.194	0.203	0.312	0.408	0	3.073
Acquisition	2046	0.017	0.052	0	0	0.004	-0.01	0.354
Loss	2046	0.105	0.306	0	0	0	0	1
Debt issuance	2046	0.017	0.060	-0.011	0.001	0.034	-0.102	0.263
Equity issuance	2046	0.004	0.051	-0.007	0	0.005	-0.069	0.59
Industry cash flow	2046	0.151	0.054	0.107	0.136	0.193	0.069	0.351
Working capital	2046	0.006	0.185	-0.046	-0.011	0.065	-4.15	0.508
Cash flow	2046	0.06	0.110	0.035	0.056	0.095	-1.923	0.309

The table provides summary statistics for a sample of 2,046 firm-year observations from 152 unique firms spanning the years 2004 to 2023. We winsorise all continuous variables at the 1 and 99 percent levels to remove any effect of outliers on the results.

4.4.3 Baseline result

Table 4.6 presents the baseline regression estimates examining the relationship between climate litigation and corporate cash holdings across alternative fixed effect models. We progressively include the fixed effect in our models to enhance the reliability of the findings. Our approach aligns with econometric best practices for obtaining reliable results in observational studies, especially when examining complex relationships affected by external factors (Angrist & Pischke, 2009). First, in Column 1, we regress the model without controlling for unobserved heterogeneity. According to Wooldridge (2000) the regression without controlling for unobserved heterogeneity is a useful preliminary step for understanding the model's structure and prepares the analysis for more complex models. Moreover, it serves as a starting comparison point to highlight the changes in coefficients and statistical significance once controls for heterogeneity are introduced. The coefficient on *litigation* is positive (0.0125) but not statistically significant because the model does not account for unobserved heterogeneity across firms, industries, or time. In Column (2), we add year fixed effects to control for macroeconomic shocks and time-varying factors common to all firms. The coefficient on *litigation* is positive (0.0110) but not statistically significant as it still does not control for firm or industry specific heterogeneity.

Column (3) introduces industry fixed effects (based on 2-digit SIC codes) to account for sector-specific differences in cash holdings, such as capital expenditure, regulation, or different business models (Dittmar & Mahrt-Smith, 2007). Like Columns 1 and 2, we find a positive coefficient (0.0184); however, we start to observe a statistically significant result. This is because the model controls for industry-specific characteristics that can affect cash holdings. Column (4) further strengthens this result by introducing firm and year fixed effects, isolating within-firm variation over time, and we find a statistically significant positive coefficient of the litigation dummy (0.0096). Although firm fixed effects are commonly used in panel data models, we rely on a matched sample to pair climate-litigated firms with observationally similar non-climate litigated firms. The inclusion of firm fixed effects causes these observations to be absorbed in the fixed effect and thus dropped from the estimation of the litigation coefficient. Also, inclusion of firm fixed effect can substantially reduce statistical power and may result in biased estimate because identification becomes weaker (Wooldridge, 2000). Climate litigation is not plausibly strictly exogenous at the firm level. In other words, it is likely that firms differ systematically in their litigation risk exposure due to industry and time-specific factors rather than purely idiosyncratic firm-level characteristics (Sato et al., 2024; Dulak & Gnabo, 2024). Also, Javadi et al., (2023) find that firms in high-carbon industries exhibit distinct cash policies under climate exposure validating the use of industry fixed effect in the regression model. Therefore, we do not rely on firm fixed effects and use Industry fixed effects model.

Across all the models, the coefficient on *litigation* dummy is positive, indicating that firms facing climate litigation tend to hold more cash reserves. Given the drawback of models 1-4, we interpret Column (5) as our baseline model. Column (5), our preferred baseline model, includes year and industry fixed effects, allowing us to compare firms within the same industry and year while preserving firm-level variation in climate litigation exposure. Our model choice is also consistent with previous studies (Boone et al., 2023; Nguyen et al., 2018, Dittmar & Mahrt-Smith, 2007). This combination controls for both industry and time-specific factors simultaneously and removing the potential biases from both temporal and industry-based unobserved characteristics.

In Column (5), the coefficient on *litigation* is 0.0179 and statistically significant at the 5% significance level, indicating that climate-related lawsuits are associated with an increase of approximately 1.79 percentage points in cash holding among litigated firms when compared to non-litigated firms. This effect is economically meaningful, indicating

a roughly 23% increase in cash holdings.¹⁶³ This behaviour aligns with the precautionary motive for cash holdings, where companies respond to the threat of litigation by accumulating cash to cushion against potential financial liabilities, legal costs and increase in cost of external finance (Graham & Leary, 2018; Harford et al., 2008; Nguyen et al., 2018; Arena & Julio, 2015). The results strongly support our hypothesis that firms involved in climate litigation respond by increasing their cash holdings.

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All the control variables exhibit expected directional relationships with the Cash holdings and is consistent with those documented in the literature (Arena & Julio, 2015). For example, tangibility, financial leverage, and acquisition expenditure are all negatively and significantly associated with cash holdings, consistent with prior studies suggesting that firms with tangible assets or easier access to external capital require lower cash holdings (Opler et al., 1999; Bates et al., 2009). Debt and equity issuance are positively associated with cash holdings, indicating that firms tend to raise capital in anticipation of future cash needs, consistent with the pecking order theory. (Myers & Majluf, 1984). MB ratio is positive and significant suggesting that growth firms, which may face higher financing need accumulate more cash (Pinkowitz et al., 2006). Leverage and Acquisition expenditures are both significantly negative, indicating that high-debt firms or M&A activity tends to deplete cash reserves. All coefficients reported in our regression model are with robust standard errors clustered at the firm level.¹⁶⁴ Hereon, all our model includes year-fixed effects to control for unobservable time-variant effects and two-digit industry fixed effects to account for time-invariant industry factors.

Table 4.6 Baseline: Different fixed effect model

	(1)	(2)	(3)	(4)	(5)
	Cash	Cash	Cash	Cash	Cash
Litigation	0.0125 (0.1082)	0.0110 (0.1462)	0.0184** (0.0205)	0.0096** (0.0414)	0.0179** (0.0188)
Size	-0.0038 (0.5237)	-0.0042 (0.4925)	-0.0040 (0.4971)	-0.0094 (0.3742)	-0.0045 (0.4705)
MB ratio	0.0154** (0.0122)	0.0153** (0.0138)	0.0114** (0.0168)	0.0134*** (0.0017)	0.0117** (0.0144)

¹⁶³ Mean cash holdings is equal to 0.078 and coefficient on Litigation Dummy is 0.0179. So, $0.0179/0.078 = 0.22.94$, which is approximately 23 percent.

¹⁶⁴ In Online Appendix Table A3, we report robustness results using alternative clustering approaches. Specifically, standard errors are clustered at the two-digit SIC industry level and double-clustered at the firm and year levels.

Tangibility	-0.1604*** (0.0000)	-0.1613*** (0.0000)	-0.2065*** (0.0001)	-0.2405*** (0.0000)	-0.2097*** (0.0001)
Dividend	-0.0293* (0.0964)	-0.0289 (0.1032)	-0.0232 (0.1795)	-0.0099 (0.2426)	-0.0231 (0.1844)
R&D	0.4460* (0.0600)	0.4349* (0.0695)	-0.0064 (0.9859)	0.7486 (0.1416)	0.0025 (0.9944)
Leverage	-0.1746*** (0.0001)	-0.1808*** (0.0001)	-0.1487*** (0.0005)	-0.1197*** (0.0053)	-0.1542*** (0.0008)
Acquisition	-0.3079*** (0.0000)	-0.3055*** (0.0000)	-0.2962*** (0.0000)	-0.2064*** (0.0000)	-0.2916*** (0.0000)
Loss	0.0271** (0.0478)	0.0261* (0.0644)	0.0255** (0.0223)	0.0048 (0.6918)	0.0248** (0.0347)
Debt issuance	0.1724*** (0.0036)	0.1736*** (0.0048)	0.1837*** (0.0011)	0.1304*** (0.0018)	0.1817*** (0.0017)
Equity issuance	0.0629 (0.2635)	0.0704 (0.2040)	0.1242** (0.0463)	0.0774* (0.0920)	0.1294** (0.0318)
Industry cash flow	0.1206 (0.3120)	0.1122 (0.3442)	0.0919 (0.5604)	0.0238 (0.8512)	0.0657 (0.6694)
Working capital	-0.0769 (0.1271)	-0.0800 (0.1251)	-0.0823* (0.0585)	-0.0850** (0.0444)	-0.0841* (0.0631)
Cash flow	0.0406 (0.3966)	0.0445 (0.3544)	-0.0019 (0.9603)	-0.0020 (0.9199)	0.0022 (0.9527)
Adjusted R squared	0.47	0.47	0.55	0.80	0.55
Firm fixed effect	No	No	No	Yes	No
Year fixed effect	No	Yes	No	Yes	Yes
Industry fixed effect	No	No	Yes	No	Yes
N	2,046.00	2,046.00	2,046.00	2,045.00	2,046.00

This table presents the baseline regression results examining the relationship between climate litigation and firm cash holdings. Each column represents a different model specification: Column (1) includes no fixed effects, Column (2) includes year fixed effects, Column (3) includes industry fixed effects, and Columns (4) include both firm and year fixed effects. However, Column (5) we include the year and industry fixed effects. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.4.4 Persistence effect of climate litigation

One legitimate concern with the precautionary cash hypothesis is the opportunity cost of capital associated with holding large reserves, especially for lawsuits with long or uncertain durations. While holding cash can buffer firms against financing frictions or adverse legal outcomes, idle cash over an extended horizon can be costly (Kling, 2018). To investigate this, we estimate a dynamic model that tracks cash holdings from the year of litigation filing through six subsequent years. The following model estimates the

persistence effect of climate litigations:

$$Cash_{i,t} = \beta_0 + \beta_1 CL_{i,t+K} + \delta Controls_{i,t} + Industry\ fixed\ effect_j + Year\ fixed\ effect_t + \epsilon_{i,t} \text{-----}(4.3)$$

Where, $Cash_{i,t}$ is cash holdings of firm i at time t , $CL_{i,t+K}$ is dummy variable equal to 1 if firm i is involved in a climate litigation case in year $t+k$, where k ranges from 0 to +6 in different specifications to capture both immediate and lagged effects. $Controls_{i,t}$ is a vector of control variables.

