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An Exploration of Climate-Related Financial Risks for Credit Guarantee Schemes in Europe

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Abstract

This paper assesses the vulnerability of credit guarantee schemes to the physical and transition risks related to climate change. Based on unique sectoral and spatial data from 29 European credit guarantee schemes linked to a range of vulnerability metrics, the paper identifies guarantees-at-risk, builds a transition risk score to rank sectors at risk, and conducts a stylized stress test to assess potential financial losses that credit guarantee schemes could incur under adverse climate-related scenarios. The results show that about one-third of credit guarantee schemes' guarantee portfolios is toward sectors that have high exposure to a disorderly energy transition. European credit guarantee schemes are also exposed to a broad range of climate-related physical risks, especially wildfires, coastal floods, and river floods, with 24–31 percent of outstanding guarantees toward sectors that have elevated exposure to climate change and weather variability. Finally, for transition and physical risk scenarios, the annual expected loss on the guarantee portfolio could increase by EUR 181 million and EUR 128 million, respectively. The results suggest that credit guarantee schemes could start integrating climate-related financial risks into their risk management frameworks.

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1. Introduction

Climate change is a complex collective action problem that may pose material risks to the safety and soundness of financial institutions and have broader financial stability implications. These risks are typically classified as transition and physical risks (see, for example, NGFS 2019). Physical impacts include the potential economic costs and financial losses resulting from the increasing severity and frequency of extreme climate-change related events, and longer-term progressive shifts in the climate, whereas transition impacts relate to the process of adjusting to a low-carbon economy. Despite methodological and data issues, a young but rapidly growing literature is providing evidence of the impacts of climate change on the financial sector. At the policy level, many central banks and supervisory authorities—among others through the Network for Greening the Financial System (NGFS)—have started exploring climate-changed related financial stability risks (see, for example, DNB 2017; BoE 2019; ECB 2021; EBA 2021, ACPR 2021). At the academic level, several studies have investigated the effects of transition risks (see, for example, Weyzig et al. 2014; Batten et al. 2016; Vermeulen et al. 2019; Battiston et al. 2017) and physical risks (see, for example, Klomp 2014; Noth and Schüwer 2018; Barth et al. 2019) on the financial sector. All studies converge on the materiality of climate-related financial risks for the financial sector.

Most studies have so far focused on banks and insurers but, to the best of our knowledge, none has ever attempted to explore climate-related financial risks for credit guarantee schemes (CGSs). CGSs are commonly deployed by countries particularly when market failures prevent or constrain access to credit by businesses, typically—but not exclusively—small and medium enterprises (SMEs). CGSs issue guarantees to lenders to cover a share of the risk of default of borrowers. They are, therefore, a mechanism of risk transfer and diversification. CGSs can also compensate for factors such as insufficient collateral and weak creditor rights. They are often established as independent legal entities.[1] When provided by the government, they can also operate through non-independent entities, either provided directly by the central government (e.g., through the Ministry of Finance) or channeled through public independent entities with a separate legal personality (e.g., through a development bank).[2] Regardless of their legal nature, CGSs are essentially financial institutions that promote public policy goals and that—like any other financial institutions—are potentially exposed to climate-related financial risks through their guarantee portfolio.

This paper represents the first attempt to assess climate-related financial risks for CGSs. Understanding the extent to which CGSs may be exposed to climate-related financial risks is important from a public policy perspective. As non-deposit taking institutions, CGSs do not pose

[1] The 'Principles for Public Credit Guarantee Schemes for SMEs' advocate for the establishment of CGSs as independent legal entities on the basis of a sound and clearly defined legal and regulatory framework to support the effective implementation of their operations and the achievement of their policy objectives (World Bank, 2015).

[2] In a few cases CGSs are operated by private entities, often in the form of cooperatives or consortia of firms.

financial stability risks per se. Moreover, their typically limited size and interconnections with the commercial banking system means their failure has no significant impact on financial stability. Ensuring the safety and soundness of CGSs is essentially a matter of public policy effectiveness, given that many SMEs depend on credit guarantees for financing working capital and investment. A financially sound and healthy CGS gives lenders the confidence to leverage it to extend lending to small businesses. Ensuring the financial sustainability of CGSs is also a fiscal imperative, given the contingent liability they represent for the government.

