Unearthing Regulatory Influences on Climate Risk Adaptation: Exploring Asset Stranding and Regulatory Shortcomings in the US Housing Market

By

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Abstract

Financial institutions have not yet exhaustively assessed the implications that ESG risk may pose to the financial industry despite anthropogenic temperature change being duly and scientifically described in the Paris Agreement in December 2015 (Schellnhuber et al., 2016). Both banks and insurance companies will be impacted, especially in their respective real estate portfolios, and for this reason, the current risk management practices should evolve in order to exhaustively embed these scenarios in their stress testing methodologies (Jung et al., 2021). On top of this, several studies identified robust evidence of long-term growth losses for both poor and rich countries driven by natural disasters. These future climate change implications have been estimated at roughly $9.7 trillion (Hsiang & Jina, 2014).

Economic growth and climate change are two closely interconnected variables whose interplay will become more and more important in the future since, as an example, higher temperatures considerably reduce economic growth (Dell et al., 2012) and political stability (Hsiang et al., 2013).

This thesis delves into the complex regulatory frameworks that will shape the financial sector, seeking to understand how politics shape and influence resilience and sustainability while exposing financial institutions to a new set of risks (Buhr, 2016), such as stranded assets and new crisis scenarios that could undermine the stability of the entire financial system. As of today, the lack of unified definitions and consensus has led financial institutions to implement ad-hoc methodologies creating discrepancies among them and a lack of unified interpretability of the underlying results.

Europe has made considerable improvements to its regulatory framework and is moving toward a homogenous regulatory landscape (Baumuller & Grbenic, 2021). Meanwhile, US political discourse has slowed down the implementation of essential regulations which are required not only by financial institutions but also by multiple stakeholders including investors, regulatory bodies, local entities, and supranational organizations (Dunlap & McCright, 2010). Numerous non-binding guidelines have emerged setting the stage for a more comprehensive and detailed Climate Act with similar magnitude to the Dodd-Frank Act.

This study's conclusion highlights the need for additional regulations and guidelines from supervisory authorities on top of recommending key approaches and areas of study not only for

financial institutions but also for future research. As such, these will need to provide the foundation for the next regulatory developments considering both a systematic shift toward a low-carbon economy and a delayed abrupt transition to mitigate the potential implications that could undermine financial stability.

Thesis Supervisor: Roberto Rigobon
Title: Society of Sloan Fellows Professor of Management

Acknowledgment

First and foremost, I would like to extend my deepest gratitude to my family for their unwavering support and encouragement to pursue the challenging objectives that I defined for my future. The last few years of my professional and academic journey have been both challenging and rewarding due to several challenges that I decided to embrace to achieve personal fulfillment. Every opportunity and difficulty I have faced has allowed me to push my limits and leverage obstacles to improve myself ultimately enabling me to engage in more challenging adventures.

I would like to express my appreciation to my supervisors Sloan Professor Roberto Rigobon and MCSC Postdoc Bram Van Der Kroft for their guidance in the development of this thesis. Their knowledge, guidance, and insightful feedback have been instrumental not only to my work but also to exploring the right research areas to enhance my expertise and career aspirations. Along with their support, I can't avoid mentioning and thanking the entire MIT community of like-minded people as well as eager to share their experiences and develop long-lasting friendships.

Moreover, I extend my sincere appreciation to MIT and all individuals within its ecosystem for their invaluable contributions to shaping my professional journey. In particular, I would like to thank the admission team for their trust and support throughout this entire experience. I was honored to be selected for this experience that truly shaped my future and provided me with the right set of values and mindset to make an impact that matters.

As I am approaching this milestone, I would also like to think about key people such as Professors Monica Billio and Simone Mazzonetto who during my initial academic and career development path provided me with their guidance and support. They represented as well steppingstones toward my dream of attending MIT and pursuing a similar path to the one of Mario Draghi, whose career as former President of the Central Bank and Italian Prime Minister inspired my journey.

Looking ahead, I am eager to embrace new challenges with the main objective of making meaningful contributions to my community and more broadly to the entire society.

Biography

Matteo Spiller is an experienced Risk Management Professional with over 6 years of experience in the banking industry and a track record of leading strategic initiatives along with navigating complex regulatory landscapes worldwide. He pursued advanced studies through a Master's in Management Studies at MIT Sloan in 2023 following his Master's in Finance and Accounting at Imperial College Business School in 2021 and the Bachelor's Degree in Business Administration at Ca' Foscari University in 2018.

His international career journey along with his passion and curiosity allowed him to develop a strong corporate, risk management, and liquidity background by working for several financial institutions in New York, Boston, Hong Kong, Milan, and Venice. Through his career and academic journey, Matteo actively engaged in various banks and sought out professional adventures to develop a well-rounded perspective of his industry.

Beyond his academic and professional development, Matteo is actively engaged in two key areas of focus that he deems essential for the improvement of today's society: mentoring and corporate social responsibility. He actively organizes initiatives with the main objective of promoting education and equality.

Within the Massachusetts Institute of Technology, Matteo focused on enhancing his leadership, quantitative analyses, and ESG capabilities while exploring cutting-edge technologies such as machine learning applied to the banking industry. The undertaken thesis project was driven by the author's curiosity to further explore the latest risk management developments, regulatory requirements, and potential machine learning applications that could be leveraged in his future career endeavors.

Looking ahead, Matteo will continue to embrace excellence and new professional adventures to enhance his professional expertise and achieve new milestones while actively engaging in activities for the betterment of society.

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Glossary

Term	Definition
NGFS	Network of Greening the Financial System
PRA	Bank of England's Prudential Regulation Authority
SASB	Sustainable Accounting Standards Board
WHO	World Health Organization
BIS	Bank for International Settlements
UN	United Nations
IPCC	Intergovernmental Panel on Climate Change
CCAR	Climate Change Adaptation Report
TCFD	Task Force on Climate-related Financial Disclosure
PRI	Principles for Responsible Investment
SFDR	Sustainable Finance Disclosure Regulation
FSB	Financial Stability Board
IOSCO	International Organization of Securities Commissions
CBAM	Carbon Border Adjustment Mechanism
CTA	Climate Training Alliance
CRA	Community Reinvestment Act
OCC	Office of the Comptroller of the Currency
IMF	International Monetary Fund
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
ESRB	European Systemic Risk Board
SEC	Securities & Exchange Commission
PRA	Prudential Regulatory Authority
WHO	World Health Organization
FED	Federal Reserve
ECB	European Central Bank
SFDR	Sustainable Finance Disclosure Regulation
ESRB	European Sustainability Reporting Standards
CSRD	Corporate Sustainability Reporting Directive
CCAR	Climate Change Financial Risk Standards & Climate Change Adaptation Report
PRA	Prudential Regulatory Authority
FDIC	Federal Deposit Insurance Corporation
RWA	Risk Weighted Assets
PPNR	Pre-Provision Net Revenue
NII	Net Interest Income
IDB	Inter-American Development Bank
CTI	Carbon Tracker Initiative
VAR	Value At Risk
SSRN	Social Science Research Network
FAR	Federal Acquisition Regulatory

1. Introduction

In the last decade, the perception and definition of economic performance have evolved as financial institutions embraced ethics and sustainability concepts in their strategy. This shift has been driven by the growing understanding that an abrupt transition to a low-carbon economy may undermine the stability of the financial sector (Engler et al., 2021). Investors, organizations, and stakeholders in general, started to attribute considerable importance to the positive and negative externalities for their societies on top of their returns (OECD, 2017).

Financial stability and crisis scenarios have been historically associated with speculative bubbles, housing market collapses, and the implications driven by the interplay of complex financial instruments. Despite this, climate risk poses a much greater risk to the stability of the financial system even though major instances of this kind of implications have not yet materialized (Battiston et al., 2021). As an example, stranded assets may be the catalyst to the next systemic financial crisis.

Investor expectations and demands have led financial institutions to recalibrate their practices and reporting frameworks to satisfy these new climate-focused requirements. On top of this, regulators are shifting their focus more and more toward these dimensions to address the increasing pressure from investors and consumers to produce more ESG risk-related information (TCFD, 2017). Some countries have adapted much faster than others supported by their local politics while other countries have been slowed down by their respective Parliament or Congress. For instance, in Europe, numerous companies are required to disclose risks associated with climate and sustainability due to the Corporate Sustainability directive of January 2023. However, in the US, despite numerous proposals published by the Securities and Exchange Commission, political debates have delayed regulatory advancements toward similar requirements (SEC, n.d.).

The lack of homogeneous regulatory requirements and guidelines has not only created a surge in greenwashing i.e. “green”, “sustainable” or “low carbon” misleading statements, but it also does not allow for a fair comparison for customers which poses a challenge to the Investment Company Act of 1940 (Yang et al., 2020).

As highlighted by both the European Central Bank (ECB) and Federal Reserve (FED), climate risk awareness is becoming one of the leading concerns in our society today as it shapes perceptions and poses concerns for the overall financial stability of our economies. Their emphasis on the micro- and macroprudential implications of climate-change-related financial risks underscores the urgency for expanded research and data availability to refine forecasting and detailed analyses (Brunetti et al., 2021).

a. Climate Risk Reporting and Future Trends

Climate risk reporting has been growing in importance in the last few years due to investors, governments, customers, regulators, and several other stakeholders' pressures to embed this concept in the business-as-usual activities of each financial institution (Alvarez et al., 2017). Despite this, its definition and exact connotation were not agreed upon initially across financial institutions due to misalignment in terms of understanding, data, and incentives.

Today, there is no doubt that climate change represents a significant issue for our society, and it is already affecting the worldwide population with increasing extreme weather events. Despite this, understanding the magnitude of climate change's impact on our economies is extremely difficult and requires a broad understanding of multiple fields (Kearns, 2022).

In 2017, the Task Force on Climate-related Financial Disclosure divided climate risk into two categories: a. (1) risks related to the transition to a lower-carbon economy and (2) risks related to the physical impacts of climate change. The first risk is defined as:

> "Transitioning to a lower-carbon economy may entail extensive policy, legal, technology, and market changes to address mitigation and adaptation requirements related to climate change. Depending on the nature, speed, and focus of these changes, transition risks may pose varying levels of financial and reputational risk to organizations" (TCFD, 2017).

On the other hand, physical risk was defined as:

> "Physical risks resulting from climate change can be event-driven (acute) or longer-term shifts (chronic) in climate patterns. Physical risks may have financial implications for organizations, such as direct damage to assets and indirect impacts from supply chain disruption. Organizations' financial performance may also be affected by changes in water availability, sourcing, and quality; food security; and extreme temperature changes affecting organizations' premises, operations, supply chain, transport needs, and employee safety" (TCFD, 2017).

The IPCC defined the concept of climate risk in 2020 as:

> "The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.
>
> In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may

change over time and space due to socio-economic changes and human decision-making" (Reisinger et al., 2020).

Several other organizations such as the Network for Greening the Financial System (NGFS), the Bank of England's Prudential Regulation Authority (PRA), and the Sustainable Accounting Standards Board (SASB) have published their own climate risk definitions seen in Table 1.

By analyzing the different climate risk and climate change definitions, it is clear that there is a common consensus in terms of the importance and magnitude of climate risk. Despite this, each organization approached this challenge from a different angle, contributing positively to the analysis of the different implications but also to the fragmentation and divergence of guidelines for financial institutions.

Table 1: Climate Risk and Climate Change Definitions - International Organizations

Organization	Definition
Network for Greening the Financial System (NGFS)	"Climate change is one of the most important challenges currently facing societies and policymakers worldwide" (NGFS, 2024).
Bank of England's Prudential Regulation Authority (PRA)	"Climate change creates financial risks and economic consequences. These risks and consequences matter for our mission to maintain monetary and financial stability" (Bank of England, 2023).
Sustainable Accounting Standards Board (SASB)	"Climate change is a sustainability issue that is both ubiquitous and differentiated—and thus presents unique risks and opportunities for companies and investors" (SASB, 2023).
United Nations (UN)	"Climate change refers to long-term shifts in temperatures and weather patterns, mainly caused by human activities, especially the burning of fossil fuels" (UN, n.d.).
World Health Organization (WHO)	"Climate change presents a fundamental threat to human health. It affects the physical environment as well as all aspects of both natural and human systems – including social and economic conditions and the functioning of health systems. It is therefore a threat multiplier, undermining and potentially reversing decades of health progress" (WHO, 2023).
Federal Reserve	"Physical risks refer to the harm to people and property arising from acute, climate-related events, such as hurricanes, wildfires, floods, and heatwaves, and chronic shifts in climate,

	including higher average temperatures, changes in precipitation patterns, sea level rise, and ocean acidification. Transition risks refer to stresses to certain institutions or sectors arising from the shifts in policy, consumer and business sentiment, or technologies associated with the changes that would be part of a transition to a lower carbon economy" (Gibson, 2023).
Board of Governors of the FED	"Climate risk is the risk financial institutions face stemming from the effects of climate change" (OIG, 2023).
Bank for International Settlements (BIS)	"Climate-related risks are risks that may arise from climate change or from efforts to mitigate climate change, their related impact and their economic financial consequences" (BIS, 2021).