We estimate models that include CL_{t0} which equals 1 in the year of the lawsuit filing and 0 otherwise; CL_{t+1} , which equals 1 in the first year following the filing; CL_{t+2} for the second year after filing; and so on, up to CL_{t+6} for the sixth post-filing year. This temporal decomposition allows us to examine how the effect of climate litigation on corporate cash holdings evolves over time, informing whether the impact is concentrated around the event year or persists in the medium to long run. This method provides a more granular understanding of the timing and duration of climate litigation effects and helps rule out the possibility that our main results are driven solely by short-term cash-holding adjustment. In Table 4.7 we report the finding of this result. A key finding is that climate litigation has a positive and statistically significant association with cash holdings, across all model specifications.

Across all seven models, the coefficient on the litigation variable remains positive, statistically significant, and economically meaningful, indicating that the effect of litigation on corporate cash holdings is persistent and not confined to the year of filing. The estimated coefficients range from 0.0148 to 0.0193, with the largest effects observed in years 4 (i.e., CL_{t+4}) in column 5. Column 1 capture the year of litigation; we find that firms begin increasing cash holdings immediately in the year the climate lawsuit is filed. This is consistent with the precautionary motive, where firms anticipate legal fees, reputational costs, and future liabilities (Opler et al., 1999; Harford et al., 2008). However, since litigation outcomes are uncertain and the full scope of costs has not yet materialized, the magnitude of the cash increase is modest. Column 2 indicate that the cash holdings increase further in the year following the lawsuit. This aligns with the idea that firms may still be evaluating ongoing litigation risk and potential penalties. Gormley & Matsa (2014) suggest that legal uncertainty tends to have lagged effects on firm's financial policy, especially when outcomes are unknown. We observe that cash levels remain elevated and continue to rise even 2 years following the lawsuit (Column 3). This persistence indicates that firms do not treat climate litigation as a one-off cost, but as a

strategic risk management issue, possibly preparing for longer trials.

By the third year, cash accumulation peaks with coefficient 0.0179 in column 4. This could primarily be attributed to the typical duration for a climate litigation to resolve, which is approximately 3 years. The firm may now have more clarity about settlement risk or reputational outcomes and is still maintaining buffers. Surprisingly, the coefficient on CL_{t+4} in column 5 is 0.0193, indicating that, four years after the litigation filing, firms hold approximately 1.93 times more cash as a share of total assets compared to non-litigated firms. In term of economic magnitude this reflects an increase of about 25% in cash holdings. This suggests firms may not disburse litigation-related payouts immediately, or may be dealing with multiple lawsuits, appeals, or longer reputational effects (Sato et al., 2024).

Interestingly, we begin to observe a slight decline in the magnitude of the effect in years 5 and large decline in year 6. Specifically, the coefficient on CL_{t+5} in column 6 remains statistically significant (0.0193, $p < 0.01$), but CL_{t+6} in column 7 shows a reduced magnitude (0.0169, $p < 0.05$), indicating a possible normalization of cash holdings 4 year after the climate litigations. This tapering effect is consistent with the settlement or reduced uncertainty typically associated with the later stages of litigation. As climate-related lawsuits progress through the legal system, firms gain greater clarity about potential outcomes, whether through settlement, dismissal, or court judgment. Once the financial exposure becomes more certain or legally finalized, the need for precautionary cash holding diminishes. This pattern aligns with the theoretical framework of the precautionary motive for cash holdings (Almeida et al., 2004), which posits that firms accumulate cash under conditions of heightened uncertainty or expected future costs. As the litigation risk resolves, the precautionary demand for cash wanes.

Moreover, our findings presented in Table 4.7 aligns with Arena & Julio (2015), who document that firms adjust their liquidity in anticipation of and during litigation but tend to revert toward pre-litigation norms as uncertainty abates. Our results support this dynamic: firms accumulate excess liquidity in the immediate and medium-term aftermath of litigation filing, but by years 5 and 6, we observe a moderate reduction in cash holdings, indicating a potential reversion to borrowing or redeployment of idle cash once the perceived legal threat subsides.

Overall, these findings offer strong evidence that the impact of climate litigation on cash holdings is both statistically significant and persistent, with firms responding not only contemporaneously but over multiple subsequent years. This finding further informs

us that climate litigation imposes a long-term risk on corporate cash holding policy.

Table 4.7 Persistence effect of climate litigation

	(1) Cash	(2) Cash	(3) Cash	(4) Cash	(5) Cash	(6) Cash	(7) Cash
CL _{t0}	0.0148* (0.0722)						
CL _{t+1}		0.0160** (0.0428)					
CL _{t+2}			0.0163** (0.0438)				
CL _{t+3}				0.0179** (0.0188)			
CL _{t+4}					0.0193** * (0.0086)		
CL _{t+5}						0.0192** * (0.0065)	
CL _{t+6}							0.0169** (0.0114)
Size	-0.0040 (0.5137)	-0.0042 (0.4964)	-0.0043 (0.4863)	-0.0045 (0.4705)	-0.0046 (0.4524)	-0.0047 (0.4425)	-0.0047 (0.4467)
MB Ratio	0.0115** (0.0165)	0.0116** (0.0158)	0.0116** (0.0153)	0.0117** (0.0144)	0.0117** (0.0136)	0.0114** (0.0153)	0.0115** (0.0151)
Tangibility	- 0.2087** * (0.0001)	- 0.2091** * (0.0001)	- 0.2097** * (0.0001)	- 0.2097** * (0.0001)	- 0.2093** * (0.0001)	- 0.2089** * (0.0001)	- 0.2085** * (0.0001)
Dividend	-0.0237 (0.1733)	-0.0236 (0.1761)	-0.0233 (0.1823)	-0.0231 (0.1844)	-0.0229 (0.1877)	-0.0232 (0.1800)	-0.0232 (0.1806)
R&D	0.0067 (0.9855)	0.0030 (0.9935)	0.0010 (0.9978)	0.0025 (0.9944)	0.0025 (0.9945)	0.0062 (0.9865)	0.0103 (0.9773)
Leverage	- 0.1543** * (0.0009)	- 0.1541** * (0.0009)	- 0.1543** * (0.0008)	- 0.1542** * (0.0008)	- 0.1537** * (0.0008)	- 0.1531** * (0.0008)	- 0.1530** * (0.0008)
Acquisition	- 0.2957** * (0.0000)	- 0.2949** * (0.0000)	- 0.2930** * (0.0000)	- 0.2916** * (0.0000)	- 0.2901** * (0.0000)	- 0.2903** * (0.0000)	- 0.2893** * (0.0000)
Loss	0.0251**	0.0248**	0.0250**	0.0248**	0.0248**	0.0243**	0.0245**

	(0.0353)	(0.0361)	(0.0348)	(0.0347)	(0.0340)	(0.0368)	(0.0366)
Debt issuance	0.1831** *	0.1816** *	0.1822** *	0.1817** *	0.1829** *	0.1852** *	0.1838** *
	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0016)	(0.0017)
Equity issuance	0.1327**	0.1330**	0.1312**	0.1294**	0.1286**	0.1259**	0.1249**
	(0.0280)	(0.0274)	(0.0301)	(0.0318)	(0.0324)	(0.0384)	(0.0420)
Industry cash flow	0.0547	0.0611	0.0644	0.0657	0.0640	0.0585	0.0584
	(0.7173)	(0.6881)	(0.6751)	(0.6694)	(0.6766)	(0.7006)	(0.7008)
Working capital	-0.0848*	-0.0844*	-0.0843*	-0.0841*	-0.0836*	-0.0835*	-0.0837*
	(0.0617)	(0.0625)	(0.0625)	(0.0631)	(0.0638)	(0.0640)	(0.0641)
Cash flow	0.0017	0.0017	0.0020	0.0022	0.0027	0.0023	0.0023
	(0.9643)	(0.9634)	(0.9587)	(0.9527)	(0.9437)	(0.9504)	(0.9514)
Adjusted R squared	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2,046.00	2,046.00	2,046.00	2,046.00	2,046.00	2,046.00	2,046.00

This table presents the regression results examining the dynamic relationship between climate litigation and corporate cash holdings. Each column presents a separate regression specification including the respective litigation timing dummy. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.4.5 Forward cash holdings and climate litigation

To further investigate whether the impact of climate litigation on corporate cash holdings is temporary or long-lasting, we conduct an additional forward-looking analysis. While the baseline regressions show that climate litigation is linked to higher cash holdings (see Table 4.6, column 5), they do not indicate how long this effect persists. From a corporate finance perspective, it is crucial to differentiate between short-term and long-term responses, as firms typically adjust their cash holdings dynamically rather than instantaneously (Brown et al., 2021; Décamps, et al., 2015). As noted above, climate litigation induces precautionary behaviour, its effect should be observable in future cash holdings rather than only in the current period. Accordingly, we estimate forward specifications in which future cash holdings (t+1 through t+6) are regressed on climate litigation exposure.

The Table 4.8 results indicate that climate litigation has a statistically significant and economically meaningful effect on firms' cash holdings in the short to medium term. Specifically, the coefficient on the litigation is positive and significant

contemporaneously ($\beta = 0.018$) and remains significant for the next three years. For example, the coefficient for $t+2$ is approximately 0.017 and statistically significant at 5%, implying that firms involved in climate litigation hold roughly 1.7 percentage points more cash after the climate litigation. Moreover, the persistence of significance through Cash_{t+3} indicates that the effect is not merely a short-run accounting adjustment but reflects a sustained cash holding response.

Importantly, beyond the Cash_{t+3} , the litigation coefficient declines in magnitude and becomes statistically insignificant. For example, Cash_{t+4} and later, the estimates are insignificantly different from zero. This pattern suggests that the effect of climate litigation on cash holdings is temporary rather than permanent. Firms appear to increase cash buffers following litigation exposure but gradually revert toward normal cash holdings. One reason for this is that when a company holds onto cash for an extended time it creates an agency problem (Nikolov & Whited, 2014). Shareholders would benefit more if the company used that money to distribute extra dividends or buy back shares (Opler et al., 1999). Such behaviour is also consistent with precautionary cash holding theory, which predicts that firms accumulate cash when facing heightened uncertainty or potential financing frictions and draw down these reserves once conditions stabilize.

Overall, the forward-looking cash holding analysis reveals that climate litigation generates a medium-term increase in cash holdings that persists for several years but does not permanently alter firms' cash holding structures. This finding reveals the interpretation that climate litigation operates as a temporary risk shock that induces firms to adopt more conservative financial policies until uncertainty surrounding legal exposure diminishes.