In particular, this paper focuses on a sample of European CGSs. Europe as a whole is heavily exposed to transition risks, which may have been exacerbated by the recent energy crisis, linked to the war in Ukraine, and the potential this poses for an associated delayed phase out of fossil fuels. The region is also significantly exposed to physical risks, especially heatwaves, droughts, floods, and sea level rise, with significant between- and within-country variation. At the same time, Europe is a frontrunner in climate policies, with ambitious targets in terms of greenhouse gas (GHG) emission reductions and a well-established yet evolving policy framework. Europe is also a region where CGSs are a historically important component of the financial system, facilitating access to finance for millions of small businesses that are relatively dependent on bank financing for their operations. CGSs in Europe can play an important role in supporting green investment by SMEs, both on the mitigation and adaptation fronts.

This paper assesses the vulnerability of European CGSs to both transition risks and physical risks. The paper is based on unique sectoral and spatial data from 29 European CGSs, accounting for EUR 278 billion or 84 percent of the total outstanding guarantee volume of the European Association of Guarantee Institutions' (AECM) members as of end-2020. We then link CGSs' guarantee portfolio data to a set of sectorally and spatially disaggregated transition and physical risk vulnerability indicators, which allows us to identify the portfolio shares at risk per indicator. We also identify sectors that are most relevant for CGSs to focus on by creating a transition risk score which combines exposure with GHG intensity. Finally, we conduct a stylized stress test to assess potential financial losses that CGSs could incur under adverse climate-related scenarios. To our knowledge, we are the first to investigate the vulnerability of CGSs to climate-related financial risks.

Results show that European CGSs' vulnerability to climate-related financial risks is non negligible. We estimate that about one-third of CGSs' guarantee portfolios is towards sectors that have elevated exposure to a disorderly energy transition. This is partly mitigated by the finding that most of the exposures are towards sectors that are in the 30^{th}-60^{th} percentile of GHG intensity. Combining guarantee exposures with GHG emission data, we also find a relatively high degree of portfolio concentration, with 72 percent of the transition risk for CGSs driven by five sectors. European CGSs are also exposed to a broad range of climate-related physical risks, especially wildfire (56 percent aggregate CGSs' portfolios in our sample), coastal flood (41 percent), and river flood (6 percent). Within CGSs' portfolios, we estimate that 24-31 percent of guarantees are towards sectors that have elevated exposure to climate change and weather

variability. Finally, we find that for transition and physical risk scenarios the annual expected loss on the guarantee portfolio could increase by EUR 181 million and EUR 128 million, respectively.

This paper fits into a small but growing strand of the literature focusing on the financial performance of CGSs. The academic literature on CGSs is mostly concerned with evaluating their financial additionality (see, for example, Riding et al. 2007; Cowling 2010; Abraham and Schmukler 2017) and economic additionality (see, for example, Benavente et al. 2006; Lelarge et al. 2010; Schmidt and Van Elkan 2010; Uesugi et al. 2010; Caselli et al. 2019), that is increased availability of credit and enhanced financial conditions for targeted firms, and the impact of CGSs on employment, tax revenues, sales growth, etc., respectively. Only a few studies focus on the financial sustainability of CGSs (Beck et al. 2008; Jonsson 2009; Schich et al. 2017; Saito and Tsuruta 2018; Caselli et al. 2021), namely the ability of a CGS to cover the costs of its operation and the defaults that occur, which is a necessary though not sufficient condition for achieving financial and economic additionality. Our paper is positioned in this latter strand of the literature and introduces a new dimension to CGS's financial sustainability and performance, namely the impacts of climate-related financial risks.

The rest of this paper proceeds as follows. Section 2 presents an overview of climate change in Europe and policy responses while highlighting the important role played by SMEs and CGSs in decarbonization policies. Section 3 describes the data and the methodology employed in this study. Section 4 presents our main results. Section 6 concludes the paper, discussing some policy implications.

