Chapter

Climate Change, Credit Risk and Financial Stability

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Abstract

Climate change is one of the greatest global challenges, posing an unprecedented challenge to the governance of global socioeconomic and financial systems. This chapter examines the climate change science and uncertainties associated with climate change, while identifying and explaining climate-related risks, the financial aspect of climate change, credit implications of climate change, integration of climate-related risks into credit risk assessment, and climate risk management. The chapter pays special attention to the triangular relationship between the three notions of climate-related risks, credit risk, and financial stability by enumerating the channels through which climate risks can cause credit risks and affect the stability of the financial system. Approaches to incorporate climate change into corporate risk management are also discussed.

Keywords: climate risk, risk management, financial stability

1. Introduction

Climate change is the disruption in the long-term seasonal weather patterns caused by global warming. How will long-term climate change affect businesses and the financial system, and how should impacts be managed over the course of the twenty-first century? These are some of the questions that have gained unprecedented attention in public discourse as global warming projections for the coming decades get worse.

Climate change exacerbates existing risks and creates new risks for natural and human systems [1]. The World Economic Forum's Global Risk Report specifies that three of the five topmost likely global risks are related to climate change. Specifically, it ranks failure of climate change mitigation and adaptation as the one most likely to impact on global risk [2]. *The adverse effects of climate change are pervasive and systemic, affecting* all asset classes, industries, and economies, and in turn, the financial system.

The bankruptcy of California's largest electric utility, Pacific Gas and Electric (PG and E), dubbed the first climate change bankruptcy [3], demonstrates the possible disruptions of production and consumption, and reduction in future asset values from impacts of climate change [4]. Notably, Mark Carney, the former governor of the Bank of England, has linked climate-related risks to financial stability. He noted that the combination of the weight of scientific evidence and the dynamics of the financial system suggest that in the fullness of time, climate change will threaten financial stability and longer-term prosperity [5].

From the foregoing that climate change has developed to one of the greatest global challenges, it is imperative to examine the climate change science and uncertainties associated with climate change, while identifying and explaining climate-related risks, the financial aspect of climate change, credit implications of climate change, integration of climate-related risks into credit risk assessment, and climate risk management.

The main aim of the chapter is to enumerate the channels through which climate change can cause credit risks and affect the stability of the financial system. Approaches to incorporate climate change into corporate risk management are also discussed. The chapter employs a systematic literature review approach to explore the relationship between the three notions of climate-related risks, credit risk, and financial stability toward achieving its objectives.

The rest of the chapter is divided into seven parts. Section 2 discusses the science and uncertainties involved in climate change. While various forms of climate-related risks are presented in Section 3, Section 4 enumerates their credit risk implications. How to integrate climate-related risks into credit risk assessment is the focus of Section 5. Sections 6 and 7 explore how climate change can negatively impact financial stability and how organizations could manage climate-related risks, respectively. Section 8 presents the findings and makes suggestions for further research.

2. Scientific uncertainty and climate change

Since Arrhenius [6] established and quantified the contribution of carbon dioxide (CO_2) to climate change, the consensus among publishing scientists, international agencies, and leading scientific societies in climate science is that the increase in the earth's temperature we are currently witnessing is anthropogenic, that is man-made [1, 7, 8] caused by the release of greenhouse gases (GHGs) into the atmosphere. The most prevalent of these GHGs is carbon dioxide (CO_2), associated with burning fossil fuels, industrial processes, forestry, and other land uses, but other gases—such as methane (CH_4) and nitrous oxide (N_2O)—are also contributing [9].

The decay rate of GHG in the atmosphere alters as the average temperature level increases. There has been a striking rise in temperatures over the last decade as the level of CO_2 in the atmosphere has skyrocketed. Global temperatures have been far higher in the past decade compared with their 100-year average, in tandem with an unprecedented rise in CO_2 in the atmosphere as shown in **Figure 1**.

Scientific advances that allow long-dated horizons suggest that irrevocable temperature increases have already been locked in (see **Figure 2**). Moreover, the current trends are on track to lead to systemic disruptions to ecosystems, societies, and economies [12] and may be catastrophic and irreversible for human populations, according to more than 11,000 scientists [13].