Table 4.8 Forward cash holdings and climate litigation

	(1) Cash _{t+0}	(2) Cash _{t+1}	(3) Cash _{t+2}	(4) Cash _{t+3}	(5) Cash _{t+4}	(6) Cash _{t+5}	(7) Cash _{t+6}
Litigation	0.0179** (0.0188)	0.0146* (0.00763)	0.0168** (0.00841)	0.0146* (0.00846)	0.0130 (0.00912)	0.00783 (0.00900)	0.0116 (0.00996)
Size	-0.0045 (0.4705)	-0.00484 (0.00632)	-0.00442 (0.00674)	-0.00472 (0.00701)	-0.00593 (0.00702)	-0.00529 (0.00716)	-0.00575 (0.00734)
MB ratio	0.0117** (0.0144)	0.00630 (0.00532)	0.00519 (0.00489)	0.00140 (0.00515)	-0.00311 (0.00576)	-0.00397 (0.00586)	0.00131 (0.00684)
Tangibility	-0.2097*** (0.0001)	-0.183*** (0.0531)	-0.162*** (0.0538)	-0.138** (0.0547)	-0.123** (0.0541)	-0.123** (0.0552)	-0.120** (0.0557)
Dividend	-0.0231 (0.1844)	-0.0275 (0.0180)	-0.0289 (0.0191)	-0.0299 (0.0202)	-0.0336 (0.0206)	-0.0325 (0.0213)	-0.0246 (0.0211)
R&D	0.0025 (0.9944)	-0.0501 (0.360)	-0.102 (0.327)	-0.0367 (0.388)	-0.0341 (0.370)	0.130 (0.376)	0.338 (0.333)
Leverage	-0.1542*** (0.0008)	-0.134*** (0.0429)	-0.120*** (0.0438)	-0.107** (0.0435)	-0.101** (0.0428)	-0.0820* (0.0426)	-0.0567 (0.0467)
Acquisition	-0.2916*** (0.0000)	-0.181*** (0.0531)	-0.166*** (0.0502)	-0.0936 (0.0638)	-0.156*** (0.0585)	-0.160** (0.0686)	-0.155* (0.0790)
Loss	0.0248** (0.0347)	0.0285** (0.0117)	0.0316*** (0.0116)	0.0193 (0.0118)	0.0165 (0.0150)	0.0247 (0.0162)	0.0151 (0.0161)
Debt issuance	0.1817***	0.106**	0.0541	0.00625	0.0356	0.0358	0.0450

	(0.0017)	(0.0490)	(0.0539)	(0.0545)	(0.0555)	(0.0587)	(0.0622)
Equity issuance	0.1294** (0.0318)	-0.0299 (0.0552)	-0.00925 (0.0541)	0.0405 (0.0795)	0.00802 (0.0654)	0.0676 (0.0735)	0.0255 (0.0734)
Industry cash flow	0.0657 (0.6694)	0.0354 (0.152)	0.0575 (0.159)	-0.0000615 (0.176)	0.113 (0.199)	0.158 (0.249)	0.0944 (0.356)
Working capital	-0.0841* (0.0631)	-0.0504 (0.0454)	-0.0317 (0.0430)	-0.0177 (0.0420)	-0.0123 (0.0396)	-0.00610 (0.0408)	-0.00849 (0.0415)
Cash flow	0.0022 (0.9527)	-0.0134 (0.0387)	-0.0230 (0.0525)	-0.0227 (0.0483)	-0.0125 (0.0495)	0.0101 (0.0503)	0.0138 (0.0542)
Adjusted R squared	0.549	0.526	0.502	0.469	0.454	0.447	0.429
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2046	1925	1808	1690	1576	1458	1348

This table presents the regression results examining the relationship between climate litigation and forward corporate cash holdings. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.4.6 Litigation outcome

In Table 4.9 we investigate whether climate litigation outcomes have a statistically and economically significant effect on corporate cash holdings. The coefficient on litigation outcome is 0.0159, statistically significant at the 10% level. This indicates that firms that experience a substantive litigation outcome hold, on average, 1.59 percentage points in cash as a share of total assets compared to firms that either not litigated or had ongoing cases. This represents a 20.3% in cash holdings. Firms typically accumulate cash as a precautionary response to litigation uncertainty (Opler et al., 1999), but once an outcome is reached our investigation suggests that the cash holdings decline from its peak. This could be due to the threat of ongoing legal costs or adverse judgments dissipates, the need to maintain excess cash for contingencies diminishes. We also assert that firms may have used cash to settle penalties or meet compliance mandates,¹⁶⁵ while others normalise cash policies as litigation ambiguity fades. Thus, while the positive coefficient underscores that climate litigation continues to influence cash holding even after the litigation outcome, the tapering effect reflects a natural adjustment in financial behaviour as legal risk resolved. These findings are consistent with the precautionary savings theory (Opler et al., 1999) and the literature on cash policy responses to risk resolution where firms may deploy accumulated cash toward operational recovery, capital expenditures, or dividend distribution once litigation is settled (Harford et al., 2008).

Table 4.9 Litigation outcomes

	(1) Cash
Litigation outcome	0.0159* (0.0775)
Size	-0.0039 (0.5181)
MB ratio	0.0114** (0.0171)
Tangibility	-0.2082***

¹⁶⁵ For example, in 2015, Volkswagen agreed to pay over USD 14.7 billion in settlements related to the diesel emissions scandal in the U.S., which included vehicle buybacks, environmental remediation, and civil penalties. See- <https://www.ftc.gov/news-events/news/press-releases/2016/06/volkswagen-spend-147-billion-settle-allegations-cheating-emissions-tests-deceiving-customers-20>

In 2023, ExxonMobil was ordered to pay USD 14.25 million for violating federal air pollution laws at a Texas facility. See- <https://www.reuters.com/legal/litigation/exxon-cant-shake-1425-mln-penalty-air-pollution-texas-refinery-2024-12-11/>

	(0.0001)
Dividend	-0.0236 (0.1761)
R&D	0.0185 (0.9599)
Leverage	-0.1543*** (0.0009)
Acquisition	-0.2950*** (0.0000)
Loss	0.0249** (0.0368)
Debt issuance	0.1830*** (0.0017)
Equity issuance	0.1329** (0.0281)
Industry cash flow	0.0486 (0.7466)
Working capital	-0.0850* (0.0612)
Cash flow	0.0017 (0.9645)
Adjusted R squared	0.55
Year fixed effect	Yes
Industry fixed effect	Yes
N	2,046.00

This table reports the regression results examining the relationship between climate litigation outcomes and corporate cash holdings. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.5 Robustness

4.5.1 Alternative definition

To test the robustness of our baseline results, Table 4.10 employs the alternative measures of liquidity i.e., total cash to assets (Cash1) and net cash to assets (Net Cash) following Dittmar & Mahrt-Smith, (2007) and Opler et al. (1999), respectively.¹⁶⁶ These alternative specifications allow us to test whether the positive association between climate litigation and cash holdings is robust to how cash is measured. Across both

¹⁶⁶ Following Harford et al. (2008), we also calculate the cash holding by scaling it with total sales. Not to our surprise, the result remains statistically significant at 5% with a coefficient of 0.0562.

specifications, we find a positive and statistically significant relationship between climate litigation and corporate cash holdings. These results indicate that firms involved in climate litigation tend to accumulate cash, both in terms of gross cash (Column 1) with coefficient of litigation dummy being 0.0114 at a 5 percent significance. Column 2 report the result of net cash after accounting for short-term debt obligations suggest an increases in litigation dummy coefficient of 0.0188 at a 5 percent significance level. Especially, Column 2 result is particularly noteworthy, as it suggests holding more net cash implies that firms not only accumulate cash but also refrain from increasing short-term debt, reinforcing the evidence that climate litigation leads to conservative financial behaviour. This aligns with real option which suggests that under conditions of heightened uncertainty, firms place greater value on financial flexibility to delay or adjust major decisions (Gamba & Triantis, 2008). By avoiding short-term debt borrowing, firms enhance their option to wait, preserving the capacity to respond to evolving legal risks. Additionally, since litigation exposure may increase perceived firm risk and thus raise the cost of external capital (Jens & Page, 2024; Li, 2019).

While the measure presented in column 1 is commonly used in cash holding literature. However, it can be inflated for high-cash firms, especially when cash represents a significant portion of total assets. This inflation may bias the coefficient estimates. To address this issue and ensure robustness, we follow the alternative definition proposed by Bates et al. (2009) and construct an additional measure. In column 3, we define cash as the ratio of cash to net assets, resulting in a coefficient magnitude of 0.0251, which is significant at the 5 percent level. Overall, these results confirm that the impact of climate litigation on firm cash is not sensitive to the cash definition used, thereby reinforcing the robustness of our main findings.

Table 4.10 Alternative definition

	(1) Cash1	(2) Net Cash	(3) Cash2
Litigation	0.0114** (0.0390)	0.0188** (0.0448)	0.0251** (0.0170)
Size	-0.0018 (0.3697)	0.0021 (0.7569)	-0.0067 (0.3918)
MB ratio	0.0121*** (0.0000)	0.0165*** (0.0005)	0.0198*** (0.0055)
Tangibility	-0.1342***	-0.1916***	-0.2901***

	(0.0000)	(0.0017)	(0.0001)
Dividend	-0.0257** (0.0172)	-0.0263 (0.1700)	-0.0466* (0.0611)
R&D	0.3105 (0.3853)	0.1357 (0.7395)	-0.0034 (0.9963)
Leverage	-0.0801*** (0.0015)	-0.2225*** (0.0007)	-0.2273*** (0.0006)
Acquisition	-0.1993*** (0.0000)	-0.3121*** (0.0000)	-0.4108*** (0.0000)
Loss	0.0214** (0.0236)	0.0174 (0.3470)	0.0358* (0.0512)
Debt issuance	0.1209*** (0.0007)	0.2580*** (0.0017)	0.2790*** (0.0014)
Equity issuance	0.1850*** (0.0001)	0.1965*** (0.0071)	0.2634** (0.0153)
Industry cash flow	-0.2620** (0.0472)	0.1749 (0.3659)	0.0186 (0.9343)
Working capital	-0.0473* (0.0609)	0.0132 (0.7550)	-0.1197* (0.0749)
Cash flow	0.0243 (0.2064)	0.0253 (0.5875)	0.0063 (0.9035)
Adjusted R squared	0.51	0.51	0.51
Year fixed effect	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes
N	2,046.00	2,046.00	2,046.00

This table presents robustness checks using alternative definitions of the dependent variable. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.5.2 Placebo test

Table 4.11 presents a placebo test to assess whether the positive association between climate litigation and corporate cash holdings documented in previous tables is driven by spurious correlation or unobserved heterogeneity. Although we control for time-varying effects in our analysis, concerns remain about potential nonlinear temporal trends that could affect our results. A study by Bates et al. (2009) indicates that cash holdings in the US firms have experienced a significant upward trend over time, with average cash holdings increasing by 129 percent from 1980 to 2004.