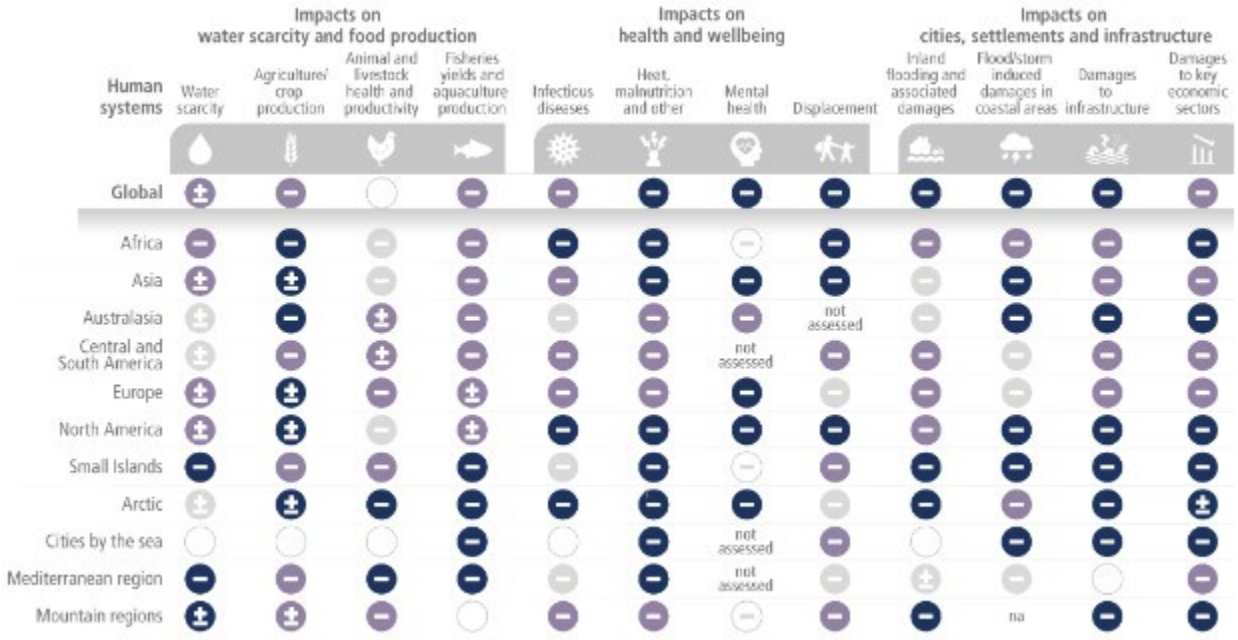
2. Climate change and credit guarantee schemes in Europe

The latest report by the Intergovernmental Panel on Climate Change (IPCC) reiterated strong warnings about the global effects of climate change. Climate change has already caused substantial damages and irreversible losses in ecosystems, with 3.3 billion to 3.6 billion people living in areas that are highly vulnerable to climate change. In the longer term, climate change will lead to numerous risks to natural and human systems, including water scarcity, decreased agricultural yields, heat waves, rising sea levels, and increased severity and frequency of natural disasters (IPCC 2022). For Europe, most assessed dimensions would see increasing adverse impacts, except for water availability and agricultural production in some regions (see Figure 1).

According to the European Environmental Agency (EEA), climate change is affecting all countries in Europe, with varying effects between regions. Overall, the Mediterranean region displays the highest number of severely affected sectors and domains. These include significant increases in heat extremes, which in turn increase risks of droughts and forest fires. Many economic sectors in the region are negatively affected, including crop yields and livestock production. Furthermore, Europe's Atlantic region will likely experience an increase in heavy precipitation events, increasing river flows and the associated risk of riverine flooding. The continental region is expected to face an increased risk of river flooding, as well as forest fires. It is also expected to see an increase in heat extremes. For the boreal region, an increase in heavy

precipitation events is expected next to an improvement of agricultural and forestry conditions (e.g., crop yields and forest growth). Finally, all coastal zones are subject to sea level rise and the associated increasing risk of coastal flooding (EEA 2017).

Figure 1: Observed impacts of climate change on human systems



Source: IPCC (2022).
Note: The + and – symbols indicate the direction of observed impacts, with a – denoting an increasing adverse impact and a ± denoting that, within a region or globally, both adverse and positive impacts have been observed (e.g., adverse impacts in one area or food item may occur with positive impacts in another area or food item).

Decarbonization policies in Europe are among the most stringent globally, with the European Union positioning itself as a global leader in achieving net zero by 2050. The Paris Agreement reached in December 2015 sets out ambitious goals for limiting global warming to well below two degrees Celsius. To achieve this goal, substantial reductions in GHG emissions are needed. In the European Union (EU) the European Commission proposed a European Green Deal in 2019 with the objective of net zero emissions of GHGs by 2050. To this end the European Commission adopted a set of proposals to reduce net GHG emissions by at least 55 percent by 2030 compared to 1990 levels (EC 2021). Furthermore, the European Green Deal Investment Plan, also referred to as the Sustainable Europe Investment Plan, was launched in 2020 and aims to mobilize at least EUR 1 trillion in sustainable investments over the next decade.