Multiple regulations and non-binding principles have been published worldwide since the Paris Agreement in 2015, such as the Global Recommendations on Voluntary Climate-related Financial Disclosure published by the Task Force on Climate-related Financial Disclosures (TCFD) in 2017, the FSB Roadmap for Addressing Financial Risks from Climate Change in 2023, the Sustainable Finance Disclosure Regulation (SFDR) developed by the European Union in 2023 and the Principles for Climate-Related Financial Risk Management for Large Financial Institutions created by the Federal Reserve in 2023.

With the growing importance and recognition of climate risk, many governing bodies have introduced task forces and panels to address the need for alignment in defining and quantifying the impact of climate change. These organizations and their climate-focused groups are listed in *Table 2*.

Table 2: Organizations and Related Framework

Name	Description
United Nations	Intergovernmental Panel on Climate Change (IPCC)
United Nations	Principles for Responsible Investment (PRI)
Financial Stability Board (FSB)	Task Force on Climate-related Financial Disclosure (TCFD)
European Union (EU)	Sustainable Finance Disclosure Regulation (SFDR)
Centra Banks and Financial Supervisors	Network for Greening the Financial Sector (NGFS)

Federal Reserve	Principles for Climate-Related Financial Risk Management for Large Financial Institutions & Supervision Climate Committee
Bank of England	Prudential Regulation Authority Climate Change Financial Risk Standards & Climate Change Adaptation Report (CCAR)
IFRS Foundation	Sustainable Accounting Standards Board (SASB)
International Organization of Securities Commissions (IOSCO)	Sustainable Finance Network

Despite the growing attention to and importance of this topic, there are still two important issues that need to be tackled in the future to allow financial institutions to adopt the new regulations: a. Standardized Regulatory Requirements and b. Data Sources.

As of today, financial institutions are in need of a unique, standardized, and reliable source of guidelines, regulatory requirements, and principles applicable worldwide. Today's landscape is filled with many organizations and principles that often force financial institutions to decide which one to adopt and which one to disregard, creating delays and a lack of comparability in the produced reports.

On top of this, the current lack of data does not allow financial institutions to reflect climate risk in their models, and consequently, the performed assessments and climate-risk implications on their own structure are unclear (FSB, 2022). Additionally, regulators are struggling to assess the potential consequences on financial stability, and investors are uncertain how to embed the risk and mitigation actions into their financial risk profiles.

For example, the lack of standardized approaches and regulatory requirements are showcased in the divergent ESG scores published by several rating agencies, including S&P Global, Refinitiv, Moody's ESG, and MSCI (Berg et al., 2022).

ESG awareness has been growing at an unprecedented rate in recent years, and this incited the creation of several frameworks, rules, non-binding guidelines, organizations, frameworks, and regulatory requirements. The lack of more notable government involvement and international coordination created a dense and fragmented regulatory environment that can only be streamlined by an international body with the support of both governments and central banks (Sulkowski & Jebe, 2022).

b. Climate Change Importance Evolution Among Leading Financial Institutions

Despite the fragmented and complex regulatory landscape, financial institutions quickly created their own requirements and performed additional disclosures following pressure from investors, clients, governments, and several other stakeholders.

We analyzed the 10-K reports of some of the top 10 banks in the United States from 2018 to 2022 in order to better understand how climate risk requirements have been embedded in financial institutions' reporting in the last few years. The five randomly selected banks are JP Morgan, Capital One, Goldman Sachs, PNC, and Truist, and the related reports were analyzed through multiple techniques from which emerged a clear trend.

The objective of this analysis is to assess the temporal evolution of ESG-related considerations that have changed in the last few years and if there is any relationship with related guidelines and principles that may have influenced these changes.

Table 3: U.S.-Chartered Commercial Banks with $300 million of Consolidated Assets or More

Bank Name	Rank	Bank ID	Location	Charter	Conso Assets (Mil $)	Domestic Assets (Mil $)	Pct Domestic Assets	Pct Cumulative Assets	Domestic Branches	Foreign Branches
JPMORGAN CHASE BK NA/JPMORGAN CHASE & CO	1	852218	COLUMBUS, OH	NAT	3,385,581	2,613,981	77	16	4,871	32
BANK OF AMER NA/BANK OF AMER CORP	2	480228	CHARLOTTE, NC	NAT	2,465,234	2,336,157	95	27	3,785	23
WELLS FARGO BK NA/WELLS FARGO & CO	3	451965	SIOUX FALLS, SD	NAT	1,704,891	1,678,100	98	35	4,430	10
CITIBANK NA/CITIGROUP	4	476810	SIOUX FALLS, SD	NAT	1,657,372	1,014,005	61	43	659	121
U S BK NA/U S BC	5	504713	CINCINNATI, OH	NAT	657,184	646,725	98	46	2,317	1
PNC BK NA/PNC FNCL SVC GROUP	6	817824	WILMINGTON, DE	NAT	553,114	551,126	100	48	2,431	1
GOLDMAN SACHS BK USA/GOLDMAN SACHS GROUP THE	7	2182786	NEW YORK, NY	SMB	538,127	463,989	86	51	2	2
TRUIST BK/TRUIST FC	8	852320	CHARLOTTE, NC	SNM	535,000	534,933	100	53	2,001	0
CAPITAL ONE NA/CAPITAL ONE FC	9	112837	MC LEAN, VA	NAT	468,780	468,225	100	55	283	1
T D BK NA/TD GRP US HOLDS LLC	10	497404	WILMINGTON, DE	NAT	366,252	366,252	100	57	1,175	0

Source: From "Large Commercial Banks" by Federal Reserve Bank for Federal Reserve Statistical Release (2023).

By analyzing the usage frequency of ESG keywords such as "esg", "climate", "climate risk" and "stranded", it is clear that these banks did not focus much on climate risk until 2021 where there was a significant change.

More in detail, 2018 was characterized by a low ESG focus across all banks while starting in 2019 we noticed a slight increase in the frequency of the term "climate" with some variations

across banks. On the other hand, the term “esg” has not been used by most banks in any of the analyzed years except for JP Morgan and Truist in 2021 and 2022.

Of the climate-associated words tested in this analysis, “Climate” and “Climate risk” were the most used across all the analyzed banks particularly in 2021 and 2022 which highlights a turning point in climate-related focus. This indicates a heightened awareness of and reporting on climate-related issues.

Across the analyzed banks, Goldman Sachs, Truist Banks, and JP Morgan stand out for consistently using the term “climate” across this five-year period while we observed variations in frequency and consequently the focus on climate-related topics for the other banks.

Overall, the analyses are in line with our expectation of observing increased attention on climate-related issues and ESG in general in the banking sector over the observed period. Despite this, the results were also unexpected as the importance of climate risk has been recognized much before 2021 but not embedded in the 10-K reports earlier. The lack of data and homogeneous regulations may have contributed to the identified delays observed for the below-analyzed financial institutions.

Table 4: Top 5 US Banks 10-K Reporting Analyses of ESG Importance

Bank	**Term**	**2018**	**2019**	**2020**	**2021**	**2022**
JP Morgan	ESG	0	0	0	2	11
	Climate	1	8	18	18	47
	Climate Risk	0	0	0	0	15
	Stranded	1	0	0	1	1
Capital One	ESG	0	0	0	0	0
	Climate	1	2	2	20	23
	Climate Risk	0	0	0	3	3
	Stranded	4	2	2	2	2
Goldman Sachs	ESG	0	0	0	1	0
	Climate	1	5	9	46	58
	Climate Risk	0	0	0	10	11
	Stranded	0	0	0	0	0
PNC	ESG	0	0	0	0	0
	Climate	5	6	8	26	30
	Climate Risk	0	0	0	1	3
	Stranded	3	1	1	0	0
Truist	ESG	0	0	0	8	2
	Climate	1	0	9	42	29
	Climate Risk	0	0	0	9	4
	Stranded	0	0	0	0	0

c. Sentiment Analysis and Climate Risk on 10K Reporting

In order to further assess the evolution of ESG focus across these banks, we performed a comprehensive sentiment analysis on the 10-K reports of the selected banks through Python with the main objective of obtaining insights into the evolution of weight attributed to environmental, social, and governance (ESG) aspects within the overall organization's financial performance and business activities. All documents have been analyzed through the same Natural Language Processing (NLP) and machine learning algorithm that processed the PDF files and analyzed the textual data.

Sentiment Analysis is sometimes defined as opinion mining and can be described as a process used to identify the tone of documents or digital text. These kinds of analyses are often used as intelligent tools to obtain information regarding customer service and brand reputation or to obtain additional insights about companies for trading purposes (AWS, 2024).

Consistent results emerged from the performed analysis across all banks: the documents are mainly characterized by a neutral or low negative tone about climate and ESG topics. On the other hand, the positive tone is low as well, but it slightly increases year over year.

These results highlight the fact that the analyzed institutions are using a similarly neutral communication style about these topics in addition to embracing a similar approach in terms of what topics are filling the reports. This may highlight that their approach is to present an objective overview or that climate risk is not explicitly addressed in the analyzed documents.

Given the limitations of this technique, additional qualitative analysis should be performed in order to assess whether these financial institutions are addressing the possible implications of climate risk and macroeconomic variables on their financial stability.

Table 5: Sentiment Analyses Results Top 5 US Banks

Bank	Term	2018	2019	2020	2021	2022
JP Morgan	Negative	0.044	0.042	0.060	0.062	0.060
	Neutral	0.874	0.873	0.796	0.793	0.793
	Positive	0.082	0.085	0.144	0.149	0.147
Capital One	Negative	0.056	0.053	0.053	0.053	0.056
	Neutral	0.805	0.802	0.801	0.799	0.798
	Positive	0.139	0.146	0.146	0.148	0.145
Goldman Sachs	Negative	0.045	0.040	0.046	0.049	0.054
	Neutral	0.820	0.829	0.814	0.807	0.791
	Positive	0.135	0.131	0.139	0.144	0.156
PNC	Negative	0.054	0.054	0.058	0.057	0.062
	Neutral	0.788	0.792	0.789	0.788	0.787
	Positive	0.158	0.154	0.153	0.155	0.151

	Negative	0.054	0.052	0.035	0.056	0.060
Truist	Neutral	0.807	0.807	0.834	0.803	0.800
	Positive	0.139	0.141	0.131	0.141	0.140

d. Word Clouds Visualization for Financial Reporting

Following the NLP textual analysis and performing Sentiment Analysis, we leveraged word clouds to contextualize how important climate risk is compared to the other key aspects presented in the 10-K reporting. Word clouds are a technique or visualization method used to identify the frequency or importance related to text data sourced from documents or digital text.

The below-presented word clouds represent the Python analysis of the textual data sourced from the 10-K reports of JP Morgan, Capital One, Goldman Sachs, PNC, and Truist from 2018 to 2022. Overall, more than one million words have been processed through the algorithm for each bank and the most frequent words identified in the dataset can be identified through their size and prominence within each output table.

As highlighted in the results below, what immediately emerged from this test is that until 2022 climate is not yet one of the main points discussed in the analyzed reports despite its growing importance and the potential macroeconomic implications that could trigger from a macroeconomic standpoint. Preferred stock, shares, fair value, respect, financial services, results, and stock price are the main aspects that these banks have been focusing on through the 10-K reporting.