The underlying reasoning is that if the observed relationship is indeed causal, then a randomly assigned litigation indicator should not predict cash holdings. To test this, we

re-estimate the baseline regressions by assigning random false litigation years across the full sample of firms. In this placebo setting, we generate a dummy variable that takes the value 1 for randomly selected firm-year observations. This procedure allows for the inclusion of both litigated and non-litigated firms in the placebo sample. By assigning random false firm-year litigation, we simulate a scenario where litigation is present only in appearance, allowing us to evaluate whether our main results are driven by anticipation effects or other time-varying confounders.

The results of the placebo model reported in Column 1 of Table 4.11; help confirm the validity of the observed relationship. The coefficient on the Litigation Placebo is 0.0023, with a p-value of 0.5223, indicating no statistically significant relationship between the placebo variable and cash holdings. This result enhances the credibility of our identification strategy. It suggests that the observed effects of climate litigation on cash holdings are not artifacts of sample structure, time trends, or other confounding factors, but rather reflect a genuine increase in cash holdings due to the risk associated with climate litigation.

Table 4.1 Placebo test

	(1) Cash
Litigation Placebo	0.0023 (0.5223)
Size	-0.0038 (0.5300)
MB ratio	0.0115** (0.0161)
Tangibility	-0.2076*** (0.0001)
Dividend	-0.0237 (0.1760)
R&D	0.0149 (0.9678)
Leverage	-0.1551*** (0.0009)
Acquisition	-0.2942*** (0.0000)
Loss	0.0251** (0.0370)

Debt issuance	0.1822*** (0.0019)
Equity issuance	0.1311** (0.0313)
Industry cash flow	0.0369 (0.8040)
Working capital	-0.0856* (0.0592)
Cash flow	0.0012 (0.9756)
Adjusted R squared	0.55
Year fixed effect	Yes
Industry fixed effect	Yes
N	2,046.00

This table presents a placebo test to assess whether the observed relationship between climate litigation and cash holdings is driven by spurious correlations. The variable Litigation Dummy Placebo is randomly assigned to firm in our sample set. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.5.3 Alternative sampling

In Table 4.12, we conduct two important robustness checks to ensure that our baseline findings are not driven by specific sample characteristics. Researchers often exclude finance and utility companies because of its distinct regulatory environments, capital structures, and operational characteristics which differ significantly from non-regulated industries (Rauh, 2006; Almeida et al., 2004; Lemmon et al., 2008; Nguyen et al., 2018).¹⁶⁷ Given that the utilities' companies cash holdings are often regulated, which could distort the relationship between climate litigation and cash holdings. Therefore, we exclude the utility firms (*SIC 4900–4999*) and re-run our baseline model to examine if utility firms drive our observed relationship between climate litigation and firm cash holding. Table 4.12 column 1 reports regression results testing the robustness of our baseline findings by excluding utilities firms from the sample. After excluding utility firms, the estimated coefficient on the climate litigation dummy increases both in magnitude and statistical significance.

Specifically, the coefficient rises to 0.0271, indicating that firms facing climate litigation hold on average 2.7 percentage points more cash, relative to their total assets. This represents an approximate 35% increase in cash, highlighting the economic

¹⁶⁷ Our sample consists of firms classified under the following two-digit SIC codes: 12, 13, 15, 20, 28, 29, 30, 32, 33, 36, 37, 45, 49, 50, 51, 53, 55, 59, 73, and 99. None of these SIC-2 digit codes fall within the financial sector (SIC 60–69).

significance of the result.¹⁶⁸ The strengthened effect further reinforces the view that climate litigation prompts firms to adopt a precautionary savings strategy in anticipation of future legal, reputational, or financial shocks (Almeida et al., 2004; Arena & Julio, 2015). The coefficient on the litigation remains positive and statistically significant, confirming that our findings are not driven by the unique dynamics of the utility sector.

In addition, owing insights from the prior research which highlights that Delaware-incorporated firms tend to be larger, more risk-tolerant, and exhibit higher growth potential (Daines, 2001). Moreover, we suspect that the Delaware's unique legal and regulatory framework, may also influence corporate behaviour and financial decisions in ways that differ from firms incorporated in other states.¹⁶⁹ To address potential confounding effects of Delaware's effect, in column 2 we re-estimate our model, excluding Delaware-incorporated firms. The results remain virtually same with significantly positive at the 5 percent significance level, reinforcing our baseline findings and suggesting that these results are robust and not driven by any Delaware-specific biases.

Table 4.12 Alternative sampling & Delaware

	(1) Cash	(2) Cash holding (Delaware)
Litigation	0.0271** (0.0142)	0.0186** (0.0275)
Size	-0.0062 (0.4351)	-0.0052 (0.4129)
MB ratio	0.0119** (0.0220)	0.0138*** (0.0025)
Tangibility	-0.2328*** (0.0001)	-0.2098*** (0.0001)
Dividend	-0.0153 (0.4556)	-0.0223 (0.2084)

¹⁶⁸ 0.0271 divided by 0.078 = 0.3474.

¹⁶⁹ Delaware has a unique and distinct court system favouring businesses, which does not utilise juries and is managed by specialised judges called chancellors with expertise in corporate law. This system ensures swift resolutions and uniform decisions, backed by a comprehensive collection of legal precedents. Consequently, companies experience greater predictability and efficiency in addressing corporate conflicts in Delaware states. See <https://corplaw.delaware.gov/why-businesses-choose-delaware/> [Accessed on 6 November 2024]

R&D	-0.0483 (0.8982)	-0.0341 (0.9300)
Leverage	-0.1774*** (0.0006)	-0.1626*** (0.0006)
Acquisition	-0.3533*** (0.0000)	-0.1582*** (0.0001)
Loss	0.0265** (0.0470)	0.0233* (0.0577)
Debt issuance	0.2311*** (0.0008)	0.0362 (0.2427)
Equity issuance	0.1299** (0.0487)	0.0165 (0.7339)
Industry cash flow	0.0769 (0.7414)	0.0965 (0.5366)
Working capital	-0.0984* (0.0566)	-0.0809* (0.0616)
Cash flow	0.0024 (0.9514)	-0.0413 (0.3043)
Adjusted R squared	0.49	0.55
Year fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
N	1,323.00	1,879.00

This table reports robustness checks using alternative sample constructions. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.5.4 Control for non-climate litigations

To ensure the robustness and specificity of our findings, we conduct an additional test to examine whether the observed effect of climate litigation on cash holdings could be confounded by other types of litigation, such as securities class actions, labour lawsuit, product liability, medical liability lawsuits, Intellectual property lawsuits (Malm & Kanuri, 2017). If this is true, then the estimated effect of climate litigation on cash holdings could be confounded or overstated.

To address this major concern, we conduct a robustness test that explicitly controls for a firm's exposure to non-climate litigation during the sample period. This

allows us to isolate the unique effect of climate-related legal risk on firms' cash holding behaviour, ruling out the possibility that non-climate litigation exposure is driving the results.

We construct a measure of non-climate litigation by manually collecting data from Audit Analytics' Litigation Database.¹⁷⁰ Audit Analytics litigation database collects data from corporate disclosures, news releases, and legal documents filed with the US Securities and Exchange Commission (SEC). The reports include specifics about the litigation, such as the types of lawsuits, the date they were originally filed and settled, and the amount of any settlements. We review all the legal cases recorded between 2004 and 2023 based on firm names and tickers for all firms in our matched sample of climate-litigated and non-climate-litigated peers. This exercise leads us to a total of 1,230 non-climate lawsuits filed against the total number of firms involved in our sample (i.e., 152 unique firms). We then created a binary indicator (*Non-Climate Litigation Dummy*), which equals 1 in firm-years where the firm was involved in at least one non-climate litigation and 0 otherwise. The empirical model is specified as follows:

$$Cash_{i,t} = \beta_0 + \beta_1 litigation_{i,t} + \beta_2 Non - climate\ dummy_{i,t} + \delta Controls_{i,t} + Industry\ fixed\ effect_j + Year\ fixed\ effect_t + \epsilon_{i,t} \text{-----}(4.4)$$

Table 4.13 presents result from two regressions examining. First, firms in our sample with non-climate litigations. Second, firms in our sample with climate litigation while controlling for non-climate related litigation exposure. To test this conjecture, we examine whether non-climate litigation affects firms' cash holding behaviour and whether it confounds the effect of climate litigation. The results provide clear differentiation across these groups. In Column 1 we test whether non-climate litigation alone affects cash holdings. The coefficient is positive (0.0075) but statistically insignificant (p = 0.1634), suggest that firms facing litigation unrelated to climate issues do not hold significantly different cash levels than firms with no litigation exposure. In contrast, the climate-litigation variable (column 2) remains positive and statistically significant ($\beta = 0.0173$, p = 0.022) when both indicators are included simultaneously. This means that, conditional on identical firm characteristics and fixed effects, only climate-litigated firms exhibit a systematic increase in cash holdings. Importantly, our finding should not be interpreted as evidence that non-climate litigation has no effect on cash holding; rather, it suggests that any such effect is not precisely estimated in this

¹⁷⁰ See <https://www.idea-gen.com/solutions/audit-and-risk/external-audit/idea-gen-audit-analytics/database-modules/litigation>

setting.

One potential explanation lies in the heterogeneity of non-climate litigation, which includes lawsuits of varying severity, type, and timing that are unlikely to affect the firm's financing conditions. While Arena & Julio (2015) focus specifically on securities class actions litigations known to directly influence firm valuation, investor trust, and future financing constraints, whereas as our non-climate litigation measure aggregates a broad and diverse range of legal actions, including product liability, employment disputes, intellectual property cases, and others. These litigation types may vary in their severity, materiality, and implications for firm-level liquidity management. Hence, pooling them into a single binary variable likely dilutes the average treatment effect, especially if many cases are low-stakes or settled quickly without major financial strain. Additionally, most of the climate litigations are skewed towards more climate-sensitive industries (e.g., material, fossil-fuels, utilities) and other generic litigations may have a much broader spectrum of sectoral impacts.

