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Biodiversity, Ecosystem Services and the Banking Industry

Exploring the Scale of Interdependency and Potential Risks

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Abstract

Biodiversity loss and ecosystem service (BES) degradation are translating into different risks for financial institutions which are not accounted for in a sufficient and adequate manner. Being a topic outside its core expertise and foci, the financial sector is lacking assessment methodologies for BES risks. Therefore, the European financial sector is lacking up-to-date estimations on the scale of interdependency between BES risks and investments of banks.

The thesis at hand aims to address this knowledge gap by estimating the value at risk due to BES dependency and related impacts of equity holding portfolios across European banks and by identifying the main sources of uncertainty when estimating the value at risk.

From a methodological point of view, the thesis used the ORBIS and EIKON Refinitiv databases to calculate equity holding portfolios for different banks. This was matched with BES dependency and impact risk materiality ratings on GICS subindustry level extracted from the ENCORE database. In addition, the thesis used different case studies from existing BES risk assessments in the EU financial sector.

The findings show that the largest EU banks have extensive financial operations that either highly depend or have high impacts on BES. The average share at risk lies at 27.21% (or USD 48.48 billion) for BES dependency and 23.55% (or USD 41.99 billion) for BES impact of the equity portfolio. Major sources of uncertainty of the analysis are missing or incorrect data, the broad materiality rating and the final risk calculation.

From a methodological perspective, several important elements for a sufficient BES risk assessment methodology are identified in the thesis. The most important ones are the completeness of the assessment (taking into account location, all environmental pressures and all asset categories) and standard metrics accompanied by a strong regulatory framework.

Keywords: BES, Ecosystem Services, Biodiversity loss, Banks, Risk assessment, Equity portfolio

Executive Summary

Businesses around the globe depend on or impact biodiversity and ecosystem services (BES) and are therefore subject to different risks as biodiversity is decreasing globally. Complex assessments have calculated the cost of BES degradation for the global economy. Between 1997 and 2011 the global economy might have lost between USD 4.3 trillion and 20.2 trillion due to BES loss (Costanza et al., 2014). For the future, research shows that global GDP could decline by 0.67% per year due to BES loss (Roxburgh et al., 2020). As banks are an intermediary between different economic stakeholders, they are connected to businesses through investments and loans (Allen et al., 2014). Therefore, BES risks can impact banks as well (OECD, 2019).

Research shows that until now, a proper risk assessment of these risks is not done by the European banking sector and it is required to better understand these risks and the exposure of banks towards them (NGFS, 2018; McCraine et al., 2019; CDC Biodiversité, 2019b; Bassen et al., 2019; De Nederlandsche Bank, 2020a; WWF, 2020; European Central Bank, 2020b). As BES risks are much more complex than climate risks, no risk assessment methodology has been adopted widely until now and more research and understanding is required to develop such a methodology (NGFS, 2020; Finance for Biodiversity, 2021). One way to increase knowledge is to show ranges for the value at risk due to BES risks. Initially, this can focus on parts of BES risks as first indications are so rare. The Dutch Central Bank has calculated the ecosystem service dependency for the Dutch financial sector (De Nederlandsche Bank, 2020a) but no research has done so for the whole European banking sector.

The objective of the thesis is to assess the dependency on and impact of BES by European banks in their equity portfolio and understand the requirements and uncertainties of such an analysis better. The thesis answers the three research questions "What is the estimated scale of the equity holdings in a bank portfolio which are dependent on and impacting BES?"; "What are the main sources of uncertainty in the analysis of equity holdings?" and "What are the main elements that a tool/methodology for analyzing bank equity holding portfolio in relation to BES should contain?".

From a methodological point, the thesis combined a quantitative risk analysis of equity holdings with the analysis of case studies in the European banking sector. For the equity holding analysis data on equity holdings was obtained from the two databases Orbis and Refinitiv EIKON. These were matched with BES dependency and impact materiality ratings which was obtained from the ENCORE database. With the information on equity holdings, the portfolios were calculated for the different banks on a GICS subindustry level. This was then matched with a calculated materiality rating for each GICS subindustry with the data from ENCORE and a calculation method used by the World Economic Forum (World Economic Forum, 2020b) and Swiss RE (Swiss Re, 2020a).

The results show that a significant part of the equity portfolio of the 25 largest European banks is either highly depending (around 25-30 %) or highly impacting (20-25%) BES. For the dependency risk, the weighted average value at risk for the 25 banks is USD 48 billion with the UBS Group reaching the highest value of USD 87 billion. For the impact risk, the weighted average value at risk for the 25 banks is USD 41 billion with the UBS Group reaching the highest value of USD 73 billion. The main uncertainties in this analysis result out of missing or incorrect data on equity holdings, the broad materiality rating on sector basis used by ENCORE and the final risk calculation for each subindustry.

The case studies showed that a well-functioning tool to assess BES risk in the equity portfolio of banks requires the following elements. A clear metric is required that includes all aspects of BES and allows to compare different industries or countries. This metric must be widely

accepted in the financial sector so that only one metric is used everywhere. The tool must take all important pressures of BES into account and allow the assessment for dependency and impact. It should also be able to show results for different asset categories so that it can be used widely. Besides all different BES pressures, it is also important that the tool takes into account important variables that distinguish business operations like the location, the sector and mitigation policies.

BES dependency and impact are an important part of financial risks for banks that must be accounted for in the correct way to lead to a better financial sustainability of banks. To assess the BES dependency and impact in a better way, future analysis should focus on obtaining better data sources, preferably directly form financial institutions. Future research should also obtain data on BES dependency and impact materiality ratings that takes locations into account and distinguishes between single businesses and not only between different subindustries. To enhance the development of a better risk assessment tool, further regulation is needed that defines BES risks and gives banks tools, methodology and definitions at hand to assess BES risks in the future.

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Abbreviations

Text style 'Abbreviation intem'

BaFin	German Federal Financial Supervisory Authority
BCBS	Basel Committee on Banking Supervision
BES	Biodiversity and ecosystem service
BFFI	Biodiversity Footprint for Financial Institutions
CDP	Carbon Disclosure Project
ENCORE	Exploring Natural Capital Opportunities, Risks and Exposure
ECB	European Central Bank
ESV	Ecosystem service value
GBS	Global Biodiversity Score
GICS	Global Industry Classification Standard
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
MSA	mean species abundance
NACE	Statistical Classification of Economic Activities in the European Community

NGFS	Network of Central Banks and Supervisors for Greening the Financial system
PDF	potentially disappeared fraction of species
TNFD	Taskforce for Nature-related Financial Disclosure
UNEP-FI	United Nations Environment Programme Finance Initiative
UNPRI	United Nation Principles for Responsible Investment

1 Introduction

The introduction will describe the background of the topic which leads to the knowledge gap this research aims to target. Then the research questions, the scope and its limitations are presented.

1.1 Background and significance

Ecosystem services are often defined as the benefits humans gain from ecosystems (Boyd & Banzhaf, 2007; Costanza et al., 1997; Daily et al., 1997; Millennium Ecosystem Assessment, 2005; Fisher et al., 2009; TEEB, 2012; Costanza et al., 2017) and are grouped into four groups: provisioning, regulating, cultural and supporting ecosystem services. Examples for each are timber and fish (provisioning), pollination (regulating), coral reefs for tourism (cultural) and nutrient cycles (supporting) (Millennium Ecosystem Assessment, 2005; FAO, 2021b, 2021c, 2021d, 2021a). Ecosystem services rely on biodiversity and are therefore strongly connected (Cambridge Conservation Initiative, 2020; De Nederlandsche Bank, 2020a; Hanson et al., 2012; United Nations, 1992; UNPRI, 2020; WWF, 2020). This thesis uses therefore the term biodiversity and ecosystem services (BES) and ecosystem services in an interchangeable manner.

Businesses can benefit from ecosystem services through the facilitation of operations (like pollinating crops or controlling predators and parasites in ecosystems), the supply of raw materials (such as timber, wool, food, fresh water or medicinal resources), water purification or cultural services (like contribution to education or tourism) (Millennium Ecosystem Assessment, 2005; FAO, 2021a, 2021b, 2021c, 2021d).

Though the value of ecosystem services is difficult to quantify (Newton et al., 2018), a number of studies have broken down the financial values delivered by ecosystem services for different products or industry sectors. Examples are (in comparison, the GDP of Sweden in 2019 was USD 530 billion (World Bank, 2021)) forest products like timber or paper which account for USD 247 billion of global trade exports (FAOSTAT-Forestry database, 2017); the pharmaceutical sector where 25-50% of products are based on genetics compounds derived from nature (IPBES, 2019); the value of the global fishery sector which is estimated to be worth USD 362 billion (FAO, 2018) or the value of soil biodiversity and their resulting ecosystem services, which is estimated to lie between USD 1.5 trillion to 13 trillion (Data European Soil Centre, 2021).

Costanza et al. have estimated the annual value of ecosystem services to be around USD 125 trillion to 140 trillion (Costanza et al., 2014). Regarding inherent uncertainties, the study provides a strong indication that ecosystem services are of great monetary value for humans. Constanza's estimations from 2014 are similar to a recent OECD publication from 2019 and equals to one and a half times the global GDP (OECD, 2019). Another publication by the World Economic Forum shows that more than half of the worlds GDP (USD 44 trillion) is moderately or highly depending on ecosystem services and natural capital assets (World Economic Forum, 2020b).

However, at the risk of oversimplification, the ongoing unsustainable economic growth (both production and consumption patterns) of humanity; which is reinforced by climate change is leading to the reduction of productivity of ecosystem services (Costanza & Daly, 1992; Millennium Ecosystem Assessment, 2005; Dasgupta, 2008; UNEP, 2016; Maxwell et al., 2016; van der Geest et al., 2019). While the global economy has been thriving between 1992 and 2014, which can be seen by the doubling of the produced capital per person and an increase of 13%

of the capital per person, studies also show that the stock of natural capital per person has decreased by 40% (Dasgupta et al., 2021). The Millenium Ecosystem Assessment had already concluded in 2005 that around 60% of the 24 evaluated ecosystem services are degraded while the only enhanced ones are strongly connected to our focus on food supply like livestock or aquaculture (Millennium Ecosystem Assessment, 2005). And the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) found out that until 2019 humans have already significantly altered 75 % of the earths land surface as well as destroyed 85% of all wetlands and deteriorated more than 85% of the ocean (IPBES, 2019).

Studies also show that unsustainable economic growth is not only extremely dangerous for most of the non-human living on earth, its impact on ecosystem services will also have severe impacts on our own livelihood, especially our economy (TEEB, 2010). In the study from 2014 Costanza et al. have estimated that the cost of biodiversity loss and ecosystem degradation for the global economy between 1997 and 2011 lies between USD 4.3 trillion 20.2 trillion (Costanza et al., 2014). Another analysis indicates that until 2050 the global GDP could decline by 0.67% per year if a business-as-usual scenario would lead to a reduced supply of 6 ecosystem services (pollination of crops, protection of coasts from flooding and erosion, supply of water, timber production, marine fisheries and carbon storage) (Roxburgh et al., 2020). Broken down to specific ecosystem services, examples are: pollinator loss is putting USD 400 billion of global crop output at risk, the overexploitation of fishing grounds causes a financial loss of USD 50 billion per year (IPBES, 2019) and land degradation can have strong impacts on the ecosystem service value (ESV) of different countries (Kertész, 2017). In China the loss per year is estimated to be 6.6%, in Russia 7.4%, for the United States it is estimated to be 8% and for India it is even expected to be a 20.3% decrease of ESV (Sutton et al., 2016). Globally speaking land degradation has decreased the ESV by USD 6.3 trillion per year (Sutton et al., 2016). And land degradation is not the only risk. The World Economic Forum for example is seeing biodiversity loss and its impact on ecosystem service as one of the most impactful and likely global risks for 2020 (World Economic Forum, 2020a). This loss of species has a negative impact on the benefits humans are gaining from ecosystems (Cardinale et al., 2012; Hooper et al., 2012).

As the negative impacts of ecosystem degradation, and thus related economic consequences, are growing, one can ask what the consequences for financial institutions like banks are. In the EU, financial institutions are grouped into monetary financial institutions, investment funds, financial vehicle corporations, payment statistics relevant institutions, insurance corporations and pension funds (European Central Bank, 2021c). In this definition, credit institutions (used as a synonym for banks) (De Nederlandsche Bank, 2021), which are part of monetary financial institutions, are defined as "an undertaking the business of which is to take deposits or other repayable funds from the public and to grant credits for its own account" (European Banking Authority, 2019, 2020). In other words, one of the core activity of banks is defined as the provision of financing and lending solutions to business (Allen et al., 2014). Based on these simple elements, if ecosystems are degraded and businesses are facing risks, financial institutions like banks can be affected as well (OECD, 2019). This thesis will focus on banks to show one important group of financial institutions. As research on the topic is limited, other financial institutions (or financial institutions in general) will be included in the research if needed.

The main biodiversity and ecosystem service (BES) risks financial institutions are facing are physical risks and transition risks (Cambridge Centre for Sustainable Finance, 2016; G20 Green Finance Study Group, 2017; NGFS, 2020). These two environmental risks can then lead to the following financial risks (i) credit risk (default of credit), (ii) market risk (decreasing value of assets), (iii) underwriting risk (increasing insurance gap and increasing losses of insurers), (iv) operational risk (disruptions in the supply chain or other operations) and (v) liquidity risk (increasing demand for capital) (Cambridge Centre for Sustainable Finance, 2016; G20 Green Finance Study Group, 2017; NGFS, 2020).

Recently awareness has increased in the financial sector which can be seen by examples like the formation of important initiatives like the Network of Central Banks and Supervisors for Greening the Financial system (NGFS) or the Taskforce for Nature-related Financial Disclosure (TNFD). Another example is the EU Taxonomy regulation which defines six environmental objectives for the EU policy agenda, with "the protection and restoration of biodiversity and ecosystems" being one of them (Regulation (EU) 2020/852, 2020). And lastly, financial institutions do research on their own like the Dutch Central Bank or the ASN Bank and CDC Biodiversity. For example, in the context of this thesis, EUR 510 billion from the equity investments of financial institutions in the Netherlands are highly or very highly depending on ecosystem services (De Nederlandsche Bank, 2020a). Another report shows that the 50 biggest banks worldwide are financing businesses that enhance the climate and biodiversity problems with USD 2.6 trillion in 2019 (Portfolio Earth, 2020). However, these estimations might only be a fraction of the real risk out there. In 2018 the 6,088 European credit institutions hold assets worth EUR 43.35 trillion (European Banking Federation, 2020a). And at the end of 2020 the 112 significant banks that are supervised by the European Central Bank (ECB) hold assets worth EUR 24.1 trillion. Of this EUR 5 trillion were loans to non-financial corporations and EUR 2.9 trillion were debt securities which are including equity holdings (European Central Bank, 2020a, 2021a).

As financial institutions follow the simple "risk/return" ratio, a better understanding of the real impact of environmental risks and dependencies and the resulting internalizing of these information in the "risk/return" ratio can lead to a shift of investments (Suttor-Sore, 2019). It is therefore in the pure interest of the financial sector and banks to incorporate environmental risks in an adequate manner as an inadequate understanding of any risks can lead to threats accumulating as well as capital allocation to higher risk activities. Not doing so can harm the long term stability of our economy (Cambridge Centre for Sustainable Finance, 2016).

Financial institutions can have a key role in addressing the economic risks of BES loss for humanity globally if they understand the risks and act on them in a stronger way than currently (ShareAction, 2020; TEEB, 2010). Long-term neglecting of environmental risks can lead to the creation of systemic risks that cause general economic instability within and outside of the financial sector (Monnin, 2018).

1.2 Problem definition

Surprisingly, research on the scale of impacts and dependency of the financial sector as a result of BES degradation is rather limited. The reviewed literature stresses its importance, however it also shows that research is just starting to materialize (McCraine et al., 2019; CDC Biodiversité, 2019b; De Nederlandsche Bank, 2020a; WWF, 2020). A systematic literature review by the University of Hamburg together with WWF Switzerland has come to the conclusion that no empirical study until today has focused on the impact of BES loss on the financial industry (Bassen et al., 2019). WWF and PwC have compared the actions in the finance sector on climate change to biodiversity and conclude: "The debate is only just beginning. However, there is a lack of clarity about how high the associated financial risks are, which asset class they hit first, if biodiversity loss is a systemic risk and which methodologies are best suited to measure biodiversity-related financial risks. Furthermore, the concept of "biodiversity-related financial risks" is not yet established in either practice or in academic literature" (WWF, 2020, p. 19).

The ECB published a report that states that European banks are lacking on climate and environmental risk disclosure (European Central Bank, 2020b). Similarly a report showed that although an accurate risk assessment is important for banks, environmental-related risks are not sufficiently accounted for in the banking sector (NGFS, 2018). For the year 2022 the ECB plans to do a stress test of the European banks regarding climate-related risks (European Central Bank, 2020d) but an assessment of BES risks is not planed yet. Others argue that investors use specific sector policies (like excluding palm oil) but that this are only first actions and despite of them, investment strategies of investors show limited awareness or commitments regarding BES risks (ShareAction, 2020). Similarly ShareAction has assessed 75 of the world's largest asset managers from which none is using a comprehensive biodiversity policy in their investment policy and whose biodiversity-related risk assessments are critically undeveloped (ShareAction, 2020).

Disclosure of biodiversity-related information in financial institutions lags far behind climate-related information. This can be seen for example in an analysis of the United Nation Principles for Responsible Investment (UNPRI) which stated that the mentioning of the terms "ecosystem services", "biodiversity", "natural capital" in the financial reports of the UNPRI signatories is extremely low compared to for example the term "climate change" which mentioning has increased in the last years (UNPRI, 2020). The fact that BES risk accounting is staying behind accounting for climate change risk accounting can also be found in other literature (ShareAction, 2020; WWF, 2020).

One reason for the difference in awareness between climate change risks and BES risks might be, that BES risks require a much more complex assessment (NGFS, 2020). BES risk assessment cannot rely on one metric like GHG emissions for climate change, and although first tools are emerging (like the later presented ENCORE tool or the "potentially disappeared fraction of species" metric), no methodology is broadly accepted or used (NGFS, 2020; Finance for Biodiversity, 2021).

Besides defining the risks better and developing new metrics and risk assessment methodologies, it is important to estimate the financial values financial institutions like banks are connected with to BES risks. In the report by the Dutch Central Bank mentioned above, the share of investments (shares, loans and bonds) of the Dutch financial sector that is highly depending on ecosystem services was estimated at 36% (EUR 510 billion) which was one of the first estimations like this (De Nederlandsche Bank, 2020a). This report was the only estimation found that described the scale of interdependency between BES risks and European financial institutions through the indication of a value at risk. More research in this direction can increase the awareness in the financial sector.

1.3 Objectives and Research questions

The main objective of this thesis is to explore the scale of interdependency between BES risks and the European banking sector. To do so this thesis uses a quantitative assessment limited to the currently available data to estimate the magnitude of financial risk related to BES dependency and impact by the equity portfolios of the largest European banks. The second objective is to understand and show the uncertainties and requirements for such a BES risk assessment of the equity portfolio of banks.

The thesis is guided by the following research questions:

- What is the estimated scale of the equity holdings in a bank portfolio which are dependent on and impacting BES?

- What are the main sources of uncertainty in the analysis of equity holdings?
- What are the main elements that a tool/methodology for analyzing bank equity holding portfolio in relation to BES should contain?

1.4 Scope and delimitations

The scope of the thesis will be to analyze potential ways how banks in Europe can assess BES risks in their financial portfolios. This will be accompanied by a quantitative analysis of the impact and dependency risk of the equity portfolio of European banks. The dataset for this analysis includes 41,399 businesses and their 1,148,151 shareholder from all over the world. The dataset was obtained in March 2021 and contained shareholder information from the end of 2019 (31.12.2019). The thesis draws upon the methodology presented by the Dutch Central Bank in their report "Indebted to Nature" and broadens the analysis to the whole European banking sector. The first part helps the current research in the field to better understand the complexity of a fully-fledged BES-related risk assessment (incl. challenges to overcome), while the second part provides the order of magnitude of the "value at risk". This can then help the current research in the field to understand better the size of risk banks in Europe are looking at. It is still important to mention that this thesis can only be understood as an exploratory first assessment that paves the path for future, more accurate, assessments.

Although the conceptual framework describes specific BES risks the banking sector is facing, the equity holding analysis is not going into depth regarding how the estimated value at risk will crystalize as which risks in the banking sector. This analysis will only show the value at risk which means how much of the investments of a bank are connected to business sectors that are strongly depending on or strongly impacting BES.

The research will also not focus on the exact impact of biodiversity loss on ecosystem services and therefore on businesses. It follows the hypothesis that the stated biodiversity loss will have a negative impact on the future delivery of ecosystem services and will therefore impact businesses negatively.

Different literature uses different wordings to talk about environmental risks. For example, nature risks, biodiversity risks, environmental risks etc. The thesis follows the assumptions that these risks are similar, and it is therefore allowed for me to compare different literature talking about risks assessment for these environmental risks. In general the thesis will use the term BES to describe the risks analyzed but if needed it will specifically name ecosystem services alone if this was used by the referenced literature.

1.5 Audience

This thesis is primarily targeting European banks and their risk assessment departments. The results of this research can show them an indication of the value of risk in their equity portfolio due to biodiversity and ecosystem service risks. On a more general note, European banks can benefit as this research lays out different requirements for a sufficient risk assessment methodology which could be used by European banks for more precise future risk assessments. Due to the similarities in the financial sector regarding lack of knowledge and investment decisions other financial institutions could use these findings as well to prepare themselves for a better biodiversity and ecosystem service risk assessment.

1.6 Ethical considerations

The research design has been reviewed against the criteria for research requiring an ethics board review at Lund University and has been found to not require a statement from the ethics committee.

