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Financial Stability and Climate Change

Abstract: Fighting climate change is one of the biggest challenges in the 21st century. Climate change that leads to global warming has been increasingly visible in our environment. Extreme weather conditions such as hurricanes, floods, and droughts have been escalating and their acceleration can be expected in the future. They cause changes in sea levels, epidemics, large fires, etc. Increasingly, we are witnessing minor or major damage caused by these extreme weather conditions. Numerous studies have proven that climate change has negative impact on economic growth and prosperity. However, this paper starts from the premise that in addition to unequivocally identified threats, climate change also creates opportunities.

The paper reaches a conclusion that climate change can adversely affect balance sheets of financial institutions. Therefore, climate change is a source of financial risk and thus a part of the mandate of central banks and supervisors in preserving financial stability. This type of risk has not been given enough attention by either supervisors or financial institutions over the past period. This paper develops a model for managing financial risks as a result of climate change.

Key words: climate change, financial stability, financial risks, management

JEL Code: Q54; E58

1. Introduction

Global temperatures have risen over the last half century at an unprecedented pace in the last twenty thousand years.

The concentration of greenhouse gases is at a level not witnessed in the past eight hundred thousand years. Global warming is leading to major climate change and continuous greenhouse gas emissions will cause further global warming. It leads to irreversible consequences such as heat waves, hurricanes, floods, droughts, rising sea levels, fires, epidemics and more. The oceans have warmed, the amount of snow has been decreasing, and the ice has been melting at the poles. All scientific studies indicate that these extreme events will be more frequent in the future as global temperatures rise and given that there is no mature technology that can reverse this process.

Since the 1980s, the number of extreme weather events has more than tripled (Munich Reinsurance Company, 2018). The number of catastrophes caused by natural hazards increased from 249 in 1980 to 820 in 2019 (Lagarde, 2020). Since the beginning of the 20th century, the global mean sea level has risen 17-21 cm, and if no action is taken to limit global warming, the sea level is projected to rise by almost 80 cm by the end of this century (IMF, 2018). From 2016 through 2018, the United States experienced 45 natural disasters that each caused at least USD1 billion in losses (Gelzinis & Steele, 2019). The IMF (2018) estimates that hurricanes and typhoons caused damage of USD 548 billion (constant 2010 dollars) worldwide during 2000–2014. According to a study by the Network for the Greening Financial System (2019), during 2018, 62 million people were affected by natural hazards and 2 million people had to move.

The conclusions of the Intergovernmental Panel on Climate Change indicate that more than half of the temperature increase since 1950 can be attributed to human activity (IPCC, 2014). Therefore, everything suggests that further global warming will largely depend on our ability to restrain greenhouse gas emissions as its main cause.

Even this year's coronavirus pandemic can be explained by climatic factors if the assumption made by most doctors and the WHO is accepted that this is a virus that has been passed from animals to humans. Namely, as a result of human activities and climate change, over 90% of plant and animal species have disappeared. In such conditions, the natural habitat for the development of viruses vanishes and, in order to prolong their existence, they adapt to new hosts, and the species that has proven to be the most resistant and adaptable to all historical changes are humans. Therefore, it is natural that viruses sought and adapted to the new habitat that can ensure the continuation of their existence.

Today, there are a number of global actions that should act in a positive direction when it comes to climate change. Certainly the most important is the Paris

Agreement which aims to limit the rise in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to the rise to 1.5°C. The role of the UN`s Intergovernmental Panel on Climate Change (IPCC) in assessing the science related to climate change should also be emphasized. Then there is the EU with the goal of achieving net zero emissions or climate neutrality by 2050. The Europe Investment Plan was created for this purpose and it is supposed to mobilize 1 trillion euros in the next 10 years. Another important role is that of the Network for the Greening Financial System (2018) which brings together central banks and supervisors on a voluntary basis and issues recommendations which are not binding but are aimed at inspiring all central banks and supervisors and relevant stakeholders to take the necessary measures to foster a greener financial system.

This paper makes at least three contributions to the existing literature. First, in contrast to the classical literature which talks mainly about two types of risk, physical and transition, this paper introduces a third indirect effect as a result of economic links with industries that will be affected by climate change. Second, in contrast to the literature, which mainly points to the economic harms of climate change, this paper also points to the possibilities and economic benefits that climate change creates. Third, the paper develops a model for managing financial risks that arise as a result of climate change.