Importantly, Table 4.13 robustness check does not invalidate prior findings; instead, it underscores that the effect of litigation on cash holdings is not uniform across all the litigation cases. While securities-related lawsuits may prompt cash hoarding (Arena & Julio, 2015), the absence of a significant effect in our pooled non-climate measure highlights the distinctive litigation risk perception by firms. To more fully understand the effect, a future research study should conduct a heterogeneity test distinguishing e.g., securities class actions, antitrust lawsuits, patent lawsuits is warranted. Such an analysis would allow us to more precisely identify whether specific forms of non-climate litigation influence cash holdings in a manner similar to climate litigation.

Overall, the consistent and statistically significant effect of climate litigation reinforces our main conclusion that the increase in cash holdings observed among climate-litigated firms is specifically attributable to climate-related litigation risk, not to other concurrent litigations.

Table 4.13 Control for non-climate litigations

	(1) Cash	(2) Cash
Non-climate dummy	0.0075 (0.1634)	0.0060 (0.2509)
Litigation		0.0173** (0.0222)

Size	-0.0043 (0.4915)	-0.0048 (0.4422)
MB ratio	0.0114** (0.0161)	0.0117** (0.0143)
Tangibility	-0.2069*** (0.0001)	- 0.2089*** (0.0001)
Dividend	-0.0232 (0.1857)	-0.0228 (0.1922)
R&D	0.0047 (0.9897)	-0.0049 (0.9893)
Leverage	-0.1540*** (0.0009)	- 0.1533*** (0.0008)
Acquisition	-0.2965*** (0.0000)	- 0.2927*** (0.0000)
Loss	0.0243** (0.0406)	0.0241** (0.0391)
Debt issuance	0.1861*** (0.0016)	0.1843*** (0.0017)
Equity issuance	0.1305** (0.0323)	0.1284** (0.0334)
Industry cash flow	0.0321 (0.8290)	0.0609 (0.6919)
Working capital	-0.0847* (0.0617)	-0.0835* (0.0643)
Cash flow	0.0017 (0.9638)	0.0024 (0.9491)
Adjusted R squared	0.55	0.55
Year fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
N	2,046.00	2,046.00

This table presents regression results controlling for the potential confounding effect of non-climate-related litigation. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.6 Endogeneity

4.6.1 Lag model

Previous research finds that cash-rich firms are more likely to be the targets of shareholder lawsuits, possibly because plaintiff can get better settlement terms from the companies (Jones, 1980; Romano, 1997). To mitigate the potential endogeneity concerns and the issue of simultaneity whereby cash holdings and climate litigation events might be jointly determined. Therefore, we estimate a lagged specification where all explanatory variables, including the climate litigation dummy, are measured at time $t-1$. The empirical model is specified as follows:

$$Cash_{i,t} = \beta_0 + \beta_1 litigation_{i,t-1} + \delta Controls_{i,t-1} + Industry\ fixed\ effect_j + Year\ fixed\ effect_t + \epsilon_{i,t} \text{ -----(4.5)}$$

This approach ensures that observed changes in firm cash holdings occur after litigation exposure, thereby strengthening causal interpretation. The lagged climate litigation dummy remains positive and statistically significant at the 10% level ($\beta = 0.0146$), indicating that firms exposed to climate litigation in the previous year hold approximately 1.5 percentage points more cash (*see table 4.14*). This finding is consistent with the theoretical argument that litigation increases uncertainty due to legal cost and financing frictions, leading firms to adopt more conservative cash policies (Arena & Julio, 2015). Especially, lagging the independent and control variables mitigates simultaneity bias and strengthens causal interpretation, suggesting that the increase in cash due to climate litigation, rather than a pre-litigation characteristic.

Table 4.14 Lag model

	(1) Cash
Litigation (t-1)	0.0146* (0.0584)
Size (t-1)	-0.0048 (0.4453)
MB ratio (t-1)	0.0063 (0.2383)
Tangibility (t-1)	-0.1833*** (0.0007)
Dividend (t-1)	-0.0275 (0.1294)

R&D (t-1)	-0.0501 (0.8894)
Leverage (t-1)	-0.1337*** (0.0022)
Acquisition (t-1)	-0.1812*** (0.0008)
Loss (t-1)	0.0285** (0.0165)
Debt issuance (t-1)	0.1058** (0.0326)
Equity issuance (t-1)	-0.0299 (0.5895)
Industry cash flow (t-1)	0.0354 (0.8169)
Working capital (t-1)	-0.0504 (0.2691)
Cash flow (t-1)	-0.0134 (0.7297)
Adjusted R squared	0.51
Year fixed effect	Yes
Industry fixed effect	Yes
N	1,925.00

This table presents results from a lagged model specification. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

4.6.2 System GMM

We further address the endogeneity concerns by estimating the model using the System Generalised Method of Moments (Sys-GMM) technique. Sys-GMM combines the conditions from both the first-differenced equation and the levels equation. Specifically, it uses lagged levels of endogenous variables as instruments for the differenced equation and lagged differences of those same variables as instruments for the equation. This setup allows us to control for omitted, time-invariant firm characteristics that may influence firm cash holding choices (e.g., business model, management style), while also mitigating simultaneity bias that may arise if firms with higher cash holdings are more likely to be sued or targeted by climate-related litigation. Equation 4.6 presents the dynamic panel data model estimated using the Sys-GMM to address endogeneity concerns:

$$Cash_{it} = \delta + \beta_1 Cash_{t-1} + \beta_2 Litigation_{it} + \delta Controls_{i,t} + \epsilon_{i,t} \text{-----} (4.6)$$

Table 4.15 reports the Sys-GMM results. We estimate a dynamic panel model using the Sys-GMM estimator (Arellano & Bover, 1995; Blundell & Bond, 1998), which controls for simultaneity, omitted variable bias, and firm-specific heterogeneity by instrumenting endogenous variables with their lagged levels and differences.

To do this we lagged the dependent variable¹⁷¹ i.e., $Cash_{it-1}$ which is motivated by the empirical evidence suggesting that corporate cash holdings exhibit strong persistence over time. Therefore, firms adjust cash holdings gradually due to adjustment costs, financing frictions, and precautionary motives; consequently, current cash holdings depend on past cash holdings (Opler et al., 1999; Bates et al., 2009). The IV-style instruments for our System GMM estimation include Litigation, Debt Issuance, MB Ratio, Leverage, and Acquisition. Both empirical findings and logical arguments support the choice of these variables. We treat litigation as a predetermined variable; the assumption is that while litigation in the prior year may influence current cash holdings, it is unlikely to be influenced by current-period shocks to cash. This logic aligns with Arena & Julio (2015), who show that firms restructure their liquidity and capital structure over time in response to litigation exposure. Debt issuance can increase cash holdings but can also respond to internal cash needs, making it potentially endogenous (Kling, 2018). Using lagged debt issuance as an instrument, we isolate the effect of prior financing decisions on current cash holdings. The MB ratio captures market expectations of firm growth and investment opportunities. While cash and MB ratio may be simultaneously determined (Magerakis et al., 2015; Opler et al., 1999), the lagged MB ratios serve as valid instruments by reflecting past valuations that shape current year cash holdings. Leverage is jointly determined with cash holdings as part of the firm's broader capital structure. In this context, Opler et al. (1999) indicate that prior year leverage provides information about firm borrowing decisions, which can influence cash holding without being confounded by contemporaneous shocks to cash. Acquisition activity directly impacts firm cash use, and firms with high cash holdings may be more likely to engage in acquisition activity. However, acquisition decisions, especially large transactions, are usually planned and announced in advance. Therefore, lagged acquisition behaviour can reflect prior planning unrelated to current-period cash holdings. Harford (1999) and Almeida et al. (2004) utilise acquisitions as predetermined variables in corporate liquidity

¹⁷¹ We do not rely solely on a single lag. Instead, consistent with standard System GMM practice, we use deeper lags of endogenous. This approach mitigates concerns that endogeneity may persist beyond one period (Roodman, 2009).

and investment behaviour models.

The coefficient on the lagged dependent variable (Cash holdings (t-1)) is positive and highly significant 0.339 at 5 %, aligns with the dynamic cash management theories emphasizing the gradual adjustments to financial policies (Bates et al., 2009). More importantly, the climate litigation dummy remains positive and significant coefficient of 0.0576 at 5% significance level, indicating that even after controlling for potential endogeneity concerns, firms exposed to climate litigation continue to hold more cash.

The model diagnostics support the validity of our model's robustness. The Hansen test p-value is 0.966, indicating that our instruments are valid and not overidentified.

The Arellano-Bond test for AR (2) in differences yields a p-value of 0.363, suggesting no second-order serial correlation in the residuals both necessary conditions for a well-specified Sys-GMM model (Roodman, 2009; Wintoki et al., 2012).

Table 4.5 System GMM result

	(1) Cash
Cash holding (t-1)	0.339** (0.160)
Litigation	0.0576** (0.0276)
Size	-0.0736** (0.0305)
MB ratio	-0.00729 (0.0125)
Tangibility	-0.117 (0.299)
Dividend	0.0159 (0.0751)
R&D	-0.276 (0.846)
Leverage	-0.120 (0.130)
Acquisition	-0.548*** (0.114)
Loss	0.0442 (0.0390)
Debt issuance	0.403***

	(0.140)
Equity issuance	0.656 (0.428)
Industry cash flow	0.445 (1.765)
Working capital	-0.437 (0.290)
Cash flow	0.274 (0.173)
Constant	0.186 (0.422)
Observations	1945
AR(1) p-value	0.019
AR(2) p-value	0.363
Diff-in-Hansen test (GMM)	0.513
Diff-in-Hansen test (IV)	0.993
Hansen p-value	0.966

The table presents the results of the Sys-GMM estimation examining the relationship between climate litigation and corporate cash holdings. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

4.7 Conclusion

In this study, we explore how the emerging landscape of climate litigation impacts on corporate financial strategy, specifically focusing on firms' cash-holding decisions. As environmental accountability becomes a pressing global issue, companies face increasing legal risks related to their environmental practices. This study provides novel empirical evidence on the relationship between climate litigation and corporate cash holding policies. Using a dataset of 205 firm-year climate litigation cases involving US listed firms from 2004 to 2023, matched with firm-level financial data from Compustat, we examine how climate litigations alter corporate cash holding behaviour. Our analysis reveals that firms involved in climate litigation systematically increase their cash holdings. This effect is statistically significant, persistent over multiple years, and economically meaningful amounting to a 20-25% increase in cash holdings for precautionary purpose. Unlike traditional litigation, climate-related lawsuits often originate from regulators, activist groups, or institutional investors and aim to align firm behaviour with broader societal goals such as the Paris Agreement. These lawsuits are longer in duration, more uncertain in outcome, and more likely to result in structural remedies, reputational damage, and regulatory scrutiny amplifying the need for firms to

hold precautionary cash.