SMEs are an important component of the European transition to a sustainable economy, given their significant aggregate footprint and potential contribution to mitigation. SMEs are the backbone of the European economy, representing 99 percent of all firms in the EU, employing 100 million people and contributing to more than half of total GDP in the region (EC 2020). Climate change is expected to have a major impact on European SMEs' operations (EIB 2021). At the same time, European SMEs' aggregate environmental footprint is substantial; hence, they are central to decarbonization efforts. SMEs contribute 64 percent to industrial pollution in

Europe (Calogirou et al. 2010), accounting for 60-70 percent of total industrial waste (Mitchell et al. 2011) and 9-29 percent of inland energy consumption (Reuter et al. 2021). In the UK, 14 percent of SMEs are involved in the top six emitting sectors, which cumulatively account for 57 percent of total business driven emissions (British Business Bank 2021). At the same time, SMEs are important contributors to eco-innovation (Keirala 2019) and while there is evidence that a large majority of European SMEs are taking steps to be more resource efficient in waste, energy or water (EC 2018), they still face several size-related constraints in their efforts to "green" their operations, including access to finance (OECD 2021).

In many European countries CGSs play an important role in supporting SMEs' access to finance. CGSs are an integral part of the system of financial intermediation in many countries in the region. Credit guarantees are provided by national/local organizations supplemented on a supranational level by the European Investment Bank Group.[3] The 48 CGSs in Europe that make up the AECM had a total outstanding guarantee volume of EUR 312 billion—or 1.8 percent of the combined GDP of AECM countries—while supporting 5.9 million SMEs in 2021.[4] National/local CGSs are typically active as not-for-profit organizations set up according to four models: public guarantee institutions, public-private partnership initiatives, mutual guarantee schemes, and other types of private guarantee schemes. The specific choice of one or the other model mainly reflects the economic and legal frameworks of the respective countries as well as historical and cultural factors, with public schemes representing the large majority across countries. CGS can play an important role in supporting SMEs' investment in climate change mitigation and adaptation.

The transition to a low-carbon economy as well as the physical effects of climate change and environmental degradation are a source of financial risks for European CGSs. There is growing global recognition that climate change, natural disasters and environmental degradation can lead to transition and physical risks for the financial sector (see, for example, NGFS 2020). CGSs are primarily vulnerable to climate risks through credit risk in their guarantee portfolio. Transition risks originate from efforts to mitigate climate change and improve local environmental conditions by decarbonizing the economy, which may create economic adjustment costs for SMEs in a broad range of sectors, ultimately resulting in stranded assets. Physical risks stem from both the gradual and abrupt impacts of climate change and natural disasters—such as droughts, floods, and hurricanes—on the value of assets and property owned by SMEs.

Both transition and physical risks can have detrimental effects on the European economy and related financial instruments, including the SME loan portfolio of banks. The European Central Bank (ECB) and European Banking Authority (EBA) have recently caried out initial climate risk assessments and exploratory stress tests of banks. For its stress testing exercise, ECB has investigated disorderly transition scenarios and a physical risk scenario in which temperatures

[3] For an overview of European CGSs see, for example, Chatzouz et al. (2017) and Vienna Initiative (2014).
[4] AECM Statistical Yearbook 2021. Available at https://aecm.eu/publications/statistics.

continue to rise ("hot house"), in line with NGFS climate scenarios.[5] These assessments have that under a short-term, three-year disorderly transition risk scenario and the two physical risk scenarios—flood risk and drought and heat risk—the combined credit and market risk losses for the 41 banks providing projections would amount to around €70 billion (ECB 2022).

Measuring climate risks in European CGSs portfolios is relevant for public policy and fiscal risks. CGSs are a traditionally important policy tool to ease access to finance for SMEs in Europe, with several studies demonstrating their financial and economic additionality (see Neuberger 2020 for a review of the literature). Financial sustainability is a necessary though not sufficient condition for CGSs to achieve financial and economic additionality. Therefore, measuring (and eventually managing) climate-related financial risks is an important step towards improving the performance of CGSs and hence potentially strengthening the effectiveness of public policy. Measuring climate-related financial risks is also important for mitigating fiscal risks, given that CGSs represent a contingent liability for many governments in Europe.

3. Data and methodology

The aim of this paper is to explore the vulnerability of European CGSs to climate-related financial risks. To this end, we collect unique exposure data from 29 CGSs across Europe on their sectoral and spatial disaggregation of guarantee portfolios. We then link the CGS portfolio data to a set of sectoral and spatially disaggregated transition and physical risk vulnerability indicators, which allows us to identify the portfolio shares at risk per indicator. We also identify sectors that are most relevant for CGSs to focus on by creating a transition risk score which combines exposure with GHG intensity. Finally, we conduct a stylized stress test to assess potential financial losses that CGSs could incur in adverse climate-related scenarios.