Figure 1: Word Cloud for JP Morgan

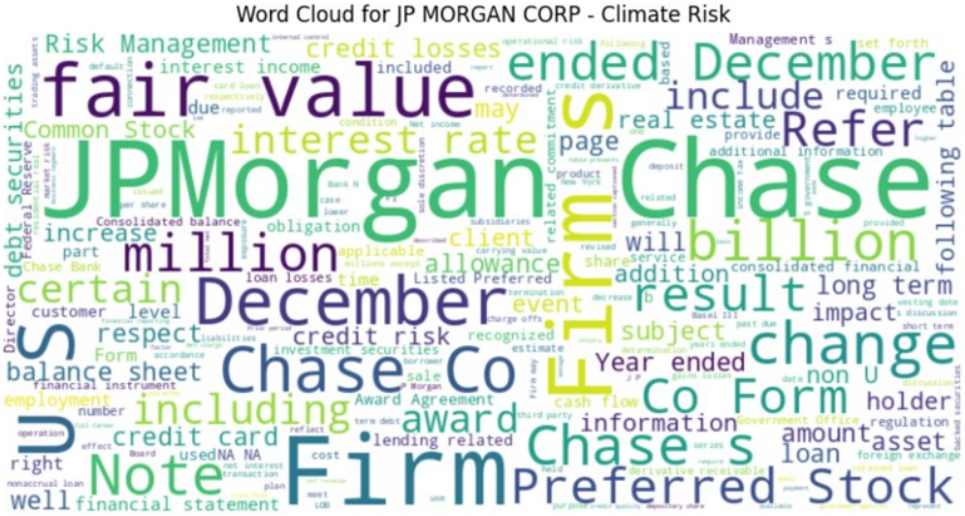


Figure 2: Word Cloud for Capital One

Figure 3: Word Cloud for Goldman Sachs

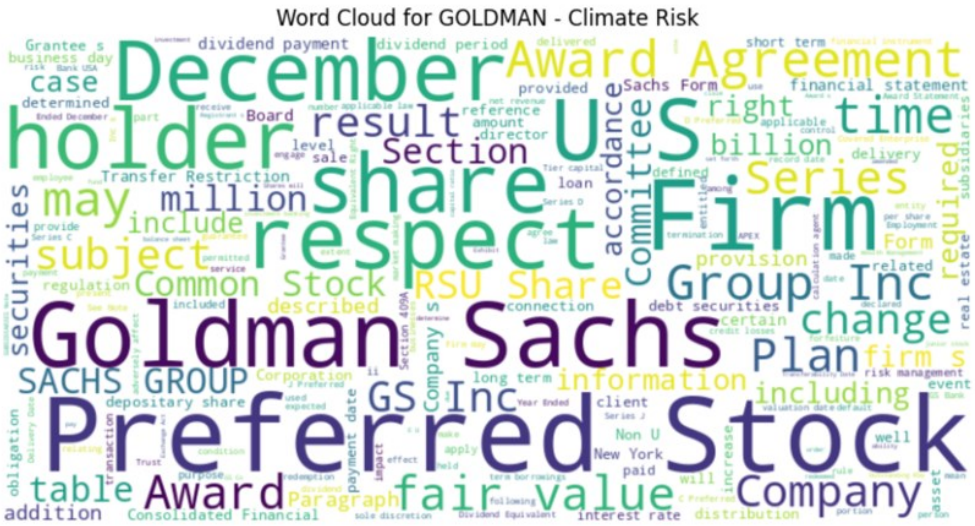


Figure 4: Word Cloud for PNC

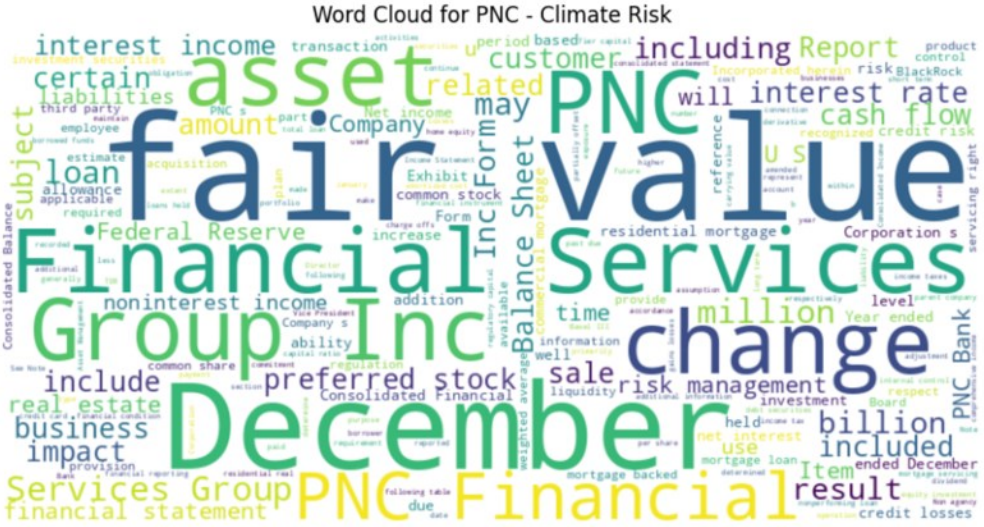


Figure 5: Word Cloud for Truist

e. ESG Correlation Heatmap Top 5 US Banks

Another interesting aspect that was observed in the 10-K reports through the ESG correlation heatmaps is the unique strengths and areas of focus within the ESG framework of each bank. Correlation Heatmaps are tools used to graphically represent correlations among different analyzed variables. These variables are placed on each row and column while the color used highlights the strength of the relationship between the two compared variables.

In the heatmap for each bank, we assessed the correlation between ESG-related terms to better understand their strategy for embedding climate risk in their own operations. Overall, all banks

demonstrated commitment to implementing ESG-related aspects in their reports while taking into account the respective operational structures and steering processes.

JP Morgan's data highlighted a strong positive correlation across multiple ESG factors, which indicates a comprehensive approach toward ESG considerations. Goldman Sachs and PNC results were similar to JP Morgan in emphasizing a holistic approach to ESG integration given the strong positive correlation across most of the analyzed aspects. On the other hand, Capital One results indicated an ESG-related strategy primarily focused on social and governance aspects while Truist's strategy seems to be more focused on environmental, governance and climate factors.

Figure 6: ESG Correlation Heatmap JP Morgan

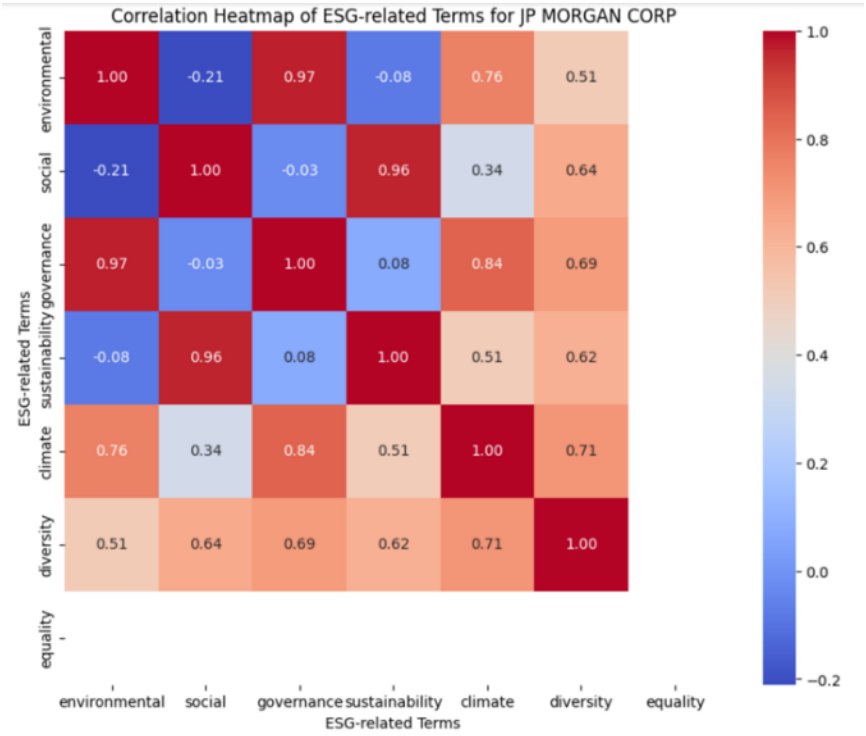


Figure 7: ESG Correlation Heatmap Capital One

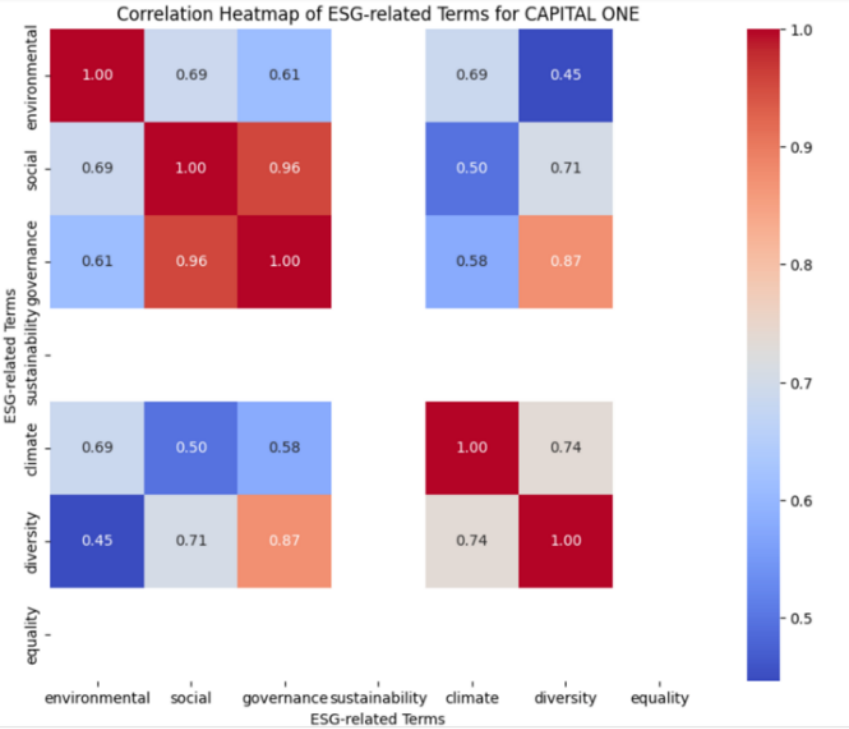


Figure 8: ESG Correlation Heatmap Goldman Sachs

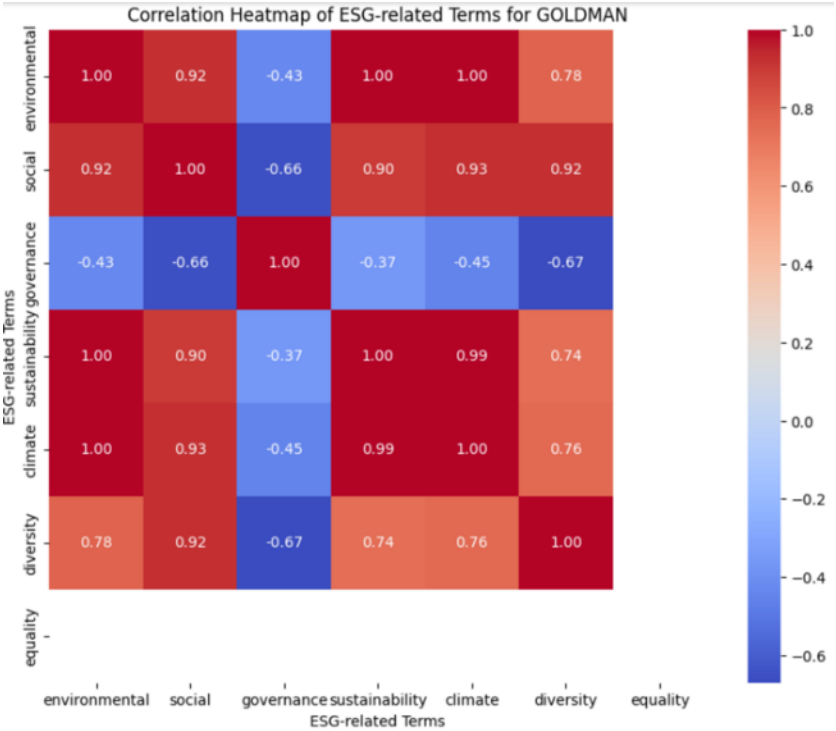


Figure 9: ESG Correlation Heatmap PNC

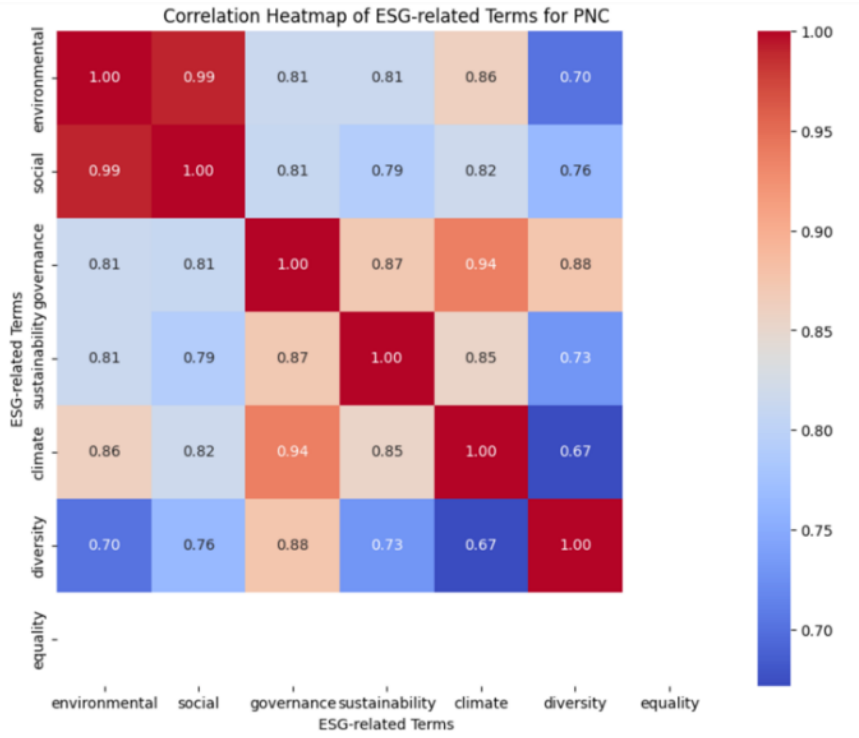
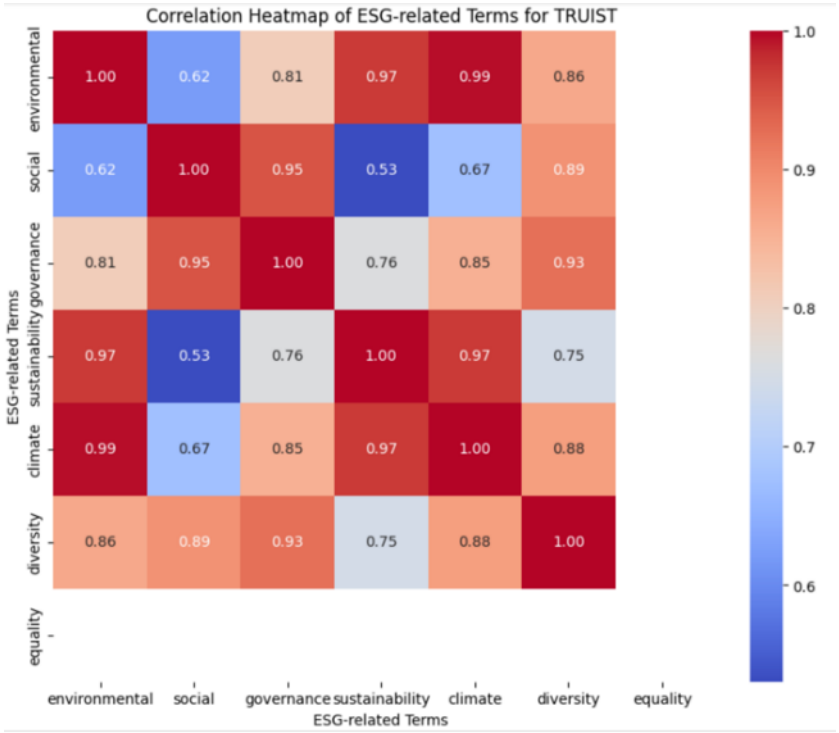