While the future is always unknown, we speak of risk if the probability distribution of possible future outcomes is known and of uncertainty if it is not. Human-induced climate change, its impacts, mitigation, and adaptation are fraught with uncertainty. The future pathways for GHG emissions and temperatures set out by climate scientists embody both risk and uncertainty.

The uncertainties involved in climate change preclude prediction of the precise nature, timing, frequency, intensity, and location of climate change impacts. These uncertainties also depend on a multitude of demographic and socioeconomic factors, such as technology, values and preferences, and policies, which are also deeply uncertain [14]. Added to these demographic and socioeconomic sources of uncertainty is scientific uncertainty which arises from our incomplete knowledge of the climate system [15].

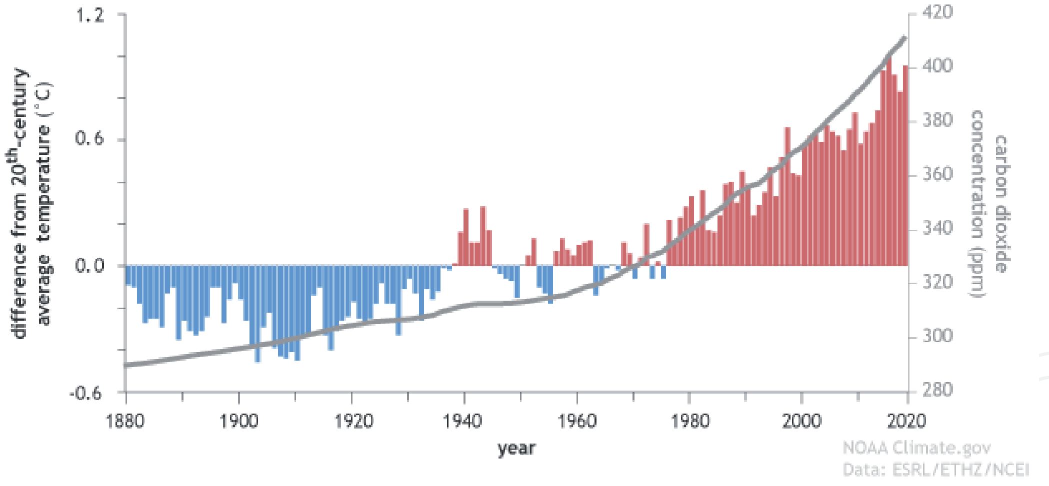

Figure 1.
Atmospheric carbon dioxide and Earth's surface temperature (1880–2019) [10]. Yearly temperature compared to the twentieth-century average (red and blue bars) from 1880 to 2019, based on the data from National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NOAA NCEI), plus atmospheric carbon dioxide concentrations (gray line): 1880–1958 from Institute for Atmospheric and Climate Science (IAC), 1959–2019 from NOAA Earth System Research Laboratories. Original graph by Dr. Howard diamond NOAA Air Resources Laboratory, and adapted by NOAA Climate.gov.