Our findings hold under various model specifications lagged variable regressions, and dynamic panel estimation via System GMM. In contrast to existing research on general litigation (e.g., Kim et al., 2018; Arena & Julio, 2015), which shows that litigation may lead to modest adjustments in financial policy, we show that climate litigation poses a unique and exogenous shock that triggers a prolonged and precautionary response. Unlike securities class action suits that often stem from internal misconduct, climate lawsuits are driven by external actors for example state regulators, NGOs, and institutional investors and often pursue long-term injunctive or reputational goals rather than direct monetary compensation.

We further demonstrate that this relationship is not attributable to other litigation risk, as our controls for non-climate litigation and find a virtually similar effect of climate litigation on cash holdings. This highlights the distinctiveness of climate litigation as a growing source of firm-level climate risk. Our observed relationship is robust to the battery of robustness checks including placebo tests, alternative definitions of cash, and alternative sampling exclusions (e.g., exclusion of utilities and Delaware-incorporated firms) further reinforce the credibility of our findings.

While our study uncovers a new ground in linking climate litigation exposure to firm financial behaviour, it is not without limitations. First, we focus exclusively on US based publicly listed firms, which may limit the generalizability of our results to private companies or firms operating in jurisdictions with less stringent climate law and policies frameworks.

Future research can build on this study in several meaningful ways. First, extending the analysis to global settings, especially in jurisdictions where climate litigation is gaining traction for example the EU region, Australia, and other emerging economies, would provide a broader understanding of its financial implications. Second, future work could explore heterogeneity in firm responses based on industry carbon intensity, ESG performance, or governance characteristics testing whether firm characteristics are prone to climate litigation due to their exposure, stakeholder pressure, or institutional readiness. Third, more granular data on the cost structure of climate litigation, including legal fees, insurance claims, and settlement terms, would help discover the channels through which litigation influences financial decisions.

These findings provide essential insights for managers, investors, and policymakers. First, the precautionary hoarding of cash in anticipation of litigation

outcomes may have unintended economic consequences such as reduced investment, innovation, or payout activity that policymakers must weigh when designing climate accountability. Second, the results of this study carry important implications for corporate managers, especially those operating in carbon-intensive or regulatory-sensitive sectors. Managers must consider climate litigation as a growing source of systemic risk therefore managers must incorporate climate litigation exposure into their enterprise risk management frameworks. Also, the persistent increase in cash holdings observed in this study suggests that managers treat climate litigation as a precautionary shock. Maintaining higher cash offers flexibility to absorb potential penalties, legal cost costs, or change in business operations. However, this also introduces opportunity costs, and managers must carefully balance precautionary motives against capital allocation efficiency.

Chapter 5

Conclusion

5.1 Conclusion

This thesis examines the impact of climate laws, policies, and climate litigation on firms' financial decision-making, with a particular focus on their debt maturity and cash holding decisions. Through three interconnected empirical chapters, this study offers a comprehensive understanding of how firms respond to the implementation of climate-related laws, policies, and the risks associated with climate litigation.

Chapter 2, “From Pledges to Actions: Decoding Global Climate Laws”, lays the empirical foundation by applying LDA method, an unsupervised machine learning technique, to decode 3,229 climate laws and policies enacted globally between 1947 and 2023 across 198 countries. This chapter identifies three dominant themes i.e., energy efficiency and power generation, climate adaptation and disaster resilience, and emissions reduction and carbon mitigation. Notably, climate-related mitigation measures have emerged as the principal CLPs response globally. A comparative analysis of three distinct economies i.e., Sub-Saharan Africa, Developing and Emerging economies and Advanced economies, demonstrated thematic consistency with energy-related laws being the primary focus across the three economic groups. Furthermore, we document CLPs focus on emission reduction, energy efficiency, and climate change adaptation across all three climate conventions. The finding further highlights the multifaceted nature of CLPs and their evolution in response to landmark international climate agreements, such as the Earth Summit, the Kyoto Protocol, and the Paris Agreement. Our international climate agreements analysis reveals that many CLPs were enacted worldwide in 2020. By revealing the thematic evolution of CLPs across time and countries, this chapter provides a novel classification of global CLPs. Further, it establishes an empirical basis for measuring the change in climate laws and policies over time and their impact on firm financial decisions.

Chapter 3, “Climate Change Laws and Policies and Corporate Debt Maturity Structure”, builds on these insights by introducing the Climate Law Index, a novel, country-level measure that captures the annual implementation of climate laws and policies enactments across 23 developed countries from 1997 to 2022. Using firm-level panel data the Chapter 3 document that increases in CLI are associated with a statistically

significant decrease in long-term debt by 106 basis points (i.e., 1.74%). This effect was particularly pronounced in the energy and transport sectors, where firms exhibited a stronger tendency to short-term debt, suggesting a heightened sensitivity to climate regulatory pressures. This chapter further investigates the moderating effects of institutional and contextual factors on the relationship between CLI and corporate debt maturity structure. First, using legal origin as a moderator, we find that the impact of CLI on debt maturity differs systematically between common law and civil law countries, indicating a variation in investor protection, creditor rights, and enforcement efficiency inherent in different legal systems. Second, national governance i.e., Rule of Law, Regulatory Quality, and Control of Corruption analysis reveal that firms operating in countries with stronger governance frameworks adjust their debt maturity structures more significantly in response to CLI enactments which is consistent with policy enforcement credibility. Overall, firms operating under stronger governance and common law systems exhibited a less significant shift in long-term debt.

Third, we examine financial constraints as a moderating factor using the KZ index to classify financially constrained firms. The findings suggest that financially constrained firms shorten their debt maturities more aggressively in response to CLI which is possibly to maintain liquidity under compliance cost pressures. Finally, we explore the moderating role of major global crises by interacting CLI with COVID-19 (2020-2021) and Global Financial Crisis (2008–2009). The analysis reveals that the relationship between CLI and debt maturity structure is moderated by macroeconomic shocks, with firms exhibiting different financing responses under systemic stress. Overall, these moderator analyses provide nuanced insights into how institutional environments, firm-level financial health, and macroeconomic crises jointly shape corporate debt maturity decisions under evolving climate laws and policies landscapes.

The chapter conducts various robustness checks, including sub-sample analysis, alternative definitions of debt maturity, and additional control variables; the main findings remain consistent despite these checks. To address potential endogeneity concerns, the study implement a lag and instrumental variable model. The study uses GHG as an instrument for CLI, arguing that countries with higher GHG emissions are more likely to enact climate laws and policies, while GHG emissions do not directly influence firms' debt maturity decision except through their effect on CLI. First-stage regression results confirm strong instrument relevance, with the Kleibergen-Paap and Wald F statistic exceeding the critical threshold, eliminating concerns of weak

instruments. Over-identification tests, including the Hansen J test (p-value = 0.51) and Sargan test (p-value = 0.48), are insignificant, indicating that the exclusion restriction holds and the instrument is exogenous. Further, the Hausman test (p-value = 0.00) rejects the null hypothesis of exogeneity of CLI in the structural equation, justifying the IV approach over OLS estimation. Overall, the IV results reinforce our baseline findings by providing causal evidence that climate laws and policies lead firms to decrease in increase in short-term debt and decrease in long-term debt. The finding supports the theoretical argument that CLP increase uncertainty and borrowing cost prompting a shift toward a short-term borrowing. This response is consistent with the real options theories.

Chapter 4 extends the thesis from climate laws and policies enactment to regulatory enforcement. Using a constructed dataset of 125 US based climate litigation cases involving listed firms between 2004 and 2023, this chapter examines whether legal actions arising from non-compliance with climate laws and policies influence firms' cash holdings decisions. The analysis reveals that firms facing climate-related lawsuits increase their cash holdings approximately 1.79 percentage points more cash as a share of total assets, representing a 23% increase in cash holdings relative to the sample mean. Importantly, to examine the persistence of this effect, the study employs a dynamic models incorporating year-by-year litigation dummies show that the increase in cash holdings is not merely contemporaneous but persists for up to four years following litigation filing. The analysis of litigation outcomes further demonstrates that once lawsuits conclude, firms' cash holdings decline, indicating a precautionary motive linked to legal uncertainty resolution.

The study conducts a series of robustness tests to verify the baseline findings. These tests include alternative definitions, sub-sample analyses, placebo tests, and controls for non-climate litigations. In placebo tests, the study randomly assigns litigation years which yield no significant results, confirming that the observed relationship is not spurious. The study also performs a sub-sample analysis excluding utility firms and Delaware-incorporated firms and findings remain robust. Furthermore, controlling for non-climate litigation exposure indicates that the initial findings about climate litigation and cash holdings remain unaffected. All of these robustness checks consistently demonstrate positive and statistically significant effects on cash holdings.

To address endogeneity concerns, including reverse causality and omitted variable bias, two identification strategies are employed. First, a lagged model specification, where key explanatory variables are lagged by one year and yields a

consistent result. Second, a System Generalized Method of Moments (System GMM) estimator is implemented, which addresses potential endogeneity of the litigation variable and time-varying controls while controlling for unobserved firm heterogeneity and autocorrelation. System GMM results remain robust and statistically significant, reinforcing the conclusion that climate litigation causes firms to increase cash holdings.

Overall, this chapter contributes to the literature by demonstrating that climate litigation risk is a distinct and material financial risk, prompting firms to adjust cash holdings in anticipation of legal expenses, compliance costs, and reputational damages. The findings underscore that climate litigation directly shapes firms' forward-looking cash management decisions, providing new insights into the intersection of climate risk, legal exposure, and corporate finance.