The paper consists of four parts. After introductory remarks on climate change, the second part analyses economic consequences of climate change. The third part deals with the impact of climate change on financial stability and it develops a model for managing financial risks as a result of climate change. The final part gives concluding remarks and policy recommendations.

2. Economic consequences of climate change

A huge number of studies have confirmed that global warming reduces well-being (Gelzinis & Steele, 2019; IMF, 2018; Dafermosa et al., 2018; Burke & Emerick 2016; OECD, 2015; Burke, Hsiang & Miguel, 2015; Lanzafame, 2014; Lobell, Schlenker & Costa-Roberts, 2011; Schlenker & Roberts, 2009). Climate change could have large impacts in terms of reducing the potential of the economy to grow in the future, by reducing labour productivity and diverting resources from investment in current productive capital and innovation to climate change adaptation (NGFS, 2018). However, on the other hand, the IMF (2018) points out that there is growing evidence that investors and financial markets do not fully understand, at least not immediately, the impact of weather shocks on output and productivity.

Climate change affects economic well-being through many channels: declining agricultural yields, declining productivity of workers exposed to rising temperatures, escalating health care costs, physical destruction of capital as a result of fires, floods and rising sea levels, losing biodiversity and adverse spillovers from affected countries. It also jeopardizes macroeconomic and fiscal stability through the destruction of infrastructure, increasing the amounts of necessary subsidies to the economy and social welfare, which all impact economic growth, public debt and its financing costs, employment, inflation, and the like. In addition, all this can lead to an increase in the prices of certain products and services such as agricultural products, insurance, water, etc.

As Sevillano and González (2019) point out, huge financial resources are being spent on exploiting new reserves, despite the fact that current reserves already exceed the carbon budget (this is known as "wasted capital") and that only a fraction of fossil fuel reserves are burnable if the rise in temperature is to be limited to 2°C by 2050. Görgen *et al.* (2017) have found that companies considered to be "brown" (that is, with a higher exposure to carbon risk) perform worse on the stock exchange, compared with those that are "greener".

Temperature rise has a negative effect on both labour supply and labour productivity. A number of studies have shown that productivity is lower at higher temperatures. Rising temperatures also affect an increase in mortality and disease (e.g. heart attack). Further adaptation to climate change also means reallocation of the labour force, so instead of dealing with the creation of new production, a part of the labour force is focused on jobs aimed at reducing the negative effects of climate change (e.g. building riverside embankments to prevent floods).

The exact impact of climate change on GDP and economic performance is difficult to determine and there are a number of different estimates of what will happen if adequate action is not taken. The OECD projection (2015) indicates that the impact on annual GDP is projected to rise over time to likely levels of 1% to 3.3% by 2060, and that the damage could build up to 12% by 2100. Burke et al. (2015) estimated that climate change could reduce GDP by 23% in 2100. Gelzinis and Steele (2019) suggest that if temperatures rise to 4 degrees Celsius above preindustrial levels over the next 80 years, global economic losses could mount to USD 23 trillion per year. Research conducted by Dietz et al. (2016) found that almost 2% of the world's financial assets are at risk if the global mean surface temperature rises by 2.5°C compared to pre-industrial levels. If sea levels rise by 6 feet by 2100, as has been estimated, about USD 900 billion worth of U.S. homes would be literally — and in turn financially — underwater (Gelzinis & Steele 2019). Lagarde (2020) estimated that overall economic losses increased from around USD 60 billion in 1980, to USD 150 billion in 2019, with a peak of USD 350 billion in 2018.

It is obvious that different regions and different countries will have different levels of damage. The OECD (2015) found in its study that 23 of 25 analysed regions would suffer negative economic consequences. However, the level of these consequences will vary from country to country and it will largely depend on how much individual countries have been affected by climate change, how many of them will be able to adapt to it through the construction of climate change protection systems, adapting their production structures, consumer behaviour and adapting to international trade flows. Countries to be most affected would be those with low level of production diversification, less climate resilient public infrastructure, less capital market flexibility and lower capacity to adapt are expected (Network for the Greening Financial System 2019).