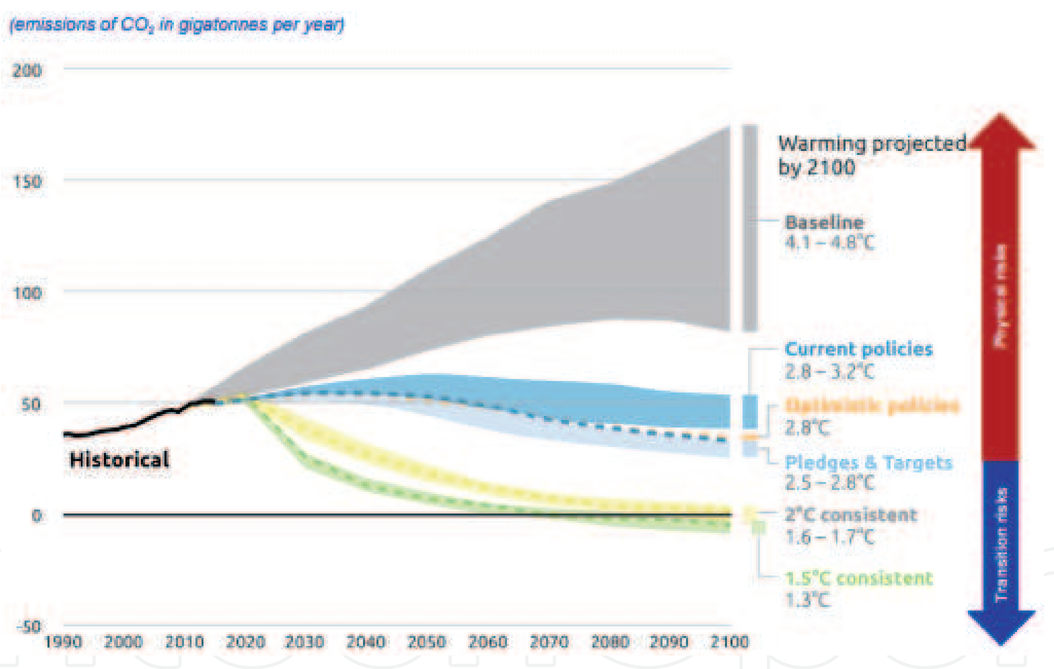

Figure 2.
Climate risk scenarios: Projections of carbon emissions and global warming (emissions of CO_2 in gigatons per year) [11].

Due to these interacting sources of uncertainty, studies of climate change and its impacts rarely yield consensus on the distribution of exposure, vulnerability, or possible outcomes. Thus, in contrast to risk situations where the probability distributions are known, there are no well-defined probability density functions (which are among the most common tools for characterizing uncertainty) for climate change [16].

Climate uncertainty leads to imprecision in estimating climate and economic outcomes. This implies not only imperfect understanding of the ability of mitigation pathways to deliver temperature outcomes but also suggests that there is a significant possibility that the tails of the distribution are considerably fatter than currently estimated. Fat-tailed climate events could not only significantly damage growth and welfare, but economic mechanisms may also be ineffective in responding appropriately. This could result in structural economic changes, and banks may find themselves facing abrupt adjustment which could be severely financially disruptive [17].

3. Climate-related risks

Climate-related risks are mainly divided into two basic sets: physical risks from more frequent and severe meteorological and hydrological events, and transition risks from the process of decarbonization that is aimed at mitigating global warming.

3.1 Physical risks

The physical climate-related risks represent the economic costs and financial losses due to increasing frequency and severity of climate-related weather events (e.g., storms, floods, or heat waves) and the effects of long-term changes in climate patterns (e.g., ocean acidification, rising sea levels, or changes in precipitation), resulting from continuously growing GHG emissions [18, 19].

Physical risks can affect both the supply and demand sides of the economy. On the supply side, natural disasters can disrupt business activity and trade and destroy infrastructure, diverting capital from technology and innovation to reconstruction and replacement [20]. It affects output levels and output growth by impacting labor productivity, speeding up the depreciation of capital stock, increasing cost of repair and replacement, and reducing funds allocated to research and innovation [21]. On the demand side, increasing expenditures for repair and replacement will, ceteris paribus, reduce investment on and consumption demand for other goods. Business investment could also be dampened by uncertainty about future demand and growth prospects and substantial price impacts [22]. Households confronted with more frequent extreme weather events might increase precautionary saving, which would depress private consumption in general [21].

3.2 Transition risks

Transition risks arise as a result of the shift to a low-carbon economy (such as changes in public regulation, technology, or in households' or investors' preferences) triggering changes in demand-related factors. This adjustment process is likely to have a significant impact on the economy and, in particular, on some financial asset values [11].

Transition risks are characterized by a radical uncertainty on the nature of the low-carbon pathway (i.e., the pathway for reducing greenhouse gas emissions, which restructures the economy) and a more usual uncertainty on the methods for implementing this pathway in economic and social terms [23].

Over the last few years, the topic of stranded assets, caused by risk factors like physical climate change impacts, as well as societal and regulatory responses to climate change, has loomed larger [24]. Stranded assets are defined as assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities [25]. With transition toward a lower-carbon economy, carbon assets are expected to suffer from unanticipated or premature write-offs, downward revaluations, or get converted to liabilities [26].