Exposure data is collected through a survey among AECM members while vulnerability data has been obtained from a range of other sources. Outstanding guarantees with sectoral and spatial breakdowns have been collected from 29 CGSs that together administered EUR 278 billion of outstanding guarantees as of December 31, 2020. Our sample covers 84 percent of the total outstanding guarantee volume of AECM members, which totaled EUR 330 billion in 2020 (AECM 2020). However, not all CGSs provide breakdowns of their guarantees into sectors and regions with equal granularity. For 1-digit sectors (NACE1) and 2-digit sectors (NACE2) our sample covers 82 percent and 35 percent of the total outstanding guarantee volume of AECM members, respectively. For regions at the second administrative level (NUTS2), our sample covers 42 percent of the total outstanding guarantee volume of AECM members. All exposure data is as of end-2020 and thus includes volumes under the extensive COVID-19 support programs. For the risk assessment we map CGSs' exposure data to vulnerability data to assess the amount of exposure at increased risk. We obtain vulnerability data from a variety of sources and at different levels of aggregation. Table 1 provides a summary of the collected vulnerability data.

[5] See https://www.ngfs.net/ngfs-scenarios-portal/.

Table 1 – Vulnerability data

Indicator	Disaggregation	Granularity	Source	Type
Climate Policy Relevant Sectors (CPRS)	Per sector	NACE1-2	University of Vienna	Transition risk
Carbon intensity	Per country/sector	NACE2	Eurostat	Transition risk
GHG intensity	Per country/sector	NACE2	Eurostat	Transition risk
Wildfire	Per region	NUTS2	Think Hazard	Physical risk
Coastal flood	Per region	NUTS2	Think Hazard	Physical risk
River flood	Per region	NUTS2	Think Hazard	Physical risk
Extreme heat	Per region	NUTS2	Think Hazard	Physical risk
Drought	Per region	NUTS2	Think Hazard	Physical risk
Landslide	Per region	NUTS2	Think Hazard	Physical risk
Sectors vulnerable to physical risk	Per sector	NACE1-2	Marco research	Physical risk

Source: Authors.

To assess the vulnerability of CGSs to transition risks, we map two-digit sectoral exposure data to emission data per industry obtained from Eurostat and transition sensitive sectors from the academic literature. We base our classification on that of Battiston et al. (2017) who identify a set of Climate Policy Relevant Sectors (CPRS). Within the CPRS classification, most sectors are identified at either the first or second level of sectoral disaggregation. However, some sectors are identified at the third or fourth level. Since our samples are at the first and second levels of disaggregation only, we weight sectors according to the number of subsectors that are identified as climate policy relevant.[6] On top of the CPRS sectors we add the companies that provide water supply, sewerage, and waste management services (NACE E) since we find that the aggregate GHG emissions in this sector are relatively high but it falls outside the CPRS classification into six high-level sectors of the economy (i.e., fossil fuels, utilities and electricity, energy-intensive, buildings, transportation, and agriculture). The detailed mapping can be found in Annex 2. Since the CPRS is a binary classification (i.e., either relevant or not) this does not allow us to rank sectors in the amount of transition risk present. We therefore also obtain Eurostat data on CO_2 and GHG emissions. We first use this data to estimate the amount of exposure of CGSs to the sectors with the highest GHG emissions. We then proceed by identifying those sectors that could potentially cause the highest absolute losses to CGSs by defining a risk metric that combines exposure with GHG emissions. Using equation (1) we identify sectors *i* that are highly relevant for CGSs from a

[6] To map our 2-digit level exposure data to the 4-digit CPRS we weigh 2-digit sectors using a factor 1.0 if all the subsectors are in CPRS, a factor 0.5 if two or more subsectors are in CPRS, and 0 if one or no subsectors are in CPRS.

transition perspective, both in terms of financial risk and in the potential for CGSs to support those sectors through the energy transition:

$$Sectoral\ transition\ risk\ score_i = \frac{Exposure_i}{Total\ exposure} * \frac{GHG\ emissions_i}{Total\ GHG\ emissions} \quad (1)$$

We furthermore compare the transition risk of individual CGSs *k* by summing the sectoral transition risk score over all *n* sectors:

$$Individual\ transition\ risk\ score_k = \sum_{i=1}^{n} \frac{Exposure_{i,k}}{Total\ exposure_k} * \frac{GHG\ emissions_i}{Total\ GHG\ emissions} \quad (2)$$