Figure 10: ESG Correlation Heatmap Truist



2. The EU and US Regulatory Landscape Evolution

a. Recent Developments and Current Landscape

Climate change is recognized today not only as a source of idiosyncratic risk but also as a potential threat to the stability of the entire financial system (Battiston et al., 2021) as mentioned by the Bank of England Governor Mark Carney in 2015 during his speech "Breaking the tragedy of the horizon - climate change and financial stability" (Carney, 2015).

Central banks and supervisory authorities have highlighted several times to investors the necessity to take into account this new rising risk and its potential implications in terms of exposure, but this kind of analysis requires additional data and methodologies in order to be embedded into financial considerations (Battiston et al., 2021). On top of this, given the numerous variables, complex interplay, and connections among socioeconomic systems and their evolution across time, it is challenging for analysts to develop reliable and accurate models that could be used to define the expected implications of the defined scenario (Li et al., 2021). As an example, climate shocks could affect market price volatility, recovery rates, asset liquidity, reputation perception, or trigger bank run-offs.

The current European and US regulatory landscapes are characterized by many different regulations, principles, guidelines, and governing bodies that are pressuring financial institutions to adopt the latest ESG-related requirements and disclosures. On the other hand, investors are also pressuring financial institutions to adopt these requirements, but, as of today, there is still a lack of standardization despite the financial industry starting to adopt frameworks such as the one defined by the Task Force on Climate-Related Financial Disclosure (TCFD) and by the Sustainability Accounting Standards Board (SASB) (Dye et al., 2021).

Europe has established itself at the forefront of this transformation, and it is pushing other countries to adopt similar requirements such as through the Carbon Border Adjustment Mechanism (CBAM). This framework imposes a fair price on the carbon emitted by the production of goods and boosts awareness toward the related implications not only locally but also at the international level (European Commission, n.d.-b). This spillover effect on carbon-intensive countries that export to the EU such as Mozambique, Bosnia and Herzegovina, Ukraine, Serbia, North Macedonia, Montenegro, Zimbabwe, Moldova, and Albania will pressure them to transition to a more sustainable economy (Trachtman & Remy, 2023).

In the financial industry, some of the latest and most impactful regulations in Europe are the Corporate Sustainability Reporting Directive (CSRD) published in 2023 and the Sustainable Finance Disclosure Regulation (SFDR) which is still under discussion.

As part of the European Green Deal, the Corporate Sustainability Reporting Directive (CSRD) requires financial institutions to disclose risks and opportunities created by social and environmental issues. This rule was enforced in January 2023 with the idea of providing investors and stakeholders with the information required to assess how their investments or interests may impact the environment but also how they may be exposed to risks. All companies that need to comply with these standards will need to rely on the guidelines defined by the

European Sustainability Reporting Standards (ESRS) (European Commission, n.d.-a). This legislation is the result of a process started in 2014 with the disclosure of non-financial and diversity information by large companies, reports built from 2015 to 2021, the legislative proposal on corporate sustainability reporting in 2021, and numerous other legislations on the European sustainability reporting standards.

On the other hand, the Sustainable Finance Disclosure Regulation (SFDR) can be considered as a transparency framework that requires financial institutions to disclose sustainability information in a defined way. This allows investors to analyze homogenously the sustainability objectives of the companies that they are investing in but also their potential sustainability exposure in a detailed manner (European Commission, n.d.-a). This regulation focused on standardizing the disclosure was issued to benefit investors and attract international resources to guarantee a smooth transition to net-zero for the entire European Union. This framework is the result of several discussions initiated in 2018 through the sustainable finance action plan, several consultations, commission delegations, and proposals that culminated with the effective application of these requirements in 2023.

On the other hand, the Bank of England published several reports on climate risk in the last few years. In particular, the Prudential Regulation Authority Climate Change Financial Risk Standards & Climate Change Adaptation Report (CCAR) published in 2021 defines early analyses on regulatory capital frameworks for banks and insurers and highlights its challenging nature due to the required estimations (Bank of England, 2023).

Regarding the US, some of the most recent and potentially impactful requirements are the Principles for Climate-Related Financial Risk Management for Large Financial Institutions published in 2022 and the SEC Climate Disclosure adopted on March 6th, 2024.

The Principles for Climate-Related Financial Risk Management for Large Financial Institutions are guidelines applicable to financial institutions with more than $100 billion in total consolidated assets aiming to establish a safe and sound management of climate-related risks (Board of Governors of the Federal Reserve System, 2023). These principles are currently being discussed and comments from financial institutions have been submitted in February of this year.

The enhancement and standardization of climate-related disclosure was published in March of 2024, and it requires public companies to enhance climate-related disclosures following investors' pressures to receive additional and consistent information regarding these topics. This new requirement is the result of extensive discussions, more than 24,000 comment letters, and 4,500 unique letters providing feedback and different points of view (SEC, 2024). These new requirements include several pieces of information ranging from climate-related risks and impact on business strategies, activities to mitigate risks, disclosures, governing bodies oversight, targets and goals, climate-related capital losses, scope 1 and scope 2 emissions, and many others.

At the international level, the Bank for International Settlements and the Financial Stability Board launched the Task Force on Climate-related Financial Disclosure (TCFD) with the main objective of issuing recommendations to companies in order to satisfy the information requirements of investors, lenders, and more broadly stakeholders (TCFD, 2023). This task force

fulfilled its objectives in October 2023, and its monitoring activities have been taken over by the IFRS Foundation.

The United Nations created the Intergovernmental Panel on Climate Change (IPCC) and published the Principles for Sustainable Investment (PRI), the IFRS Foundation published the Sustainable Accounting Standards Board (SASB) while the International Organization of Securities Commissions (IOSCO) created the Sustainable Finance Network.

Lastly, another prominent international organization created by supervisors and central banks is the Network for Greening the Financial System (NGFS), which is focused on best practices, climate risk management, and supporting the transition toward a sustainable economy.

On top of the developments analyzed so far, there are many other initiatives around the world to boost financial institutions' attention toward exposure and climate risk management which were published by regulators (Sacchi & Volland, 2022). As an example, the Financial Services Agency of Japan (JFSA) pressured banks to shape their business models and strategies based on the rising upcoming risks, while the Hong Kong Monetary Authority analyzed the potential climate impact on 27 banks by performing climate risk stress testing (Sacchi & Volland, 2022). Moreover, the Central Bank of the People's Republic of China performed its first climate stress test on 23 commercial banks, the Bank of Canada and the Office of the Superintendent of Financial Institutions conducted a pilot project with six financial institutions to estimate vulnerability toward climate transition risk, Bank of Mexico launched stress tests focused on physical risk events, and the banks of Brazil developed multiple social and environmental resolutions (Sacchi & Volland, 2022).

b. Challenges and Opportunities to be Embraced

The reason why regulators and central banks are focusing on banks and financial institutions in general is that these have a pivotal role in today's transition given their credit intermediaries' nature. At the same time, they are also one of the main counterparties in the market that will incur the expected losses derived from transition and physical risk, posing a possible systemic repercussion to the entire financial system (Engler, 2021). This could be mitigated by embracing the expected challenges to gain a competitive advantage stemming from the necessary transition. As an example, it was estimated that the annual required spending on physical assets to accomplish a net-zero transition was in the trillions of dollars. More in detail, the necessary investments between 2021 and 2050 will be close to reaching $280 trillion or around $9 trillion a year (Krishnan et al., 2022). These investments will create numerous reinforcing loops derived from incremental capital spending that will trigger additional growth opportunities on top of improving the overall quality of life for communities.

Despite this, abiding to these regulations and implementing all required principles represents a considerable challenge not only for financial institutions but also for all companies that decided or that are required to comply such as by disclosing their carbon emissions or by committing to producing sustainable products.

Several analyses highlighted that in the European market complying with ESG requirements and a positive ESG score in general mitigates bank fragility during financial distress (Chiaramonte et al., 2021). Evidence of correlation was demonstrated between bank financial resilience and the duration of ESG-related disclosure. This proved to be related to the fact that banks sensitive to these topics are keener to invest in risk mitigation and long-term investment. For example, based on the latest research, companies' credibility toward climate-related commitments increases with the issuance of green bonds (Flammer, 2021).

On top of this, sustainability is often associated with reputation, trust, and credibility and this is another factor driving financial resilience in times of turmoil or short-term volatility (Schultz, Castelló, and Morsing, 2013). This is determined by the fact that today's stakeholders are no longer aiming only to achieve the highest rate of return in the short term but are also valuing positive externalities toward local communities. On top of this, climate-friendly investments have been proven to be the most remunerative in the long term in certain circumstances and for this reason a possible alternative to the less remunerative but safe government yields (Orsato, 2009).

In terms of opportunities, the ongoing challenges will create temporary disruptions allowing the financial institutions at the forefront of this transition to gain market share and leverage the transition as a competitive advantage not only in terms of profitability but also from a reputational perspective. This can be achieved by investing in the right infrastructure, governance framework, analytical skills, and forward-looking perspective required to embrace the expected changes.

The biggest challenge for financial institutions is channeling the resources required to comply with the most recent guidelines, principles, and stakeholders' requirements. Moreover, the systemic nature of climate risk makes it difficult to estimate or mitigate; there is still a lack of a standardized taxonomy that could be applied internationally, and the timeframe over which these risks are expected to arise is uncertain (Gonzalez and Nunez, 2021). To these key points, we also need to add the lack of data, metrics, and developed methodologies to accurately estimate the future impact of these aspects. In particular, climate risk is a forward-looking type of risk and for this reason, it is difficult to embed it in the usual risk metrics that are usually computed on historical data and unable to capture the necessary dynamic variables (Battiston et al., 2019).

From an ESG perspective, it may seem simple to categorize risks for banks in environmental, social, and governance risks, but the underlying interplay of the variables that determine the magnitude and exposure from a balance sheet perspective are numerous and require complex models, methodologies, and assumptions.

Moreover, the required calibration models will need to be structured for each type of industry as the implied risk stemming from each of them may be different and non-linear depending on the implications of multiple external variables.

In order to tackle these challenges, the Network for Greening the Financial System (NGFS) launched the Climate Training Alliance (CTA) with the objective of sharing the best practices that should be leveraged for embedding climate risk in banks' activities (Engler, 2021). This

alliance was launched in 2021, and it provides risk training resources provided by central banks and supervisors to tackle the best practices necessary for a smooth transition.

To summarize, given the dynamic nature and evolving variables embedded in climate risk, effective governance and oversight from skilled employees represent the necessary strategic advantage that companies will need to develop in order to stay at the forefront of this transition (Engler, 2021).

From a more analytical standpoint, banks will need to develop detailed models and scenarios to analyze how climate change will impact financial statements through macro and micro transmission channels and how this will impact the traditional risk categories driving these institutions' risk appetite (i.e. credit risk, market risk, liquidity risk, operational risk and reputational risk) (BIS, 2021).

Parallelly, without clear guidance from regulators and additional research conducted by the academic community, it will not be possible to minimize the losses and shortfalls stemming from this transition. In particular, the necessary research will need to provide support for defining plausible ranges of scenarios for both physical and transition risk exposures and explore the affected transmission channels. Moreover, the non-linearity behavior of climate risk adds a layer of volatility in the estimations (BIS, 2021).

c. Future Trends, Emerging Key Drivers and Methodologies

The current climate risk environment is being driven by several trends and key drivers that are affecting the speed and structural aspects of the overall transition that financial institutions need to undertake. This is not only referring to regulatory requirements but also to stakeholder pressures, commercial advertising, skills development, and competitive advantage more in general.