Together, these chapters demonstrate that climate governance significantly shapes corporate financial strategies. CLPs implementation drive firms to adopt shorter debt maturities, while climate litigation prompts increased cash holdings, suggesting adaptive responses to regulatory and legal pressures. Overall, this thesis contributes by demonstrating that climate-related policy and legal frameworks influence corporate financial decisions through multiple channels i.e., debt maturity, liquidity, and risk management while exhibiting strong non-linearity, sectoral variation, and macroeconomic dependence. Moreover, it provides firms and investors with actionable insights into how climate risks both regulatory and legal translate into financing and liquidity strategies, enabling better decision-making under uncertainty. For the policymakers, the study highlights that climate policies and litigation mechanisms have financial implications, suggesting that policymakers should consider financial stability and firm behaviour when designing climate frameworks.

5.2 Theoretical Implications

This study advances theoretical understanding in several key areas. First, it extends the literature on regulatory uncertainty and corporate finance by demonstrating that climate-specific regulations induce firms to adopt more flexible financing strategies, such as shorter debt maturities, to manage risks associated with CLPs implementation. This aligns with real options theory, which posits that firms prioritise flexibility in uncertain environments to retain the ability to adapt or abandon strategies as new information emerges. The observed shift toward shorter debt maturities reflects firms' strategic decline in long-term debt as a real option to navigate the unpredictable landscape

of CLP enforcement and compliance costs. Second, the thesis enriches institutional theory by illustrating how firms adjust their financial structures to maintain legitimacy and compliance within evolving regulatory frameworks. The pressure to align with societal expectations and regulatory norms compels firms to reconfigure their debt maturity decisions, highlighting the role of institutional forces in shaping corporate behaviour. This dual theoretical lens i.e., real options and institutional theory provide a robust framework for understanding the interplay between CLPs and corporate financial decision-making.

The study further reinforces precautionary motive theory which argues that firms hold cash as a buffer against uncertainties, especially when external financing is costly or uncertain. The study provides clear evidence of this theory, showing that firms increase cash holdings in response to climate litigation, with the effect persisting over years. This behaviour reflects a precautionary strategy to manage legal and financial risks tied to climate lawsuits. While traditionally applied to conventional risks (e.g., economic downturns), the study extends the theory to climate litigation, an emerging risk with unique complexities (e.g., operational changes, emission reduction, and multiple stakeholder involvement).

5.3 Practical and Policy Implications

The findings carry significant practical implications. For policymakers, the research highlights the dual challenge of pursuing environmental goals while maintaining financial stability. It reveals that while CLPs are essential for combating climate change, it can unintentionally increase corporate financial risks by pushing firms toward shorter debt maturities due to increase in uncertainty. To address this, policymakers could introduce transitional mechanisms such as subsidies, tax incentives, or detailed regulatory guidance to minimise uncertainty and encourage long-term investments in climate-friendly practices. Policymakers should consider the broader economic ramifications of CLPs, balancing environmental goals with financial stability. Furthermore, the study notes that climate litigation though a powerful tool for firm accountability. However, it can also put a strain on corporate liquidity, indicating a need for improved legal frameworks that enforce climate accountability without compromising firms' finances.

For corporate managers, particularly in sectors like energy and transport, the findings stress the importance of embedding climate regulatory risks into financial planning. Proactive measures such as diversifying funding sources, adopting flexible debt

structures, and holding cash reserves can help firms adapt to regulatory shifts and legal pressures while ensuring operational continuity. Meanwhile, investors and financial institutions gain valuable insights into how CLPs and climate litigation alter firm risk profiles, potentially facing higher refinancing risks. Additionally, this understanding can inform investors to adjust portfolio allocation and risk pricing due to the evolving climate regulatory shifts and legal pressures.

5.4 Limitation and Future Research Directions

While this thesis offers important contributions, several limitations warrant discussion and offer avenues for future research. First, although the LDA-based thematic analysis in Chapter 2 spans 198 countries, the empirical analyses in Chapters 3 and 4 are constrained by firm-level data availability and focus largely on developed markets. Extending the CLI framework and climate litigation analysis to emerging economies would be worthwhile because these jurisdictions often face greater climate vulnerability, weaker institutional enforcement, and different financial market dynamics. By extending the analysis to these regions, future studies can uncover whether firms in these regions respond differently due to governance or market structure constraints. This would provide a more global, inclusive perspective, which is currently underdeveloped in climate finance literature.

Second, the CLI used in this study aggregates the count of CLPs in a country-year and assigns them equal weight. However, this design choice ensures transparency and replicability, it treats all CLPs equally. For example, the UK's Climate Change Programme (2000) is a non-binding framework laying out intentions without imposing direct legal obligations on firms. In contrast, the UK Climate Change Act (2008) introduced legally binding carbon budgets and enforceable targets for emissions reductions. Therefore, a more refined CLI construction could be developed using subject-matter expert based weighting, where individual laws are assigned, weights based on clearly defined criteria, such as the degree of legal bindingness. For example, laws could be differentiated between binding laws with enforceable targets (e.g., the UK Climate Change Act, 2008), binding laws without strict enforcement mechanisms, and non-binding frameworks or policy roadmaps (e.g., the UK Climate Change Programme, 2000), with each category assigned a different weight. In addition, such a framework could incorporate sectoral coverage and economic impact, assigning higher weights to economy-wide policies (e.g., carbon pricing mechanisms) relative to narrowly targeted

sector-specific regulations. For instance, CLPs that mandate emissions caps in high-impact sectors like transport or energy, such as the EU-ETS should carry higher weight. Such an index would better capture the difference between symbolic commitments and CLPs with real financial consequences. This will provide a more granular insights into how firms respond to CLPs. Refining the index by applying weights based on stringency, sectoral coverage, or implementation strength would be a valuable methodological CLI improvement. Such an extension would help distinguish between symbolic legislation and impactful regulatory action, leading to more nuanced empirical insights into how substantive policy quality not just quantity shapes corporate financial behaviour.

Third, incorporating firm-level measures of climate exposure such as carbon intensity, scope 1-3 emissions, corporate governance related variables such as gender diversity, CEO Greed, Overconfident CEOs or ESG risk scores would enrich the analysis of how different types of CLPs affect firms heterogeneously. This would allow researchers to differentiate the impact of policy based on a firm's baseline climate risk, advancing the literature on risk-adjusted financial outcomes. For instance, high-emission firms may face more refinancing constraints or longer debt maturities in jurisdictions with stringent mitigation laws hypotheses that can only be tested by integrating climate risk metrics.

Fourth, the thesis focuses on debt maturity and cash holdings, but CLPs or climate litigations likely affect a wider array of financial outcomes. Future research should examine investment efficiency, cost of capital, corporate risk-taking, or M&A behaviour, since these are core strategic decisions that determine long-term resilience and competitiveness. For example, a firm operating under stringent CLPs might experience decline in firm performance. Investigating these channels would yield practically relevant insights for investors and policymakers interested in the economic costs (or benefits) of CLPs.

Fifth, methodologically, future research could employ event studies around major notable CLP enactments or use staggered difference-in-differences to move closer to identifying causal effects. Additionally, investigating long-term firm outcomes such as post-CLP innovation, valuation shifts, or business model transitions would shed light on the dynamic consequences of CLPs enactment.

Future research could extend our work by decomposing aggregate debt into bank loans and publicly issued corporate bonds separately, as the regulatory impact on debt maturity may operate through heterogeneous channels depending on the instrument.

Related to this, adopting a flow-based approach by examining newly issued debt rather than balance-sheet stock measures would allow researchers to capture how firms adjust the maturity of incremental financing decisions in real time as CLPs implemented. Given that Seltzer et al. (2022) demonstrate that climate regulatory risk raises bond yield spreads and alters asset volatility specifically for high-emitting US firms, future studies isolating new bond issuance and syndicated loan data could more precisely identify whether the maturity-shortening effect is concentrated in public or private debt markets.

In sum, this thesis opens a new line of inquiry into the financial consequences of climate governance, underscoring the importance of integrating legal and regulatory dimensions into climate finance research. As climate risks continue to evolve, so too must the frameworks used to understand their impact on corporate financial behaviour.

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Appendix A

Sample distribution of firm across countries

Country	Legal Origin	Freq.	Percent	Cum.
Australia	Common law	12015	6.84	6.84
Austria	German Civil law	1244	0.71	7.54
Belgium	French Civil law	1354	0.77	8.31
Canada	Common law	7918	4.51	12.82
Czech Republic	German Civil law	127	0.07	12.89
Denmark	Scandinavian civil law	1802	1.03	13.92
Finland	Scandinavian civil law	2223	1.26	15.18
France	French Civil law	8140	4.63	19.81
Germany	German Civil law	8310	4.73	24.54
Ireland	Common law	1472	0.84	25.38
Italy	French Civil law	4062	2.31	27.69
Japan	German Civil law	10812	6.15	33.84
Korea (South)	German Civil law	21974	12.50	46.35
Luxembourg	French Civil law	570	0.32	46.67
Netherlands	French Civil law	2615	1.49	48.16
New Zealand	Common law	1178	0.67	48.83
Norway	Scandinavian civil law	2218	1.26	50.09
Singapore	Common law	7735	4.40	54.49
Spain	French Civil law	1938	1.10	55.60
Sweden	Scandinavian civil law	4577	2.60	58.20
Switzerland	German Civil law	3532	2.01	60.21
United Kingdom	Common law	19767	11.25	71.46
United States	Common law	50162	28.54	100
Total		175745	100	

This table provides an overview of the distribution of observations across countries in the sample across 23 countries from 1997 to 2022. The frequency column represents the number of firm observations for each country in the sample. The percentage column indicates the proportion of the firm's observation relative to the total number of observations. The cumulative frequency column shows the running total of observations up to each row in the table.