1.7 Disposition

Chapter 1 (Introduction) presents the background of the topic and the justification of the problem discussed in the research. Further on the section presents the aim of the research and the research questions the research wants to answer. Finally, the scope and its limitations are presented.

Chapter 2 (Conceptual Framework) extends the presented knowledge from the background part in the introduction and describes BES risks and its connection to the financial sector with a focus on banks. The section summarizes current existing BES risk analysis frameworks in the financial sector and ends with different case studies from the financial sector (with a focus on the banking sector) in Europe that have analyzed or incorporated BES risks.

Chapter 3 (Methodology) presents the methods used to answer the research questions. This includes methods and origin for the data collection as well as the methods used for the data analysis. The description allows the reader to understand step by step how the research has come to its findings.

Chapter 4 (Findings and Results) presents the main findings from the equity holding analysis regarding BES dependency and impact by the European banking sector as well as the main findings from the conceptual framework section.

Chapter 5 (Discussion) discusses the findings and results and emphasizes the importance or unimportance of specific findings. Here the limitations of the data analysis are described as well.

Chapter 6 (Conclusion) presents the main conclusions of the research that were extracted from the discussion section. These conclusions allow to describe recommendations and areas of future research.

2 Conceptual framework

The conceptual framework presents the existing literature on the topic of the research and is grouped in three different broad topics. The reader will first learn about the position of BES in the broad environmental frame and the path BES risks can take from an environmental problem to a financial risk for banks. Second, the banking sector in Europe is explained in more detail, focusing on the (environmental) risk assessment of these banks. Lastly, different case studies from the European financial sector are presented which take BES risks already into account and offer therefore interesting findings for this research.

2.1 Linkage between ecosystem services and banks

In order to explain why banks should incorporate ecosystem service dependency or impact into their risk assessment, it is important to understand what ecosystem services are and what risks businesses and through them banks are facing. As ecosystem service risks are a part of environmental risks and banks are a part of the financial sector and the distinction between each of these 2 groups can sometimes be very fluid, incorporating the two broader wordings allows to incorporate more literature and findings.

2.1.1 Ecosystem services

The term ecosystem services comes from the interlinkage of ecology and economics and its origins date back to the late 1970s (Braat & de Groot, 2012) but has become more widespread and described in the last 20 years. Besides different wordings most definitions see ecosystem services as the benefits humans gain from ecosystems with benefits meaning the positive impact on our well-being (Boyd & Banzhaf, 2007; Costanza et al., 1997; Daily et al., 1997; Millennium Ecosystem Assessment, 2005; Fisher et al., 2009; TEEB, 2012; Costanza et al., 2017). Important to state here is that ecosystem services must always have an impact on human well-being, they cannot be described without a connection to humans. Non-human related ecosystem work is described as ecosystem processes or ecosystem functions (Costanza et al., 2017). The past research in the field of ecosystem services has led to the establishment of an own journal for ecosystem services (Braat & de Groot, 2012) and even more important two UN lead research groups which brought together many different international experts and have published different research since their founding, the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2021) and The Economics of Ecosystem & Biodiversity (TEEB, 2021).

As ecosystem services are derived from ecosystems and ecosystems are part of biodiversity (which also includes the variability of organism in species and between species (United Nations, 1992)), ecosystem services and biodiversity are clearly connected. For example, biodiversity is necessary for the supply of different ecosystem services (Hanson et al., 2012). Biodiversity can also affect the quantity, quality and resilience of ecosystem services (Cambridge Conservation Initiative, 2020). This can also be seen by different practitioner views where ecosystem service degradation and biodiversity loss are seen interchangeable (De Nederlandsche Bank, 2020a; WWF, 2020). The UNPRI (UNPRI, 2020) explains the connection as ecosystem services require natural capital (=the assets) to supply their benefits to humans. Biodiversity is what makes up the living part of natural capital and is therefore required for a steady ecosystem service supply. Figure 1 explains this relationship.

Figure 1: Relationship between natural capital, biodiversity and ecosystem services

Source: (Cambridge Conservation Initiative, 2020)

Most relevant literature groups ecosystem services in the four different groups provisioning, regulating, cultural and supporting services (Millennium Ecosystem Assessment, 2005; Hanson et al., 2012; Roxburgh et al., 2020; FAO, 2021b, 2021c, 2021d, 2021a). Provisioning services include all the resources or raw materials humans are extracting from ecosystems such as timber, wool, food, fresh water or medicinal resources. The regulating services do not focus on the direct raw material extraction but are required for the existence of these raw materials in the first place. Examples for this are the pollination of crops, controlling of predators and parasites in ecosystems, maintaining the quality of air and soil, carbon sequestration and storage or flood and disease control. Third, the cultural services focus on the non-material benefits humans are gaining from ecosystems like contributions to education, tourism, health or recreation. And lastly the supporting services make up a broader collection of services that are required for the well-functioning of the other services by for example maintaining the genetic diversity or the provision of habitats. Examples for this are nutrient cycling or soil formation.

However, it is also important to acknowledge different or emerging taxonomies. For example, a newer classification from the IPBES (IPBES, 2019) used only the following three groups basic life support for humanity (regulating), material goods (material) and spiritual inspiration (non-material).

Different to the above mentioned classifications, the ENCORE tool is grouping ecosystem services in the four groups direct physical input, enables production process, mitigate direct impacts, protection from disruption (ENCORE, 2021c; UNEPFI, 2021). Examples for the direct physical input group are animal-based energy, fibres and other material, genetic materials, ground water and surface water. Examples for the enables production process group are maintain nursery habitats, pollination, soil quality, ventilation, water flow maintenance and water quality. Examples for the mitigate direct impacts group are bioremediation, dilution by atmosphere and ecosystems, filtration and mediation of sensory impacts. And lastly, examples for the protection from disruption group are buffering and attenuation of mass flows, climate regulation, disease control, flood and storm protection, mass stabilization and erosion control and pest control

From the above and from the previously mentioned numbers, it might be obvious how businesses in general are dependent on ecosystem services. A simple albeit remarkable example is the provisioning group, in which forest products (timber, paper) account for USD 247 billion of global trade exports (FAOSTAT-Forestry database, 2017). Then, the pharmaceutical sector where 70% of cancer drugs are inspired by nature (IPBES, 2019) or the global fishery sector which is estimated to be worth USD 362 billion (FAO, 2018) can also be taken as significant examples. But the other ecosystem service groups can have a significant impact on the global economy as well as for example the food sector is heavily dependent on pollination through insects. It is estimated that pollination is contributing with a financial value of USD 235 billion to 577 billion to the global agricultural food production (IPBES, 2019). At the same time 75% of all food crops used worldwide rely on animal pollination (IPBES, 2019). It has also been estimated that the value of soil biodiversity, and their resulting ecosystem services, range between USD 1.5 trillion to 13 trillion (Data European Soil Centre, 2021). Then there is the cultural service where mainly tourism can be used as an example. Many tropical countries rely on functioning coral reefs for tourism which create a value of USD 36 billion in global tourism value per year (Spalding et al., 2017).

The figures indicated above are not entirely new. First estimations about the total value of global ecosystem services were conducted by Costanza in 1997 and summed up to USD 33 trillion per year, nearly twice the amount of global GNP at that time of around USD 18 trillion (Costanza et al., 1997). This was calculated as an estimation of the total value of 17 ecosystem services with a range of the estimation between USD 16 trillion to 54 trillion. This was considered by the authors to be a minimum value due to uncertainties (Costanza et al., 2014). An updated study by the same authors from 2014 using the same methodology but updated data together with updated unit values estimated the value of ecosystem services at USD 125 trillion per year (Costanza et al., 2014). The OECD estimated recently the global value of ecosystem services between USD 125 trillion to 140 trillion per year (OECD, 2019). As seen by the different publications by Costanza as well as other researchers (e.g. Turner et al., 2016) the calculation of the value of all ecosystem services is very complex and will most likely never reach an exact number. However, and regardless the inherent amount of uncertainty, quantitative studies show the importance for businesses and banks to better understand in their own language (i.e. monetary values) their (potential) dependency and impact on ecosystem services as good as possible.

2.1.2 Risks for businesses

To understand why banks face risks due to BES it is important to understand how businesses are facing risks regarding BES. Literature as well as practitioner view is not consistent on this matter. Therefore, different risk groupings are presented in the following to show the reader the different ideas as well as the recurring risk groups. This section includes assessments of the industry sectors that are most at risk as well as this information is used later on in the discussion section.

Research mainly focuses on the six different risk types operational, liability, regulatory, reputational, market and financial risk (Dempsey, 2013; OECD, 2019). The operational risk occurs when a business depends on a raw material like wood or fresh water for their operation. BES degradation can lead to higher costs for this raw material or in the worst case to an end of the original business operation. The liability risk comes from the possibility that businesses are sued for BES destruction by other businesses that suffer from BES-related damages. If policies enforce legal penalties on businesses due to new BES conservation regulations, this will lead to a regulatory risk. This could include restrictions on land and resources access, clean-up and compensation costs, procurement standards, and licensing and permitting procedures or moratoriums on new permits. The reputational risk results out of the decreasing interest of costumers for specific brands that are connected to the damaging of BES. Opposite to that a market risk is defined as the possibility that costumers favor BES-friendly brands. A financial risk is the possibility that a business loses the access to the capital market if financial institutions tighten shareholder criteria. In that case banks or other kinds of investors would not invest in these specific companies anymore.

A similar grouping is provided by WWF. Based on the review of 30 different frameworks WWF has grouped the nature-related risks in five major types (McCraine et al., 2019) which is similar to the grouping of the World Resource Institute (Hanson et al., 2012). The five risk groups are the operational risk (e.g. resource scarcity that results in higher cost), the regulatory and legal risk (e.g. fines, lawsuits or government regulations), the reputational risk (e.g. social awareness campaigns by NGOs that target destructive businesses), the market and product risk (e.g. customers favoring other (more environmentally friendly) businesses) and the financing risk (e.g. banks implementing stronger lending requirements for corporate loan). Different to the OECD risk grouping explained above, the regulatory and legal risk combines the two groups liability risk and regulatory risk from above (Hanson et al., 2012; McCraine et al., 2019)

KPMG together with United Nations Environment Programme Finance Initiative (UNEP-FI) (KPMG, 2011) defined similar risk groups as mentioned above (operational, reputational, legal liability, regulatory) while the market and financial risk are not mentioned. For these a systemic risk group is defined. Systemic risk means the potential risk that a whole industry sector gets strongly affected by a BES decline (for example the heavily dependent fruit producers who would get in serious troubles without pollinators).

Another report groups the risks in the five groups operational risk, legal and regulatory risk, reputational and marketing risk, financing risk, societal risk (Cambridge Conservation Initiative, 2020). The operational risk is described as the risks resulting out of the regular business activities and processes. Legal and regulatory risk includes laws, public policies, and regulations that affect the business performance. The reputational and marketing risk includes the relationship of a business to its direct stakeholders like customers, suppliers or employees. The financing risk is connected to the access and cost of all types of capital like debt and equity. The societal risk includes the relationship with other stakeholders in the wider society like NGOs, local communities or government agencies.

Although these risks might seem logic, businesses globally do not account for these risks as an analysis of the Fortune 100 list (the 100 largest businesses in the world) shows that only a few businesses incorporate biodiversity loss in their reporting or take quantifiable measures against biodiversity loss (Addison et al., 2019).

In the same report as mentioned above by KPMG and UNEP-FI, a qualitative review of different BES risk assessment was used to define sectors that have a high-risk of BES dependency and impact. The assessments reviewed provided a rating or an indication for a BES risk for one or more sectors. Through this qualitative review, the food & beverage, oil & gas, and mining (including minerals) sector were rated as high-risk sectors. The report also states that sectors like extractives, construction, agribusinesses as well as finance do not adopt the required risk management needed for the magnitude of the issue of BES dependency and impact (KPMG, 2011).

UNEP has looked into the most dependent industry sectors as well as the most influential industry sectors (the ones who damage biodiversity and ecosystem services the most). The industry sectors globally that face the highest dependency and have the strongest impact on biodiversity are (Leach et al., 2020):

1. Agricultural Products (priority from both impacts and dependencies perspective)
2. Apparel, Accessories & Luxury Goods (priority from dependencies perspective)

3. Brewers (priority from dependencies perspective)
4. Distribution (priority from impacts perspective)
5. Electric Utilities (priority from dependencies perspective)
6. Independent Power Producers & Energy Traders (priority from dependencies perspective)
7. Mining (priority from impacts perspective)
8. Oil & Gas Exploration & Production (priority from impacts perspective)
9. Oil & Gas Storage & Transportation (priority from impacts perspective)

A study based on interviews with companies in the UK found out that the sector with the associated highest dependency on ecosystem services was agricultural and forestry sector while financial services reached the lowest dependency value in the study. This study also showed that for the assessed businesses the ecosystem service water quality and waste water treatment are of the utmost importance (Watson & Newton, 2018).

2.1.3 The connection to banks

Banks are an important part of a functioning economy as they are the intermediary between economic agents (Allen et al., 2014). Banks can transform financial resources coming from one economic agent into lending sources for stimulating other economic agents (Nițescu & Cristea, 2020). To do so banks are therefore investing into businesses through different financial instruments. The main ones are loans, equity holdings (e.g. stocks) and bond holdings (e.g. tradable debt securities) (Battiston et al., 2017). Banks are a very important source of external funding for businesses. In the EU banks are responsible for the majority of external finance for businesses (European Banking Federation, 2020b). For example, in 2018 the 6,088 European credit institutions held assets worth EUR 43.35[1] trillion. From this EUR 5.5 trillion were loans given to non-financial corporations but no further information on equity holdings was published (European Banking Federation, 2020a). The regularly publicized report by the ECB on "supervisory banking statistics" breaks these amounts even further down (European Central Bank, 2021b). These reports include data on the most significant banks in Europe as defined by the ECB. At the end of 2020 the 112 banks in the report held assets worth EUR 24.1 trillion. Of this, EUR 5 trillion were loans to non-financial corporations and EUR 2.9 trillion were debt securities (European Central Bank, 2020a). Debt securities were not broken down further but are including different types of financial securities which includes equity holdings as well (European Central Bank, 2021a).

The (financial) sustainability of banks relies therefore on the (financial) sustainability of the businesses banks are invested into. And as these businesses are depending on BES as explained above and are at risk due to BES loss, banks can suffer from BES loss as well.

2.1.4 Risks for the financial sector with a focus on banks

Banks show the lowest level of awareness between all assessed industry sectors about the BES risk and should therefore better understand the risk to take action against it (KPMG, 2011).

The University of Hamburg together with WWF Switzerland (Bassen et al., 2019) has conducted a systematic literature review on the connection of nature risks and the financial sector[2]. To define nature risks the study concentrated on different key words like for example "biodiversity-

[1] These amounts were not broken down to a business sector classification

[2] According to the report, this was the first study of its kind besides one other study that has assessed the connection between climate change and the financial sector in 2019

loss" or "ecosystem destruction". The study did not find any empirical study that focuses on the impact of BES loss on the financial industry. The study found 154 articles (published between 1967 and 2019) addressing the connection between nature risks and the financial industry (which includes the four groups banking, insurance, real estate and stock market) from which the majority focuses on the real estate sector. The results of the analysis of the 154 articles shows that nature risks pose a financial risk through bank defaults, drop in stock prices (market capitalization), and drop in house (property) prices (Bassen et al., 2019).

Interviews with 75 of the world's largest asset managers have revealed different important findings regarding their biodiversity-risk approach (ShareAction, 2020):

1. Biodiversity-risk related policies remain critically undeveloped as the asset manager lack specific commitments on biodiversity-related issues.
2. Climate change is examined more systematically than biodiversity-loss.
3. If biodiversity-related risks are examined, legal and regulatory risks are most commonly named and focus sectors are agriculture, forest and paper products and the extractive industry.
4. Asset managers do not incorporate biodiversity-related metrics into their general risk assessment processes and if they do so they rely heavily on third-party ESG data.

The UNPRI has researched the origin of risk exposure for financial investors. According to a recent report by UNPRI eight different main factors are contributing to a higher risk exposure of investors regarding BES risk: the sector of the investment; the geographic location; the regulatory frameworks; the market-capitalization; the operational arrangements; the value chain position (upstream versus downstream) of the investment; the extent of dependence and impact on biodiversity by the investment; and the ability of the business to substitute raw materials (UNPRI, 2020).

The WWF report from 2019 mentioned in section 2.1.2 explains the nature-related financial risks in further detail and gives the following examples for financial risks: Increased cost of capital or lending requirements, decrease of asset value and complete loss of assets, increased insurance claims, higher premiums and loss of insurance value, increased risk of default, loss of investment value related to reputational risks, changes in market value of the business (McCraine et al., 2019).

In 2020, WWF and PwC brought together the McCraine et al. grouping with learnings from the financial risk groupings done by the Task Force on Climate-related Financial Disclosure regarding climate change and ended with four different types of biodiversity-related financial risks which could be used by financial institutions or financial regulators (WWF, 2020):

- Risks related to the transition to an economy which conserves and restores biodiversity.
- Risks related to the physical impacts of biodiversity loss.
- Risks related to litigation pertaining to biodiversity loss and breach of the underlying legal frameworks.
- Risks related to systemic impacts of biodiversity loss.

According to the monetary Authority of Singapore (Monetary Authority of Singapore, 2020) environmental risks can have an impact on banks either through financial risks or through reputational risks. Both types can arise through physical and transition risk channels meaning either the impact of long-term environmental changes or destructive environmental events as well as the transition towards an environmentally sustainable economy through changes of public policy, new technologies or changes of consumer behavior. The financial risks that can arise through this are credit risk, market risk, liquidity risk, operational risk, and reputational risk.

The Network of Central Banks and Supervisors for Greening the Financial System (NGFS) was founded in December 2017 by eight global central banks with the purpose to strengthen the actions taken by the financial sector to achieve the goals of the Paris Agreement while as well improve the risk management and capital mobilization in broader environmental and sustainable terms (NGFS, 2019b). Since its foundation the NGFS has grown to 89 members and 13 observers worldwide, which include most of the national central banks in Europe, their other banking regulation organizations as well as the ECB (NGFS, 2019a). The NGFS (NGFS, 2020) defines two key risk categories as sources of financial risks, the physical risks and the transition risks. Both categories include many different subcategories but can be summed up under these two terms. Physical risks include all direct impacts coming from environmental disasters or degradation like extreme climate events, losses of ecosystem services, rises in sea levels, or environmental incidents. Transition risks include all impact resulting out of human action to mitigate environmental challenges like for example changes of policies, technological innovations, shifts of investment capital or changes of public sentiments. The NGFS sees then 5 financial risk which can arise through different transmission channels from these two environmental and climate related risk categories. The five financial risks are the credit risk (default of credit), market risk (decreasing value of assets), underwriting risk (increasing insurance gap and increasing losses of insurers), operational risk (disruptions in the supply chain or other operations) and liquidity risk (increasing demand for capital). The same categorization and transmission process of risks is also used by the G20 (G20 Green Finance Study Group, 2017) and the Cambridge Centre for Sustainable Finance (Cambridge Centre for Sustainable Finance, 2016).

2.2 Banks in Europe

After understanding the importance of BES as well as the risks resulting out of BES loss to the financial sector and specifically banks, it is important to explain how banks in general assess risks, how environmental risks are already assessed and what current regulatory drivers for a better risk assessment are.

2.2.1 Risk assessment of banks

The ECB (European Central Bank, 2019) explains the risk assessment of banks as the tool to evaluate how much capital a bank must hold to absorb the materialization of risks. Through their operational activity banks take risks all the time and as some of them might materialize as a loss, the banks must keep enough capital to stay in healthy financial conditions. A good risk assessment therefore is needed to obtain enough capital for bad times (like economic downturns, recession or even global pandemics) and is therefore essential for the market sustainability of a bank.

To understand this risk assessment better, it is necessary to look at the balance sheet of a bank. Simply speaking, a balance sheet of a bank contains a list of assets and liabilities. On one side the two sources of funds (i.e. capital and debts) and on the other side the use of these funds in form of assets (see figure 2). The first source of funds is the capital, which is the obtained profit from the banks operations as well as the money obtained from investors. The other source is debt, which is the money the banks has borrowed from somewhere and needs to pay back. These two sources of funds can be employed by the bank for example by giving out loans or by investing into companies among other ways of investment. The non-invested part of the assets remains as cash.

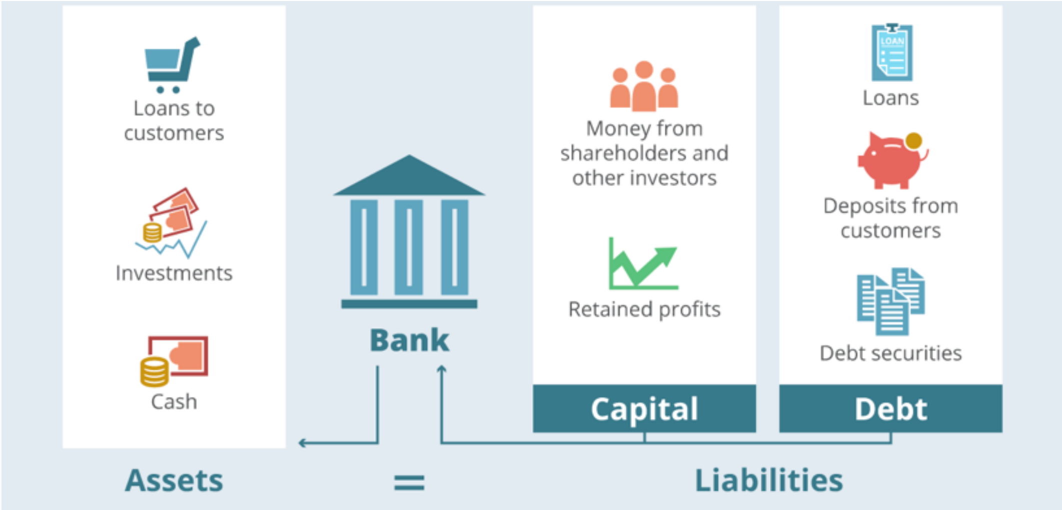


Figure 2: A balance sheet of a bank

Source: (European Central Bank, 2019)

The bank requires sufficient capital to absorb losses materializing on the assets side without suddenly going bankrupt which is why a good risk assessment to obtain enough capital is important for banks (see figure 3).