Given the defined trend, regulators and stakeholders will keep increasing their scrutiny in the near future as more and more efforts will be required the closer we will get to the tipping point. As investor perception about climate risk and investment preferences have shifted recently given the latest climate-related results, banks should adapt their strategic decision based on this evolving landscape.

As such, revamping sustainable finance, leveraging ESG-related KPIs, and mobilizing climate-friendly capital are among the most common actions recently taken but the financial landscape will be characterized by such decisions even more in the near future (Eceiza et al., 2020).

On top of this, protecting the balance sheet from uncertainty driven by both physical and transition risk itself will be the main key objective for financial institutions. As a comparison to highlight the possible impact of this transition, an analysis from McKinsey highlighted the loss-given default rates in Florida under a severe flooding scenario for 2030 are just slightly lower than the observed ones during the financial crisis. While this expectation would more than double considering a simultaneous economic slowdown (Eceiza et al., 2020).

The European Central Bank, through its third assessment of the progress that has been achieved by banks in disclosing climate and environmental risks, highlighted that the disclosure qualities achieved by banks so far are not enough compared to the expected standards. Stricter rules and scrutiny are expected to increase even though European banks outperform their global peers (ECB, 2023). The expected new requirements will aim to not only include basic climate-related information but also to provide stakeholders with concrete information deemed useful to assess exposures and investment objectives.

On the other hand, in the US the Acting Comptroller of the Currency Micheal J. Hsu issued a statement at FDIC Board Meeting in October 2023 highlighting the importance for large banks to enhance their climate-related risk management practices given the recent observed extreme event. In the note, Hsu explained that this is necessary to promote and maintain a sound financial system on top of avoiding long-term repercussions. This message was echoed again in November 2023 when the Acting Comptroller of the Currency had to testify on bank supervision and was supported by the publication of the Principles for Climate-Related Financial Risk Management for Large Financial Institutions (OCC, 2023).

These principles are setting the stage in terms of expectations for the US for banks with more than $100 billion in total consolidated assets to promote sound and consistent guidance on top of defining a high-level framework to be followed.

Given the recent developments and precise level of required detail, banks will be required to perform climate-related stress tests with higher precision not only in Europe but also in the US. This could be achieved by further analyzing the unique features of climate-related financial risks on top of gathering granular and forward-looking measurement methodologies to assess exposures (BIS, 2021).

As of today, regulators and central banks have been mainly analyzing credit risk as the translation of climate risk on this type of risk is straightforward and relatively easier compared to the other types of risks to assess. On the other hand, not much has been done so far from a research perspective on the other types of risks, in particular in the US – for example liquidity risk, reputational risk, operational risk, and market risk triggered by climate risk.

As described by the Bank for International Settlements, a three-step framework is suggested which comprehends a. identifying material climate risk drivers and related transmission channels, b. mapping and measuring climate-related exposure, and c. translating climate-related risks into quantifiable metrics – which represents the most difficult step as of today there is no standardization or clear modeling guideline.

In terms of methodologies, different ones have been developed where Risk Weighted Assets (RWA), Capital, and Liquidity Adequacy metrics are impacted by risk modeling of interest rate risk, credit risk, market risk, and liquidity risk on top of loss projections driven by insurance claim payouts, trading portfolio and loans. The more advanced models take into account feedback loops where interbank contagion, cross-sector spillovers, and macroeconomic feedback are taken into account in order to consider the possible effects of these intensifier variables.

Despite this, one key variable that is missing in almost all of the so far developed models is politics and its influence on climate risk impact driven by ad-hoc initiatives. As an example, Italy has launched the Ecobonus and Sismabonus credit – two government-driven opportunities with an extensive impact from a sustainability and resilience point of view on residential and commercial properties for the whole country.

For this reason, as a next step of this research, it is analyzed whether it is possible to identify a relationship between specific political administrations and the degree of sustainability and resilience of determined states in the US.

3. Republican and Democratic Influence on Resilience and Sustainability Evolution

a. Research Hypothesis and Methodology Definition

In order to enhance the currently proposed risk modeling methodologies related to climate risk, the following analysis assessed whether the macroeconomic feedback loop is affected by government actions and more specifically by regulations. The outcome of these findings could be used to draw inferences and improve the underlying assumptions used by financial institutions as part of their exposure assessments. The research hypothesis is focused on analyzing the relationship between Democratic and Republican affiliations and the evolution of environmental governance policies across the various states of the United States. The main objective is to draw inferences that could be used today even though climate-related data is still limited and not publicly available.

The underlying thesis stems from the fact that the US is lagging behind compared to the EU, and trends that may seem not yet relevant could underpin key competitive advantages if modeled accurately through stress testing methodologies and expected losses. Risk exposure and risk appetite are two important aspects taken into account to steer a financial institution, but these could be misled by excessive risk aversion or too conservative assumptions, which are detrimental to the maximization of future profitability but necessary when there isn't precise data to rely on. This instance does not only affect financial institutions' profitability but the broader society as investment decisions bring indirect benefits to local economies.

In terms of results, it is expected to observe a direct relationship or at least a higher degree of resilience in the US states led by Republican parties and a stronger level of sustainability in the Democratic states given the underlying values and key forces driving their political agenda. The hypothesis is based on the fact that the Democratic party in the US historically placed emphasis on environmental protection, climate change, and social equity as opposed to the Republican party, which is more focused on economic growth and reduction of regulatory burden.

The following analyses leveraged not publicly available data received from MIT through license agreements, and it encompasses climate-related information that is key to understanding the relationship between climate risk, political dynamics, and property characteristics. Overall, four datasets were analyzed: a. Moody's database, b. Buildzoom Geocoded, c. Buildzoom Building Permits, and d. US Elections results from 1996 to 2020. More in detail, the database a. Moody's contains extensive climate-related metrics and locations at the property level as well as key identifiers such as address and building characteristics which were used to connect the overall data sample with the other ones. Database b. Buildzoom Geocoded includes property identifiers in the United States at address level such as 'Match_addr', 'property_id', 'state', 'zip_code', 'latitude', and 'longitude' and it was used to identify the property IDs associated with each address. Additionally, database c. Buildzoom Building Permits includes property level data as well as key renovation information such as type of renovation, estimated cost, and property identifier. Database d. US Elections 1996-2020 provides publicly available information on the share of Democrats across each state of the United States for several years.

In terms of methodologies to back-test the hypothesis, four different assessments were performed for the overall analyses. As a starting point, this study assessed the overall climate risk score and other metrics of randomly identified Republican and Democratic states. These analyses were necessary to identify driving trends and to verify whether the actual results were in line with the overall expectations drawn from the theoretical analysis.

Following this step, more extensive assessments were performed by analyzing the average scores of more than three million addresses across the US. This aimed to identify strong evidence about the expected differences between the two analyzed political parties and their administration influences on the respective states. Given the extensive database, it was possible to draw unequivocal results that could be used in today's stress testing methodologies.

The third analysis explored the renovation costs of properties across the United States and investigated whether there is a clear difference between the Democratic and Republican states as this aspect could be embedded in the stress testing modeling methodologies leveraged to estimate the amount of stranded assets in a determined location compared to another.

The last step of the investigation analyzed the different types of renovations performed in each state and further investigated whether there is a relationship between the sustainability and resilience categorization with the overall climate score and political affiliation of each state. As such, this could be used to draw forward-looking inferences and forecast which buildings or areas are more likely to become stranded to consequently adjust financial pricing based on the evolving risk and risk aversion. For this reason, two regression equations were developed, one for the resilience relationship and one for the sustainability one.

There is no material difference in terms of interpretation between the two following equations except that the first equation analyzes the sustainability relationship while the second investigates the resilience relationship.

Equation 1: Share of Sustainable Renovations

$$Share\ of\ Sustainable\ Renovations = \alpha 1 + \beta 1{,}1 * OverallClimateRiskScore + \beta 1{,}2 * ShareDemocrat + \beta 1{,}3 * (OverallClimateRiskScore * ShareDemocrat) + \varepsilon i$$

Equation 2: Share of Resilience Renovations

$$Share\ of\ Resilience\ Renovations = \alpha 1 + \beta 1{,}1 * OverallClimateRiskScore + \beta 1{,}2 * ShareDemocrat + \beta 1{,}3 * (OverallClimateRiskScore * ShareDemocrat) + \varepsilon i$$

Where:

- α1 represents the intercept and provides the level of sustainable renovations when the independent variables are zero.
- β1,1 is the coefficient used for OverallClimateScore and it is useful to further investigate how the share of sustainable renovations is impacted given one unit increase in OverallClimateRiskScore
- β1,2 represents the coefficient of ShareDemocrat and it is used to assess how one unit of ShareDemocrat affects the Share of Sustainable Renovations
- β1,3 is the coefficient related to OverallClimateRiskScore *ShareDemocrat and it estimates the relationship between this and the Share of Sustainable Renovations
- εi can be defined as an error term and it provides an estimation of the unobserved factors.

b. Data Analysis and Performed Assessments

Analysis Step 1: Climate Score Vermont vs Wyoming

As a first step to assess our hypothesis and before conducting any regressions or other extensive analyses, we performed a simpler test to validate the initial hypothesis.

For this reason, the below analyses compared the overall climate risk score of one of the most Democratic states compared to one of the most Republican states. To be noted that these were randomly picked in order to avoid any bias in this first step of the analysis. The randomly selected state to represent the Democratic Party is Vermont and the one for the Republican Party is Wyoming.

The results of this test were in line with the expectations, and what emerged is that the selected Democratic state has a higher climate score compared to the Republican one by around 2.5 points. MAX and MIN comparisons highlighted a similar distance between the top and lowest scores of the two analyzed states. The top overall score across the around 3.5 million addresses analyzed was 66.96 points and it was identified in Vermont.

Table 6: Overall Climate Risk Score Vermont and Wyoming

Overall Climate Score	Vermont	Wyoming
Average	39.03	35.66
Top	66.97	62.21
Lowest	22.32	20.12

Analysis Step 2: Climate Score Democratic vs Republican States

As a next step, the analysis was extended to assess the average overall climate risk score of the Democratic states compared to the average climate score of the Republican states. This step was performed to obtain a higher degree of confidence and validate the expectation that there are differences between the Democratic-led states compared to the Republican-led ones in terms of overall climate risk score.

This analysis was performed by leveraging the Moody's database and the US Election database. More in detail, the extensive dataset was cleaned as some records were missing and some key variables were extracted: overall climate risk score, address, water stress score, sea level rise score, overall floods score, overall wildfire score, and overall earthquake score (step 1).

As part of step 2, the state of each address was extracted in order to use this variable as a link variable with the US elections file and to assign a democratic score to each record (step 3). In step 4, the Democratic and Republican classifications were added based on the share_democratic variable. On top of this, within these specific analyses, the states defined as Democratic and Republican with a low share (0.55 or 0.45) were removed from the computation as they were likely to have been swing states in the past few years and for this reason, it is assumed that in the short-term the respective administrations were not able to materially affect the local climate policies.

From the results, it emerged that on average Democratic states have an overall climate risk score that is 3 points higher than the Republican states (45.6 vs 42.6) which is a remarkable result considering that the highest score was 67 and the lowest score was 20.

Regarding the additional metrics that were analyzed, some key findings are that Republican states have a lower risk score compared to Democratic states for all scores except for overall flood (27.31 compared to 21.40) and wildfire scores (64.98 compared to 60.18). More in detail, the Republican states are characterized on average by a better water stress score and are less exposed to sea level rise and earthquakes. On the other hand, Democratic states are subject to fewer wildfires and floods.

Despite this, additional assessments should be conducted to further identify states that could represent outliers and for this reason, skew the overall results. Additional research is also needed

to further explain the underlying drivers of these metrics i.e. geographical characteristics, regulations, and or underlying data consistency.

Table 7: Risk Scores Democrat and Republican States

	Democrat	Republican
Climate Risk Score	45.60	42.67
Water Stress Score	73.00	48.20
Sea Level Rise Score	18.40	3.55
Floods Score	21.40	27.31
Wildfire Score	60.18	64.98
Earthquakes Score	33.95	13.22

Analysis Step 3: Cost of Renovating Democratic vs Republican States Properties

As a next step, the research analyzed the building permits file and in particular the cost to perform renovations needed to achieve necessary improvements for each property, and the final results were aggregated based on each state. This step required some data manipulation as the required information was contained in different databases, more in detail the building.permits file contained the property id of each property and the total dollar amount of the related necessary renovations. The property id variable was leveraged to add in this database the state linked to each property id and as a final step, the state was used to add a new column containing the share of democrat voters for each state. To be noted that the data used to define each state's political party share was as of 2020.

Overall, this analysis aimed to verify whether the required renovations to improve the climate risk score of the properties analyzed are more or less expensive in the Republican states compared to the Democratic ones as this could be used in risk modeling.