Appendix B

Entropy balancing method

	(1) Cash
Litigation	0.0130*** (0.0031)
Size	-0.0020 (0.3948)
MB ratio	0.0089*** (0.0000)
Tangibility	-0.1546*** (0.0000)
Dividend	-0.0139* (0.0783)
R&D	0.6021*** (0.0000)
Leverage	-0.0232 (0.2030)
Acquisition	-0.2662*** (0.0000)
Loss	0.0125* (0.0975)
Debt issuance	0.1469*** (0.0000)
Equity issuance	0.1793*** (0.0000)
Industry cash flow	-0.3065** (0.0109)
Working capital	0.0233*** (0.0023)
Cash flow	0.0103*** (0.0013)
Adjusted R squared	0.60
Year fixed effect	Yes
Industry fixed effect	Yes
N	51,412.00

This table presents regression results using a sample reweighted via entropy balancing method. All

continuous variables are winsorized at the 1st and 99th percentiles to reduce the influence of outliers. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix C

Climate litigation

Name of Company	Litigation year	Litigation outcome year	Decision	Years to litigation outcome
AMERICAN ELECTRIC POWER CO	2004	2011	Against	7
OWENS CORNING	2004	2006	Against	2
GENERAL MOTORS CO	2005	2010	Against	5
GENERAL MOTORS CO	2006	2009	Dismissed	3
OTTER TAIL CORP	2006	2008	Favour	2
VISTRA CORP	2006	2008	Favour	2
DUKE ENERGY CORP	2007	2008	Favour	1
NUCOR CORP	2007	2007	Favour	0
CONOCOPHILLIPS	2007	2007	Against	0
CHEVRON CORP	2008	2015	Against	7
DOMINION ENERGY INC	2008	2011	Favour	3
DUKE ENERGY CORP	2008	2010	Partly Dismissed	2
EXXON MOBIL CORP	2008	2013	Favour	5
GENERAL MOTORS CO	2008	2008	Against	0
CONOCOPHILLIPS	2008	2013	Favour	5
WALMART INC	2008	2010	Settles	2
AES CORP (THE)	2008	2012	Against	4
PEABODY ENERGY CORP	2008	2013	Favour	5
MGP INGREDIENTS INC	2009	2010	Against	1
DELTA AIR LINES INC	2010	2020	Favour	10
NEWMARKET CORP	2010	2010	Against	0

UNITED AIRLINES HOLDINGS INC	2010	2020	Favour	10
CALPINE CORP	2010	2010	Against	0
MURPHY OIL CORP	2011	2013	Favour	2
D R HORTON INC	2011	2013	Against	2
DELTA AIR LINES INC	2013	2014	Favour	1
EXXON MOBIL CORP	2013	2014	Favour	1
PG&E CORP	2013	2016	Favour	3
SEMPRA ENERGY	2013	2013	Favour	0
EDISON INTERNATIONAL	2013	2014	Against	1
CLEAN ENERGY FUELS CORP	2013	2014	Against	1
ARCHER-DANIELS-MIDLAND CO	2014	2014	V. Dismissed	0
CLEVELAND-CLIFFS INC	2014	2016	Favour	2
DOMINION ENERGY INC	2014	2016	Favour	2
XCEL ENERGY INC	2014	2018	Dismissed	4
NUCOR CORP	2014	2016	Against	2
COSTCO WHOLESALE CORP	2014	2014	Against	0
HAWAIIAN ELECTRIC INDS	2015	2022	Favour	7
SEMPRA ENERGY	2015	2018	Against	3
PEABODY ENERGY CORP	2015	2017	Favour	2
PINNACLE WEST CAPITAL CORP	2016	2016	Against	0
EXXON MOBIL CORP	2016	2023	Settles	7
SEMPRA ENERGY	2016	NA	Pending	NA
AVISTA CORP	2016	2020	Dismissed	4
DELEK US HOLDINGS INC	2016	2019	Against	3
TESLA INC	2016	2023	Favour	7

NGL ENERGY PARTNERS LP	2016	2018	Against	2
CHEVRON CORP	2017	2023	Against	6
DOMINION ENERGY INC	2017	2022	V. Dismissed	5
EXXON MOBIL CORP	2017	2023	Against	6
HAWAIIAN ELECTRIC INDS	2017	2019	Against	2
NEW JERSEY RESOURCES CORP	2017	2019	Favour	2
CONOCOPHILLIPS	2017	2023	Against	6
HESS CORP	2018	NA	Pending	NA
CHEVRON CORP	2018	2021	Favour	3
EXXON MOBIL CORP	2018	2019	Favour	1
MARATHON OIL CORP	2018	NA	Pending	NA
CONOCOPHILLIPS	2018	2021	Favour	3
EDISON INTERNATIONAL	2018	2022	Favour	4
KEURIG DR PEPPER INC	2018	NA	Pending	NA
CONSOL ENERGY INC	2018	NA	Pending	NA
CNX RESOURCES CORPORATION	2018	NA	Pending	NA
TRANSDIGM GROUP INC	2018	2019	Settles	1
PHILLIPS 67	2018	NA	Pending	NA
MARATHON PETROLEUM CORP	2018	2023	Against	5
BOEING CO	2019	NA	Pending	NA
EXXON MOBIL CORP	2019	2024	Against	5
NEXTERA ENERGY INC	2019	2020	Against	1
ALLETE INC	2019	2021	Favour	2
SEMPRA ENERGY	2019	2021	Favour	2
EDISON INTERNATIONAL	2019	NA	Pending	NA

ENERGY TRANSFER LP	2019	NA	Pending	NA
HESS CORP	2020	NA	Pending	NA
CHEVRON CORP	2020	NA	Pending	NA
EXXON MOBIL CORP	2020	2023	Against	3
HAWAIIAN ELECTRIC INDS	2020	NA	Pending	NA
MARATHON OIL CORP	2020	NA	Pending	NA
MURPHY OIL CORP	2020	NA	Pending	NA
PG&E CORP	2020	NA	Pending	NA
SEMPRA ENERGY	2020	2021	Settles	1
CONOCOPHILLIPS	2020	NA	Pending	NA
PUBLIC SERVICE ENTRP GRP INC	2020	NA	Pending	NA
WILLIAMS COS INC	2020	2022	Favour	2
SUNOCO LP	2020	NA	Pending	NA
MURPHY USA INC	2020	NA	Pending	NA
BLOOM ENERGY CORP	2020	2021	Favour	1
PHILLIPS 67	2020	NA	Pending	NA
MARATHON PETROLEUM CORP	2020	NA	Pending	NA
HESS CORP	2021	2024	Favour	3
CHEVRON CORP	2021	2024	Favour	3
COCA-COLA CO	2021	NA	Pending	NA
CONTINENTAL RESOURCES INC	2021	2021	V. Dismissed	0
EXXON MOBIL CORP	2021	NA	Pending	NA
HAWAIIAN ELECTRIC INDS	2021	2022	Favour	1
MARATHON OIL CORP	2021	NA	Pending	NA
ENTERGY CORP	2021	NA	Pending	NA

CONOCOPHILLIPS	2021	NA	Pending	NA
AVISTA CORP	2021	2022	Favour	1
PORTLAND GENERAL ELECTRIC CO	2021	2022	Favour	1
SUNOCO LP	2021	NA	Pending	NA
AVANGRID INC	2021	NA	Pending	NA
DANIMER SCIENTIFIC INC	2021	NA	Pending	NA
ALLBIRDS INC	2021	2022	Favour	1
CNX RESOURCES CORPORATION	2021	2024	Favour	3
ENERGY TRANSFER LP	2021	NA	Pending	NA
META PLATFORMS INC	2021	2022	Favour	1
PHILLIPS 67	2021	2024	Favour	3
MARATHON PETROLEUM CORP	2021	NA	Pending	NA
CHEVRON CORP	2022	2024	Against	2
EXXON MOBIL CORP	2022	2024	Against	2
CONOCOPHILLIPS	2022	2023	Against	1
RADIUS RECYCLING INC	2022	NA	Pending	NA
PHILLIPS 66	2022	2022	Against	0
CHEVRON CORP	2023	2024	Against	1
DELTA AIR LINES INC	2023	2024	Partly Dismissed	1
EXXON MOBIL CORP	2023	2024	Against	1
HF SINCLAIR CORP	2023	2023	V. Dismissed	0
NIKE INC -CL B	2023	2024	Favour	1
CONOCOPHILLIPS	2023	NA	Pending	NA
UNITED AIRLINES HOLDINGS INC	2023	NA	Pending	NA
ETSY INC	2023	2023	Favour	0

PEABODY ENERGY CORP	2023	2024	Against	1
PHILLIPS 66	2023	NA	Pending	NA
MARATHON PETROLEUM CORP	2023	2024	Against	1
				Average = 2.56 years

The table presents an overview of litigation cases involving a diverse set of companies across various industry sectors. Notably, the dataset includes companies from the energy, materials, utilities, and consumer discretionary sectors, reflecting a broad spectrum of industries exposed to legal risks. The data reveals important insights into the litigation landscape, revealing the relatively high frequency of “Against” decisions in cases involving US based companies with headquarters in the United States.

Appendix D

Alternative clustering

	(1) Cash	(2) Cash
Litigation	0.0179 (0.1093)	0.0179** (0.0233)
Size	-0.0045 (0.5469)	-0.0045 (0.4723)
MB ratio	0.0117** (0.0281)	0.0117** (0.0243)
Tangibility	-0.2097*** (0.0017)	-0.2097*** (0.0007)
Dividend	-0.0231 (0.2394)	-0.0231 (0.1906)
R&D	0.0025 (0.9966)	0.0025 (0.9945)
Leverage	-0.1542*** (0.0068)	-0.1542*** (0.0025)
Acquisition	-0.2916*** (0.0008)	-0.2916*** (0.0000)
Loss	0.0248*** (0.0074)	0.0248** (0.0232)
Debt issuance	0.1817*** (0.0027)	0.1817*** (0.0044)
Equity issuance	0.1293* (0.0815)	0.1293** (0.0206)
Industry cash flow	0.0673 (0.6696)	0.0673 (0.6531)
Working capital	-0.0841 (0.1304)	-0.0841* (0.0594)
Cash flow	0.0022 (0.9485)	0.0022 (0.9547)
Adjusted R square	0.55	0.55
Year fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
N	2,046.00	2,046.00

The table present the regression result using the alternative clustering. In Column 1, we report results with standard errors clustered at the 2-digit SIC industry level. The estimated coefficient on the Litigation Dummy remains similar in sign and magnitude to our baseline model; however, statistical significance is lost under this specification. Not surprisingly, this is because the total number of industries in our sample is relatively small (20 clusters), which can result in inflated standard errors and reduced statistical power (Petersen, 2009; Cameron & Miller, 2015).

In Column 2, we implement two-way clustering by firm and year. This approach allows to account for correlation of residuals within firms over time and across firms within a given year. Under this more flexible error structure, the coefficient of Litigation Dummy remains statistically significant, reinforcing the robustness of our main findings. These results suggest that while significance under industry-level clustering is sensitive to the small number of clusters, the observed relationship between climate litigation and corporate cash holdings is robust when accounting for residuals within firms over time and across firms in a given year.