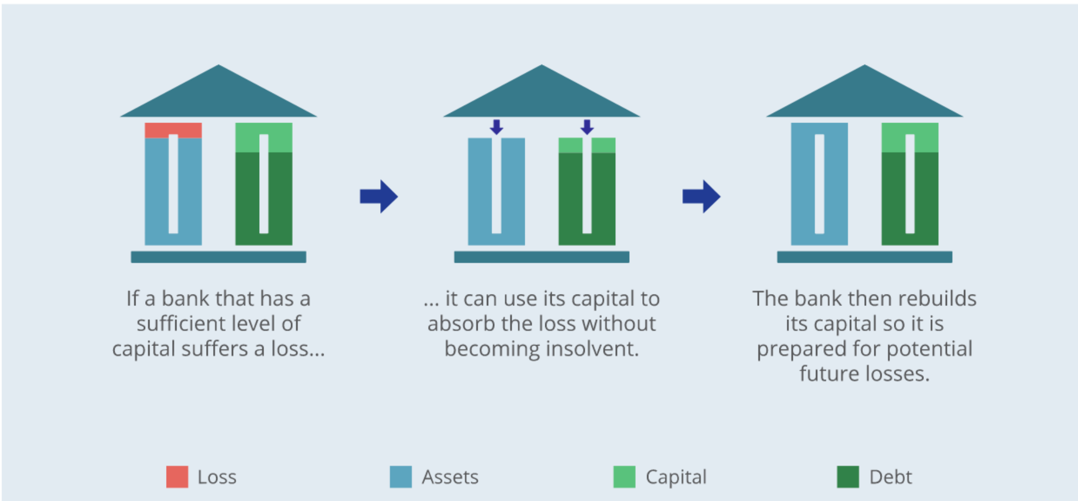


Figure 3: The usage of capital in case of a loss materialization for a bank

Source: (European Central Bank, 2019)

Banks falling under European banking supervision must comply to 3 different capital requirements which is the regulatory definition of the above mentioned "obtaining enough capital for bad times". These requirements are therefore the most important regulatory frameworks for the risk assessment of European banks (European Central Bank, 2019):

- minimum capital requirements, known as Pillar 1 requirements
- an additional capital requirement, known as the Pillar 2 requirement

- buffer requirements, known as Pillar 3 requirements

Before explaining each of the three capital requirements in more depth it is important to look into the history of banking supervision. Global banking supervision is strongly influenced by the work of the Basel Committee on Banking Supervision (BCBS) and its so-called Basel regulations. The BCBS was founded in 1974 as a reaction to major economic disturbances in the international banking sector (e.g. the collapse of the Bretton Woods Accord in 1971, the stock market crash in 1973 and the oil price shock in 1974). First founded by the central bank Governors of the Group of Ten countries (G10), the BCBS currently has members from 45 institutions (central banks and financial regulators) from 28 countries (Moody's Analytics, 2011; Bank for International Settlements, 2021). The BCBS aims "to enhance understanding of key supervisory issues and improve the quality of banking supervision worldwide" (Bank for International Settlements, 2021). To do so the BCBS has published different international standards on capital adequacy, namely Basel I in 1988, Basel II in 2004 and Basel III in 2010. As the most important countries in the world (like G20) endorse these standards, the Basel standards have become the normal risk assessment standard for most banks worldwide (Moody's Analytics, 2011; Bank for International Settlements, 2021).

Coming back to the 3 capital requirements mentioned above, the pillar 1 (or the minimum total capital requirement) requirements mean that banks must keep capital in the range of 8% of their risk-weighted assets which in this context means that each class of assets is multiplied by its respective risk factor[3]. According to the Basel III standard three different types of risks must be assessed here (Moody's Analytics, 2011):

- Credit risk is the risk associated with the possibility that customers cannot repay their loans.
- Market risk is the risk of decreasing value of investments which applies to all trading products.
- Operational risk is the risk resulting from inadequate or failed internal processes, people and systems. This includes as well external incidents.

A bank can either choose standardized measurements to assess the assets regarding each of the different risk types or it can build up own measurement tools (that must comply with European law). For example, in the credit risk group banks could use the rating classification of global rating agencies like Moody's or Fitch who have given different businesses different ratings (Kiene & Hessmert, 2017). The following figure 4 shows the complexity of the different assessment methodologies for each of the different types of risk:

[3] For example, in Basel I a development bank debt would get a risk factor of 0.2 meaning that the final capital requirement would be 0.2*debt value*0.08 (Chen, 2021).

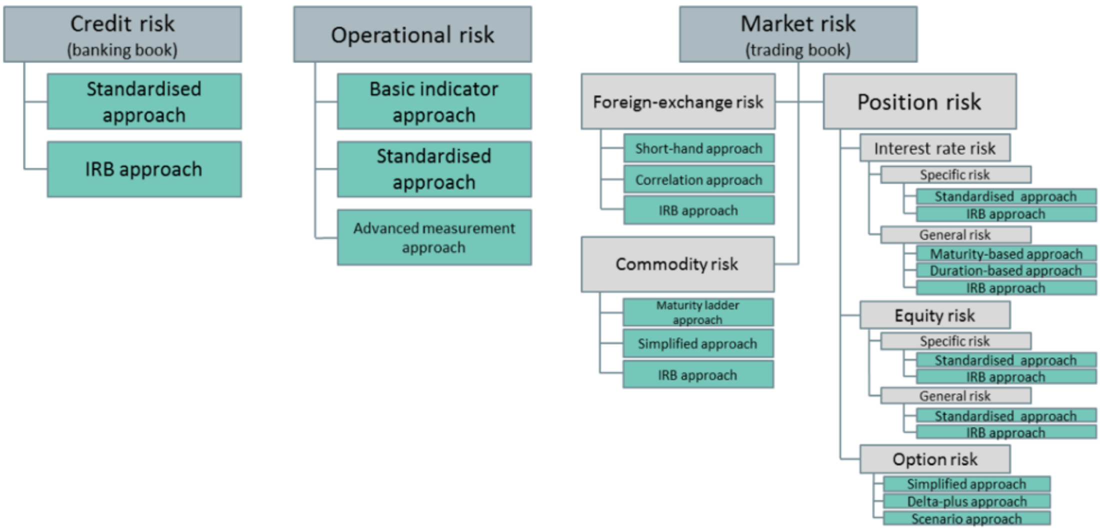


Figure 4: Type of risks and the corresponding risk-weighted assets assessment methodologies

Source: (Kiene & Hessmert, 2017)

Pillar 2 (or additional capital requirement) is depending on the European banking supervision. The ECB together with the national banking supervisors look at individual banks through the Supervisory Review and Evaluation Process and assess their risk exposure. If the assessment comes to the conclusions that the minimum total capital requirement is not sufficient the bank is asked to hold additional capital. This can be done through so called banking stress tests which are conducted by the European Banking Authority, in cooperation with the European Systemic Risk Board. The stress test is assessing the resilience of banks in the EU to economic shocks/scenarios. It is based on a common methodology using a common macroeconomic baseline scenario as well as a common adverse scenario which are always covering a period of two years (European Banking Authority, 2021).

And lastly for pillar 3 banks should hold buffer capital for example against systemic risks.

2.2.2 Ideas on environmental risk assessment by banks

Although the Basel standards do not take environmental risks, like ecosystem service dependency or biodiversity loss, into account, different literature shows different approaches how banks can assess these risks. For example, the Natural Capital Coalition which is guided by the UN led Natural Capital Finance Alliance has published a general framework for financial institutions to take nature risks into account. In the first step of the framework the justification of the assessment is defined (why this assessment is needed). After that the scope of the assessment is defined followed by the measure and value step. In this stage, the ways of measuring and valuing different nature risks are defined and explained. Lastly, the application of the assessment leads to the results which then need to be interpreted and these interpretations should result in the "next steps" (Natural Capital Coalition, 2018).

The German Federal Financial Supervisory Authority (BaFin) (BaFin, 2019) has recently published a Guidance Notice on Dealing with Sustainability Risks to offer non-binding good practice guidelines for financial institutions in Germany to address sustainability risks (which includes biodiversity related risks). Regarding risk categories the BaFin (BaFin, 2019) says that sustainability risks should not be assessed in its own risk groups but better be assessed in the existing risk groups (like credit or market risk). The reason for this suggestion by the BaFin is that sustainability risks are very complex and a segregation between a sustainability risk and the other existing risk types would be complicated. Sustainability risks can have an impact on all the existing risk types and should therefore be accounted for in each of the existing risk types. Therefore, the BaFin sees the following risk types in the financial sector that can be impacted by sustainability risks: Credit risk/counterparty default risk, market risk, liquidity risk, operational risk, insurance risk, strategic risk, reputational risk (BaFin, 2019). WWF and PwC have adapted this view to create a classification matrix that brings together the four biodiversity risk groups with the three main current risk groups in the banking sector (see figure 5).

	Credit risk	Market risk	Operational risk
Transition risk	Investee suffers substantial losses due to sanctions, damages or increased taxes stemming from its negative impact on biodiversity	Long-term price increases as a result of biodiversity change	Image loss resulting from failure to switch to biodiversity management
Physical risk	Revaluation of debt-servicing capacity and collateral	Rating downgrades and share price losses after biodiversity loss	Biodiversity loss affects balance sheet
Litigation risk	• Litigation as pertaining to biodiversity loss and breach of the under-lying legal frameworks • New regulatory rules impose limitations on investing in activities with an impact on biodiversity • Damages due to false reporting of biodiversity risks • Damages due to greenwashing		
Systemic risk	Economy can no longer be insured at reasonable cost	Market-threatening effects from biodiversity loss in an entire region	Reputational losses for entire industries/entire markets

Figure 5: Classification of biodiversity-related financial risks into current risk types

Source: (WWF, 2020)

On the other hand, the literature also shows the remaining problems the financial sector still has regarding the BES risk assessment. For example, literature shows that an accurate risk assessment is important for banks and as environmental-related risks are not sufficiently accounted for (NGFS, 2018), environmental risks can cause potentially large financial losses. This can then even create systemic risks that create general economic instability outside of the financial sector (Monnin, 2018).

A research in 2019 approached 25 different central banks which all stated that they all see the need to improve the sustainability risk management to protect themselves from financial risks as well as to set a good example for commercial banks (NGFS, 2019c). Besides publishing different surveys regarding sustainability risk assessment by banks, the NGFS has defined its own environmental risk analysis for financial institutions (NGFS, 2020) which is a common approach also found in other literature (Cambridge Centre for Sustainable Finance, 2016). The first step includes the risk identification which requires an analysis of the environmental factors that may cause financial risks. Next, the exposure of a financial institution to these financial risks must be measured. Third, the risk assessment is calculating the probabilities that these exposed financial values will be lost. And lastly, a risk mitigation should take place that minimizes the exposure of the financial institution towards the financial risks by for example disinvesting from specific risk-prone assets (NGFS, 2020). This report presents different methodologies to do an environmental risk analysis but all of them focus on climate change. This can also be seen in the fact that the report states that risk metrics and methods are underdeveloped for general environmental related risks (e.g. biodiversity loss) compared to climate change. Besides that, the report mentions different gaps in the application of environmental risk analysis. The report states that still in 2020 environmental risk analysis tools are only used by large financial institutions in OECD countries or China, but these applications remain at the experimental stage. One reason for this lacking usage of environmental risk analysis is that financial institutions lack the understanding of how environmental risks can result in financial risks. Other gaps are poor data quality and methodology in the financial institutions which can come from the significant size of resources that is needed to develop environmental risk analysis tools in a financial institution (e.g. specialized researchers or investments into data sources). Another reason for the lack of good data quality and methodologies is that the current environmental risk analysis tools mostly focus on the direct physical impact by environmental risks (on infrastructure or agriculture) but do not take into account the indirect feedback loops on the whole economy (NGFS, 2020).

In the EU, the ECB has recently published a guide on climate-related and environmental risks for banks. European banks are expected to include the supervisory demands and self-assess them in 2021, followed by a full supervisory review of the bank's practices in this matter in 2022. In 2022 climate-related risks will also be included in the banking stress test. (European Central Bank, 2020c, 2020d). Although focusing on climate-related risks, the guide mentions biodiversity loss as one type of physical risk next to water stress, resource scarcity and pollution. The guide is mentioning 13 different expectations in the fields of business models and strategy, disclosure policies and procedures, risk management and governance (European Central Bank, 2020c).

2.2.3 European regulation

One driver (or one result) of the overall increase of attention and knowledge regarding BES issues is that more and more policy initiatives have arisen, which are presented in the following.

The EU has a strong intention (European Commission, 2018, 2020b, 2021e, 2021d, 2021c) to enhance sustainable finance in the European Union to help achieving the environmental goals (like the Paris Agreement) and increase the transition to an environmentally friendly economy and society. These efforts are connected in the EU Action Plan on Sustainable Finance, which was adopted by the EU Commission in 2018.

One main part of this action plan is the development of a EU taxonomy, "a common classification system for sustainable economic activities", which entered into force in July 2020 (European Commission, 2021c). The aim of the EU Taxonomy is to define what environmentally sustainable economic activities are so that companies, investors and policy makers have strong definitions at hand which will then "create security for investors, protect private investors from greenwashing, help companies to plan the transition, mitigate market fragmentation and eventually help shift investments where they are most needed" (European Commission, 2021c).

There are six environmental objectives defined in the EU Taxonomy regulation (European Commission, 2021c):

1. Climate change mitigation
2. Climate change adaptation

3. The sustainable use and protection of water and marine resources
4. The transition to a circular economy
5. Pollution prevention and control
6. The protection and restoration of biodiversity and ecosystems

Following the EU Taxonomy an economic activity can only be included in the taxonomy if it does not harm any of the six objectives while as well contributing substantially to one of the objectives (KPMG, 2020).

Another relevant regulation is the EU Biodiversity Strategy which has the aim to lead to a recovery of biodiversity in Europe by 2030. The strategy mostly focuses on specific targets for biodiversity and ecosystem restoration and saving (e.g. increasing the amount of protected area to 30%, planting 3 billion trees, reducing pesticide usage as well as halting and reversing the decline of pollinators) (European Commission, 2021b). But besides this main aim, the strategy also mentions the importance of businesses and finance as it aims to improve investments, knowledge and financing in the field. This should for example be achieved by a review of the reporting obligations of businesses under the Non-Financial Reporting Directive (European Commission, 2020a, 2021a).

2.3 Current examples of BES risk assessments by financial institutions

After explaining the connection of BES and banks and the risk assessment of banks this section will focus on recent examples of tools/risk assessments/methodologies used in the European financial sector to assess BES risks. As findings on this matter are rather limited (as explained above the financial sector in general and the banking sector specifically is lacking awareness for these risks and therefore lacks risk assessment initiatives in this field), the examples come from different financial institutions, also outside the banking sector. After the different case studies, a report from the Finance for Biodiversity pledge (Finance for Biodiversity, 2021) which is organized by the European Commission will be explained as it summarizes much of the findings from the case studies.

2.3.1 ASN Bank and CDC Biodiversity

The Dutch ASN Bank has committed to become biodiversity positive until 2030 which means that none of its investments and loans should have a negative effect on biodiversity (WWF, 2020). To understand its impact on biodiversity, the ASN Bank developed its own methodology called Biodiversity Footprint for Financial Institutions (BFFI) in 2016 together with the two research and consultancy companies CREM and PRé Consultants. This methodology calculates the potentially disappeared fraction of species (PDF) to express the impact of an investment portfolio on biodiversity. This method uses the Exiobase database which gives information about the connection of economic activities and their resulting environmental pressures. The data from Exiobase are country-specific average values for economic sectors. The environmental pressures are then translated through the ReCiPe model into an impact on biodiversity scale which gives out “a parameter that expresses the fraction of species lost in a certain area during a certain time”, the PDF (Crem & PRé Consultants, 2016, p. 4). After that the biodiversity impacts from the different companies are then attributed to the financial investor based on the share of investment into this company. In the whole assessment the four different investment types of the ASN Bank government bonds, mortgages, renewable energy projects and equities were assessed (Crem & PRé Consultants, 2016; Dutch Ministry of Agriculture, Nature and Food Quality, 2019). For the equity portfolio of the ASN Bank the assessment only considered the companies that represented the biggest investments. For each of these companies, the NACE sector of their operation as well as data on the country of operation(s) (share of turnover in each country) was gathered. This information was then connected to the Exiobase to give the environmental pressure values for each company which was then connected to the ReCiPe model (Crem & PRé Consultants, 2016).

The results of the analysis can be seen in figure 6. The final result of 7,000 PDF per km^2 per year can be read as an area of 7,000 km^2 will lose all its biodiversity over the period of one year. This value can be seen in reference to regions like the Dutch provinces of Noord- and Zuid Holland (6,382 km^2), the US state of Delaware (6,452 km^2), Puerto Rico or Cyprus (both around 9,000 km^2). As seen in figure 6 the equity portfolio has reached the second highest value although its investment sum is only the third biggest part of the investment portfolio of ASN Bank (Crem & PRé Consultants, 2016). In the analysis of the results, the report mentioned that the impact on biodiversity by equity investments is relatively high compared to the other investment types. It also mentioned that the sectors with the highest impact of the investment are the sectors food, chemicals, publishing and printing as well as apparel. For these sectors the main impact comes from land use (like agriculture, and forestry) (Crem & PRé Consultants, 2016).

	Investments in m€	*Impact in km²*	*Index m²/€*
Government bonds	3,700	4,000	1.11
Mortages	4,600	240	0.05
Wind energy	120	- 310	- 2.51
Solar energy	130	3	0.02
Other energy	260	- 450	- 1.70
Equities	1,300	3,400	2.54
Total	**10,000**	**7,000**	**0.69**

Figure 6: Results of the biodiversity footprint analysis of the financial portfolio of ASN Bank

Source: (Crem & PRé Consultants, 2016)

CDC Biodiversity, a subsidiary of the largest French public financial institution Caisse des Dépôts, has taken similar actions like ASN Bank and has created another assessment tool called Global Biodiversity Score (GBS) to evaluate the impact of its different business activities on ecosystems along the value chain (WWF, 2020). After 5 years of development, the GBS was published in May 2020. The development was achieved in close collaboration with Business for Positive Biodiversity Club which is a group of 25 businesses and 10 financial institutions that want to improve the measurement of their impact on biodiversity (CDC Biodiversité, 2020b; Mission Economie de la Biodiversite, 2020). In the reasoning for this CDC Biodiversity mentioned that the previous research had made it clear, that an assessment tool must focus on biodiversity itself and not only on ecosystem services. The aim of the tool was described as "a tool which uses an aggregated metric understandable by all and measures the biodiversity footprint of companies from various sectors at the scale of the entire value chain (from cradle to grave)" (CDC Biodiversité, 2020b, p. 7). Different from the ASN Bank is that this tool uses the value mean species abundance (MSA) per km^2. The MSA is a share value of the observed biodiversity (number of species) over a theoretical reference value of the undisturbed biodiversity (number of species) at the same location and shows therefore the intactness of ecosystems. The GBS is always showing two numbers, the static footprint and the dynamic footprint. The aim of using the terms static and dynamic is to add a time layer into the assessment. Static footprint includes all the changes that are persistent and remain over time like for example GHG emissions (even after emission they still heat up the earth); dynamic footprint includes the changes that have occurred during the time of assessment (CDC Biodiversité, 2020b). Similar to the PDF metric from the ASN Bank, the MSA metric relies on the data from Exiobase to connect economic activities with pressures on biodiversity which are then translated into biodiversity impacts (CDC Biodiversité, 2020a). Until today the GBS tool covers direct operations and upstream impacts on terrestrial and freshwater biodiversity and the following pressures on biodiversity: Land use, Fragmentation of natural ecosystems, Human encroachment, Atmospheric nitrogen deposition, Climate change, Hydrological disturbance, Wetland conversion, Freshwater eutrophication, Land use in catchment, Ecotoxicity. In the future the GBS tool should be improved so that it can cover all biodiversity impacts in the complete value chain (upstream and downstream of the assessed operations) (CDC Biodiversité, 2020b). In the development of the GBS, different pilot case studies were used by CDC Biodiversite to create lessons learned and improve the tool. One of the pilots was done with BNP Paribas Asset Management. Here the GBS was used to assess one of BNP Paribas portfolios worth EUR 20.1 million of turnover financed which contained 10 companies operating in the agri-food industry (food processing, retail, catering). The overall biodiversity footprint of the portfolio was 4.857 MSA per km^2 (CDC Biodiversité, 2019a; WWF, 2020).

In 2018 the ASN Bank and CDC Biodiversity have decided to share their previous experiences as their objectives are quite similar. Their aim was to look for common rules or ideas regarding the biodiversity footprint assessment for financial institutions. In this, they collaborated with the two asset managers ACTIAM and Finance in Motion as both of them are focusing on impact investing and had valuable experiences to share. As a result, a report called "Common ground in biodiversity footprint methodologies for the financial sector" was published in 2018 which will be presented in the following (J. Berger et al., 2018).