To assess the vulnerability of CGSs to physical risks, we map spatial exposure data at the second administrative level to vulnerability data from Think Hazard. We obtain the full data set from Think Hazard, covering wildfire, coastal floods, river floods, extreme heat, drought, earthquakes, and landslides. We exclude earthquake risk since it is not climate related. We then map our data to NUTS 2 by combining administrative regions in the Think Hazard data set. For those regions where there is more than one administrative region per NUTS 2 region, we average the Think Hazard score. Next, we sum the regional exposures in our sample per risk category in Think Hazard (high, medium, low, and very low risk). For missing Think Hazard data we use the no data label. For coastal flood we furthermore introduce a "non-coastal" category representing zero risk.

We also map sectoral exposures to a set of physical risk sensitive sectors. We use two classifications for sectoral climate change sensitivity. The first is based on Lazo et al. (2011) who analyze the weather sensitivity of US economic sectors. Agriculture, mining, manufacturing, finance and insurance, and real estate are identified as being highly impacted by annual weather variability. For these sectors year-to-year variations in weather characteristics are found to affect economic performance by 10 percent or more. A second classification is based on a set of sectors identified by Skougaard et al. (2017), who capture sectors that are vulnerable specifically in the European context. Vulnerable sectors include agriculture, mining, utilities, transportation and storage, accommodation and food, professional, scientific and technical activities, and human health. The detailed mapping can be found in Annex 3.

As a final step, we conduct a stylized stress test to assess potential financial losses that CGSs could incur under adverse climate-related scenarios. For this we combine (i) scenario variables on increases in the probability of default (PD) per sector obtained from the European Central Bank (ECB); (ii) CGSs' specific estimates on baseline PD and loss given default (LGD); and (iii) CGSs' specific exposure data per sector (exposure at default, EAD). We present the ECB scenario variables in Annex 4. Our first scenario reflects a short-term orderly transition scenario compared to a scenario where almost no action would be taken globally to reduce GHG emissions

("hothouse world"). We also investigate the inverse scenario which reflects a hothouse world scenario in 2050 compared to an orderly transition. The main difference between the two scenarios is the time horizon over which increased credit losses are expected. For the transition scenario these are mainly expected in the years between 2025 and 2030 and would not persist thereafter. For the hot house world scenario losses increase gradually until 2050 and are persistent. To obtain quantitative estimates we employ a standard expected loss (EL) formula which reflects the annual expected losses in a credit risk portfolio, for *n* sectors *i* and for scenarios *j*:

$$Expected\ Loss_j = \sum_{i=1}^{n} PD_{i,j} * LGD_{i,j} * EAD_i \quad (3)$$

Baseline estimates for PD and LGD were obtained from several European CGSs, averaged, and rounded. We assume constant balance sheets and constant LGDs over time for most sectors.[7]