Based on the results, it emerged that on average the cost associated with renovating properties in Republican states is less compared to the Democratic ones ($34.901 vs $59.358). Even though the analysis did not further investigate the type of the necessary project, this is already a relevant finding as it allows to factor an additional key aspect in the overall risk associated with a mortgage granted for properties in a specific state compared to another.

Additional analyses could be performed to further analyze outliers and or key variables that could have skewed the final result, but no particular bias was identified at this stage. As an example, with additional resources, this research could further analyze across states the type of projects and related average cost associated based on the state of reference.

Analysis Step 4: Political Affiliation and Type of Renovation

In the last step, the analyses assessed whether there is a relationship between the

shares of sustainable and resilient renovations with the overall climate risk score and political affiliation across the different analyzed states. To do so, the type of renovation for each observation was categorized as sustainable or resilient based on the specific characteristics. As an example, the building improvements increasing the energy efficiency or reducing the GHG emissions were classified as sustainable while the ones focused on containing the possible damages derived from earthquakes or tornados were identified as resilient.

Two regressions were performed to isolate the relationship between sustainability with overall climate score and political affiliation as opposed to the relationship between the same independent variables and the share of resilience renovations.

The results of these regressions provided clear evidence regarding whether the political affiliation of a state or area affects the type of renovation undergoing for a property in the United States. In other words, it provided evidence of whether today's politics are affecting or influencing the US asset-stranding environment and indirectly property values through climate-related regulations and incentives.

Equation 3: Share of Sustainable Renovations

$$Share\ of\ Sustainable\ Renovations = \alpha 1 + \beta 1{,}1 * OverallClimateRiskScore + \beta 1{,}2 * ShareDemocrat + \beta 1{,}3 * (OverallClimateRiskScore * ShareDemocrat) + \varepsilon i$$

Equation 2: Share of Resilience Renovations

$$Share\ of\ Resilience\ Renovations = \alpha 1 + \beta 1{,}1 * OverallClimateRiskScore + \beta 1{,}2 * ShareDemocrat + \beta 1{,}3 * (OverallClimateRiskScore * ShareDemocrat) + \varepsilon i$$

Table 8: OLS Regression Results Sustainable Renovations

OLS Regression Results			
Dep. Variable:	Share_Sustainable	R-squared:	0.296
Model:	OLS	Adj. R-squared:	0.294
Method	Least Squares	F-statistic:	179.8
Date:	Sun, 28 Apr 2024	Prob (F-statistic):	0.00
Time:	13:28:36	Log-Likelihood:	-434.87
No. Observations:	1287	AIC:	877.7
Df Residuals:	1287	BIC:	898.4
Df Model:	3		
Covariance Type:	nonrobust		

Table 9: OLS Regression Results Resilient Renovations

OLS Regression Results			
Dep. Variable:	Share_Resilience	R-squared:	0.269
Model:	OLS	Adj. R-squared:	0.264
Method	Least Squares	F-statistic:	179.8
Date:	Sun, 28 Apr 2024	Prob (F-statistic):	0.00
Time:	13:44:07	Log-Likelihood:	-434.87
No. Observations:	1287	AIC:	877.7
Df Residuals:	1287	BIC:	898.4
Df Model:	3		
Covariance Type:	nonrobust		

c. Analytical Assessment of the Identified Findings and Results

The results highlighted that there is no relationship between political affiliation and type of renovation which is in line with today's political landscape because, compared to Europe, the US has not yet implemented any major policies or measures to mitigate climate risk from an asset stranding perspective. Despite this, there is a clear relationship between overall climate risk and

type of renovations as the regression highlighted that around 30% of the type of renovations are driven by the overall climate risk score associated with each address.

Moreover, the results provided evidence that homeowners in the US today are more influenced by the actual climate evolution rather than their political affiliation and this information represents a key finding as it can be leveraged by financial institutions and in particular banks to adjust the weight attributed to climate risk metrics in the implemented forward-looking models. On the other hand, the positive mitigation effects derived from government actions in the US cannot yet be included in risk modeling as opposed to Europe because no significant relationship was identified. As an example, US financial institutions should not mitigate climate risk forecasts due to government action while computing portfolio loan exposure and value at risk (VAR) as this cannot be considered today as a valuable driver from a macroeconomic perspective.

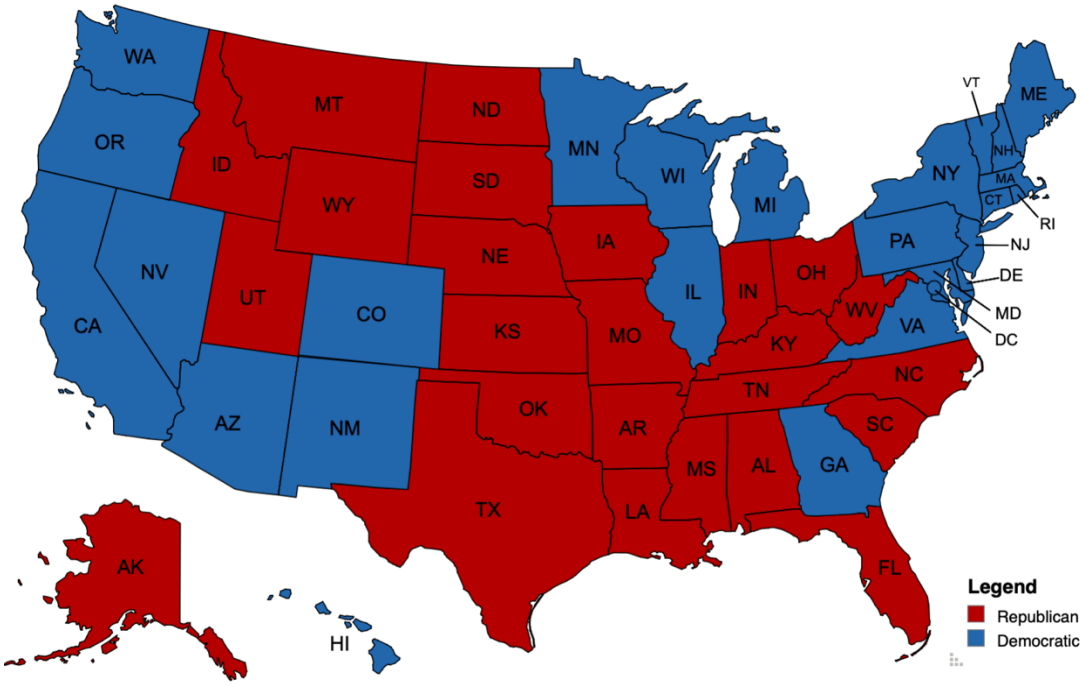
In conclusion, the current climate risk exposure landscape analyzed by each state seems to be more driven by geographical factors and citizen perception of climate risk rather than any regulations or government affiliation.

Moreover, from a consistency perspective, the overall results that there is no relationship between sustainability and resilience and political affiliation is in line with the lack of regulations in the US. In the previous analysis, it emerged that properties situated in Republican states are characterized on average by an overall climate risk score that is lower compared to properties geographically located in Democratic states, and this can be confirmed by visually analyzing the location and political affiliation of each state.

As an example, it was observed that the sea level rise score is on average 15 points higher in Democratic states. This is consistent with the current geographical location of Democratic states, which are closer to the coastal areas compared to the Republican ones. On top of this, it is known that the western US experiences more earthquakes compared to the East, and the higher overall score for this metric identified for Democratic states (33.95 compared to 13.20 for Republican states) reflects the fact that on the West Coast, the majority of the states are Democratic (California, Washington, Oregon, Nevada, Arizona, and New Mexico).

Regarding the wildfires, the results show an approximate even split, overall wildfire score of 60.20 for Democrats and 65.00 for Republicans. This is confirmed by visually analyzing the government-sourced maps retrieved from the Federal Emergency Government Agency and by comparing them to the geographical dispersion of Democratic states and Republican ones.

Figure 11: Republican & Democratic States 2020



Source: Developed using MapChart.com.

4. Implications for Financial Institutions

a. Stranded Assets Definition

The attention to stranded assets has been growing consistently in the last few years, in particular, concerning oil and carbon-intensive industries that will no longer be viable alternatives in the near future given the climate requirements to meet the Paris Agreement targets adopted in 2015. The Paris Agreement is an accord endorsed by more than 190 countries in the world with the objective of limiting the overall global temperature increase well below 2 °C above pre-industrial levels.

This agreement along with the previously analyzed regulations, guidelines, principles, and objectives set up internationally, not only affected investors' perspectives but also asset valuations even though the related effects are not yet entirely priced in the market today. For this reason, the notion of stranded assets gained importance since it started to raise some concerns in 2011. The implications of this topic are broad and range from investment exposure to financial stability (Caldecot, 2017). More in detail, the stranded asset is a wide topic as it not only potentially affects investment exposure but could also have implications from a macroprudential

perspective, financial stability, decarbonization campaigns, cooperate strategies, and decision-making processes of financial institutions and the broader society (Caldecot, 2017).

Today, regulators have not yet published an official definition to identify what should be classified as a stranded asset, but different resources classify them as assets that have suffered from unanticipated or mature write-downs, devaluations, or conversion to liabilities (Caldecott, Howarth, and McSharry, 2013).

Different organizations and institutions worked on the definition of stranded assets as well as the main underlying drivers of environment-related risk, and in particular, the Inter-American Development Bank (IDB) identified six main categories: a. environmental challenges, b. changing resource landscape, c. new government regulations, d. falling clean technology costs, e. evolving social norms, and f. litigations. These variables are closely interconnected with different aspects of today's economies such are sovereign debt, bond pricing, exposure, and more generally speaking companies' valuation, and for this reason, should not only be considered in regard to the fossil fuel industry.

Overall, awareness has been growing in the last few decades from both investors and society's perspectives which has driven the more recent analyses to shift to a broader range of environmental-related political, economic, and societal implications that are likely to strand different categories of assets (Caldecott et al., 2016). Despite this, there is still not enough data or developed methodologies that financial institutions could promptly leverage to assess their exposure and mitigate through contingency plans that would trigger climate-related stress circumstances.

Two main aspects that research has been working on in the last few years and from which it is possible to infer some quantifiable climate-related risk exposures are unburnable carbon and carbon bubble. Despite this, these are not exhaustive in terms of potential implications for financial institutions, and little work has been conducted on more extensive categories such as physical climate change, biodiversity loss, and litigations (Caldecott et al., 2021).

The unburnable carbon can be defined as the fossil fuel reserves estimated and not yet extracted worldwide that if utilized would not allow to respect the Paris Agreement warming limit defined to avoid irreversible effects. On the other hand, the carbon bubble considers the trillions of dollars of investments that today's economies are carrying related to assets such as fossil fuels extraction equipment and infrastructures, coal mines, and oil wells.

The Carbon Tracker Initiative estimated around $30 trillion in the amount of assets related to fossil fuels that are likely to be impacted by this transition and highlighted how governments could impose restrictions to prioritize global warming rather than economic profit while of course destabilizing the related industries. On the other hand, the climate value at risk (VAR) computed considering financial assets at the global level was estimated to potentially imply an impact of $2.5 trillion in a relatively optimistic scenario while this amount would increase to $24 trillion if considering a 99^{th} percentile confidence (Dietz et al., 2016).

Despite this evidence and estimations highlighted by several researchers, it is clear that the private sector is underestimating the potential impact of physical climate risk and adaptation. In particular, it has been analyzed that only 21% of private companies provide quantitative assessments of these impacts on their business and long-term sustainability (Goldstein et al., 2018). Several initiatives and actions have been pursued by banks and financial institutions toward fossil fuels' stranded assets while almost no plan has been defined to address the expected climate value at risk (VAR).

From a high-level standpoint, financial institutions should define a framework that considers both of these aspects as a starting point to further analyze the related exposure and necessary mitigation actions. In particular, this should be framed in three main steps: a. definition of the climate change expected evolution under three scenarios (optimistic, business as usual, and conservative), b. quantification of the climate change evolution based on business model and risk exposure, and c. write off and impact methodological approach and mitigation actions.

To be noted that the first scenario definition and write-off or impact methodologies should be based on guidelines provided by the regulator or central bank authorities in order to allow comparability among financial institutions otherwise this entire exercise could be prone to bias and result in a misleading result.

This requires overcoming challenges such as defining inferences related to global expectations and translating them into the specific structure of the financial institution considered, and for this reason academic research, regulators, and the private sector should collaborate with the common objective of mitigating the climate risk transition. Regulators and central bank authorities should be responsible for a. coordinating the overall action and different stakeholders' responsibilities and b. defining a standardized approach at the international level to simplify the regulatory burden. On the other hand, the academic research should further investigate the different scenarios and related impacts that could be deemed as realistic while the private sector should be responsible for a. translating these scenarios to their own business model and b. developing the necessary mitigation actions to overcome potential climate-related stress testing scenarios.

b. Crisis Scenarios Formulations and Expectations

Stress testing could be defined as a tool or method leveraged to assess the financial resilience of financial institutions by assessing the implications of expected adverse events on their structure (Cihak, 2007). These kinds of assessments are usually performed by assessing how external or internal shocks such as macroeconomic models (e.g. interest rates and GDP) and idiosyncratic risks (e.g. reputational risk and risk appetite exposure) may impact the financial stability of the analyzed bank or insurance company.