In the report (J. Berger et al., 2018) a biodiversity footprint is described as a potential tool to assess quantitively the actual impacts on biodiversity or the potential impacts (through contribution to drivers of biodiversity loss or gain) of an economic activity. To complement this quantitative analysis a biodiversity footprint tool could also gather qualitative data that is not perfectly covered in the quantitative analysis. Different to other environmental footprint tools (like water or carbon foot printing), biodiversity lacks a broadly accepted metric like the carbon dioxide equivalent (CO_2eq) used by the IPCC. In the report, the four companies state that they focus on biodiversity intactness and not endangered species or ecosystem services without giving a reasoning for this. Both methodologies from ASN Bank and CDC Biodiversity take an unaffected piece of nature as a baseline and assess the impact then depending on either a decrease or increase of species from this baseline. Both methodologies focus only on the impact on biodiversity, but do not assess dependencies.

Together they came up with a specific methodology to assess biodiversity risks of investments and loans which follows the framework of the Natural Capital Coalition mentioned above. ASN Bank and CDC Biodiversity propose four steps as well (J. Berger et al., 2018).

The first step is the analysis of the focus of the investment. In this step all the information about the investment is gathered, especially the connected economic activity and its location. It is important to define the economic activity for the specific investment (into a business, an organization or a project) as only these economic activities allow a link of the investment with environmental pressure data. Another important part of this first step is to discuss the scope of the analysis meaning if only the direct investment is accounted for or also the impact down the supply chain (for example only the impact of a fashion retailer or also the production of the fashion products by the supply chain). The report suggests here to use the same distinguishment of scopes as used in carbon emission analyses. Scope 1 only focuses on the direct impact by the consumption or on the area controlled by the entity. Scope 2 focuses on the impacts of emissions coming from electricity, steam, heat or cooling. Scope 3 focuses on the impacts coming from activities upstream or downstream the supply chain of the business which are not controlled by the business. In addition to these three scopes, the report sees a scope 0 which is unique to biodiversity assessments. Scope 0 focuses on the impacts resulting out of existing facilities like for example an already existing palm oil plantation that stops biodiversity to thrive on this area. The final part of the first step is to define the attribution methodology so that each stakeholder involved gets attributed the right share of the impact of one operation. This can be done through the three possible approaches financial control (the entity controls more than 50% of the assessed business operation and therefore gets 100% of the impact attributed to), operational control (again 100% of the impact of a business operation is attributed to the entity that owns full authority over the operation processes) and the share of the assets owned (the impact is divided depending on the share an entity is owning of the operation).

In the second step, all important pressures on biodiversity which can be caused by the economic activity are assessed. These assessments can either be very precise as they are gathered directly from a project or more broad using sector averages. As both sides have advantages and disadvantages like better data quality vs lower cost, it is always important to be as transparent as possible about the choice and reasoning of the methodology.

In the third step the impact on biodiversity through the pressures occurring by the economic activity is quantitively assessed. This assessment should have a spatial and time dimension as environmental pressures are not lasting for eternity and depend on the area they are impacting.

Finally, the interpretation of the results should take place. In this step it is important to understand/mention the limitations of the assessment. The aim of a financial portfolio footprint analysis is to identify biodiversity hotspots in the portfolio that allow next steps measurements by the financial institution. If hotspots are found it is possible to conduct a more precise footprinting analysis to understand the hotspots even better.

Besides a methodology, the report (J. Berger et al., 2018) described eight requirements and five characteristics that a successful biodiversity footprint tool should include. These are summarized in the following paragraphs.
The first requirement is that the footprint tool should include the most important pressures on biodiversity (according to the report these are land use change, overexploitation, invasive alien species, pollution, and climate change). Pressures that cannot be included in a quantitative analysis must be covered through a qualitative analysis.
Second, the footprint tool should be responsive to changes in the economic activity. If a company takes efforts to minimize their environmental impact or dependency, the footprint tool should be able to take this for the calculation into account.
Requirement three to five included the need for the data and methodology of the footprint tool to be made transparent, to fit to the objective, application and scope of the whole assessment and to be developed according to current scientific and economic knowledge.
For the sixth requirement, the footprint tool should be consistent to allow the comparison between different economic activities and over time.
The footprint tool should account for changes in the intensity of pressures by changing the footprint results.
As the last requirement, the report mentioned the need for compatibility. As no tool can cover all different needs, a good footprint tool should be compatible with other assessment tools.

Regarding the characteristics, the report (J. Berger et al., 2018) mentions first that the footprint tool should assess biodiversity as a whole, not only on a specific part (for example a species).
The second and third characteristic focuses on the scope of the metric used which should be

cross-sectoral and global. The footprint tool should use one common metric for all industries and countries to allow comparison and assessment between industries and countries.
For the fourth characteristic, the footprint tool should cover the entire value chain with all indirect and direct impacts that occur there.
For the last characteristic, the footprint tool should reach a high level of consensus meaning it is highly accepted and legitimated. This can be achieved through peer reviewing the methodology and the inclusion of stakeholders from research, public authorities, NGOs and businesses into the development of the tool.

2.3.2 Dutch Central Bank

Another recent practitioner view comes from the Dutch central Bank which has evaluated the biodiversity related risk in the Dutch financial sector. Findings include for example a strong dependency (36%) of investments on ecosystem services (De Nederlandsche Bank, 2020a).

In the Netherlands different banks have joined together to form a Partnership for Biodiversity Accounting Financials and the Sustainable Finance Platform (De Nederlandsche Bank, 2020a).

In 2020, the Dutch Central Bank (De Nederlandsche Bank) together with the Environmental Assessment Agency of the Netherlands (Planbureau voor de Leefomgeving) has published a report called "Indebted to nature – Exploring biodiversity risks for the Dutch financial sector" (De Nederlandsche Bank, 2020a). In this report they explore how and to what extent financial institutions in the Netherlands are exposed to biodiversity loss and its causing risks.

The report first explains the (indirect) connection between biodiversity loss and financial institutions resulting out of the different ways of investments by financial institutions into businesses that then can be affected by biodiversity loss. The report then analyzes three different risk groups and is evaluating the financial value at risk for each of them using different methodologies and data.

The first risk is the physical risk, which means the risk coming from companies depending on ecosystem services for their operations. Regarding the methodology (De Nederlandsche Bank, 2020b), the report uses the ENCORE database explained above. The report then matches the high and very highly dependent business sectors from ENCORE with the financial interactions (shares, loans and bonds) of the Dutch financial sector. A result is that of all investments (1,400 billion EUR) of the Dutch financial sector 36% (510 billion EUR) are depending highly or very highly on one or more ecosystem services. Figure 7 shows the connection between the different financial institutions to the business processes and the dependency on the different ecosystem services. The data basis for the assessed investments are statistics of the equity and bond holdings of pension funds, insurers and banks, as well as databases on the loans banks issued to businesses (De Nederlandsche Bank, 2020b).

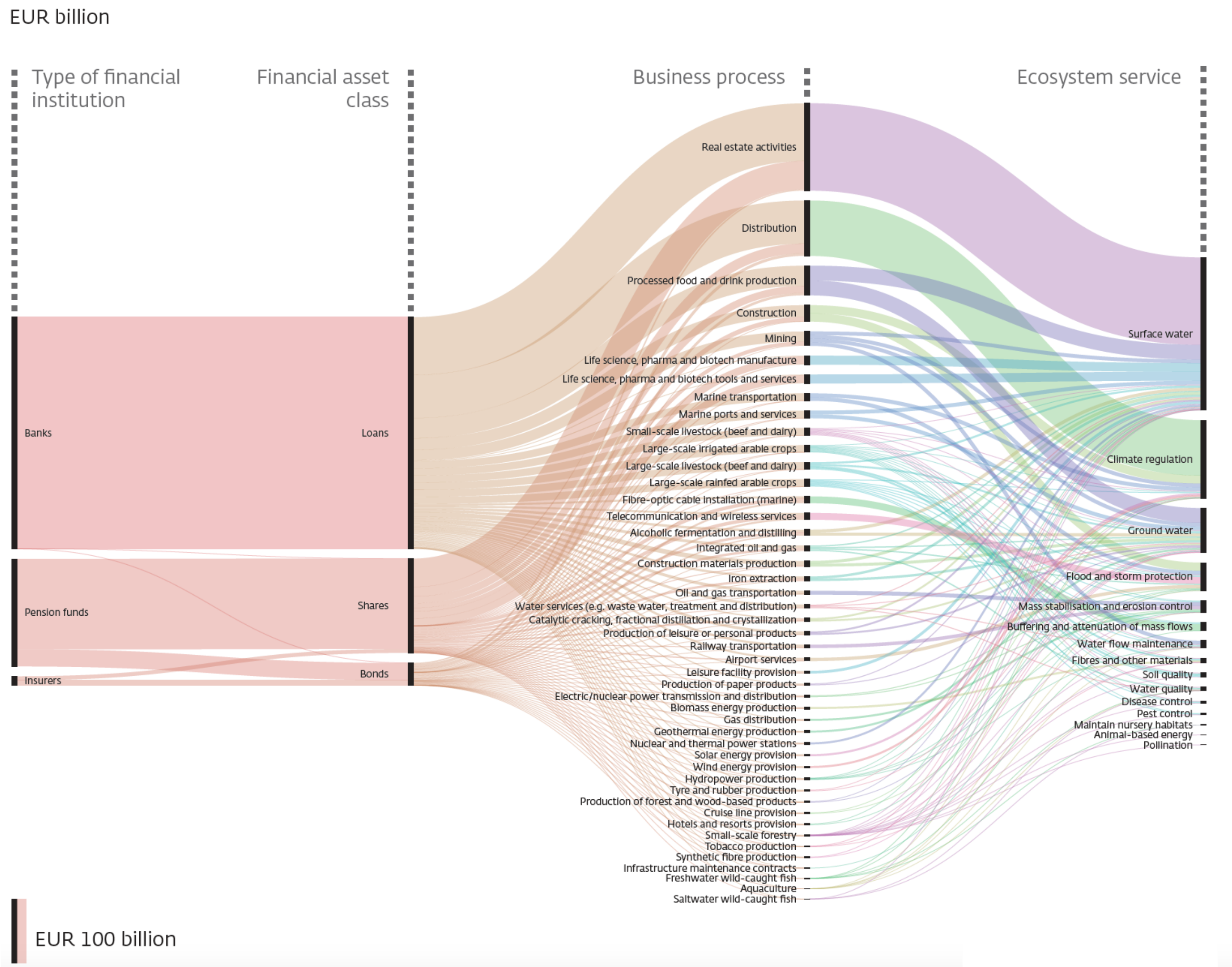


Figure 7: The financial sector and ecosystem services dependencies per euro invested

Source: (De Nederlandsche Bank, 2020b)

The second risk the report analyzes is the transition risk. This includes financial interactions with companies that are heavily damaging biodiversity and could therefore lose their license to operate if policies demand a transition to a more biodiversity-friendly economy. Therefore, the report estimates the biodiversity footprint of companies which are worth EUR 320 billion in the equity portfolio of the financial institutions. Overall, the footprint of these companies adds up to an area of 58,000 km^2 of pristine nature that is lost which is more than 1.7 times the area of the Netherlands. Following that, the report compares protected areas worldwide with the location of operation for 1,783 multinational companies the financial institutions are invested in. The investments into these companies sum up to EUR 308 billion in shares and EUR 81 billion in loans. From these investments, EUR 15 billion are invested into companies that operate in already protected areas. This number could even increase, if global environmental policies would lead to an increase of protective areas in the future. The report explains these with two different scenarios of global area protection. The businesses behind the EUR 15 billion are at risk as operation in these areas is in theory not legal and could therefore be stopped by governments. The data basis for the assessed investments are statistics of the equity and bond holdings of pension funds, insurers and banks, as well as databases on the loans banks issued to businesses (De Nederlandsche Bank, 2020b).

The last and third risk analyzed is the reputational risk. This means a risk resulting out of environmental controversies businesses are facing when their operation is damaging the environment and the public finds out about this. Here the report looks at the MSCI environmental controversy database and all the companies Dutch financial institutions are invested into and that are listed in this database regarding biodiversity damage. In this historic analysis it was shown that in total EUR 96 billion was given to companies that faced environmental controversies, ranging from moderate controversies (EUR 74 billion) to very severe controversies (EUR 4.7 billion). The total value of assessed investments was EUR 700 billion. In a second step the report looked at the ability of the companies the Dutch financial institutions are invested in to report about deforestation as a low extent of information provision can lead to a reputational risk as well. This is done by using the data of the Carbon Disclosure Project (CDP), a deforestation reporting standard more than 1,400 companies are globally asked to use. Here the report found out that the Dutch financial institutions are exposed with EUR 97 billion to companies that either are not reporting to the CDP (EUR 62 billion), are reporting but without making the information public (EUR 31 billion), are reporting but are not addressing deforestation (EUR 4 billion) or companies that address deforestation risk in their reporting (EUR 51 billion). The report mentions that the different types of reporting should be seen as different risks as a company that reports about a risk is usually better managing this risk than a company that does not even know about this risk (De Nederlandsche Bank, 2020a). The data basis for the assessed investments are statistics of the equity and bond holdings of pension funds, insurers and banks, as well as databases on the loans banks issued to businesses (De Nederlandsche Bank, 2020b).

2.3.3 Finance for Biodiversity pledge

The Finance for Biodiversity pledge was started in September 2020 by a group of 26 financial institutions like ACTIAM, ASN Bank, AXA Group or Caisse de Dépôt and has grown since to 37 signatories. These financial institutions are commited to "protect and restore biodiversity through their finance activities and investments" (Finance for Biodiversity, 2020). Together with the Finance@Biodiversity community and the EU Business@Biodiversity Platform (both initiatives started by the European Commission), Finance for Biodiversity has published a report (Finance for Biodiversity, 2021) that compared the most significant biodiversity measurement tools that fit to the three requirements (i) the tool is currently explored or used by the financial sector, (ii) the tool includes all main drivers of biodiversity loss, and (iii) the tool is scientifically robust. Only six different measurement approaches were found and were further explained and compared in the report. These six tools are:

- BFFI – Biodiversity Footprint Financial Institutions (CREM and PRé Sustainability, together with ASN Bank)
- GBSFI – Global Biodiversity Score for Financial Institutions (CDC Biodiversité)
- ENCORE – Exploring Natural Capital Opportunities, Risks and Exposure (UNEP-WCMC, UNEP FI & NCFA)
- BIA – Biodiversity Impact Analytics (Carbon 4 Finance, CDC Biodiversité)
- CBF – Corporate Biodiversity Footprint (Iceberg Datalab and I Care Consult as scientific partner)
- STAR – Species Threat Abatement and Restoration (IUCN)

The report (Finance for Biodiversity, 2021) used different criteria to compare the different measurement tools which can be seen as necessary parts for a sufficient BES risk assessment tool. The different criteria are organizational focus area, finance application, asset categories, pressures, coverage, scope and metric. For each criteria the six different measurement tools were compares which can be seen in figure 11.

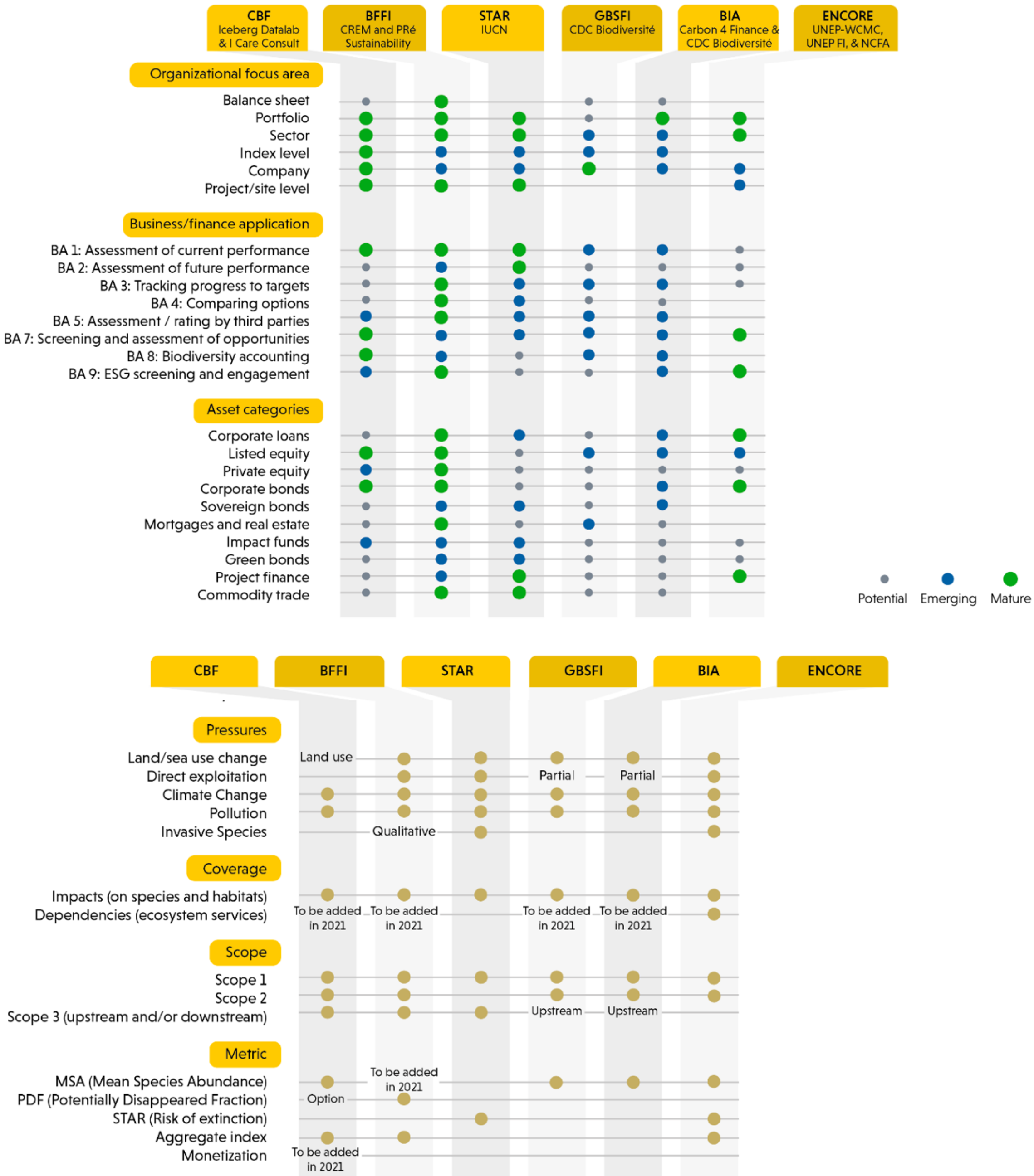


Figure 8: Comparison of different biodiversity measurement tools

Source: (Finance for Biodiversity, 2021)

The organizational focus area represents the scope of investments that is assessed (Finance for Biodiversity, 2021). The different investments types are the balance sheet (looking at a specific point of time at all the assets, liabilities, equity of the financial institution), the portfolio (looking at a collection of financial activities), the sector (looking at a group of companies that offer the same group of products/services), the index level (looking in a standardized way on a group of assets most likely stocks), company (looking at one company) or project & site level (looking at one long-term project for example infrastructure or an industrial project). The comparison shows that not one of the tools can look at all different investment scopes, with the CBF tool being close to offering an assessment of all scopes. The portfolio scope is nearly offered by all tools.

The finance application describes the type of application the measurement approach is used to. There are eight different applications mentioned in the report (Finance for Biodiversity, 2021) which are the assessment of current performance (assessing current biodiversity loss status to identify hotspots), the assessment of future performance (assessing the future biodiversity development due to pressure reduction or restorative actions), the tracking progress (assessing the performance of the financial institution regarding different time-bond targets like for example "Net positive effect by 2030", "No deforestation and water neutral by 2030"), the comparing options (comparing different investment options on their biodiversity impact), the assessment/ rating by third parties (the assessment is done by a third party rating agency or a data provider and looks at some kind of biodiversity criteria), the screening and assessment of opportunities (finding interesting investment options that help biodiversity), the biodiversity accounting (creating internal reporting and/or external disclosure regarding biodiversity while using reporting standards), the ESG screening and engagement (follow regulatorily made ESG criteria).

The asset categories define the different investment types a financial institution can hold and can therefore assess (Finance for Biodiversity, 2021). The different asset types are corporate loans, listed equity, private equity, corporate bonds, sovereign bonds, mortgages and real estate, impact funds, green bonds, project finance, commodity trade. The different maturity of the tools reflects in the different asset categories each can cover although not one tool can cover all different asset categories. The BFFI comes closest with either covering asset categories or including them currently into their tool.

The pressures (Finance for Biodiversity, 2021) describe the direct human impact on biodiversity and ecosystem services. These could be land/sea use change, direct exploitation, climate change, pollution and invasive species. Again, the tools show different scopes as ENCORE and STAR can cover all different pressures while the other four tools can only assess some of the different pressure's humans are putting onto biodiversity and ecosystem services.

Under coverage (Finance for Biodiversity, 2021), the report distinguishes between impacts and dependencies which a measurement tool could include. Impacts are described as the negative effects business activities can have on species and habitat services. Dependencies are described as the essential benefits ecosystems are providing the society with. All tools cover impacts but only ENCORE also covers dependencies, although CBF, BFFI, GBSFI and BIA are planning to implement a dependency assessment this year.

The different scopes (Finance for Biodiversity, 2021) describe the boundaries of the assessment regarding which impacts or dependencies in a value chain are included. This could be scope 1, scope 2, scope 3. Only STAR and ENCORE are missing one scope while the other tools are able to focus on all three scopes.

The metric (Finance for Biodiversity, 2021) describes what exactly is measured regarding the different types of views on biodiversity like species, ecosystem intactness or ecosystem benefits. The report mentions 5 different metrics, the MSA, the PDF, the STAR (this metric measures the risk of extinction of a species while weighting it by its threat status), the aggregate index (this is an index based on several parameters which are not further explained) and the monetary value (of ecosystem systems). The tools rely on similar metrics with the MSA being used by most of them. It can be seen that some tools like ENCORE, CBF and BFFI include more than one metric.