Estimation by McGlade and Ekins [27] shows that approximately one third of the current oil reserves, half the gas reserves, and almost 90% of the coal reserves would become stranded assets if global temperature target of the Paris Agreement is attained. While an early and smooth transition results in much fewer risks, too rapid an adjustment of asset prices due to a late transition might eventually bring about a climate Minsky moment—a sudden drop in assets prices [21].

3.3 Relationship between physical and transition risks

Physical risk and transition risks are correlated, because the more transition policies enter into force, the fewer physical risks are likely to materialize. On the other hand, the harder the economy is hit by physical risks, the stronger the demand will be for effective transition measures [21].

3.4 Liability risks

Materializing physical and potentially also transition risks will drive up liability risks [21]. Liability risks materialize when organizations are directly or indirectly adjudged legally responsible for climate-related losses and must financially compensate other parties [28, 29]. Organizations are also prone to increasing liability risk if they do not manage transition risks well as enshrined in the polluter pays principle. Organizations whose activities are negatively affected by unmitigated climate change could seek compensation from those who had caused or allowed the damage and thereby at least partially internalize the negative externalities [21].

4. Credit risks implications of climate change

Credit risk is the risk of a financial loss resulting from a borrower's failure to repay part of or all the interests and the principal of a loan. Climate-related risks affect all three dimensions of credit risk—a borrower's capacity to generate enough income to service and repay its debt as well as the capital and collateral that back the loan [30].

For financial institutions, credit risks can materialize directly, through their exposures to corporations, households, and countries that experience climate shocks, or indirectly, through the effects of climate change on the wider economy and feedback effects within the financial system. Exposures manifest themselves through increased default risk of loan portfolios or lower values of assets [31].

Corporate credit portfolios are also at risk, as highlighted by the PG&E's bankruptcy. Increase in extreme and severe weather events could have second-round effects on the price of corporate bonds, and the rise in debt defaults would induce climate-related financial instability which would adversely affect credit expansion and magnify the negative impact of climate change on financial activity [19].

Transition risks materialize on the asset side of financial institutions, which could incur losses on exposure to firms with business models not built around the economics of low-carbon emissions [31]. Climate change mitigation policies to reduce GHG emissions can create costs for carbon-intensive sectors and companies, thereby influencing the credit quality of GHG-intensive borrowers and also credit risks to banks [32]. Ongoing developments in the international climate policy arena show there will be more rigorous future global climate policy regime. Noncompliance with mitigation policies might become reputational risks and therefore credit risks. Hence, both compliance and noncompliance with the mitigation policies will have implications for loan providers, equity investors, and project financiers [32].

Literature establishing the link between climate change and credit risk is growing. Kleimeier and Viehs [33] show a significant and negative relation between CO_2 emission levels and the cost of bank loans. Delis, De Greif, and Ongena [34] observe that banks appeared to start pricing climate policy risk after the Paris Climate Agreement, while Ginglinger and Quentin [35] find that greater climate risk leads to lower leverage in the post-2015 period.

Capasso et al. [36] investigated the relationship between exposure to climate change and firm credit risk and found that the exposure to climate risks affects the creditworthiness of loans and bonds issued by corporates. Similarly, Delis et al. [34] demonstrated that climate policy risk is priced in syndicated loans, especially in sectors related to fossil fuel. Jung et al. [37] provided evidence of the existence of a positive association between the cost of debt and carbon-related risks for firms. Rajhi and Albuquerque [38] submitted that natural disasters are predictive of higher nonperforming loans and higher likelihood of default in developing countries. Battiston et al. [39] found that while direct exposures to the fossil fuel sector are small, the combined exposures to climate policy-relevant sectors are large, heterogeneous, and amplified by large indirect exposures via financial counterparties. Ilhan et al. [40] showed for a sample of S&P 500 companies that higher emissions increase downside risk—the potential losses that may occur if a particular investment position is taken. Monasterolo and De Angelis [41] indicated that investors require higher risk premia for carbon-intensive industries' equity.

5. Integrating climate-related risks into credit risk assessment

There are two approaches for integrating climate-related risks into credit risk assessments. On the one hand, there is a risk approach whose objective is to integrate a new source of risk in order to accurately measure credit risk and assumes that a risk differential between green and brown assets exists; on the other hand, there is an economic policy approach, aiming to foster the transition to a low-carbon economy by shifting credit from brown to green activities [42].