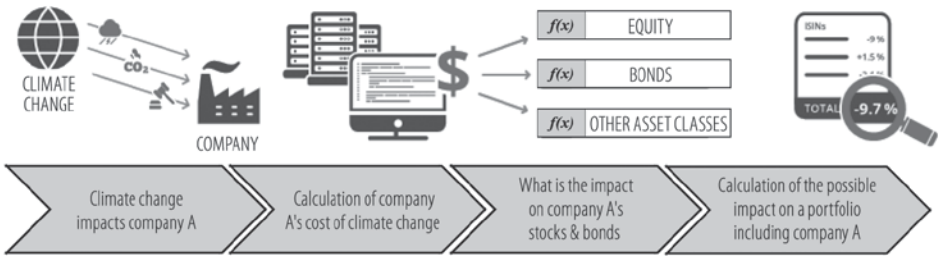
Also, different industries and sectors have different degrees of sensitivity to climate change. It is usually pointed out that agriculture, tourism, as well as branches based on carbon fuel are the ones most affected due to the expected tightening of standards and the introduction of carbon tax. In this context, the possibility that industries, workers, and other stakeholders associated with fossil fuels and other industries that cause global warming can organize and resist climate change management should not be overlooked (IMF, 2019). Table 1 shows the potential impact of climate change on different sectors.

Table 1: Impact of climate change on observed sectors

Sector	Economic impact
Agriculture	- Reduced yiel - Loss of agricultural land
Fishery	- Lower fish catch
Health	- Increased medical expenses
Energy and industry	- Carbon tax - Closing plants with large CO_2 emissions - Change in the structure of energy generation (green energy growth)
Tourism	- Change in tourism flows
Public sector	- Increased costs of investment in damaged infrastructure - Growth of subsidies to the economy - Growing social welfare expenses
Construction	- New standards aimed at increasing resilience to negative effects of climate change - Difficult working conditions at elevated temperatures
Financial sector	- Increase in bad loans and write-offs - Growth in paid insurance premiums - Loss of value of individual financial instruments
All sectors	- Capital losses due to floods and hurricanes - Capital losses in the coastal areas due to rising sea levels

In that context, the Task Force on Climate-related Financial Disclosures scheme is very telling, showing the impact of climate change at the level of an individual company, as well as companies having in their portfolios shares or securities of companies affected by climate change.

Figure 1: Impact of climate change



Source: TFCD (2019) Task Force on Climate-related Financial Disclosures: Status Report, retrieved from https://www.fsb-tcfd.org/publications/tcfd-2019-status-report/

However, what is neglected in other studies is that climate change also provides opportunities. It is the so-called "Porter Hypothesis" which was formulated in the mid-1990s and completely neglected in recent works dealing with climate change. According to the Porter hypothesis (Porter & Linde, 1995), strict environmental regulations can induce efficiency and encourage innovations that help improve commercial competitiveness. It is now obvious that there are branches that are developing rapidly on this basis. Currently, one of the most promising industries is the production of car batteries that significantly contribute to reducing CO_2 emissions. The introduction of stricter technological standards and carbon tax can give a great stimulus to the research in new energy sources. It is already widely speculated that a new cheap and environmentally friendly source of energy could be the most abundant element - hydrogen. Furthermore, it should not be overlooked that global warming will cause certain zones, especially those in cold and polar regions, to become more receptive to life. Ice melting or the presence of snow cover in shorter periods over the year could provide additional agricultural land as well as access to the exploitation of raw materials that was not possible before. All this clearly indicates that climate change will create both winners and losers.

3. Climate change impact on financial stability

Climate change is one of the many structural changes that affect the financial system. While the exact outcomes, time horizon and future pathway are uncertain, there is a high degree of certainty that some combination of physical and transition risks will materialise in the future (Network for the Greening Financial System, 2019).

The essence of the problem was excellently reflected by the Bank of England (2018): "The future will be past. Climate change is a tragedy of the horizon which will impose major costs on future generations that the current one has no direct incentive to fix. The catastrophic impacts of climate change will be felt beyond the horizons of most actors. Once climate change becomes a clear and present danger to financial stability it may already be too late to stabilise the atmosphere".