2.3.4 Swiss Re Institute biodiversity and ecosystem service index

Swiss Re, a re/insurance company from Switzerland has developed a biodiversity and ecosystem service (BES) index through its internal Swiss Re Institute (Swiss Re, 2021). The aim is to provide information about the state of BES on a regional scale all over the world that allows companies as well as policy makers to assess the state of ecosystems that underpin the economies at the same location. The index assesses the state of ten different BES categories (water security, timber provision, food provision, habitat intactness, pollination, soil fertility, water quality, regulation of air quality & local climate, erosion control and coastal protection) at a resolution of 1km² across the globe (Swiss Re, 2020b). The ten BES categories are all only taking place on terrestrial land and were chosen as they represent the majority of risk locations (according to Swiss Re) as well as they offer a broad range of data sources. The results were then grouped on a 7-point scale from "very high" to "very low" meaning that locations with a very high value were considered to offer an intact ecosystem and very low values were considered to be a fragile ecosystem (Swiss Re, 2020a). Figure 8 shows the index on a global scale.

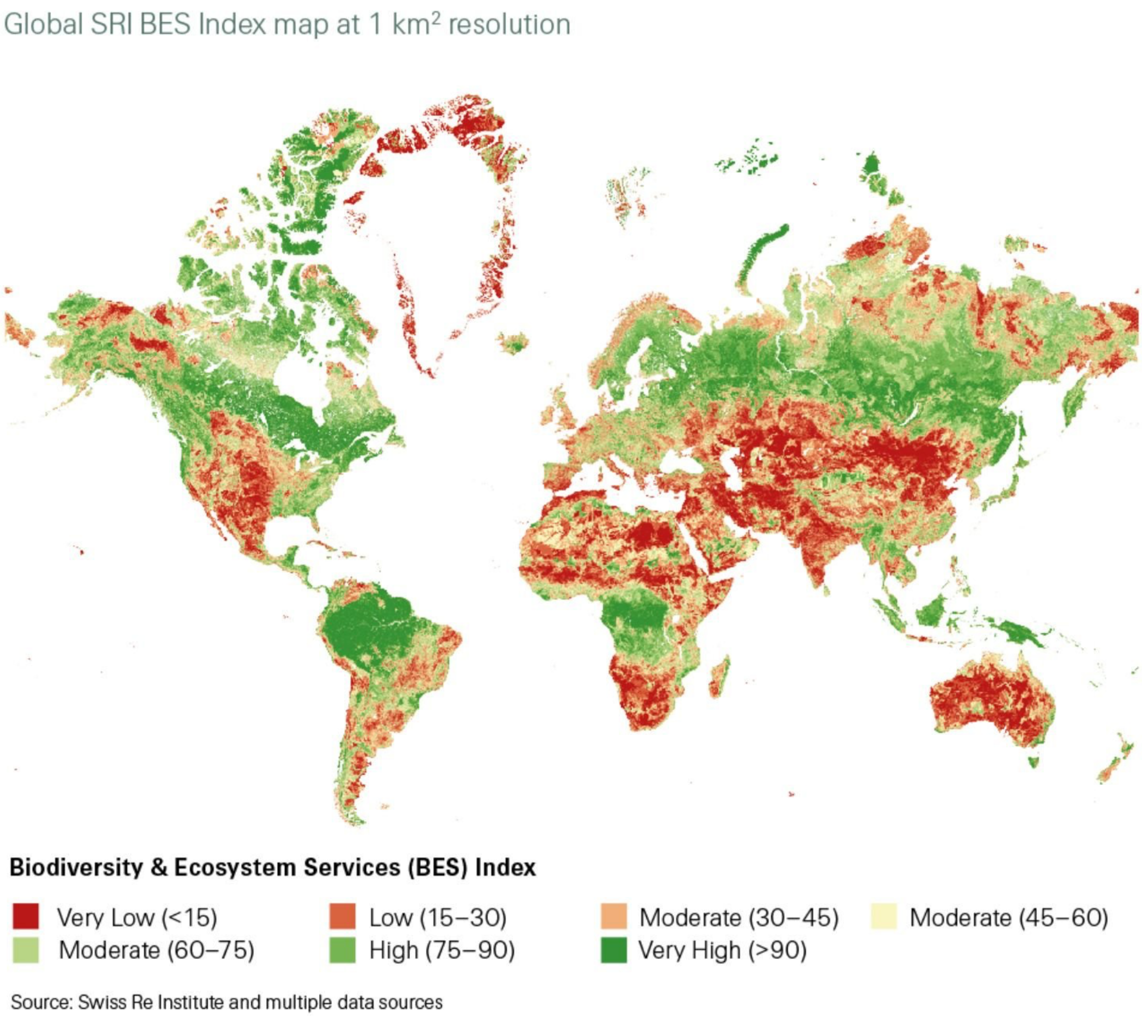


Figure 9: Global SRI index that shows intact and fragile ecosystems globally in 2020

Source: (Swiss Re, 2021)

To show the results in another way figure 9 and figure 10 show the 20 countries with the highest share of fragile and intact BES respectively.

Country	Population Density 2018 [people per km²]	Share of Fragile Ecosystems in BES Index	Share of Intact Ecosystems in BES Index	GDP Dependency on BES
Malta	1 514.5	100%	0%	0.23
Israel	410.5	53%	0%	0.30
Bahrain	2 017.3	50%	0%	0.43
Cyprus	128.7	47%	0%	0.24
Kazakhstan	6.8	43%	0%	0.54
South Africa	47.6	40%	0%	0.40
Greece	83.3	35%	0%	0.41
Australia	3.3	34%	2%	0.30
Singapore	7 953.0	33%	0%	0.35
India	454.9	28%	2%	0.71
Morocco	80.7	27%	2%	0.71
Pakistan	275.3	26%	3%	0.88
Turkey	107.0	24%	1%	0.56
Mexico	64.9	24%	4%	0.44
Spain	93.7	23%	1%	0.36
Belgium	377.4	23%	0%	0.25
Iraq	88.5	21%	0%	0.75
Italy	205.4	21%	2%	0.35
Tunisia	74.4	18%	10%	0.64
Algeria	17.7	18%	1%	0.70

Figure 10: 20 countries with the highest share of fragile BES

Source: (Swiss Re, 2020a)

Peru	25.0	4%	55%	0.63
Colombia	44.8	1%	45%	0.54
Brazil	25.1	4%	42%	0.41
Ecuador	68.8	4%	40%	0.65
Indonesia	147.8	3%	37%	0.80
Canada	4.1	3%	30%	0.34
Malaysia	96.0	0%	29%	0.63
Latvia	31.0	0%	26%	0.36
Finland	18.2	0%	20%	0.39
Russia	8.8	4%	19%	0.52
Sweden	25.0	0%	18%	0.31
Japan	347.1	4%	18%	0.37
New Zealand	18.4	2%	18%	0.36
Estonia	30.4	2%	14%	0.39
Austria	107.1	0%	13%	0.41
Angola	24.7	10%	13%	0.53
Slovenia	103.0	0%	12%	0.47
Lithuania	44.7	0%	11%	0.45
Poland	124.0	1%	11%	0.43
Croatia	73.1	1%	11%	0.43

Figure 11: 20 countries with the highest share of intact BES

Source: (Swiss Re, 2020a)

The Swiss Re Institute sees three different ways how the ten ecosystem services are contributing to economic activities (Swiss Re, 2020a):

- Direct contribution through physical input for production processes
- Indirect contribution through processes that support production processes
- Protecting the production processes from disruptions like for example extreme weather events

To connect their analysis to the dependency of economic sectors, the Swiss Re Institute (Swiss Re, 2020a) used the ENCORE database. To do so the ENCORE rating got exchanged with a 5-point rating from 1 (very low dependency) to 5 (very high dependency). To receive the final risk ratings on the requried GICS subindsutry level, a weighted average value was calculated for each GICS production process which each have different ecosystem services they are depending on. The weighted average value took into account three criteria: the average materiality score of the production process, the maximum materiality score and the number of ecosystem services that the production process depends on. After that the values per production process are agregated as an average value for each subindustry. As ENCORE only includes the GICS industry classification, the subindustry were matched to another industry classification system called Statistical Classification of Economic Activities in the European Community (NACE REV2) on the NACE level 4 (which is the 4th hierarchical NACE level) as this was required to be matched to the global SRI index. In total 15 sectors like agriculture, forestry & fishing, mining & quarrying or manufacturing were assessed. Regarding the final risk rating, Swiss Re used the following methodology to consider the top tercile as "high risk" (values greater than 3.15) and the bottom tercile as "low risk" (values smaller than 2.3). Through this methdology the results were that 55% (which equals to USD 41.7 trillion (Swiss Re, 2020b)) of the global GDP is dependent on BES and that for a fifth of all countries 30% of their ecosystem area is allready in a fragile state. This can be broken down further to 29% of the global GDP (which equals to USD 21.9 trillion) being highly dependent and 26% of the global GDP (which equals to USD 19.7 trillion) being moderatly dependent on BES (Swiss Re, 2020a).

3 Methodology

This section describes the applied methodology and is divided into quantitative and qualitative analysis. The quantitative analysis explores the ecosystem service dependency and impact of equity portfolios and the qualitative analysis includes the findings resulting from the conceptual framework. Explanation of the research design and methods is provided in the sections below.

3.1 Quantitative equity holding analysis

This section presents the research design, data origin and methods of the data analysis of the ecosystem service equity holding analysis.

3.1.1 Research design

As explained in section 1.3, this thesis has the objective to estimate the interdependency between BES risks and the equity portfolio of European banks. The quantitative equity holding analysis of this thesis closely follows one part of the research design presented and used by the Dutch Central Bank (De Nederlandsche Bank, 2020a, 2020b), explained already in more depth in section 2.3.2. In short, this part of the report connects information on investments by the Dutch financial sector grouped by industry sectors with information on the ecosystem service dependency of these different industry sectors. However, the assessment by the Dutch Central Bank does not include an analysis of the impact on ecosystem services of the equity holdings, does not distinguish between different financial institutions (like banks or asset managers) and does not look at the whole European area. The quantitative analysis presented in this thesis aims to incorporate all three of these limitations. This thesis therefore estimates the interdependency between BES risks and the equity portfolio of European banks by showing the connection of equity portfolios to first, the BES dependency of industry sectors and second the BES impact of industry sectors.

The distinguishment between BES dependency and BES impact has three reasons. First, ENCORE includes data on dependencies and impacts and justifies both of them in different ways (explained in section 3.1.2.1). Second, important literature has shown that dependencies and impacts are both important and describe different parts of the interdependency of BES and the financial sector (Finance for Biodiversity, 2021). Third, the above-mentioned risks for financial institutions (see section 2.1.4) like the transition risk or litigation risk (McCraine et al., 2019; Monetary Authority of Singapore, 2020; NGFS, 2020; WWF, 2020) are connected to BES impacts when businesses that harm BES must stop their operations, or must align to changes in the regulatory framework. Therefore it is possible to say that BES dependency and BES impacts show the two different sides of BES risks for financial institutions, either investments that require inputs from BES or investments that destroy BES.

Two main points were important to obtain valuable results out of the quantitative analysis. First, data on all shareholders globally needed to be obtained and connected with materiality ratings about the ecosystem service impact and dependency of each investment. Subsequently, the collected data was cleaned from missing values, misspellings and other obvious errors. Then, the ecosystem service impact and dependency risks for each portfolio of the different shareholders was calculated.

3.1.2 Methods for data collection

Three different sources are used to obtain the necessary data for the quantitative equity holding assessment: the ENCORE, Orbis, and the Refinitiv EIKON databases.

3.1.2.1 ENCORE database

The Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) database allows for the extraction of ecosystem service dependency and impact materiality ratings. ENCORE is a global tool which is linking environmental change with its impacts on the economy developed by the Natural Capital Finance Alliance, which is a worldwide finance initiative founded by UNEP-FI and the UK-based NGO Global Canopy Programme, and UNEP WCMC. Its aim is to help financial institutions to understand their impact on biodiversity better (ENCORE, 2021a).

ENCORE shows the connection of 12 economic sectors with 21 ecosystem services and differentiates between dependency and impact. The economic sectors are further differentiated into 138 subindustries. This classification scheme follows the Global Industry Classification Standard (GICS). ENCORE has then defined 86 production processes (which are each connected to the 138 GICS subindustries) and provides the materiality rating for each of them (ENCORE, 2021b). The information for the materiality ratings are obtained through an extensive literature review for each assessed ecosystem service followed by expert interviews to validate the information (ENCORE, 2021d).

Building upon this obtained knowledge, the final dependency materiality ratings were formed by taking two different aspects into account (ENCORE, 2021e). The first one looked at the significance of the loss of functionality of the production process resulting out of a disruption of the specific ecosystem service which gave three different possible answers, either limited loss of functionality, moderate loss of functionality or severe loss of functionality. The second aspect looked at the significance of the financial loss for the production process due to the loss in functionality resulting out of a disrupted ecosystem service for which again three different answers were possible, a limited financial loss, moderate financial loss or a severe financial loss. A very high materiality rating meant therefore that a disruption in the ecosystem service will lead to a severe loss of functionality and a severe financial loss for the production process (ENCORE, 2021e).

For the impact materiality rating three different aspects were considered. The first one described the frequency of the impact which could either be high, medium or low. The second looked at the time period until the impact would affect natural capital which could either be smaller than a year, between one and three years or above three years. The last aspect described the severity of the impact as either high, medium or low. An ecosystem service rated with a very high impact materiality rating therefore required to occur continuously and will start within one year of the start of the production process and will cause long-lasting and irreparable effects on natural capital (ENCORE, 2021e).

ENCORE mentions here already 5 different limitations to these materiality ratings (ENCORE, 2021e): (i) The ratings indicate only potential impacts or dependencies as specific companies with the same production process could have different actual ratings. (ii) The ratings are only a generic global assessment although many dependencies and impacts are location specific. (iii) Although ratings were assigned on the best available literature, sufficiency is not guaranteed. (iv) The ratings for production processes are based on current technologies and industry norms which can be different for specific companies that have strong measures in place to tackle dependencies or impacts. (v) The ratings for different production processes are independent from each other.

From ENCORE, two datasets for impact materiality and dependency materiality were obtained. Another dataset contained the GICS subindustry names and codes with the matching ENCORE business processes. As mentioned in section 3.1.1, this adds to the methodology used by the Dutch Central Bank as the impact materiality ratings were not included in that report.

The impacts dataset shows the materiality ranking of each subindustry-business process couple for 11 environmental impacts (Disturbances, Freshwater ecosystem use, GHG emissions, Marine ecosystem use, Non-GHG air pollutants, Other resource use, Soil pollutants, Solid waste, Terrestrial ecosystem use, Water pollutants, Water use) on a 4-point scale from low to very high while as well indicating an NA if no link was found. This allows to sum up the materiality ranking for each subindustry.

The dependency dataset shows the materiality ranking for 85 business processes regarding 21 ecosystem services (Mass stabilization and erosion control, Ground water, Surface water, Climate regulation, Flood and storm protection, Filtration, Dilution by atmosphere and ecosystems, Genetic materials, Water flow maintenance, Water quality, Soil quality, Pest control, Disease control, Ventilation, Buffering and attenuation of mass flows, Bio-remediation, Fibres and other materials, Mediation of sensory impacts, Maintain nursery habitats, Animal-based energy, Pollination) on a 5-point scale from very low to very high. As each business process is connected to one or more business sectors it is possible to sum up the materiality ranking for each subindustry.

ENCORE therefore allows to show the level of potential risk (connection to ecosystem services) for different GICS classified subindustries. This needs to be connected to information of financial connections of banks to the highlighted subindustries in ENCORE.

3.1.2.2 Orbis database

Data about the equity holdings in the portfolio of banks has been obtained via the Orbis database, which is a business information tool, delivered by the company Bureau van Dijk. As the Orbis database is a private tool, the access was granted through the Lund University student access. The Orbis database allows to search for different businesses using different parameters and then showing different information for the selected businesses in the created database. With the Orbis database it was possible to extract an excel sheet of the publicly listed companies from all over the world which have more than two employees (the last parameter was used as Orbis only allows a specific amount of data to be displayed and the exclusion of companies with 1 or fewer employees allowed that). This dataset includes 41,399 business from all countries of the world 41,399 (from which only 32,598 have an ISIN number and can be used in this thesis) business with all of their 1,148,151 shareholders (this number includes same shareholders for different businesses; there are 463,390 unique shareholders in the dataset). In total, nine different columns of information were collected to support the analysis. They are described as follows:

- Company name: The company name for which shareholder information is disclosed.
- ISIN number: The International Securities Identification Number (ISIN) number which is unique for (publicly) listed businesses.
- Enterprise value in 2019: The enterprise value at the stock exchange at the 31.12.2019 which is needed to calculate the value of each shareholders equity holding in each company.
- Enterprise value in last available year: As the column "Enterprise value in 2019" does not include data for every company, this column allowed to extract values for the missing data rows.
- Shareholder – Name: The name of each shareholder.

- Shareholder - Direct %: This are shareholder that hold the share in the company in their own legal name and not through other intermediaries.
- Shareholder - Total %: The total shareholder includes holdings in the company by intermediaries that are controlled by the shareholder (like subsidiaries).

3.1.2.3 Refinitv EIKON database

The Refinitiv EIKON database was used to obtain information on the GICS subindustry code for each of the companies mentioned in the Orbis dataset as ENCORE only includes materiality ratings for GICS subindustry codes.

From there a dataset was extracted that includes 49,567 publicly listed companies from all countries of the world. The dataset shows the company name, the ISIN number and the GICS subindustry code. The ISIN number allows to cross reference the GICS code with the companies fond in the Orbis database.

All three datasets (ENCORE, Refinitiv Eikon and Orbis) were downloaded in Microsoft Excel file format. Combined, the three datasets allow the analysis of equity portfolios of European banks regarding the ecosystem impact and dependency risk.

Table 1 shows an overview of the data in the two company datasets and the reasons for data reduction. It shows that from the first dataset contained from Orbis, only 32,244 companies contained the important ISIN number. After merging this with the dataset obtained from Refinitiv Eikon, only 26,029 companies were remaining as the GICS subindustry code was missing for some companies. From that dataset, only 22,753 companies contained an enterprise value which was the final number of companies used before the table got grouped after shareholder-GICS code-couples. Finally, 166,105 shareholders remained after data merging and data cleaning.

Table 1: Distinct values in the different datasets before and after merging

	Companies	Shareholder
Orbis	41,358	463,390
	32,244 with ISIN number	401,375
Refinitiv Eikon	49,534	
	48,911 with ISIN number	
Merged Orbis + Eikon (deleted every row with no GICS subindustry)	26,029	361,192
	22,753 with enterprise value	317,488
Final dataset after equity grouping and further data clearing		**166,105**

3.1.3 Method for data analysis

As the complete data analysis method is quite comprehensive, it will be explained in the five sections: General approach, Method used for risk classification, Risk calculation of this research, Calculation of equity portfolios for different shareholders, Obtaining final results.

3.1.3.1 General approach

To follow the proposed methodology and be able to calculate the risk of many different equity portfolios a data management tool was needed that could handle these amounts of data. The calculation of the equity portfolios for the banks is therefore done with the programming language Python, version 3.8.5 (Python Software Foundation, 2020). Python allows a much easier and faster handling of big datasets compared to handling the data directly in Excel.

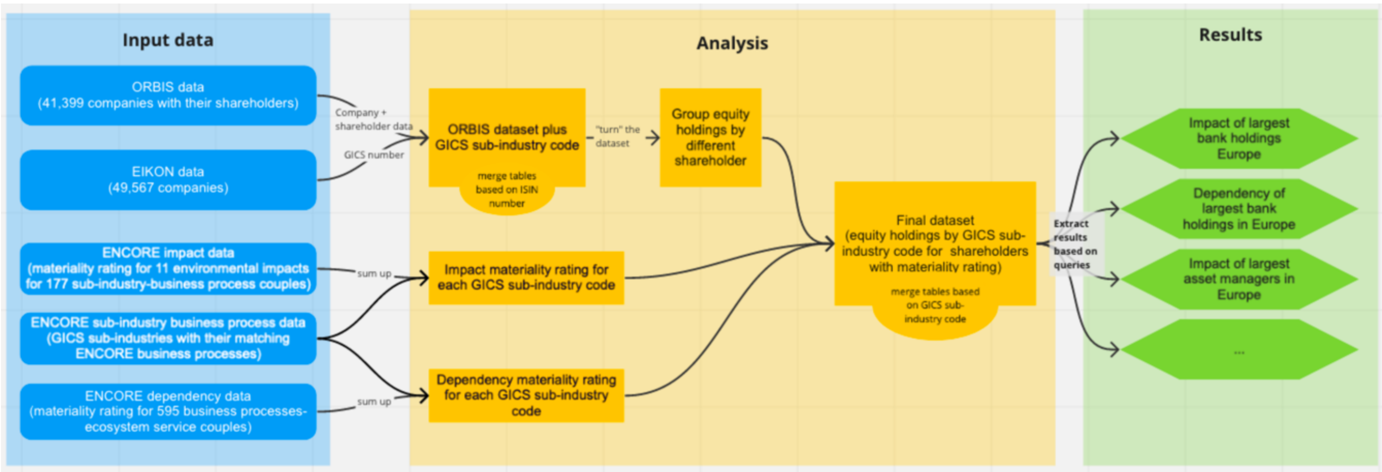


Figure 12: Flow chart of the quantitative analysis to analyze the ecosystem service dependency and impact of European banks

The method for data analysis is summarized in Figure 12. This data analysis method follows the general steps in programing development which are defining the problem, designing the program, coding the program, testing and debugging the program and deploying or extracting results (CourseHero, 2021; GeeksforGeeks, 2018). The problem definition is equal to the research design mentioned in section 3.1.1. and can be described as following: the program should be able to calculate the ecosystem service dependency and impact risk of the equity holdings of financial institutions in Europe. The design of the program can be seen in figure 12. The final coding will be explained in the following in more detail including decisions taken during the program design phase. This already incorporates the changes and learning reached after the testing and debugging throughout the programing process.