Under the risk approach, the risk-weight factor is recalibrated for all categories of assets to identify the differential due to climate-related risks. The differential should be taken into consideration when determining pricing and capital requirements. When the objective is to adjust capital requirements as an economic policy tool to allocate credit to specific sectors, the accurate level of climate-related risks is not a central concern anymore. This approach rather focuses on channeling credits to facilitate the transition toward a low-carbon economy. The objective is to foster transition by introducing a financial incentive through the capital adequacy regulation without following a risk reasoning [42].

Climate-related risks are expected to be included in all relevant stages of the credit-granting process and credit processing. Specifically, institutions are expected to form an opinion on how climate-related risks affect the borrower's default risk. The climate factors that are material to the borrower's default risk of the exposure are expected to be identified and assessed. As part of this assessment, institutions may take into consideration the quality of the clients' own management of climate-related risks. They are also to give appropriate consideration to changes in the risk profile of sectors and geographies driven by climate-related risks [28].

In quantifying, evaluating, and factoring climate-related risks into credit risk assessment, institutions require risk indicators or ratings for their counterparties that take into account climate-related and environmental risks. This is achieved by identifying borrowers that may be exposed, directly or indirectly, to increased climate-related risks. Critical exposures to such risks should be highlighted and, where applicable, considered under various scenarios with the aim of ensuring the ability to assess and introduce in a timely manner any appropriate risk mitigation measures including pricing [28].

Counterparty credit scoring requires detailed sectoral and geographic metrics to interpret climate-related risks as a view of financial vulnerability, taking into account mitigation measures. The resulting risk score can be used to inform credit decisions and to create a portfolio overview. The score can also be embedded in internal and external climate-related risk reporting (**Table 1**) [43].

1. Defining climate scenarios	2. Estimating economic and financial impacts	3. Translating financial impacts into credit risk measures
"The estimation of the impact of climate change and of the transition to a low-carbon economy on credit risk relies first on the definition of physical scenarios for climate change and for the transition. These scenarios define how climate change will impact the variables that are relevant for economic activities, how a transition will mitigate these impacts and which measures are taken to steer the transition."	"Once the impact of climate change on the variables relevant for economic activities has been estimated, its consequences must be translated into economic terms though macro and microeconomic simulations. This step basically assesses the direct and indirect repercussions of climate change and the transition to a low-carbon economy in economic terms and identifies which actors are affected by them and by how much. Once the economic effects on actors have been identified, the next step is to estimate the impact of these effects on both their cash flows and their balance sheets."	"Based on this assessment of financial impacts on firms and households, the next step is to compute how changes in cash flows and balance sheets will affect their credit worthiness in terms of probability of default and loss given default – and thus also in their credit ratings."

Table 1.
Steps for integrating physical climate risk into credit risk assessment processes [44].

For better integration of climate-related risks into credit risk assessment, Monnin [30] advocates addressing the limitations of historical data; expanding the horizon of credit risk models; finding the right level of data granularity; identifying the relevant climate-related risk exposure metrics; and translating economic impact into financial risk metrics.

6. Climate change and financial stability

Estimates of the aggregate economic impacts of climate change and the costs of mitigation both vary widely and are highly dependent on factors such as core assumptions, model design, sectoral coverage, and scenario selection [45]. On the one hand, available estimates suggest that physical damage from climate change could reach one tenth, or even one fifth, of global GDP by the end of this century, with considerable uncertainties around amplifying dynamics. In terms of current global output, this would amount to USD 8–17 trillion. On the other hand, some estimates suggest the transition to a low-carbon economy will require investment of between USD 1 trillion and USD 4 trillion in constant terms when considering the energy sector alone, or up to USD 20 trillion when looking at the economy more broadly [11].

Dietz et al. [46] employed standard integrated assessment model (IAM) and the climate value-at-risk (VAR) framework to quantitatively investigate the physical impact of climate change on the financial system. They found that without mitigation efforts, physical risks related to climate change could lead to a loss of USD

2.5–24.2 trillion of the value of global financial assets. For the transition risks, estimate by Mercure et al. [47] put the discounted global wealth losses from stranded fossil fuel assets may amount from USD 1–4 trillion.