4. Results

4.1 Transition risk vulnerability

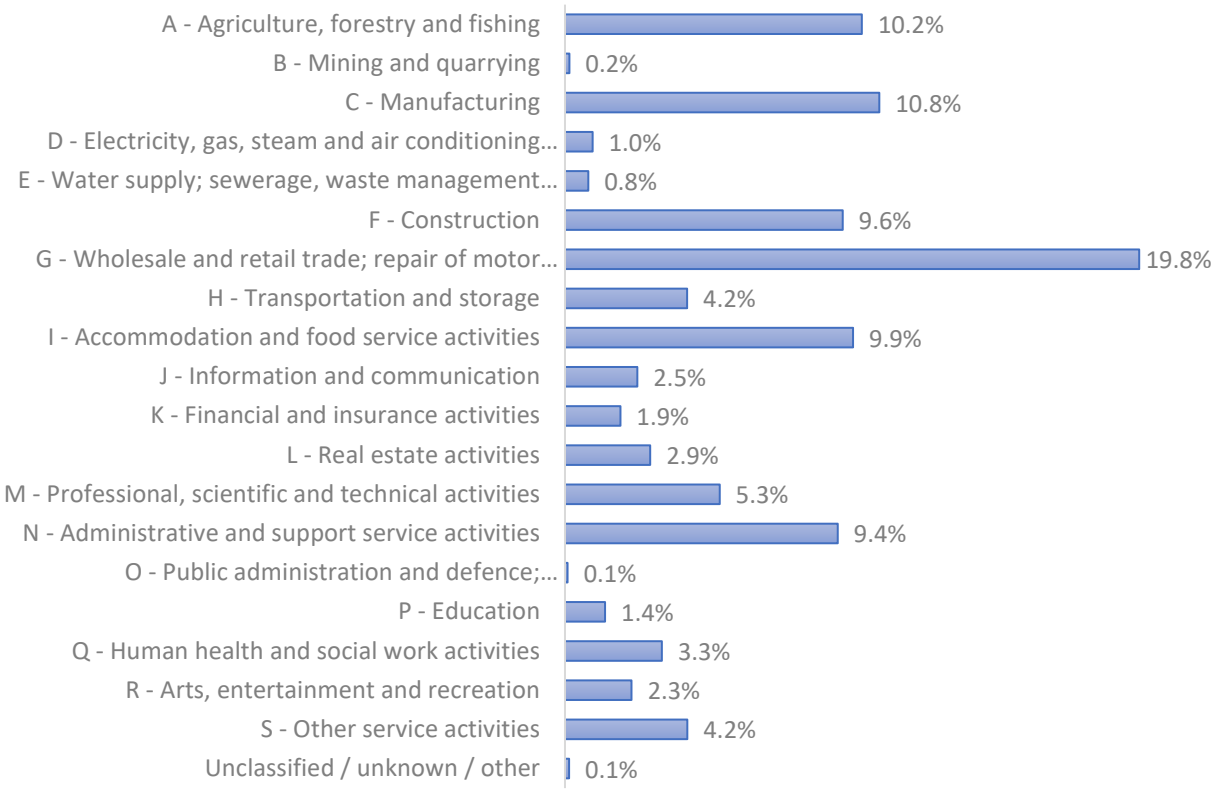
European CGSs provide guarantees to all sectors, with an allocation that differs from the value-added shares to the overall economy. Figure 2 shows the distribution of CGSs' guarantees at the first level of sectoral disaggregation (NACE level 1). Labels indicate the percentages of the total outstanding guarantee portfolio in each sector. The five sectors with the largest outstanding guaranteed amounts are wholesale and retail trade (20 percent), manufacturing (11 percent), agriculture (10 percent), accommodation and food services (10 percent), and construction (10 percent). When comparing the shares of guarantees per sector (as percentage of the overall portfolio) to the share of value added in Europe, we find that CGSs are relatively highly exposed to agriculture (a multiple of 5.6 times), accommodation and food (5.6 times) and administration and support services (2.1 times). Sectors with relatively low fractions of guarantees to value added are real estate (0.3 times), education (0.3 times) and financial services (0.4 times). CGSs are also relatively underexposed to capital-intensive sectors including mining, manufacturing, and utilities, probably reflecting their focus on SMEs that are not typically found in those sectors. Annex 1 provides details for the sectoral shares of CGSs' guarantees and sectoral value added.

We estimate that about one-third of CGSs' guarantee portfolios are towards sectors that have elevated exposure to a disorderly energy transition. Using our largest sample, we find that 34 percent of guarantees are towards sectors that are identified to be most sensitive to an energy transition, namely agriculture (A), mining (B), manufacturing (C), utilities (D), water, sewerage,

[7] Baseline PD is set at 3 percent. We furthermore set an LGD of 25 percent in most cases. For mining and utilities, we increase the LGD to 75 percent in our transition scenario since the residual value of the capital will likely be very low, as assets in those sectors become mostly stranded (Cahen-Fourot et al., 2021).

and waste management (E), construction (F), transportation (H), and real estate (L).[8] Using a smaller sample, for which a more detailed breakdown into 89 sectors (NACE 2) is available, we obtain similar results, finding that 33 percent of guarantees are toward transition sensitive sectors.

Figure 2 – Sectoral breakdown of CGSs' guarantee portfolio (NACE1 sample, 2020)



Source: Authors based on AECM survey.

Most of the exposures of CGSs are towards sectors that are in the 30-60 percentile of GHG intensity. Table 2 shows the shares of GHG emissions, CO_2 emissions, CGS exposures, and value added per sector for our sample for which 2-digit sectoral data is available. Sectors are grouped into deciles based on GHG intensity. We find that CGSs are not highly exposed to the most GHG intensive sectors, such as coke and refined petroleum products, chemicals, basic metals, utilities, and air transport. This also holds when comparing exposures to value added. In the second decile, CGSs have a higher exposure share compared to the share of value added. This is mostly driven by a relative high exposure of CGSs to crop and animal production and land transport. The majority of CGS exposures are however found in the fourth, fifth and sixth deciles, with a

[8] Since not all manufacturing is equally climate policy relevant, we weight this sector using a factor of 0.5. All other sectors are weighted using a factor of 1.0.

combined share of 59 percent. The largest exposures of CGSs in these deciles are wholesale and retail trade, construction of buildings, specialized construction activities, and accommodation.