3.1.3.2 Method used for risk classification

As said this thesis follows the general methodology used in the report by the Dutch Central Bank. One very important part of this methodology is the way how the business sector risk ratings are calculated with the ENCORE data (which business sector is classified as "high risk"). In this specific case this thesis does not follow the methodology by the Dutch Central Bank but tries to take more variables into account for the risk classification. This decision was reached after reviewing different research approaches that worked with the ENCORE database. These different approaches for a risk rating found in the literature will be explained in the following before explaining the chosen approach for this thesis in the last three paragraphs of this section.

The World Economic Forum together with PwC have used the ENCORE database for their calculation of the dependency of global GDP on nature and its services that resulted in USD 44 trillion being moderately or highly dependent. From this, USD 13 trillion are highly dependent and USD 31 trillion are moderately dependent while the three largest sectors that are dependent are construction, agriculture and food & beverages (World Economic Forum, 2020b). In their methodology they have exchanged the very low to very high ratings with values between 1 to 5. Then they calculated for each production process a dependency rating using three equally weighted factors: the number of different ecosystem services the production process is depending upon, the average score of the ecosystem services for a production process and the maximum score of ecosystem services for a production process. The resulting dependency rating for a production process was then aggregated on sector level (by average). After that a risk classification took place that considered scores above 3 as "high risk", scores below 2 as "low risk" and scores in between as "medium risk" (World Economic Forum, 2020b).

Swiss Re (Swiss Re, 2020a) followed the methodology of the World Economic Forum explained above, using the same three criteria (average materiality score for a production process, number of ecosystem services per production process and the maximum materiality score of each production process) to calculate dependency values for each production process which were then aggregated on subindustry level. The Swiss Re approach differs then as dependencies on water security and timber provision are receiving double weighting in the calculation of the average materiality score for each production process as Swiss Re wanted to take into account the importance of ecosystem services that offer a direct input to the economy (Swiss Re, 2020a). After that the subindustry materiality scores were calculated by the average value of all the production processes below the subindustry, similar to the approach used by the World Economic Forum. The classification of what is considered a "high risk" differs from the approach used by the World Economic Forum as the Swiss Re divided the dependency materiality ratings into three terciles, with the bottom tercile (values below 2.3) being classified as "low risk", the top tercile (values above 3.15) being classified as "high risk" and the values in between being classified as "moderate risk" (Swiss Re, 2020a).

The Dutch Central Bank (De Nederlandsche Bank, 2020b, 2020a) only included production processes that showed an ecosystem service dependency of "high risk" or "very high risk" into their analysis. As their analysis required a different industry-classification system (NACE compared to the GICS system used in ENCORE), each production process was matched with corresponding sectors in NACE. For the case that more than one production process made up a sector, the values were aggregated using the average value over the production processes in question.

The risk definition of the ENCORE data for this thesis followed therefore the approach presented by Swiss RE (Swiss Re, 2020a) as their approach took different criteria into account for calculating the final materiality scores which showed a better understanding of the complexity of the relationship between ecosystem services and economic sectors.

To do so, the first step was to calculate ecosystem service impact and dependency materiality ratings for the production processes. As both ratings used a non-numeric 5-point scale, each point on the two scales received a numeric value between 1 and 5, with 5 being a very high dependency/impact rating and 1 being a very low one. Then the average materiality score for a production process, the number of ecosystem services/impacts per production process and the maximum materiality score of each production process were calculated; subsequently, the weighted materiality score for each production process was calculated. After that the final materiality scores for the different GICS subindustries were calculated as the average score of the different production process ratings below each subindustry.

Figure 13 shows an exemplary calculation of the ecosystem service dependency risk rating for the subindustries "Airlines" and "Airport services" from the original ENCORE data on the underlying production process "Airport Service". After applying a numerical scale to the original ENCORE data, the number of ES per process, the average score per process and the maximum score per process is used to calculate the weighted risk value per production process (1). Then the data per production process is matched with the data on GICS subindustries (2). Finally, all unimportant information is deleted to only show the GICS subindustry and its GICS code with the materiality rating (3).

Process	Ecosystem Service	total rating
Airport services	Mass stabilisation and erosion control	M
Airport services	Ground water	M
Airport services	Surface water	M
Airport services	Climate regulation	M
Airport services	Flood and storm protection	H

1

Process	number of ES for process	average of process	max materiality score of process	total weighted value of process
Airport services	5	3.200000	4	4.066667

2

Sector	Subindustry	sub-industry code	Process	total sum of process	total weighted value of process
Industrials	Airlines	20302010	Airport services	16.0	4.066667
Industrials	Airport Services	20305010	Airport services	16.0	4.066667

3

Subindustry	sub-industry code	Weighted average sum rating
Airlines	20302010	4.066667
Airport Services	20305010	4.066667

Figure 13: the dependency materiality calculation for the production process "airport services" and the resulting values for the subindustries "Airlines" and "Airport Services"

It is important to mention here that the ENCORE dataset included 7 different subindustries that are not used in the GICS coding: Iron, Pharmaceuticals manufacturing, Life Sciences manufacturing, Biotechnology manufacturing, Pharmaceuticals services, Life Sciences Tools services and Biotechnology services. Therefore, these subindustries were replaced accordingly to the following GICS subindustries: Steel, Pharmaceuticals, Life Sciences Tools & Services, Biotechnology, Pharmaceuticals, Life Sciences Tools & Services and Biotechnology (MSCI, 2021).

For the final analysis it was necessary to distinguish between what counts as risk and what counts as no risk. Different risk classifications were used as this allowed to show the different implications of different risk classifications, an important learning for answering RQ 2 (What are the main sources of uncertainty in the analysis of equity holdings). To do so first the top tercile of materiality ratings was considered as "high risk", and then compared to the materiality ratings when the top 20% was considered as "high risk".

3.1.4 Calculation of equity portfolios for different shareholders

The next step was to prepare the shareholder dataset obtained from the Orbis database. The purpose of this was to create a dataset that included all the different shareholders mentioned in the Orbis dataset with their total value of equity holdings over all investments and the total value of equity holdings for each distinct GICS subindustry. As Orbis did not include GICS subindustry codes, first the ISINs were used to cross-reference the GICS subindustry code and name from the Refinitiv Eikon database to the shareholder dataset. One important step afterwards was to clear numerical data from non-numerical characters. All rows that contained no numerical values afterwards were dropped as they had no value for the further analysis. Only including numerical values allowed to calculate the value of each respective equity holding in the dataset. This was required as the dataset until this point included information on the enterprise value of each company and information on the share each shareholder hold from each company in percentage (to give an example: the dataset included the information that the company Amazon INC had an enterprise value of USD 902 billion in 2019 and that the shareholder Blackrock owned 5.52% of Amazon at the same point of time). Therefore, the value of each specific equity holding was calculated by multiplying the enterprise value in USD with the shareholder value in percentage (in the used example the new information calculated was that Blackrock owned a share of Amazon that was worth USD 49 billion).

After this the dataset showed all companies globally with their respective shareholders. For the sake of this thesis, it was important to change the view from the global companies to the shareholders. The final dataset needed to show the shareholders first with the different GICS subindustries they are invested into. And each GICS subindustry for each shareholder needed to include the sum of equity holdings into all the (two sentences before mentioned) global companies. To do so the data was sorted by shareholders so that it was possible to calculate the sum of the total equity holdings for each shareholder (meaning the sum of the different investments into all GICS subindustries for each shareholder) as well as the sum of the value of equity holdings for each individual GICS subindustry. After this the dataset included information about the shareholder, the total value of equity holdings by this shareholder in the dataset, the GICS subindustry, the value of the equity holding in this specific GICS subindustry and the share of these investments from the total equity holdings of this shareholder.

The final step was then to match this dataset with the ENCORE materiality rating so that each subindustry group got an ecosystem service rating regarding the impact and regarding the dependency. As both datasets included the GICS subindustry code, the information on the materiality rating was just inserted through matching the GICS subindustry codes in each dataset.

The final dataset contained 379,992 rows, including of 166,105 unique shareholders (this is a smaller number than the number of rows as each shareholder has multiple rows that contain the value of equity holdings for each GICS subindustry). The financial value of total equity holdings in the final dataset is USD 64.3 trillion. An example of a row of the final dataset is given in Figure 14. Each row contains a shareholder-equity holding combination and the following information:

- Name of the shareholder
- GICS subindustry of the equity holding
- GICS subindustry code of the equity holding

- The value of the specific equity holding of this row (in th. USD)
- The total value of equity holdings of this shareholder (in th. USD)
- The share of the value of the specific equity holding of all equity holdings by this shareholder (in %)
- The ecosystem service impact rating of this equity holding, depending on the GICS subindustry code, being displayed as the weighted score explained above
- The ecosystem service dependency rating of this equity holding, depending on the GICS subindustry code, being displayed as the weighted score explained above

Figure 14 shows an exemplary row of this final dataset.

Shareholder - Name	Subindustry	sub-industry code	Value equity holding in th USD	Total value equity holdings in th USD	Equity value in %	Weighted average sum impact subindustry	Weighted average sum dependency subindustry
UBS GROUP AG	Oil & Gas Drilling	10101010	76,634.85	350,206,559.52	0.02	6.40	3.38

Figure 14: Exemplary row in the final dataset

3.1.4.1 Obtaining final results

Final results were obtained by performing different queries focusing on specific investors to show their ecosystem service dependency and impact. As the final dataset contained 166,105 different shareholders, the task was to extract shareholders that are relevant to the research aim. Therefore, different ways of extracting a manageable number of shareholders were used and if needed they were based on a small internet research to obtain the names of the needed shareholders. With these names it was possible to specifically filter the dataset after these queries. The queries used to obtain the results were the following:

- Query 1: The 25 biggest banks in Europe. This information was taken from the webpage https://www.consultancy.eu/news/4199/the-50-largest-banks-of-europe-by-assets (Consultancy.eu, 2020) which shows the biggest banks (or bank holding companies) in Europe sorted by the total value of assets. Not all banks were found in the final dataset (missing ones: Royal Bank of Scotland Group plc) which means that from the biggest 25 banks only 24 are displayed in the results.
- Query 2: The 10 biggest asset managers in Europe. This information was taken from https://www.advratings.com/top-asset-management-firms (advratings, 2021). For each of the two French companies Amundi and Natixis Investment managers the final database contained two possible shareholders (Amundi Asset Management or Amundi SA; Natixis Investment Managers International or Natixis SA). Both times the asset management/investment managers company was chosen as they had the higher value of equity portfolio in the database. This query is similar to the ones regarding banks as UBS Group AG, Deutsche Bank AG, Credit Suisse Group AG and BNP Paribas are listed as an asset manager as well.
- Query 3: The 10 biggest asset managers globally. This information was taken from https://www.statista.com/statistics/431790/leading-asset-management-companies-worldwide-by-assets/ (Statista, 2021). As explained in Query 2, Amundi Asset Management was chosen. Similarly, the State Street Corporation was chosen as the respective business of the State Street Global business mentioned in the source.

The final dataset still contained different rows for the same shareholder, each showing the "equity value at risk in %" for the different GICS subindustries. As the final results did not require this differentiation, each query was followed by summing up the "equity value at risk in %" for each shareholder and then calculating the "equity value at risk" for each shareholder. Figure 15 shows an exemplary row of this.

Shareholder - Name	Total value equity holdings in bn USD	Equity share at risk in %	Equity value at risk in bn USD
UBS GROUP AG	350.21	24.88	87.12

Figure 15: Exemplary row of the results

From there, the average share of the equity holding portfolio that is at risk, the average value of the equity holding portfolio that is at risk, the weighted average share of the equity holding portfolio that is at risk and the weighted average value of the equity holding portfolio that is at risk were calculated. The average share is calculated by

$$\frac{\sum \text{equity value at risk in \%}}{\text{number of shareholder in query}}$$

and the average value at risk is calculated similarly, just by

$$\frac{\sum(\text{equity value at risk in bn USD}}{\text{number of shareholders in query}}$$

Besides that, a weighted average share is calculated that takes into account the value of the total equity portfolio of each shareholder. This is done as some shareholders have a very low value of equity portfolio in the database and others have a very high one. A general average treats the share at risk and the value at risk from these different shareholders completely the same. A weighted average values the shareholders with a high number in the equity portfolio stronger. The weighted average share at risk is calculated by

$$\frac{\sum(\text{total value of the equity holding} \times \text{equity value at risk in \%})}{\sum(\text{total value of the equity holding})}$$

Again, the weighted average value at risk is calculated similarly by

$$\frac{\sum(\text{equity value at risk in bn USD} \times \text{total value of the equity holding})}{\sum \text{total value of the equity holding}}$$

After this, for each query a graph-table-combination is created that visualizes the results better. The graph shows for each shareholder in one bar the "total value of the equity holdings" (grey colour) and the "Equity value at risk" (red colour) in billion USD. Next to the graph a table shows for the same shareholders the share of the equity portfolio at risk in % and the corresponding value in billion USD.

To interpret the results, the origin of the value at risk for the European banks is examined. For this, the top 4 shareholders from query 1 with the highest value at risk are examined. For each shareholder, a pie chart is created of the GICS subindustries that are causing the risk in the equity portfolio. Each piece of the pie chart represents the share of this GICS subindustry from the sum of the GICS subindustries that are at risk.

Each high-risk rating of GICS subindustries is coming from the underlying ecosystem services in ENCORE this subindustry either impacts or depends on. Therefore, for the most important

GICS subindustries that cause the highest shares of the value at risk, the underlying ecosystem services are presented.

3.2 Qualitative analysis of case studies

The aim of the qualitative analysis was mainly to find information for the third research question and in parts also for research question 2. This was done through a literature review of the connection between BES risks and the equity portfolio of banks, (BES) risk assessments in the financial sector together with an in-depth analysis of specific case studies in the financial sector that focus on the incorporation of BES risks. For the part on banking risk assessment, the literature review focused on the European sector. The literature review used a synthesis matrix and relied on literature sources like Web of Science, Google Scholar and LUBsearch. Search terms include for example "ecosystems services", "biodiversity", "banking supervision", "sustainability risks", "risk assessment", "environmental risks", "European banking sector", "financial institutions". Besides academic literature important institutional literature was used for example from the ECB, UNEP-FI, WWF, TEEB, NGFS.

4 Findings and results of the risk assessment of equity holding portfolio of European financial institutions

In this section, the main findings of this thesis are presented. In the following the results from the analysis regarding BES dependency and BES impact in the equity holding portfolios of European financial institutions are presented. As mentioned in section 3.1.1, the difference between dependency and impact is that: The dependency assessment shows the risk of investments into businesses that require to take input from BES on a large scale for their operations which can be negatively influenced by the BES decline. The impact assessment shows the risk of investments into businesses that harm BES through their operations which might be penalized by either regulations, customers or other stakeholders.

First some overall results from the complete database are presented, followed by more in-depth analysis of the specific queries of shareholders explained in section 3.1.4.1.

As a general note, uncertainties and limitations of this BES dependency and impact assessment will be discussed in the next chapter in section 5.2.

4.1 BES dependency

As mentioned in the methodology two different risk classifications will be used, the first one classified the subindustries as “high risk” that reached a BES dependency rating above 4.27 which was the top tercile (top 33%) of all subindustries. The second one classified subindustries as “high risk” that received a dependency rating above 5.36 which was the top 20% of all subindustries. As the top tercile approach follows the literature (Swiss Re, 2020a), this will be used as the general risk classification. Results using the 20% approach will be specifically mentioned.

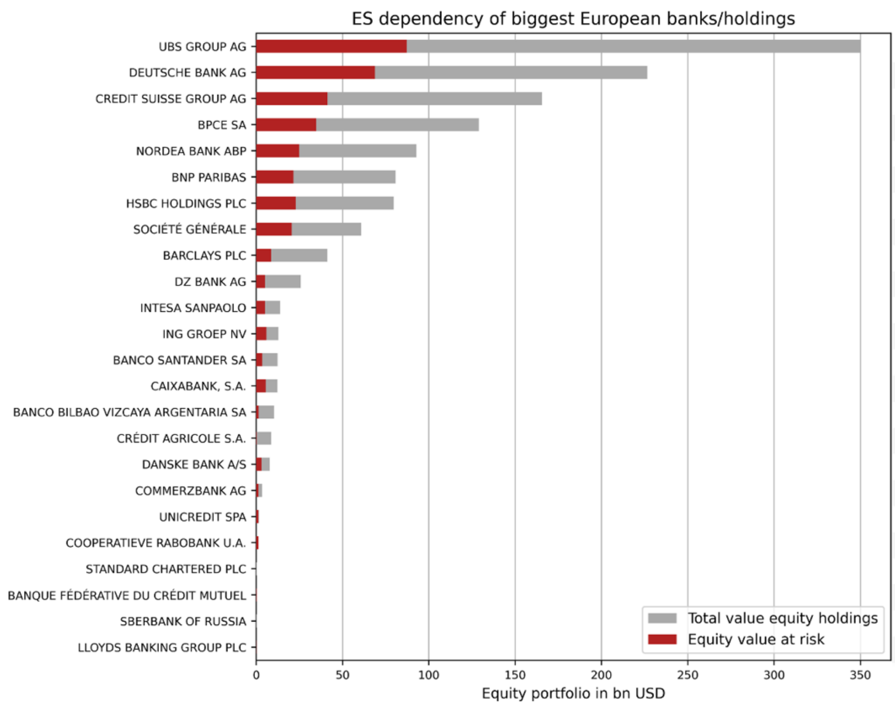
With this in mind, the first result is that from the whole equity portfolio value in the database (USD 65.7 trillion), USD 24.5 trillion is at risk of high BES dependency. This represents 37.2%. In the following the results for the three different queries are presented.

4.1.1 BES dependency – largest banks in Europe

In the first query the 25 biggest banks in Europe are examined.

As explained in section 3.1.4, first the average values of the whole set of 25 banks are calculated. The average share of the equity portfolio of the biggest European banks that is highly depending on BES is 37.04% and the average value of the equity portfolio is USD 15.15 billion. The weighted average share of the equity portfolio of the biggest European banks that is highly depending on BES is 27.21% and the weighted average value of the equity portfolio is USD 48.84 billion.

Figure 16 combines the “total value of equity holdings” in the database for each bank in grey color and shows the share of this total value that is at risk due to BES dependency, in percentage as well as in absolute numbers.



Equity share at risk	Equity value at risk
24.9%	87.12 bn USD
30.4%	68.78 bn USD
24.9%	41.19 bn USD
27.0%	34.77 bn USD
26.8%	24.86 bn USD
26.5%	21.38 bn USD
28.8%	22.89 bn USD
33.7%	20.45 bn USD
21.1%	8.67 bn USD
19.8%	5.09 bn USD
36.7%	5.04 bn USD
45.0%	5.76 bn USD
29.2%	3.58 bn USD
44.8%	5.47 bn USD
13.4%	1.38 bn USD
3.2%	0.28 bn USD
39.4%	3.09 bn USD
35.9%	1.24 bn USD
76.8%	1.19 bn USD
98.8%	1.25 bn USD
2.0%	0.01 bn USD
100.0%	0.21 bn USD
0.0%	0.00 bn USD
100.0%	0.06 bn USD

Figure 16: Total value of equity holdings and the equity value at risk that is highly depending on BES of the 25 biggest European banks in 2019 using the top tercile risk classification

The value at risk can reach significant amounts as seen by the top banks in figure 16 with UBS having a value at risk of USD 87 billion, Deutsche Bank of USD 68 billion or Credit Suisse of USD 41 billion. For these banks at the top of the figure that have a high total value of their equity holding in the database, the share at risk lies around 25-30%, similar to the weighted average value but a bit smaller than the normal average value mentioned above. The further down on the figure (and a lower total value of equity holdings in the database), the share at risk number varies stronger, from Standard Chartered with only 2% to Cooperatieve Rabobank with 98.8%. The last three banks in the figure Banque Federative du Credit Mutuel, Sberbank of Russia and Lloyds Banking Group PLC even reach 100% and 0% share at risk which comes from the fact that these banks have very limited numbers of equity holdings in the database (for example only 1 equity holding for Banque Federative du Credit Mutuel in the original dataset obtained from Orbis) and these few equity holdings then do not have a BES dependency or all of them have a BES dependency. This can be seen by the different total values of equity portfolio. The UBS Group for example has a total value of the equity portfolio of USD 350.2 billion in the database whereas Lloyds Banking Group PLC only has a total value of USD 0.06 billion in the database.

To show the impact of a slightly different risk classification for the results, figure 17 shows the equity value at risk for the same banks, only using the top 20% risk classification approach. As here less GICS subindustries are classified as "high risk", the results reach lower numbers than for the tercile approach (seen in figure 16). The share at risk for the top banks in figure 17 differs between 15-20% with the weighted average share at risk being 17.9%. The weighted average value at risk reaches USD 32.19 billion and can reach amounts like USD 57 billion for the UBS Group or USD 46 billion for the Deutsche Bank.