Physical impacts of climate change as well as the transition toward a resilient low-carbon economy pose significant challenges for macro-financial management, as they can damage the balance sheets of governments, households, firms, and financial institutions due to the adverse and possibly abrupt impacts on investment and economic growth, fiscal revenue and expenditure, debt sustainability, and the valuation of financial assets. In turn, macro-financial risks translate into weakened resilience to physical climate risks and constrained capacity for climate adaptation and mitigation efforts. Transition risks are particularly high for countries that generate a significant share of public revenue from carbon-intensive industries. Lower-income and conflict-affected oil and gas exporters (mostly in Africa and the Middle East) are more vulnerable and less able to manage a low-carbon transition. They have not yet converted hydrocarbon rents into other sources of export revenues needed to grow and diversify [48].

For banks, climate-related risk factors manifest as increasing credit, market, and operational risks [49]. Climate-related financial risks may weaken financial sector balance sheets and induce or amplify macro-financial risks, particularly in the case of shocks. Such shocks could stem from disasters or sudden changes in policy, technology, or consumer preferences. The resulting financial sector losses and volatility in financial and commodity markets can adversely impact funding, liquidity, and lending conditions and weaken financial sector balance sheets, giving rise to negative feedback loops with macro-fiscal implications. Emerging markets and developing economies may be particularly affected, given that their financial markets are less resilient to such shocks [48]. By destroying the capital of firms and reducing their profitability and liquidity, climate change is likely to increase the rate of default of corporate loans that could harm the stability of the banking system [19]. A recent survey by the Bank of England on the preparedness of UK banks for climate change found their planning horizons averaged 4 years, likely too short even to account for likely physical and liability risks [50].

Climate change also has implications for insurance companies on both sides of the balance sheet: as investors and as underwriters. As institutional investors, insurance companies face largely similar transition and physical risks as other asset managers. They are disproportionally affected due to the long-term nature of their equity and infrastructure investments. As underwriters, pricing risks may arise from changing risk profiles to insured assets [48]. According to Lloyd's of London, damages from weather-related losses around the world have increased from an annual average of USD 50 billion in the 1980s to close to USD 200 billion in the past 10 years [51].

Institutional investors will be disproportionately affected by climate change, given their much longer-term investment horizons. In addition to the climate-related risks that affect financial stability, second-tier impacts from climate change (such as food security, social, and political unrest, and biodiversity loss) are likely to be nonlinear, characterized by tipping points, and material over the long term [48]. The Economist Intelligence Unit (EIU) [52] put the value of global stock of manageable assets at risk from climate change till the end of the century at USD 4.2–43 trillion (in 2015 value terms).

Climate change qualifies as a systemic event. A systemic event is defined in economics by three essential elements: a shock, which can be a broad shock simultaneously affecting a wide range of institutions, or a limited shock followed by an important domino effect; contagion effects through a web of interrelations; and the endogenous nature of this shock, meaning that it is caused by cumulated disequilibria over time [53].

Three fundamental reasons at least can justify this transposition of the financial concept of systemic risk to climate change. First, climate change impacts are systemic in nature. They affect the whole planet, in most of its dimensions. They have the ability to profoundly change the earth system as we currently know it. The second is the radical uncertainty. Historical data provide no useful guidance to future climate events or/and outcomes. Finally, the notion of a climate systemic risk at world scale provides a powerful new rationale in the debate on international monetary reform [53].

Climate and financial fragilities reinforce each other. They are intertwined into positive feedback loops so that climate systemic risks also incur financial systemic risks. Financial fragility to external risks may increase climate fragility through negative externality effects. Conversely, climate fragility incurs new risks that may reinforce financial fragility, as **Figure 3** illustrates. The realization of a climate systemic risk translates into potential financial turmoil and this in turn can increase around the provision of the ultimate liquidity [53].