More in detail, a bank's balance sheet is characterized by the need for capital and liquidity in order to carry over business-as-usual activities. These are two requirements needed to mitigate a financial crisis that could destabilize the entire financial stability while affecting other financial institutions operating in related industries (Sheuermann, 2014). Some examples of such

situations are the Great Depression of 1929, the dot-com bubble in the United States, and the more recent SVB collapse.

In terms of climate risk stress testing, regulators and central bank authorities are raising their concerns regarding the implications stemming from physical risk and transition risk as it is challenging to model. Additionally, it is difficult to identify the economic relationship between these variables, the macroeconomic variables, and the firm-specific characteristics. The understanding of this kind of relationship is essential to not only draw inferences and assumptions but also to define mitigation actions or contingency plans.

The current stress testing methodology frameworks could be applied, but two main aspects should first be adapted to adequately reflect climate risk implications. These aspects are the scenario definition and the modeling which determine the implications and the economic outcomes (Acharya et al., 2023). More in detail, the scenario definition should consider physical and transition risk while risk modeling should draw inferences on how these types of risk will impact the analyzed bank or insurance company from an economic standpoint. Moreover, this assessment needs to take into account external variables such as macroeconomic conditions, government intervention, and or current legislation. These aspects should be embedded in the overall assessment as the expected economic impact will be different in each specific circumstance. In other words, climate risk stress testing requires consideration of both systemic and idiosyncratic variables.

Numerous potential methodologies have been published to assess climate risk, but only a few of these accurately embed all the necessary variables that would actually be impacted in a crisis scenario in the overall framework as well as the related feedback loops that would stem from the implied relationships. Moreover, the majority of proposed frameworks do not provide a clear process to quantify in absolute terms the expected impact based on the specific characteristics of the financial institution being analyzed. For this reason, in the overall assessment of climate risk exposure, it is important to include these mentioned aspects in the model development in order to produce accurate figures that could be leveraged for appropriate risk appetite assessments.

There are two main channels that can be identified as the main sources of climate risk, there are multiple potential implications such as a. business disruptions, b. asset destruction, c. migration, d. restructuring, e. lower value of stranded assets, and f. increase in energy prices (Grippa et al., 2019). These variables, if considered at a large scale, have implications for the financial system from a market, credit, and underwriting losses perspective as well as in terms of operational risk due to a lower property and corporate asset value, household wealth, lower corporate profits, more litigations, and lower growth. This dynamic generates negative feedback that creates additional stress on the initially considered variables. By this logic, it is then necessary to consider how these dynamics are translated in terms of specific risks. To do so, it is necessary to consider the fact that climate risk can impact multiple variables such as loan books, trading portfolios, and reputation, and for this reason, we can identify three main categories of risk: a. credit risk, b. market risk, and c. liquidity risk (Acharya, 2023).

To summarize, despite the multitude of working papers and research conducted so far, there is still a lack of methodologies and scenario analyses to translate today's climate-risk expectations

into quantifiable metrics and define risk mitigation actions that financial institutions could leverage for their strategies or stress-testing methodologies. Even though some preliminary research highlighted that banks' credit exposure in regard to transition risk could be mitigated, additional research should be conducted to further understand the macro relationship between economy and climate risk as well as how to translate them into quantifiable and understandable results (Jung et al., 2023).

Moreover, markets are evolving at a faster rate compared to the past in order to adapt and price new rising trends or risks. As such, another important variable along with regulatory and climate risk is biodiversity risk and the related economic value loss, which has already been proven to drive risk exposure and ultimately impact equity prices (Giglio et al., 2023). In other words, financial institutions and regulatory supervisors have not yet completely adapted and fully understood the climate risk implications while this new type of risk is evolving along with its economic implications.

The reason why regulators and central banks did not yet fully integrate climate risk and all related risks in their financial stability mandate is that these are particularly uncertain and constantly changing along with the expected economic implications that could be derived from the outcomes of the different scenarios (Bolton et al., 2020). Moreover, these analyses are radically different compared to the usual risk assessments as they require forward-looking analysis rather than backward-looking ones while leveraging limited available data in order to predict or mitigate what can be defined as the "green swan" (Bolton et al., 2020). On top of this, it is necessary to consider the governance challenge as these kinds of assessments require the interaction of multiple stakeholders such as academic research, the private sector, governments, and central banks in order to achieve accurate results. This coordination issue should be delegated to central bank authorities while financial institutions and the academic world should collaborate to leverage the latest AI techniques to refresh the defined models continuously and efficiently while reflecting on the expected implications at the institutional level.

c. Stakeholders' Perspective and Communication

Climate risk brings unprecedented challenges to financial institutions not only because of necessary methodological adaptation driven by forward-looking models but also because of the extensive coordination and regulatory disclosure requirements to abide by.

Stakeholders' influence and pressure toward climate risk disclosure have been growing consistently in the last few years, highlighting the growing importance of this topic from an investment and exposure point of view. This pressure urged regulatory authorities to consider the financial stability implications of climate risk on top of the investor requests in terms of disclosure and communication.

In particular, the EU published the Corporate Sustainability Reporting Directive (CSRD) in 2021 requiring defined standards concerning sustainability reporting (Lashitew, 2022) while the Securities and Exchange Commission enhanced the necessary disclosure concerning climate-related exposure while defining a standardized requirement for public companies in March 2024

(SEC, 2024). These two regulations along with the "Disclosure of Greenhouse Gas Emissions and Climate-Related Financial Risk" published by the Federal Acquisition Regulatory (FAR) Council, the "Climate Corporate Data Accountability Act" and the "Voluntary Carbon Markets Disclosures" published in California and the "Climate Corporate Accountability Act along with the "Climate-related financial risk and required disclosures" from the New York State aim two tackle two main objectives: 1. Requiring companies to disclose the expected losses and risks that are expected due to climate change and 2. Disclosing greenhouse emissions (Assereto and Hanawalt, 2023).

Despite the recent developments, additional coordination should be promoted between the EU and the US to define a standardized and globally accepted disclosure methodology and avoid unnecessary regulatory burdens for financial institutions operating in both the US and the EU simultaneously. The disclosure requirement discrepancies between the EU and the US along with the Carbon Border Adjustment Mechanism imposed in Europe are expected to create friction in terms of comparability and investments (Lashitew, 2022). For this reason, it would be beneficial for the EU and the US to align on disclosure requirements.

A viable compromise to align the disclosure requirements could be led by the International Sustainability Standards Board (ISSB) created by the IFRS foundation with the main objective of developing a global framework guiding financial institutions in a homogeneous disclosure to meet investors' pressures and requirements.

Conclusion

a. Unearthed Summary and Findings

This thesis project has been focused on reviewing the most recent climate risk-related literature and providing a comprehensive overview of the EU regulatory landscape for financial institutions in comparison with the US landscape. Moreover, it provided a brief summary of trends and main developments currently ongoing in other continents and countries, such as China, India, Mexico, and Japan.

The findings highlighted the increasing importance for financial institutions to develop the right capabilities and practices needed to embrace this changing trend as it could represent one of the most impactful variables affecting profitability in the future. Under specific circumstances and without appropriate mitigation actions, climate risk could also undermine the entire financial system by affecting multiple types of risks such as liquidity, market, reputational, and credit risk. For this reason, financial institutions need to embrace this challenging transition by developing the right capabilities and stress-testing methodologies including these new aspects.

Even though there is still a lot to do not only to achieve net zero by 2050 but also to embed this new type of risk in banks' risk appetite statements and risk assessments, the analyses of the 10K reporting along with the word cloud and ESG correlation analyses highlighted that financial institutions are on the right path to embrace this transition. As highlighted in the first few sections of this research, year over year this topic has gained importance in the analyzed banks'

reports along with their approach to include it from a governance, social, and or sustainability perspective. Despite this, as explored through the word cloud analyses, none of the analyzed banks have yet approached climate risk as a competitive opportunity that could offer a competitive advantage compared to the other financial institutions.

From a regulatory perspective, it is clear that both the EU and US regulators along with central banks lagged behind compared to stakeholders and society more broadly from a climate risk perspective. This led to the development of several organizations, initiatives, and projects aiming to raise awareness and create shared action to tackle the raising concerns. Despite this, such a transition created a fragmented environment due to the several guidelines and a lack of standardized methodologies or reporting requirements that financial institutions had to navigate in order to satisfy stakeholders' requests. On the other hand, regulators and central bank authorities should have coordinated more structured guidelines that would allow investors to accurately price their portfolio risk appetite based on comparable climate risk exposure and coordinate the effort toward maintaining financial stability and net zero by 2050.

Regarding the performed assessments, the second main takeaway of this research emerged from the regressions. Banks and financial institutions lack the necessary data to fine-tune their risk assessments and mitigation actions needed to better familiarize themselves with these newly raised concerns. The lack of scenario analyses and data may imply an abrupt transition compared to the planned swift one necessary to adapt to a more sustainable economic model. In particular, the assessment performed by this research highlighted the possibility of enhancing the current stress testing methodologies and consequently risk exposure by taking into account the political affiliation of each state. As such, additional inferences and assumptions should be explored and used by financial institutions to mitigate climate risk while contributing to the stability of the financial system.

Climate risk is difficult to quantify, and also its relationship with several other types of risks and variables makes its integration into financial institutions steering actions difficult to take into account. This is mainly due to three main drivers, a. the lack of academic research on climate risk implications from a financial standpoint, b. insufficient historical data to assess possible implications, and c. insufficient investments that should have been made by financial institutions.

b. Recommendations for Future Research

The performed literature review and assessments highlighted the necessity to gather additional data that could be leveraged by financial institutions to perform forward-looking assessments and implications analyses in terms of repercussions that one shortcoming could imply to another in terms of climate risk. As of today, it is still not clear how to properly embed climate risk in the other risk assessments and which assumptions should be used to perform an exhaustive assessment of the implications that a physical or transition scenario may imply for a bank or insurance company.

More in detail, additional research is needed to a. better define and analyze the scenarios that financial institutions should try to mitigate and that should also be assessed by regulators and

central banks to maintain financial stability, b. explore the necessary risk modeling methodologies that could be used to assess climate risk, c. forecast the expected loss projection such as loan losses, trading portfolio losses, or insurance claim payouts that could realistically occur, and d. quantify the outcome implications in terms of risk-weighted assets (RWA), net interest income (NII), pre-provision net revenue (PPNR), balance sheet projections, and capital and liquidity requirements.

Additionally, the related feedback loops, including interbank contagion, cross-sector spillover, and macroeconomic feedback, should also be studied to better analyze the overall understanding and steering actions required to mitigate climate risk (Baudino & Svoronos, 2021).

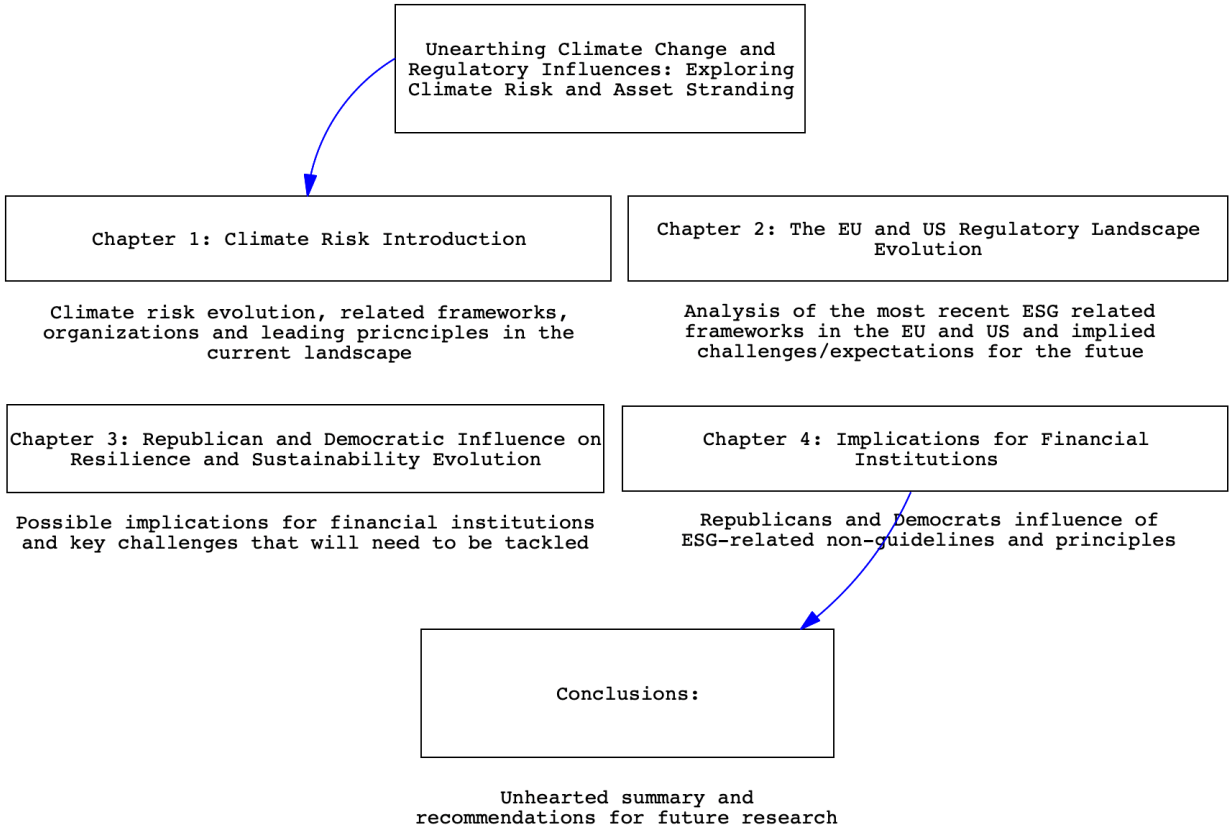
These aspects are not only essential in order to develop and draw accurate steering plans for financial institutions based on the defined milestones but also to transform these challenges into a competitive advantage. This would allow them to remain competitive from a long-term perspective rather than only focusing on short-term profitability.