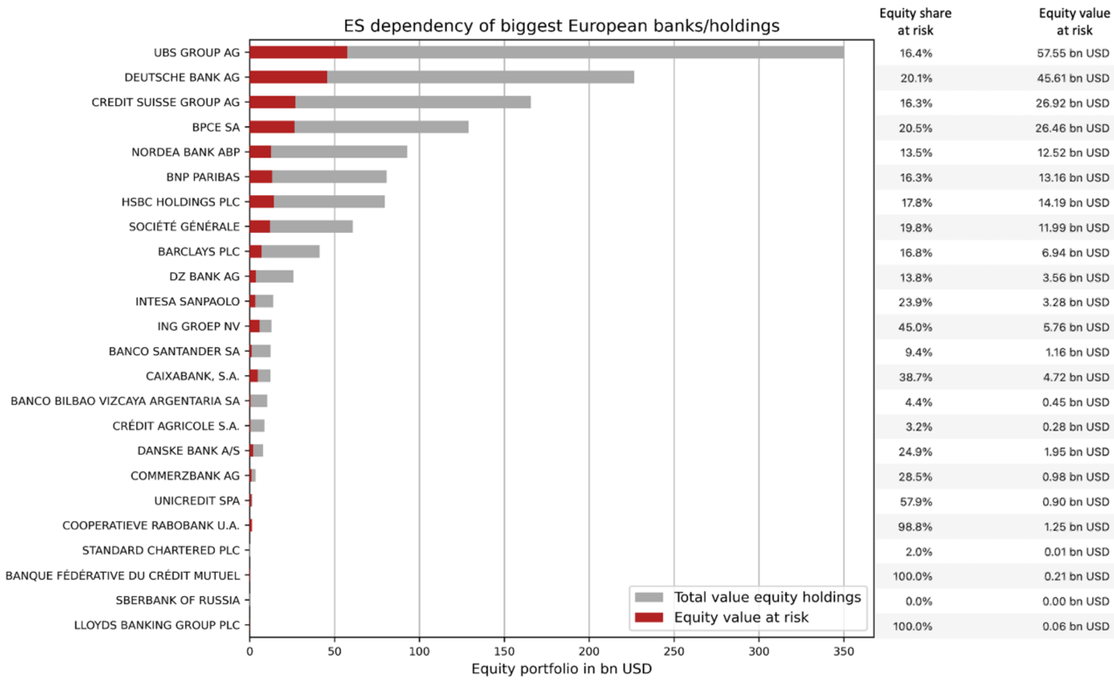


Figure 17: Total value of equity holdings and the equity value at risk that is highly depending on BES of the 25 biggest European banks in 2019 using the top 20% risk classification

In the next step the origin of these values at risk is further examined. Figure 18 shows for the top 4 banks with the highest value at risk (UBS Group, Deutsche Bank, Credit Suisse Group, BPCE) the different GICS subindustries that are causing the classification as dependent on BES. The total pie chart makes up the value at risk.

Figure 18: Share of GICS subindustries of the total value at risk that is dependent of BES for UBS Group, Deutsche Bank, Credit Suisse Group and BPCE in 2019

As seen in figure 18, the GICS subindustries with the highest share on the total value at risk are electric utilities, aerospace & defense, automobile manufacturers and integrated oil and gas (how to read this: for UBS Group, electric utilities is responsible for 11.8% of the USD 87.12 billion value at risk). In the following, the ecosystem services that cause the subindustry to be classified as dependent over these four banks are described:

- Electric utilities: Climate regulation, Mass stabilisation and erosion control, Flood and storm protection, Water quality, Filtration, Bio-remediation, Ground water, Surface water, Water flow maintenance
- Aerospace & defense: Flood and storm protection, Dilution by atmosphere and ecosystems, Water quality, Mediation of sensory impacts, Filtration, Mass stabilisation and erosion control, Ventilation, Climate regulation, Surface water, Water flow maintenance, Ground water
- Automobile manufacturers: Flood and storm protection, Dilution by atmosphere and ecosystems, Water quality, Mediation of sensory impacts, Filtration, Mass stabilisation and erosion control, Ventilation, Climate regulation, Surface water, Water flow maintenance, Ground water
- Integrated oil and gas: Filtration, Mass stabilisation and erosion control, Climate regulation, Surface water, Bio-remediation, Flood and storm protection, Water quality, Ground water
- Agricultural & farm machinery: Flood and storm protection, Dilution by atmosphere and ecosystems, Water quality, Mediation of sensory impacts, Filtration, Mass stabilisation and erosion control, Ventilation, Climate regulation, Surface water, Water flow maintenance, Ground water
- Tobacco: Mass stabilisation and erosion control, Water flow maintenance, Fibres and other materials, Ground water, Surface water
- Apparel, accessories & luxury goods: Bio-remediation, Dilution by atmosphere and ecosystems, Fibres and other materials, Filtration, Flood and storm protection, Flood and storm protection, Ground water, Mass stabilisation and erosion control, Surface water, Water flow maintenance, Water quality

Aerospace & defense and automobile manufacturers are both based on the same production process (Manufacture of machinery, parts and equipment) which is why their ecosystem service dependencies are the same.

4.1.2 BES dependency – largest asset managers in Europe

Looking at the biggest European asset managers, the average share of the equity portfolio that is highly depending on BES is 24.4% and the average value of the equity portfolio is USD 32.08 billion. The weighted average share of the equity portfolio of the biggest European asset managers that is highly depending on BES is 26.03% and the weighted average value of the equity portfolio is USD 57.88 billion.

Figure 19 combines the “total value of equity holdings” in the database for each asset manager in grey colour and shows the share of this total value that is at risk due to BES dependency, in percentage as well as in absolute numbers.

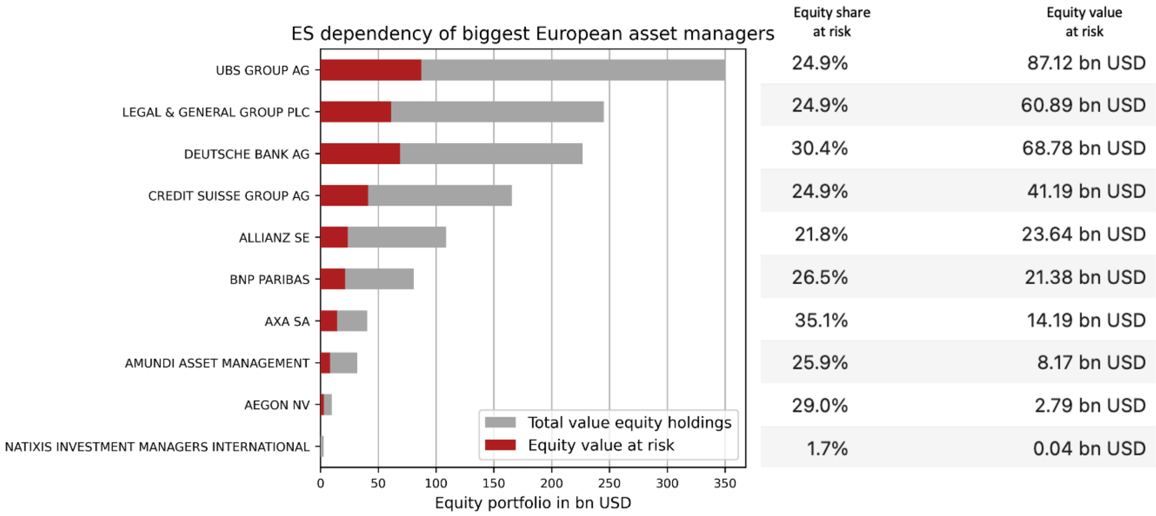


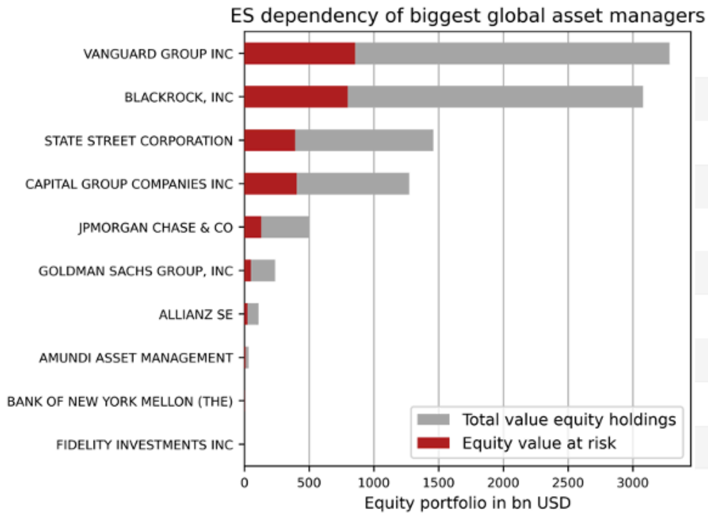
Figure 19: Total value of equity holdings and the equity value at risk that is highly depending on BES of the biggest European asset managers in 2019

Looking at asset managers in Europe reveals a similar picture as looking at banks in Europe in Query 1, also because similar businesses are looked at like UBS Group, Deutsche Bank, Credit Suisse and BNP Paribas (as explained in the methodology section 3.1.4, the values for the same businesses is exactly the same, as the same analysis steps are done between the queries for the same businesses). Still the general findings remain the same for the other businesses in figure 19. The share at risk lies around 20-30% with the last business Natixis Investment Managers International being an outlier with a very low percentage of its portfolio being dependent on ES.

4.1.3 BES dependency – largest asset managers worldwide

Regarding the biggest global asset managers the following can be said: Looking at a global scale, businesses from the USA are now included which have a much bigger total value of equity holdings in the database. The Vanguard group tops the list with a total value of USD 3,284 billion, followed by Blackrock with a total value USD 3,078 billion. Therefore, the values at risk can reach here significantly higher numbers. The average share of the equity portfolio of the biggest global asset managers that is highly depending on BES is 28.09% and the average value of the equity portfolio is USD 266.01 billion. The weighted average share of the equity portfolio of the biggest global asset managers that is highly depending on BES is 26.66% and the weighted average value of the equity portfolio is USD 644.02 billion.

Figure 20 combines the "total value of equity holdings" in the database for each asset manager in grey color and shows the share of this total value that is at risk due to BES dependency, in percentage as well as in absolute numbers.



Equity share at risk	Equity value at risk
26.0%	853.64 bn USD
25.9%	798.21 bn USD
26.8%	391.51 bn USD
31.7%	403.65 bn USD
25.7%	129.43 bn USD
21.2%	50.08 bn USD
21.8%	23.64 bn USD
25.9%	8.17 bn USD
75.5%	1.79 bn USD
0.4%	0.00 bn USD

Figure 20: Total value of equity holdings and the equity value at risk that is highly depending on BES of the globally biggest asset managers in 2019

Similar to the queries before, the equity share at risk for most of the businesses in figure 20 lies around 25 to 30%. Only the last two businesses (Bank of New York Mellon and Fidelity Investments INC) reach either much lower or much higher percentages due to the reason mentioned above (only very few equity holdings in the database). Looking at the value at risk in billion USD reveals that the inclusion of American businesses into the analysis reaches a completely new scale of value at risk. Although the fifth biggest asset manager JP Morgan Chase already reaches a number above USD 100 billion (higher than in both the other queries above), the asset managers like Vanguard and Blackrock reach far higher values at risk with close to and even above USD 800 billion at risk of ES dependency in their portfolios due to their higher total value of equity portfolio in the database.

4.2 Impact on BES

Again, and similar to section 4.1, the top tercile risk classification will be used as the general risk classification. Only in section 4.2.1 the top 20% risk classification will be used to show for the banking sector the different impact on the results coming from a different risk classification.

Compared to BES dependency the value of all shareholdings that is highly impacting BES is estimated to be USD 22.6 trillion from the whole equity portfolio value in the database (USD 65.7 trillion) which is approximately 34.3%.

4.2.1 Impact on BES – largest banks in Europe

In the first query the 25 biggest banks in Europe are examined.

The average share of the equity portfolio of the biggest European banks that is highly impacting BES is 30.73% and the average value of the equity portfolio is USD 13.11 billion. The weighted average share of the equity portfolio of the biggest European banks that is highly impacting BES is 23.55% and the weighted average value of the equity portfolio is USD 41.99 billion.

Figure 21 combines the "total value of equity holdings" in the database for each bank in grey color and shows the share of this total value that is at risk due to BES impact, in percentage as well as in absolute numbers.

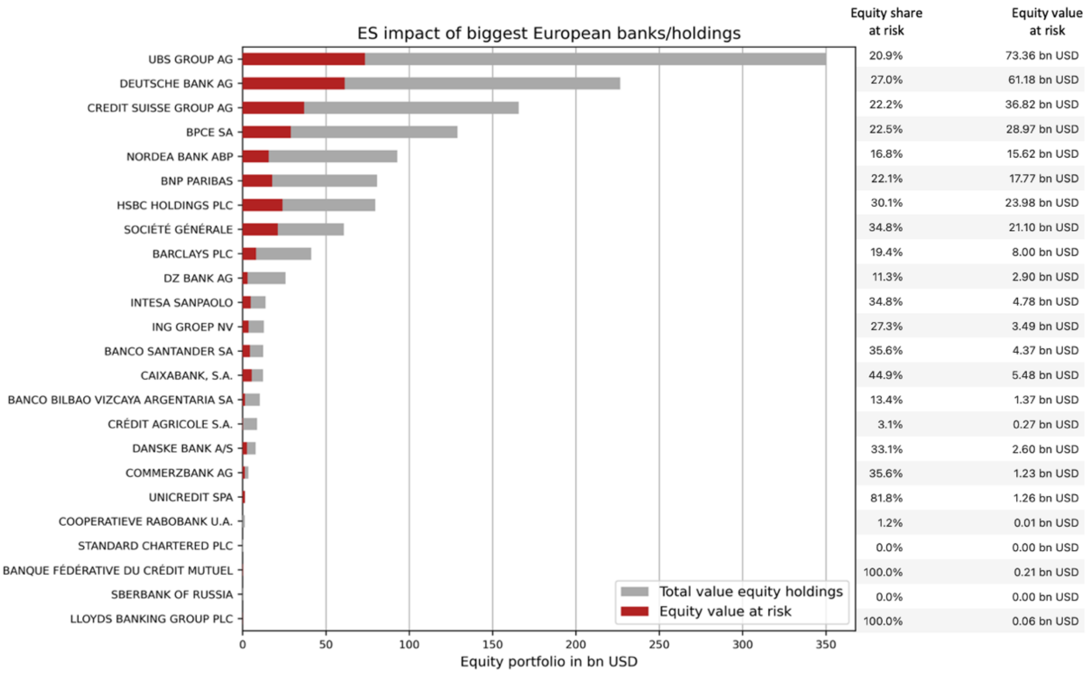


Figure 21: Total value of equity holdings and the equity value at risk that is highly depending on BES of the 25 biggest European banks in 2019 using the top tercile risk classification

Compared to query 1 for the BES dependency analysis, the share and value at risk due to BES impact is smaller and shows in general not such a consistent picture. For the largest (large after the total value of the equity portfolio) banks in figure 21, the share of the equity portfolio that is at risk differs between 15-30% but after that the spread gets bigger with DZ Bank AG and Banco Bilbao Vizcaya Argentaria having a share at risk of 11 and 13% respectively but Société Générale, Intesa Sanpaolo or Caixabank even reach values above 30 or 40%. Still, the value at risk stays smaller with UBS reaching USD 73.3 billion (compared to USD 87.1 billion in the dependency analysis) or Deutsche Bank with USD 61.1 billion (compared to USD 68.7 billion). These are still big financial values that are at risk. For the last four banks Standard Chartered PLC, Banque Federative du Credit Mutuel, Sberbank of Russia and Lloyds Banking Group PLC the same applies as already mentioned above that as their equity portfolio in the database is very small (sometimes only one investment into one subindustry), the share at risk can either reach 100% or 0% depending on the materiality rating of this one subindustry-investment.

Figure 22 then shows the same results using the stricter risk classification of top 20% of GICS subindustries being classified as "high risk". Again, the value at risk is smaller with the weighted average share at risk being 15.49% and the weighted average value at risk being USD 27.78 billion.

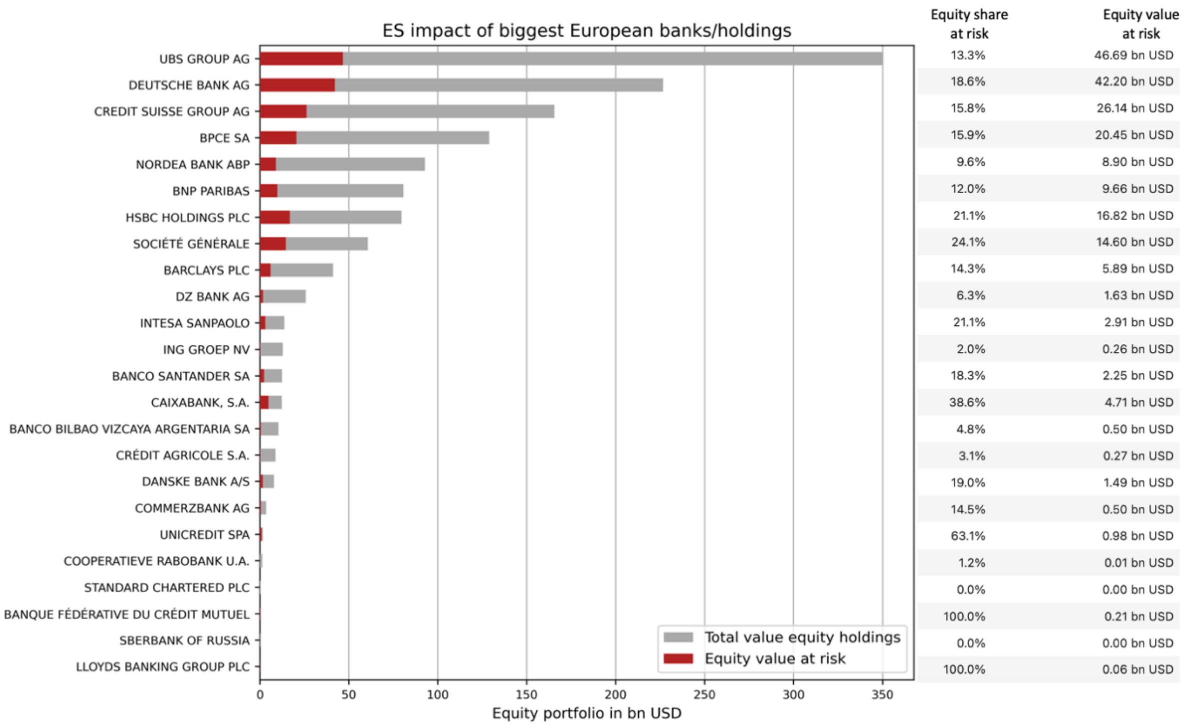


Figure 22: Total value of equity holdings and the equity value at risk that is highly impacting BES of the 25 biggest European banks in 2019 using the top 20% risk classification

In the next step the origin of these values at risk is further examined. Figure 23 shows for the top 4 banks with the highest value at risk (UBS Group, Deutsche Bank, Credit Suisse Group, BPCE) the different GICS subindustries that are causing the classification as high BES impact. The total pie chart makes up the value at risk.

Figure 23: Share of GICS subindustries of the total value at risk that is impacting BES for UBS Group, Deutsche Bank, Credit Suisse Group and BPCE in 2019

As seen in figure 23, the most important GICS subindustries are electric utilities, automobile manufacturers, aerospace & defense and integrated oil & gas. As explained in the methodology section 3.1.2.1, the impact dataset from ENCORE does not contain information on the relationship between GICS subindustries and Ecosystem Services but rather on the connection between GICS subindustries and environmental impacts (the GICS subindustry is causing the stated environmental impacts). Therefore, in the following the environmental impacts that are caused by the most important subindustries from figure 23 are described below:

- Electric utilities: Water pollutants, freshwater ecosystem use, terrestrial ecosystem use, non-GHG air pollutants, disturbances, GHG emissions, water use, soil pollutants, solid waste
- Automobile manufacturers: Water use, water pollutants, solid waste, disturbances, non-GHG air pollutants, GHG emissions, soil pollutants
- Aerospace & Defense: Water use, water pollutants, solid waste, disturbances, non-GHG air pollutants, GHG emissions, soil pollutants
- Integrated oil & gas: Water use, water pollutants, GHG emissions, freshwater ecosystem use, marine ecosystem use, solid waste, terrestrial ecosystem use, disturbances, non-GHG air pollutants, soil pollutants
- Tobacco: Terrestrial ecosystem use, Water pollutants, Other resource use, Soil pollutants, Water use, GHG emissions
- Agricultural & farm machinery: Non-GHG air pollutants, Disturbances, GHG emissions, Water use, Soil pollutants, Water pollutants, Solid waste

As automobile manufacturers and aerospace & defense rely on the same production process (Manufacture of machinery, parts and equipment), their impacts are the same. The subindustries found to be most impacting are similar to the ones found to be most dependent as mentioned in section 4.1.1. The dependency analysis included on top the subindustry "Apparel, accessories & luxury goods". The difference between impacts and dependency lies here in the environmental impacts the subindustry causes shown above (for the impact assessment) and the ecosystem services the subindustry is dependent on shown in section 4.1.1

4.2.2 Impact on BES – largest asset managers in Europe

Regarding the biggest European asset managers the following can be said: The average share of the equity portfolio of the biggest European asset managers that is highly impacting BES is 23.61% and the average value of the equity portfolio is USD 28.74 billion. The weighted average share of the equity portfolio of the biggest European asset managers that is highly impacting BES is 22.79% and the weighted average value of the equity portfolio is USD 50.11 billion.

Figure 24 combines the "total value of equity holdings" in the database for each asset manager in grey color and shows the share of this total value that is at risk due to BES impact, in percentage as well as in absolute numbers.