Physical and transition risk drivers impact economic activities, which in turn impact the financial system. This impact can occur directly through, for example, lower corporate profitability or the devaluation of assets, or indirectly, through macro-financial changes [28]. Climate-related risks—in particular, transition risks—are actually closer to being in a state of uncertainty. Further uncertainty is created by the highly interconnected nature of the modern financial system. Interlinkages among financial institutions—both banks and nonbanks—can amplify both positive and negative shocks and significantly decrease the accuracy of default probabilities [54].

Physical risks can cause economic costs and financial losses across different financial portfolios (e.g., loans, equities, and bonds) and also affect the expectation of future losses, which can threaten the solvency of households, businesses, and governments and therefore financial institutions [18]. The exposure of financial institutions to physical risks can trigger contagion and asset devaluations propagating throughout the financial system [18]. Rapid and ambitious transition to low-carbon economy will lead to transition risks with large fractions of proven reserves of fossil fuel becoming stranded assets, with potentially systemic consequences for the financial system. Other fossil fuel-dependent sectors will probably be impacted indirectly as a consequence [55]. The size of the impact depends on the assumptions made about when and how the transition happens and which sectors it affects. The risk is that a sharp reassessment of climate change risks could

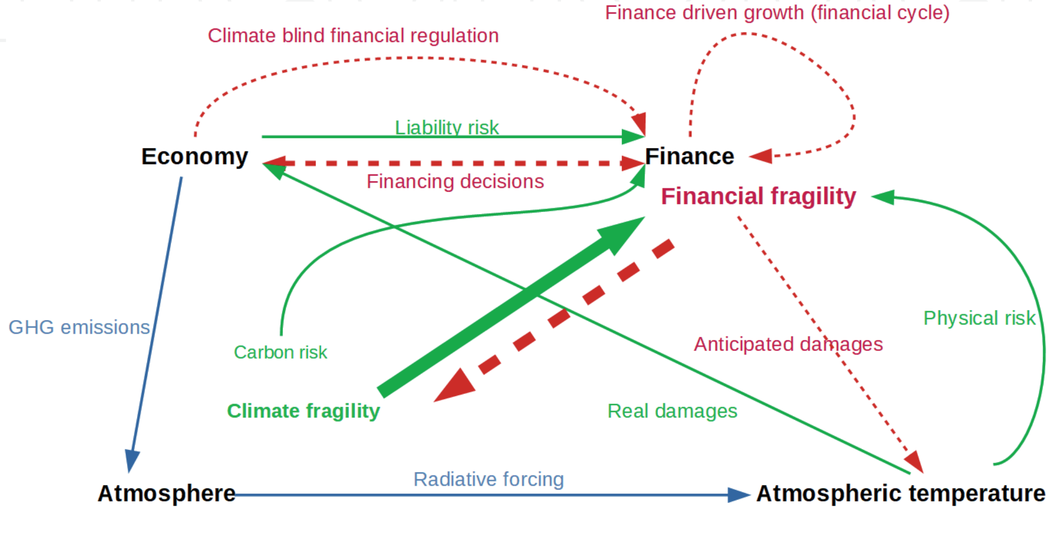

Figure 3.
Relationship between climate and financial fragilities [53].

lead to a financial market reassessment, leading to a spiral of persistent tightening of financial conditions as losses ensue [18].

A wholesale reassessment of prospects, as climate-related risks are reevaluated, could destabilize markets, spark a pro-cyclical crystallization of losses, and lead to a persistent tightening of financial conditions: a climate Minsky moment—involving a rapid, system-wide (downward) repricing of carbon assets which would threaten financial stability [56].

The economic effects of bank losses and asset price deflation can exacerbate climate-induced financial instability [57]. This calls for a collective prudential approach—monetary policies and banking regulations, which intend to act on eliminating possible future outcomes more than on internalizing externality, because of radical uncertainty [53].

7. Climate-related risk management

Risk management has increasingly become a well-established tool for climate change adaptation, given the significant uncertainty about future impacts and the inability to rely on historic data as a basis for current action [58, 59]. Risk management is part of a comprehensive suite of tools for climate change adaptation, with international and national standards being developed to assist governments, businesses, and communities [59].