On the other hand, as highlighted by this research, financial institutions are not yet prioritizing this topic as much as financial profitability, stock value, and regulatory requirements. In particular, the impact and profitability opportunity of this trend are not clear because no climate-related stress event has materialized yet. For this reason, research should shed light on this aspect on top of exploring the right governance and disclosure requirements that regulators should impose for a smoother transition and more broadly climate risk mitigation. The lack of historical data is a challenge that academic research could overcome by developing stress-testing methodologies, scenario analyses, mitigation actions, and dynamic modeling.

Another important aspect that research should put pressure on is climate risk disclosure and stakeholders' requirements. An international effort should be kicked off by regulators and central banks to simplify and standardize disclosure requirements needed by investors to properly assess risk exposure. Such an initiative would not only be beneficial for investors and stakeholders, but it would also allow them to reduce the regulatory and governance burden that financial institutions are currently undergoing due to the lack of clarity and the multitude of expectations.

Appendix

Project Development Flow



Project Research

The structure and methodology of this thesis are centered on two primary objectives defined by the author's interests and future career development aspirations.

Overall, this project is focused on conducting an in-depth assessment of the literature and regulatory requirements related to climate risk for financial institutions that are currently shaping banks' structures. And additionally, defining the potential systemic risk implications embedded in these new challenges and opportunities. The research examines the EU's evolving landscape, and it infers expectations for the US banking system, which is lagging behind. As a second step, this research analyzes the currently leveraged climate-related stress testing methodologies, and it proposes some improvements that could be embedded in the macroeconomic dimension used to define the expected scenarios shaping liquidity, market, operational, and reputational risk. These aspects are partially driven by government regulations and the underlying hypothesis has been back tested by analyzing how Democratic and Republican parties in the US affected the resilience and sustainability of proprieties in the last few years. While the exact impact of these relationships has not been computed in absolute value as banks' loan exposures are not publicly available, the findings provide evidence of potential methodological improvements that could be further investigated with proprietary data.

On a personal level, this research has been conducted based on the author's interest in the evolving regulatory landscape that plays into his risk management career. This study enhances the author's understanding of the main drivers, assumptions, and expectations embedded in the modeling assumptions that risk management functions worldwide need to develop to avoid severe repercussions from a balance sheet perspective. Multiple technical methodologies have been conducted not only to identify data relationships while also to familiarize himself with tools that combine ESG and machine learning. These are two relevant areas of interest for the author's future professional endeavors.

In terms of outputs, this research aims to provide suggestions and recommendations on the necessary future areas of study as well as to identify shortcomings from regulators and central bank authorities that delayed the implementation of a standardized approach across financial institutions.

Tools

Term	Definition
Python	Programming language leveraged for the analyses of the initial assessments and fixed effect regression.
ArcGIS	Geographic information system (GIS) software used for spatial analyses.
Scimago Journal and Country Rank	Platform to assess academic ranking of the analyzed articles and journals.
Vensim	Software tool to design and analyze assumptions/dynamic models of process flows or impact analyses.
Github	Web based platform used to correct code issues and find solutions to analyses problems.
MapChart	Online mapping tool used to create interactive maps and graphics

Additional Python Outputs

ESG Correlations

JP Morgan Summary Table

	Environmental	Social	Governance	Sustainability	Climate	Diversity	Equality
Environmental	1.00000	-0.210298	0.967247	-0.081832	0.764606	0.514272	NaN
Social	-0.210298	1.000000	-0.026897	0.963705	0.339323	0.644364	NaN
Governance	0.967247	-0.026897	1.000000	0.076753	0.842065	0.688747	NaN
Sustainability	-0.081832	0.963705	0.076753	1.000000	0.508758	0.621545	NaN
Climate	0.764606	0.339323	0.842065	0.508758	1.000000	0.711060	NaN
Diversity	0.514272	0.644364	0.688747	0.621545	0.711060	1.000000	NaN
Equality	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Capital One Summary Table

	Environmental	Social	Governance	Sustainability	Climate	Diversity	Equality
Environmental	1.000000	0.688247	0.612372	NaN	0.685819	0.446663	NaN
Social	0.688247	1.000000	0.956656	NaN	0.495496	0.705914	NaN
Governance	0.612372	0.956656	1.000000	NaN	0.576684	0.874118	NaN
Sustainability	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Climate	0.685819	0.495496	0.576684	NaN	1.000000	0.735598	NaN
Diversity	0.446663	0.705914	0.874118	NaN	0.735598	1.000000	NaN
Equality	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Goldman Sachs Summary Table

	Environmental	Social	Governance	Sustainability	Climate	Diversity	Equality
Environmental	1.000000	0.922822	-0.434878	0.997204	0.997752	0.780555	NaN
Social	0.922822	1.000000	-0.656798	0.896515	0.925361	0.923714	NaN
Governance	-0.434878	-0.656798	1.000000	-0.369921	-0.452391	-0.670114	NaN
Sustainability	0.997204	0.896515	-0.369921	1.000000	0.994812	0.740573	NaN
Climate	0.997752	0.925361	-0.452391	0.994812	1.000000	0.763379	NaN
Diversity	0.780555	0.923714	-0.670114	0.740573	0.763379	1.000000	NaN
Equality	NaN	NaN	NaN	NaN	NaN	NaN	NaN

PNC Summary Table

	Environmental	Social	Governance	Sustainability	Climate	Diversity	Equality
Environmental	1.000000	0.990661	0.814017	0.813292	0.860849	0.701934	NaN
Social	0.990661	1.000000	0.810907	0.790912	0.815896	0.764471	NaN
Governance	0.814017	0.810907	1.000000	0.871489	0.938174	0.875113	NaN
Sustainability	0.813292	0.790912	0.871489	1.000000	0.853997	0.730297	NaN
Climate	0.860849	0.815896	0.938174	0.853997	1.000000	0.671984	NaN
Diversity	0.701934	0.764471	0.875113	0.730297	0.671984	1.000000	NaN
Equality	NaN	NaN	NaN	NaN	NaN	NaN	NaN

TRUIST Summary Table

	Environmental	Social	Governance	Sustainability	Climate	Diversity	Equality
Environmental	1.000000	0.622017	0.809174	0.971123	0.994707	0.863322	NaN
Social	0.622017	1.000000	0.951027	0.530425	0.674044	0.890326	NaN
Governance	0.809174	0.951027	1.000000	0.761629	0.852930	0.926316	NaN
Sustainability	0.971123	0.530425	0.761629	1.000000	0.970937	0.747503	NaN
Climate	0.994707	0.674044	0.852930	0.970937	1.000000	0.876466	NaN
Diversity	0.863322	0.890326	0.926316	0.747503	0.876466	1.000000	NaN
Equality	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Data loading, filtering and cleaning

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2222544  65 N Beacon Street, Watertown, Massachusetts, ...
1171186                     22nd Pl, Lubbock, Texas, 79411
173724      1501 Westport Rd, Kansas City, Missouri, 64111
3120707        508 President St, Brooklyn, New York, 11215

         USER_overall_climate_risk_score  USER_overall_water_stress_score  \
2812442                        39.738631                        46.978736
2222544                        44.125236                        54.795778
1171186                        39.928639                        98.485544
173724                         33.906516                        61.526694
3120707                        51.788954                        78.499312

         USER_overall_sea_level_rise_score  USER_overall_floods_score  \
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2222544                                0.0                  39.874302
1171186                                0.0                   0.484121
173724                                 0.0                   3.042427
3120707                               50.0                  11.591565

         USER_overall_wildfire_score  USER_overall_earthquakes_score
2812442                    57.476696                             NaN
2222544                    52.532306                             0.0
1171186                    65.593704                             NaN
173724                     61.249456                             NaN
3120707                    31.221481                             0.0
```

State extraction for each address

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1727147         1177 E 24th St, Brooklyn, New York, 11210
2542832       163 N 145th St, Seattle, Washington, 98133
2813393    8300 Hindry Ave, Los Angeles, California, 90045
1731747  5346 Hilltop Rd, Castro Valley, California, 94552

         USER_overall_climate_risk_score  USER_overall_water_stress_score  \
548082                         52.400602                        43.445005
1727147                        51.788954                        78.499312
2542832                        47.877462                        54.872266
2813393                        40.627585                        97.957779
1731747                        37.995088                        83.279792

         USER_overall_sea_level_rise_score  USER_overall_floods_score  \
548082                                 0.0                  80.360007
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2542832                               40.0                  68.297408
2813393                                0.0                   7.565891
1731747                                0.0                  14.759690

         USER_overall_wildfire_score  USER_overall_earthquakes_score  \
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1727147                    31.221481                        0.000000
2542832                    73.067206                       93.771562
2813393                    64.906059                       96.297808
1731747                    69.002507                       97.178840

             State
548082    New York
1727147   New York
2542832  Washington
2813393  California
1731747  California
```

Databases merge elections and climate data

```
                                  Match_addr  \
0            222 Elmira Rd, Ithaca, New York, 14850
1         1177 E 24th St, Brooklyn, New York, 11210
2        163 N 145th St, Seattle, Washington, 98133
3   8300 Hindry Ave, Los Angeles, California, 90045
4  5346 Hilltop Rd, Castro Valley, California, 94552

   USER_overall_climate_risk_score  USER_overall_water_stress_score  \
0                        52.400602                        43.445005
1                        51.788954                        78.499312
2                        47.877462                        54.872266
3                        40.627585                        97.957779
4                        37.995088                        83.279792

   USER_overall_sea_level_rise_score  USER_overall_floods_score  \
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1                              50.0                  11.591565
2                              40.0                  68.297408
3                               0.0                   7.565891
4                               0.0                  14.759690

   USER_overall_wildfire_score  USER_overall_earthquakes_score       State  \
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1                    31.221481                        0.000000    New York
2                    73.067206                       93.771562  Washington
3                    64.906059                       96.297808  California
4                    69.002507                       97.178840  California

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0        0.617280
1        0.617280
2        0.599235
3        0.649080
4        0.649080
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Democratic and Republican party classification

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0            222 Elmira Rd, Ithaca, New York, 14850
1         1177 E 24th St, Brooklyn, New York, 11210
2        163 N 145th St, Seattle, Washington, 98133
3   8300 Hindry Ave, Los Angeles, California, 90045
4  5346 Hilltop Rd, Castro Valley, California, 94552

   USER_overall_climate_risk_score  USER_overall_water_stress_score  \
0                        52.400602                        43.445005
1                        51.788954                        78.499312
2                        47.877462                        54.872266
3                        40.627585                        97.957779
4                        37.995088                        83.279792

   USER_overall_sea_level_rise_score  USER_overall_floods_score  \
0                               0.0                  80.360007
1                              50.0                  11.591565
2                              40.0                  68.297408
3                               0.0                   7.565891
4                               0.0                  14.759690

   USER_overall_wildfire_score  USER_overall_earthquakes_score       State  \
0                    70.847845                        0.000000    New York
1                    31.221481                        0.000000    New York
2                    73.067206                       93.771562  Washington
3                    64.906059                       96.297808  California
4                    69.002507                       97.178840  California

   share_democrat     Party
0        0.617280  Democrat
1        0.617280  Democrat
2        0.599235  Democrat
3        0.649080  Democrat
4        0.649080  Democrat
```

Average climate score for Republican and Democratic states

```
Party
Democrat      45.599589
Republican    42.674423
Name: USER_overall_climate_risk_score, dtype: float64
```

Additional metrics computation and analysis

```
            USER_overall_climate_risk_score  USER_overall_water_stress_score  \
Party
Democrat                          45.599589                        72.999519
Republican                        42.674423                        48.196935

            USER_overall_sea_level_rise_score  USER_overall_floods_score  \
Party
Democrat                             18.404464                  21.404966
Republican                            3.551724                  27.309085

            USER_overall_wildfire_score  USER_overall_earthquakes_score
Party
Democrat                      60.179568                       33.950647
Republican                    64.979704                       13.215555
```

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