"The increase in the brutality and frequency of hurricanes, droughts, floods, fires, and other environmental shifts could decrease the value of damaged assets and put a strain on borrowers' ability to repay lenders—leading to increased levels of default and losses on these credit portfolios" (Gelzinis & Steele, 2019). If the value of assets does not accurately reflect climate-related risks, a sudden correction could result in losses to financial institutions, which could in turn reduce lending in the economy (Brainard, 2019). Therefore, the goal is to create a financial system that will be resilient to climate risks.

Some studies (mostly on European banks) have concluded that the banking system is beginning to take climate risks into account although they have found significant shortcomings in the identification, measurement and management of banks' exposure which makes predictions regarding their vulnerability to these risks difficult (Sevillano & González 2019). The key problem is that some of these risks, primarily the transition ones, materialize in the long run, while the financial system generally takes into account the risks in the short run. The key problem is that some of these risks, primarily the transition ones, materialize in the long run, while the financial system is generally concerned with risks in the short run. The Governor of the Bank of England, Mark Carney, called this phenomenon the "tragedy of the horizon". The "tragedy" here lies in the fact that when these risks become clearly visible it will be too late to prevent them and so keep global warming below 2°C (Carney, 2015).

Climate risk does not lead to any new type of risk in financial institutions but translates to the existing ones: credit risk, market risk, and operational risk. **Market risk** is the risk of unfavourable movement of market prices. Banks are the

ones most exposed to it through the risk on securities they have. For example, climate change could increase sovereign risk that could further lead to deterioration in a country's credit rating, ultimately affecting the value of government securities held by banks.

Operational risk in banks can occur as a result of jeopardized business continuity of a financial institution due to some extreme events such as flood that would prevent its operation or that of any of their branches.

Credit risk can manifest in different forms. If new technologies lead to lower costs, companies that do business using outdated technologies could incur higher costs, thus jeopardizing their profitability and having higher default risk. The introduction of carbon tax or a ban on the use of some technologies that emit large amounts of CO_2 has exactly the same effect. In the event of a flood or a hurricane, it can lead to destruction or a significant reduction in the value of collateral. Extreme temperatures lower agricultural yields and productivity in some sectors, especially in those involving working outdoors such as construction. And finally, we should not ignore, of course, the losses that can be faced by companies whose business is not directly affected by climate change, but that of their key partners is. All this reduces debt repayment capacity of the affected companies.

Climate risk affects banks over three negative and one positive channel. **Physical risk** occurs with weather-related events, such as droughts, floods, storms and sea-level rise and increasing temperatures. Financial institutions can be affected by physical risk directly, for instance by reduced value of assets and collateral, increasing insured damages, or by disrupting their own business operations. It can materialize directly through operational risk or indirectly through portfolio as credit risk and market risk, depending on location, sectoral diversification, property insurance, and the like.

Transition risk is a financial risk that arises as a result of adjusting to low carbon production. If governments impose carbon tax or restrictions on CO_2 emissions, this could lead to an increase in the costs for companies from carbon-intensive industries. This risk can also emerge with technological innovations creating a new technology that reduces greenhouse emissions such as the transition from classic petrol and diesel engine cars to electric cars. Also, a potential risk for these companies is raised awareness of consumers who would start turning to those companies with lower emission production. Actions of green movements to boycott these producers could also have an impact. The financial system could be destabilized by potentially rapid losses to carbon-intensive assets caused by the urgently needed transition to a greener economy, so governments could tight-

en standards. This all means that carbon sensitive assets would lose value. This would result in large losses for shareholders of these companies, banks that finance them, as well as holders of their securities and corporate bonds, thus significantly reducing their debt repayment capacity.

Indirect risk is a risk that is almost completely ignored in scientific studies. This risk occurs with companies whose business is not directly affected by climate change, but the business of their key partners is at risk and this can lead to disruptions of global supply chains. For example, a catering company is not directly affected by climate change, but if it prepares meals e.g. for workers working in a coal mine which may be closed in the future, then its business is already affected by climate change. This impact can also manifest through disrupted trade flows, which has also been confirmed by a number of studies (Gassebner et al., 2010; Oh and Reuveny, 2010).