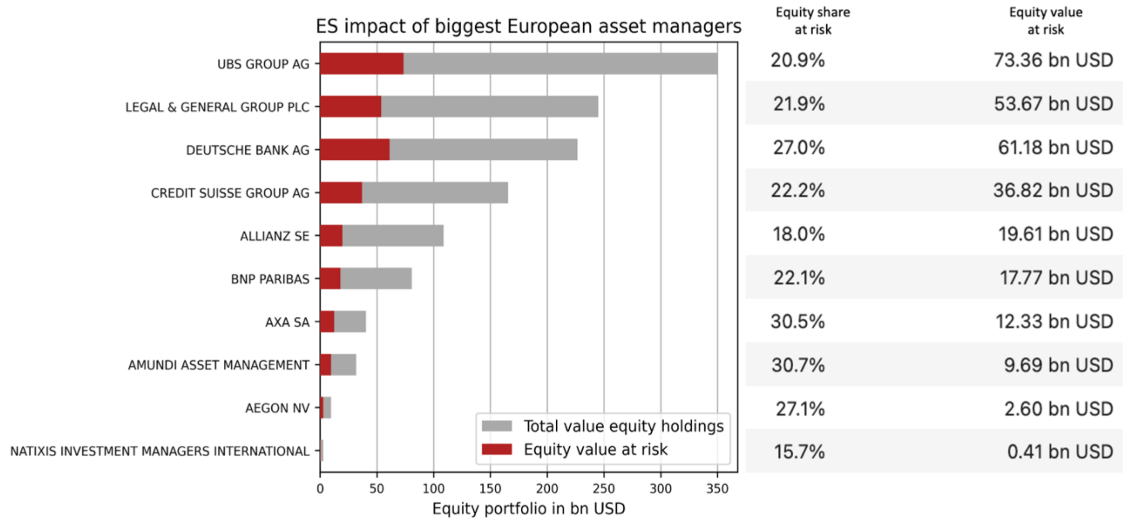


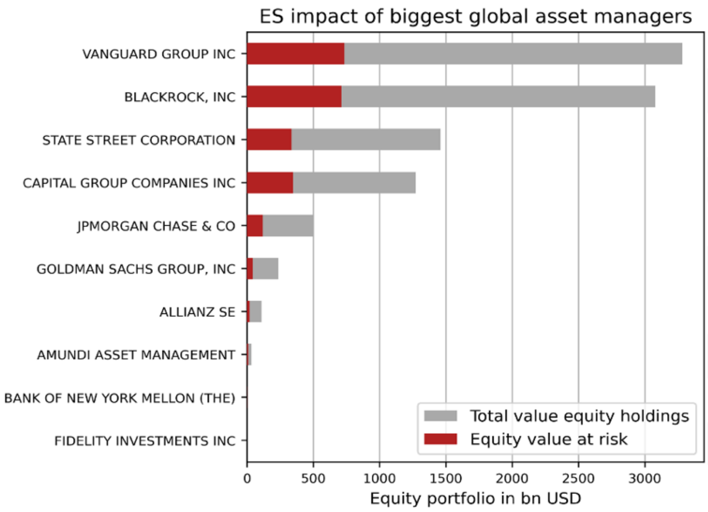
Figure 24: Total value of equity holdings and the equity value at risk that is highly impacting BES of the biggest European asset managers in 2019

The analysis of European asset managers shows a similar picture to the case of the biggest European banks. The share at risk is lower for BES impact compared to dependency on BES but the difference for the asset managers is very small with only a few percentages (less than 5%). The share at risk lies mostly between 20-30% and the value at risk can reach therefore significant numbers like USD 73 billion for UBS or USD 53 billion for the Legal & General Group PLC.

4.2.3 Impact on BES – largest asset managers worldwide

Regarding the biggest global asset managers the following can be said. Again, the global scale brings now bigger American business into the view which results in significantly higher total values at risk. The average share of the equity portfolio of the biggest global asset managers that is highly impacting BES is 34.22% and the average value of the equity portfolio is USD 232.29 billion. The weighted average share of the equity portfolio of the biggest global asset managers that is highly impacting BES is 23.28% and the weighted average value of the equity portfolio is USD 562 billion.

Figure 25 combines the "total value of equity holdings" in the database for each asset manager in grey color and shows the share of this total value that is at risk due to BES impact, in percentage as well as in absolute numbers.



Equity share at risk	Equity value at risk
22.4%	734.10 bn USD
23.1%	711.41 bn USD
23.1%	336.53 bn USD
27.3%	347.96 bn USD
23.7%	119.09 bn USD
17.9%	42.34 bn USD
18.0%	19.61 bn USD
30.7%	9.69 bn USD
56.1%	1.33 bn USD
100.0%	0.84 bn USD

Figure 25: Total value of equity holdings and the equity value at risk that is highly impacting BES of the globally biggest asset managers in 2019

Similar to the dependency analysis, a view on American businesses reveals much higher values at risk than for European businesses. Vanguard Group and Blackrock reach even over USD 700 billion. Still, these are lower values than the value at risk calculated for the dependency on BES analysis which again fits into the findings presented above. The share at risk lies mostly around 20-25%.

5 Discussion

This chapter aims to interpret the results of the thesis from a wider perspective and to confront them with the current knowledge presented in the conceptual framework. In addition, this chapter also aims to discuss methodological aspects related to the equity portfolio analysis, limitations and validity of the results.

5.1 Equity holdings and BES risks

The results of the equity portfolio analysis show that the value at risk in the equity portfolio of financial institutions like banks or asset managers lies around 20-30% for both dependency on and impact of BES although the dependency values are slightly higher than the impact values. Compared to the one other study found that did a similar analysis these numbers are lower. In the study by the Dutch Central Bank (De Nederlandsche Bank, 2020a) the dependency on BES in the Dutch financial sector was calculated at 36%. Compared to this thesis, the report of the Dutch Central Bank included all types of investments, not only equity holdings as well as all types of financial institutions, not only banks or asset managers but it only looked at the Dutch financial sector. As this research still indicates a significant risk for BES dependency and impact throughout Europe, national assessment using better data could then show similar results as the report by the Dutch Central Bank.

Specific banks in Europe reach even much higher values like the Caixabank SA with a share of the equity portfolio at risk due to high BES impact of 38.6% or USD 4.71 billion or the ING Group with a share of the equity portfolio at risk due to high BES dependency of 45% or USD 5.76 billion. For these banks a loss of BES can have a significant impact on their financial assets. Besides having a smaller share at risk, banks like UBS Group reach a much larger value at risk, due to the size of their total equity portfolio. For the UBS Group the value at risk of high BES impact is USD 73.6 billion and the value at risk due to high BES dependency is USD 87.12 billion.

As this thesis was not able to calculate a value at risk for the whole banking sector in Europe, it is possible to extrapolate the results using the statistics on financial data of banks shown in section 1.1. According to the ECB the most important European banks supervised under the banking supervision had at the end of 2020 debt securities worth EUR 2.9 trillion in their balance sheet (European Central Bank, 2020a, 2021a). The weighted average share at risk can then be extrapolated to these numbers. For the high BES dependency and applying a weighted average share of 27.21% this would result in debt securities being at risk worth EUR 0.78 trillion. For the high BES impact and applying a weighted average share at risk of 23.55% this would result in debt securities worth EUR 0.68 trillion being at risk. It is important to state that this is only a very rough indication as first it is unclear if debt securities only include equity holdings or (most likely) also other types of securities and as second the values for the 25 banks could be different to the banks assessed by the ECB. But it still gives again a good indication that there is a significant financial value at risk and it is important for the banking sector to understand these numbers better.

As stated in section 4.1 the thesis also found a result for the BES dependency of all equity holdings globally, without a focus on a specific financial industry. Here the results show that USD 24.5 trillion or 37.2% of equity holdings are at risk of high BES dependency. This can be compared to the two other studies that did a similar analysis and calculated the BES dependency globally, the report by the World Economic Forum (World Economic Forum, 2020b) and the report by Swiss Re (Swiss Re, 2020a). In the report of the World Economic

Forum (World Economic Forum, 2020b) the highly depending value of global GDP was calculated at USD 13 trillion. Another comparison can be drawn to the assessment done by Swiss Re (Swiss Re, 2020a), which calculated the value of the global GDP that is highly dependent on BES as 29% or USD 21.9 trillion. Of course GDP and the value of equity holdings are two different things and should not be compared just number by number. But still this thesis shows that the value at risk of equity portfolios can reach significant numbers that are even higher than values calculated for the global GDP dependency. It is important to include equity portfolios into future research as that could increase the total value at risk significantly.

This importance of the equity portfolio can also be seen in the analysis of the ASN Bank (Crem & PRé Consultants, 2016). In their results, the report mentioned that the impact on biodiversity by equity investments is relatively high compared to the other investment types (Crem & PRé Consultants, 2016). Although this report uses with the PDF another metric to this thesis, both can still be seen as an indication that the BES risk of equity portfolios should be assessed better.

It is not possible to compare the results on the impact of BES with other numbers as no research was found that did a similar analysis. The results show that the value at risk due to BES impact is smaller than the dependency value but still a large amount of financial assets is at risk and should therefore be included in future research.

This thesis also indicated the most responsible subindustries for the reached value at risk due to BES dependency and impact in the European banking sector. As mentioned, these subindustries are electric utilities, aerospace & defense, automobile manufacturers, integrated oil and gas, agricultural & farm machinery and tobacco for dependency and impact. For the dependency analysis the subindustry apparel, accessories & luxury goods was mentioned as well. The similarities between dependency and impact show that similar sectors are dependent on and impacting BES at the same time. This can be compared to other studies like the one by the World Economic Forum that declared the sectors construction, agriculture and food & beverages as being the industries with the largest dependency on BES (World Economic Forum, 2020b). The study of the most dependent and most influential industry sectors regarding BES by UNEP mentioned electric utilities (only from a dependency perspective) and oil & gas (from an impact perspective) as well (Leach et al., 2020). Besides these similar industries, the study mentioned agricultural products (impact and dependency), apparel & accessories & luxury goods (dependency), brewers (dependency), distribution (impact), independent power producers & energy traders (dependency) and mining (impact) as important sectors as well. An assessment of companies in the UK named the agricultural and forestry sector the most dependent on BES industry sector (Watson & Newton, 2018).

5.2 Uncertainties with the analysis of equity portfolio

The quantitative analysis of the equity holding portfolios has showed different uncertainties for the results which will be explained in the following.

As explained in section 3.1.2, the data on global equity holdings obtained from Orbis and Refinitiv EIKON contained missing values. For example, missing data in the "enterprise value" column (15,896 companies which make up 249,357 rows of shareholder data), the "ISIN code" column (9,151 companies which make up 93,586 rows of shareholder data) or the "Shareholder Total/Direct" column (403,039 rows in both columns contain no value). A missing value in any of these three columns resulted in non-usable data, as it is not possible to calculate the value of the specific equity holding for the shareholder without the enterprise value or the shareholder value in percentage and it is not possible to add the GICS subindustry code from the Refinitiv EIKON dataset without the ISIN code. Other reasons are that the EIKON dataset does not include all ISINs mentioned in the Orbis dataset which results in 162,600 more rows that do not contain a GICS subindustry code. From the original 1,149,311 rows in the Orbis dataset, 567,223 rows are lost. Missing values in the original data can therefore be considered as an important reason of uncertainty. Future research could minimize this problem by either updating the missing values by hand or by communicating with the owners of the databases so that they correct the missing values from the beginning. A private risk assessment as done by the Dutch Central Bank, ASN bank or CDC Biodiversity will most likely have the advantage that they can use their own financial data and can demand correct data from the beginning. The same will most likely also apply to a measurement tool which is offered as a business product to financial institutions.

An important uncertainty comes from the fact that ENCORE until today only offers materiality ratings on a production process level which can only be linked to an industry classification system like GICS. Therefore, companies that are classified under the same sector or subindustry will receive the same materiality rating, independent from their location and their mitigation efforts. The location is important as the same business operation can have very different BES impacts or dependencies depending as ecosystems all over the world are degraded in different levels. The impact of a business operation could potentially harm the ecosystem much more if it is already strongly degraded compared to a very healthy ecosystem. This was seen from figure 8 in the report by Swiss Re (Swiss Re, 2020a) which showed the very different states of BES all over the world. Literature also shows that a mitigation effort can decrease the dependency and impact risk. For example, forests with a diverse tree number have a lower possibility to be affected by water stress, fires or pests compared to monoculture forest (Brockerhoff et al., 2017). Therefore, companies under the GICS subindustry forest products can, depending on the level of forest diversity, show different materiality ratings in real life. This is an uncertainty stressed by literature as ASN Bank and CDC Biodiversity (J. Berger et al., 2018) state in their report that a functioning BES risk assessment tool must distinguish between companies with different mitigation efforts.

Another uncertainty results out of the risk classification method that is used for the analysis. As explained in section 3.1.3.3 this thesis used a weighted risk classification method used by Swiss Re (Swiss Re, 2020a) and the World Economic Forum (World Economic Forum, 2020b). Changing the final risk classification from the top tercile (as used by Swiss Re and the World Economic Forum) to the top 20% reduces the value at risk strongly. For example, for the UBS Group the share at risk falls from 24.9% to 16.4% which reduces the value at risk from USD 87.12 billion to USD 57.55 billion. But for the ING Group the share at risk stays exactly the same (45% and USD 5.76 billion). This comes from the fact that the subindustry-investments of ING Group reach materiality ratings high enough to be not excluded by the change of the risk classification. The choice of the risk classification can therefore have impacts on the final results and can potentially change the messages drawn from the results. This can also be an explanation for the higher value calculated by the Dutch Central Bank (De Nederlandsche Bank, 2020a, 2020b) in their dependency risk analysis of the Dutch financial sector. The report calculated a share of all investments of 36% being highly or very highly depending on ecosystem services, using a risk classification approach where the top 40% were classified as a risk.

5.3 A sufficient BES risk assessment?

This thesis found 3 important points which are needed so that a future BES risk assessment will work. These are the regulatory framework, the completeness of the assessment and a widely accepted metric.

The regulatory framework regarding BES risk assessments is tightening, and it is expected to become even stronger in the future, correlating with the importance of BES degradation happening on earth. Examples for this are the NGFS (NGFS, 2020) that increases attention for BES risks in central banks and regulators. The German BaFin is another institution that has already published some non-binding good practice guidelines on the topic of environmental risk assessment. The ECB is also slowly including environmental risks (starting with climate change related risks) into their risk assessment guidelines. Likewise, the EU Taxonomy that defines environmental sustainability and therefore also environmentally harming business activities. The risk assessment of banks today is heavily influenced by the Basel standards (Moody's Analytics, 2011; Bank for International Settlements, 2021). A stricter regulatory framework regarding BES risks can lead to a similar strong acceptance of BES risks by banks. Maybe the Basel standard would even include environmental risks into their risk assessment standard which would allow banks to copy this methodology.

In the comparison of different BES measurement tools by the Finance for Biodiversity pledge (Finance for Biodiversity, 2021), it becomes clear that until now, no tool allows a complete assessment. Each tool has important points that are missing. ENCORE for example covers all the pressures as well as impacts and dependencies, two scopes and uses different metrics. But it only covers three different asset categories and can only be used for a small number of different finance applications and organizational focus areas. The BFFI has nearly included all asset categories and allows an assessment of most of the financial applications and organizational focus areas. But it misses the dependencies as well as one of the pressures (although these two negative points are currently tackled as they should be included soon). The report also showed that the most promising BES measurement tools are currently only focusing on the impact side and not on dependencies. This can also be seen by the fact that the most promising metric used by the assessed tools is the MSA which focuses on the loss of species caused by economic activity which is impact-focused as well. Dependencies are something that is not incorporated widely into measurement tools. The different usages of metrics again shows that the one metric that can be used by different tools and includes all importance assessment parts for a sufficient BES risk assessment is not developed until today. Another aspect to the completeness is that BES risks must be assessed taking many different variables into account. In the case studies and the literature presented above it became clear, that the location of a business operation (ENCORE, 2021e; UNPRI, 2020) as well as the environmental mitigation policy of a business operation (J. Berger et al., 2018; ENCORE, 2021e) is equally important than the nature of the business operation itself.

Different to climate change and greenhouse gas emissions (in CO_2eq), BES risks lack clear wordings and metrics in the financial sector. Biodiversity risks (Crem & PRé Consultants, 2016; De Nederlandsche Bank, 2020a; Finance for Biodiversity, 2021), ecosystem service risks (KPMG, 2011), nature-related risks (McCraine et al., 2019) or sustainability risks (BaFin, 2019) appear to be terms addressing a similar topic, namely the financial risks that profit-seeking companies are (or will be) confronting due the scarce natural resources and fragile, receding ecosystem services. Through the case studies and the equity holding analysis of this thesis, the same became clear as different metrics like BES dependency or impact (used in this thesis), potentially disappeared fraction of species (used by ASN bank) or mean species abundance (used by CDC Biodiversity) are different metrics to evaluate the same risk topic. Therefore, it is clear that a BES risk assessment tool in the financial sector requires either a way to compare its results with other, different metrics or (the better idea) builds upon a metric that is widely used and accepted.

6 Conclusion

This thesis wanted to help understanding the value at risk due to BES risks for banks in Europe. It did so by answering the three different research questions "What is the estimated scale of the equity holdings in a bank portfolio which are dependent on and impacting BES?", "What are the main sources of uncertainty in the analysis of equity holdings?" and "What are the main elements that a tool/methodology for analyzing bank equity holding portfolio in relation to BES should contain?" through a quantitative data analysis that matched the equity portfolio of the biggest European banks with materiality ratings on the BES dependency and impact risk of GICS subindustries. Besides that, the thesis included different European case studies of financial institutions that are taking BES risks already into account.

The main conclusion of the thesis is that it confirms the critical economic importance of BES risks across the equity holdings of European banks and other financial institutions. Besides the limitations of the thesis, the role of European financial institutions to actively work on sustainable development in order to ensure the sustainability of their own business is underscored. The critical economic importance can be seen through the share of around 25% of the equity portfolio of the 25 biggest European banks that is at risk due to high BES dependency or impact. For the risk of high dependency, the weighted average share of the equity portfolio of the 25 banks at risk is 27% which equals to a financial value at risk of USD 48 billion. For individual banks the value at risk can differ between the UBS Group with USD 87 billion at risk (coming from a share at risk of 24%) and the Sberbank of Russia with no risk at all.

The values for the risk of BES impact lie below this with the weighted average share being 23% which translates to a weighted value at risk of USD 41 billion. The UBS group tops the ranking again with a value at risk of USD 73 billion (coming from a share at risk of 20%) while Standard Chartered and Sberbank of Russia reach no risk at all.

The main sources of uncertainty that were found in this analysis of equity portfolio are missing data, materiality rating and risk classification. The data on global equity portfolios used for this thesis contained 567,223 missing rows (from 1,149,311) due to either complete lack of data (important data was missing in some rows) or differences between databases (Refinitiv EIKON database did not include the same companies as the Orbis database). Using the materiality rating of ENCORE led to the uncertainty that companies from the same GICS subindustry received the same materiality rating. This materiality rating was independent from the actual location of the business operation and the specific mitigation efforts by the businesses. As ecosystems across the globe are in different health statuses and are therefore differently impacted by similar business operations, the location of a business operation is an important variable. And as one business could take many efforts to reduce their dependencies or impacts while another one did not do these efforts, the mitigation effort is an important variable as well. Besides this, the risk classification that defined which subindustry is counted as "high risk" used for the final results can change the results as well. Applying a more stricter risk classification (less subindustries are classified as "high risk" leaving more investments as being rated "no risk") changes the weighted average share of the equity portfolio of the 25 banks at risk to 17% for the dependency and 15% for the impact assessment. Compared to the above-mentioned results, applying the different risk classification reduced the weighted average share at risk by 8-10%.

Through the equity portfolio analysis as well as the analysis of different case studies, 3 main elements for a tool for analyzing bank equity holding portfolio in relation to BES risks were found. The most important element is a sufficient metric that takes into account all the different pressures and problems of BES risks, similarly to the CO_2eq used to describe greenhouse gas emissions. Until today no such metric has been developed and it is therefore a huge burden to current BES risk assessments. The next important element is the completeness of the assessment. An assessment tool must be able to include the different BES pressures, it must be able to analyze the different asset categories and it should include dependency and impact ratings. Besides that, it is important that the tool is taking different variables into account to calculate the final materiality rating. Most important seems to be the business operation, the location of the business operation and the mitigation level regarding BES of the specific assessed business operation.

6.1 Recommendations

Although this thesis was able to calculate the BES risks in the equity portfolio of European banks, more knowledge and understanding is required into what these risks exactly mean. Future research should focus on understanding the implication of a high BES dependency or impact risk in an equity portfolio as the dependency/impact share alone does not include information about the possibility these financial values will definitely vanish. To do so information on BES loss needs to be connected to equity portfolio shares that have BES dependency and impact to show how much financial value will be affected if the BES loss goes on as expected (or goes on as shown by different scenarios). Another future research could focus on the better understanding of the materiality ratings for BES dependency and impact as the methodology presented in this thesis (grouping investments under GICS subindustries) can only be seen as a first indication but a more narrow view on different businesses (a large industrial agricultural business compared to a smaller ecological farming business) or different locations (an agricultural business in Brazil compared to an agricultural business in Germany) will make the results much more valid.

For the banking sector specifically, this means that each bank must understand the connection of their investments to BES better. Harvesting data on this could be used in the investment process to either avoid specific industry sector (for example oil and gas) or focus on the businesses in industry sectors that mitigate the BES impacts or dependencies better than others (for example forestry companies that use diverse forests instead of monocultures). The banking sector should also work closer together to share the existing knowledge on BES risk assessments (like the ASN Bank and CDC Biodiversity) so that similar methodologies are developed that can be used broadly and are comparable.

To build up a sufficient BES risk assessment tool, regulation is required that goes above what is seen today, and leads and pushes banks to take BES risks into account. Accepting BES risks can lead to the development of widely accepted risk assessment standards comparable to the Basel standards used for other types of risks.

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