ISO 14090:2019: Adaptation to climate change—Principles, requirements and guidelines specifies the principles, requirements, and guidelines for adaptation to climate change. These include the integration of adaptation within or across organizations, understanding impacts and uncertainties, and how these can be used to inform decisions. ISO 14091:2019 provides guidance for assessing the risks related to the potential impacts of climate change. It describes how to understand vulnerability and how to develop and implement a sound risk assessment in the context of climate change. It can be used for assessing both present and future climate change risks.

As part of their overall internal control framework, organizations should have an institution-wide risk management framework that extends across all business lines and internal units, including internal control functions [28]. The risk management framework should encompass financial and nonfinancial risks, on-balance-sheet risks, and off-balance-sheet risks, including risks that the institution is currently exposed to and for risks that the institution may be exposed to going forward [28].

Eceiza et al. [43] enumerate five principles of climate-related risk management to include formulation of climate-related risk governance, to ensure the board focuses on the risks and for climate-risk management, and to cascade throughout the organization; tailor strategic plans and business models toward embedding climate-related risks in risk frameworks and capital allocation processes; inject climate-related risk considerations into all risk-management processes to align climate-related risk exposure with risk appetite; periodic scenario analysis and stress tests to assess the organization's resilience; and focus on enablers and build capacity, including technology, data, and talent to manage climate-related risks.

A strategic approach to managing the financial risks from climate change developed by the Prudential Regulation Authority (PRA) (Bank of England) entails governance, risk management, scenario analysis, and disclosure. A firm's board should understand and assess the financial risks from climate change that affect the firm and should be able to address and oversee these risks within the firm's overall business strategy and risk appetite. Firms are expected to employ their existing business strategy and risk management frameworks to address financial risks from climate change, in line with their board-approved risk appetite. Firms should identify, measure, monitor, manage, and report on their exposure to these risks to their stakeholders. Material exposures should be included in their Internal Capital Adequacy Assessment Process (ICAAP) or Own Risk and Solvency Assessment (ORSA). Where appropriate, the PRA expects firms to consider a range of quantitative and qualitative tools and metrics to monitor their exposure to financial risks from climate change. Firms should provide evidence of how material risks will be mitigated and have credible plans or policies to manage these exposures. The management information should enable the board to discuss, challenge, and take decisions relating to the firm's management of the financial risks from climate change. Scenario analysis should also be used to explore the resilience and vulnerabilities of a firm's business model to a range of outcomes, based on different transition paths to a low-carbon economy, as well as a path where no transition occurs. Disclosures should be as insightful as possible, reflecting the firm's evolving understanding of the financial risks from climate change (**Figure 4**) [60].

Figure 4.
Elements of climate-related risk management [60].

Similar good practices of governance and climate-related risk management recommended by the French Prudential Supervision and Resolution Authority (Banque de France) [61] include the following: integration of climate-related risks, including their implementation and monitoring, into the strategy of institutions; the internal organization of institutions, both in terms of the allocation of responsibility over all business lines, and in terms of the structuring of climate risk control, should align with the institutions' strategic orientations; full integration of the material risks induced by climate change into the risk appetite framework of the institution, and also mobilization of appropriate tools to allow for a thorough assessment of these risks; and disclosure of the institution's strategy and its risk management mechanisms with regard to climate change to ensure both a better understanding and a better integration of climate-related risks.

8. Conclusion

Climate change is rapidly proceeding, and climate-related risks are being exacerbated. While the mechanisms of physical climate change and the possible impacts are scientifically well understood, the specific estimates of these impacts are associated with uncertainty.

Climate change will affect all sectors of the economy, and it is relevant to investors and financial institutions, posing an unprecedented challenge to the governance of global socioeconomic and financial systems. Climate-related risks touch on the interests of a broad range of stakeholders across the private and public sectors, impact all the key dimensions of credit risk, and are the main channels through which climate change can affect financial stability.

This chapter establishes the need for organizations to have a holistic, well-documented, and institution-wide risk management framework that extends across all business lines and internal units to manage their climate-related risks.

In all, the chapter provides a preliminary view on how climate change can cause credit risk and financial instability. As such, the chapter does not comprehensively address the complex tasks of managing climate-related risks in organizations. A more comprehensive study is required on what strategies and approaches are needed to manage uncertainties and risks that are an integral part of climate change in organizations.

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