Table 2: Climate change impact on the financial system

	Credit risk	Market risk	Operational risk
Physical	- Increasing flood risk to mortgage portfolio - Declining agricultural outputs	- Re-pricing of sovereign debt	- Impact on business continuity
Transition	- Tightening technological standards affects company business - Carbon taxes lead to growing expenses - Prohibition of use of outdated technologies - Long-term investments become unprofitable - Innovations jeopardize companies` business based on outdated technologies	- Tightening climate-related policy leads to re-pricing of securities	- Changing sentiment on climate issues leads to reputational risk
Indirect risk	- Losses for companies connected with firms affected by climate change	- Re-pricing of securities	- Low probability of negative impact (jeopardizing of a bank`s supply chains)

Source: Author`s modifications based on the Bank of England`s (2018) Transition in thinking: The impact of climate change on the UK banking sector, Bank of England, London.

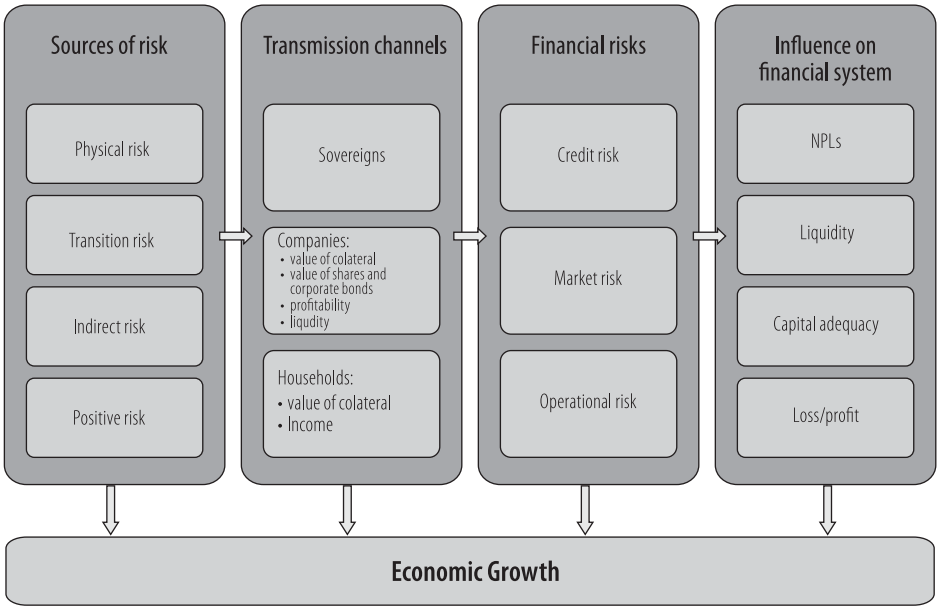
Finally, all these risks can affect a lower level of lending activity which can ultimately lead to slower economic growth and lower employment.

However, we should not overlook that, as already mentioned, climate change could result in the emerging of companies for which this would be a chance to

enter the market and develop rapidly. This is also an opportunity for the financial market outreach and expansions. This impact of climate change can partially compensate for the negative impact of previously analysed risks and it is basically a positive risk.

Figure 2 shows all the interdependencies and channels of the climate change impact on financial stability and economic growth.

Figure 2: Climate change and financial risk implications



We can conclude that there is insufficient understanding of the nature of these risks and their impact on business by both supervisors and financial institutions. Given that financial markets and institutions underwent radical transformation and a sudden expansion induced by general trends in deregulation, liberalization, globalization, as well as computer technologies advances over the past several decades, the situation gained additional importance and implications (Fabris, 2019). With the exception of a small number of countries, such as the Netherlands and the UK where analyses of the financial system`s exposure to climate risk or carbon-intensive industries have begun, they are not involved in risk management at all. As pointed out by NGFS (2018), authorities and financial institutions need to develop some new analytical and supervisory approaches, including those based on forward looking scenario analysis and stress tests to re-

duce future financial risk although historical data is not sufficient to estimate this impact. The goal is to determine the resilience of the financial sector to climate change and to increase it. There are a number of factors underlying this situation, but the lack of disclosure by companies, absence of a common taxonomy for classifying what is considered green, and the lack of experience quantifying climate risks and opportunities, are probably the main factors that need to be addressed most urgently (Sevillano & González, 2019).

There is no doubt that climate change threatens financial stability, and financial stability is the objective of central banks which will become increasingly important in the future (Fabris, 2018). The nine-step framework model for climate risk management, developed by the author of this paper, is presented below.

Step 1 – Development of the matrix of sectors exposure. The problem, however, is that there is no universal taxonomy for defining which activities or financial instruments could be considered environmentally sustainable (green) or harmful (brown) (Guizio et al., 2019). It would be best if such classification were to be developed at the global level and then adjusted at national levels. However, until such a universal classification is reached, national authorities should develop their national classifications of green and brown sectors, covering also sectors that are potentially exposed to physical risk. The sectoral classification of physical risk exposure is very challenging because it addresses potential risk that may or may not materialize, especially in the near future, and it depends on the geographical location, exposure of a particular sector to climate change, its resilience, connectivity with other sectors, and the like. This taxonomy also makes it easier for investors to focus their investments on long-term sustainable programs, as well as for banks to assess the riskiness of their portfolio. At this stage, it is also important to improve supervisors` knowledge of financial risks as a result of climate change. "A relevant analysis needs to focus on long-term consequences while accounting for historically unprecedented risks and the possibility of major irreversible changes" (NGFS, 2018).

Step 2 – Macroeconomic modelling. This is not at all simple because, as De Nederlandsche Bank (2018) pointed out, it requires the modelling of dynamic interactions between the macroeconomy, the financial system, climate change, and environmental policies. Here we should add positive effects (risks) as well. The aim is to develop a model that would measure climate risks and their potential positive and negative implications for national economy.

Step 3 – At this stage, companies and assets should be classified according to the established taxonomy as per their exposure to climate risk. Firms should identify, measure, monitor, manage, and report on their exposure to these risks. TFCD

(2019) identified four major categories through which climate-related issues may affect a company's financial position: revenues, expenditures, assets and liabilities, capital and financing.

It is necessary to assess the following:

- Exposure of the financial institution to the operations of firms in the high carbon sectors,
- Exposure to firms that may be exposed to extreme weather conditions (floods, droughts, hurricanes, and the like),
- Exposure of the financial institution to enterprises whose business is not directly related to climate change but it is to some extent related to firms that are exposed to climate change, and
- Positive risk, i.e. exposure to firms that are winners.

Step 4 – The identification of scenarios is carried out at this stage. Scenario analysis is a process for identifying and assessing a potential range of outcomes of future events under conditions of uncertainty. It is best to develop more alternative scenarios.

Step 5 – Asset impact identification provides asset managers and owners with an approach to define financial impact on an asset and to identify options to improve the asset resilience. The asset impact assessment is used to build risk and contingency scenarios within in-house asset financial models. This will enable stress testing and opportunity identification through quantifying the potential financial impact. Risk classification depends not only on the exposure of a company but also on its ability to adapt, which is difficult to quantify and assess. The key issue is the difficulty of identifying which assets are exposed to climate change. Financial institutions should explore and develop an understanding of how climate risk (positive and negative) may affect its operations, strategies, and financial performance over time.

Step 6 – Integration of climate risks into the prudential framework and stress testing. This means that regulators would first set supervisory expectations regarding governance, risk management and provisioning. At this stage, it should be determined whether climate risks are understood, identified, discussed by the board[1], and integrated into risk management by financial institutions. Stress testing would check the sensitivity of individual financial institutions to climate risks.

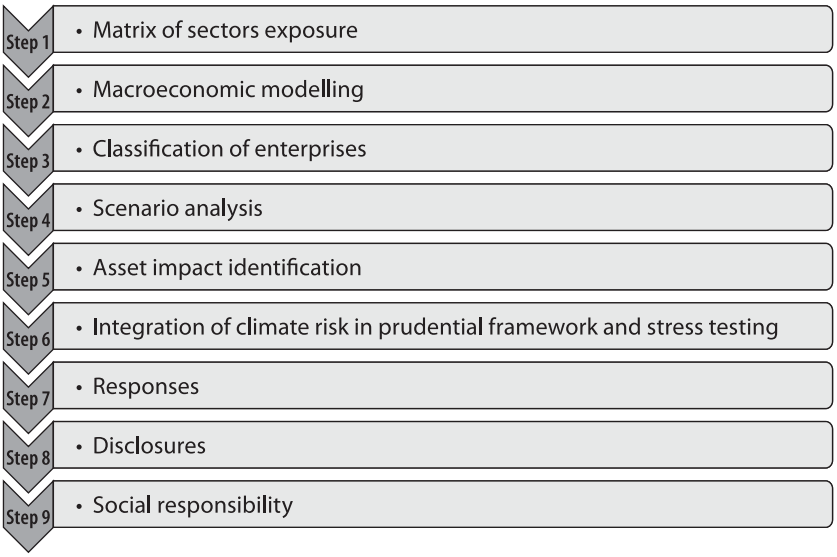
[1] The role of the board of directors is very important as it needs to discuss, understand, and consider climate-related risks from the aspect of risk management, and take them into account when formulating business strategy.

Step 7 – This step involves the development of potential responses by a financial institution following the results of stress testing and supervisory findings. It should be verified whether the risks in the portfolio correspond to the firm`s risk appetite, whether the financial institution has sufficient capital to absorb climate risks, the impact on liquidity, adequate provisioning, etc.

Step 8 – Investors, financial institutions, general public and others would benefit from a more standardized framework for environmental disclosures. When it comes to the disclosure, the model developed by the Task Force on Climate-related Financial Disclosures (TCFD, 2019) should be accepted. The Financial Stability Board established an industry-led task force, TCFD, which developed consistent climate-related financial disclosures (TFCD, 2019). This should lead to internationally consistent climate-related disclosures.

Step 9 – Social responsibility. It involves actions by both regulators and financial institutions. At this stage, it is necessary to engage with clients to understand long-term climate risks they face, as well as public support for actions to prevent climate change. Companies should describe to stakeholders how well their strategies, including financial and operating plans, might perform over a range of plausible future climate state.

Figure 3: Climate risk management model



4. Conclusions and policy implications

Climate change is threatening our planet, the business of a number of companies, as well as the standard of living of a large number of inhabitants. Going forward, it is reasonable to expect that all countries will increasingly face negative effects of climate change. Also, there is great uncertainty about the effects of climate change, as well as how the environment will react. Actions taken so far have not yielded satisfactory results, but the Paris Agreement seems promising.

Regardless of a growing economic awareness of climate change, it appears that a sufficient level of global awareness about all the dangers and why it is necessary to take measures to limit greenhouse gas emissions as soon as possible has not yet been reached. The reason for this is probably that economic damage as a result of climate change is sporadic, more pronounced in the long run, and there is a misconception that these one-off events are unlikely to recur in the future. On the contrary, the intensity of their action can only mount up in the future. In other words, the problem is that it is necessary to bare costs today in order to repair the major damage in the future. That is why it is difficult to convince the public to invest today for the benefit and well-being of future generations. However, if we have created a high level of public debt today, which means that our current spending will be repaid by future generations, then investing in preventing climate change is a way to repay them.

Climate change increases the likelihood of credit default, which in turn could jeopardize financial stability. As a result of growing bad loans, climate change can lead to a decline in lending activity, which ultimately leads to slower economic growth, lower employment, and a negative impact on welfare. However, the problem is that the management of financial risks arising from climate change is very rarely exercised both by financial institutions and their supervisors. Therefore, this paper develops a model for managing financial risks arising from climate change. As Luburić points out (2019), every organization that strives to survive, to develop and to be sustainable must be ready to face all the challenges that today's turbulent and uncertain times carry with them.

The key recommendation, which goes beyond the framework of financial stability, is that it is necessary to continue with mitigation policies in order to reduce the emission sources of climate change. In this context, it is necessary to continue with the implementation of the Paris Agreement.

It is very important that budgets, on the global level, provide sufficient funding for climate change mitigation, subsidies for the transition to technologies reduc-

ing global warming, and funding for strong resilience to climate-induced events. It is useful to form climate change councils at national levels to be tasked with analysing the impact of climate change, proposing measures to reduce it, and increasing the system resilience.

When it comes to the financial system, an important policy recommendation is that national authorities insist on the urgent inclusion of climate risks in their supervisory frameworks. In order to implement this, it is necessary to increase the level of supervisory understanding of the nature of these risks and their implications. Additional research is needed on the likely future implications of these risks, as well as the exposure of individual sectors.

Also, it would be useful to supplement Basel III with climate risks.

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