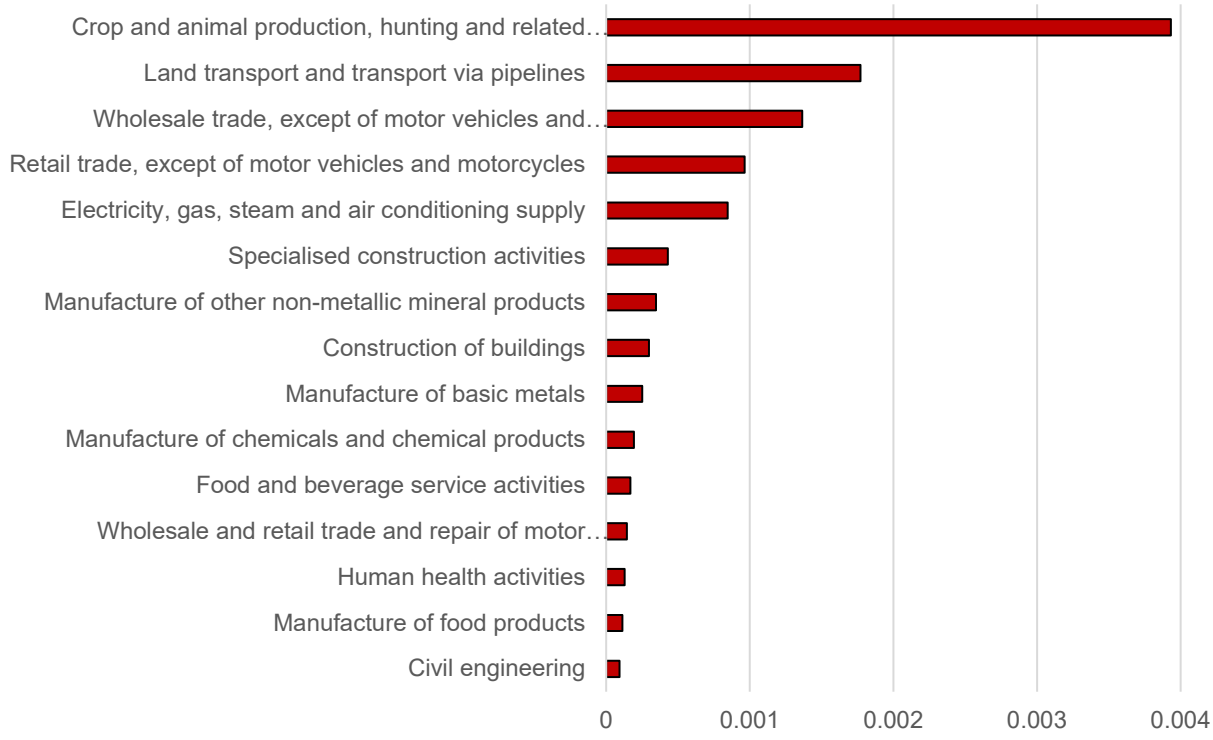
By combining exposures with GHG emission data we find that 72 percent of the transition risk for CGSs is driven by five sectors. Figure 3 shows the 15 sectors at a 2-digit sectoral level that have the highest value for the indicator. The top five sectors are crop and animal production, land transport, wholesale trade, retail trade, and electricity, gas, steam and air-conditioning supply. For crop and animal production the transition risk is highly concentrated, with two CGSs having more than 40 percent of their total guarantee portfolios allocated to this sector. For wholesale and retail trade the GHG emission intensity is more limited than for the other three top-5 industries, however their exposure share is much higher (about three times).

Table 2 – Emissions, exposure, and value-added shares per decile (NACE 2 sample, 2020)

GHG emissions decile	GHG emissions share	CO2 emissions share	CGS exposure share	Value added share
1	53%	67%	2%	4%
2	27%	14%	6%	5%
3	6%	4%	4%	7%
4	3%	4%	16%	15%
5	3%	4%	21%	9%
6	3%	3%	22%	13%
7	2%	2%	3%	10%
8	1%	1%	7%	7%
9	2%	2%	11%	16%
10	1%	1%	8%	15%

Source: Authors based on AECM survey; Eurostat.

Figure 3 –Sectoral transition risk scores for highest ranking 15 sectors, based on GHG emissions and total CGS exposures (NACE 2 sample, 2020)



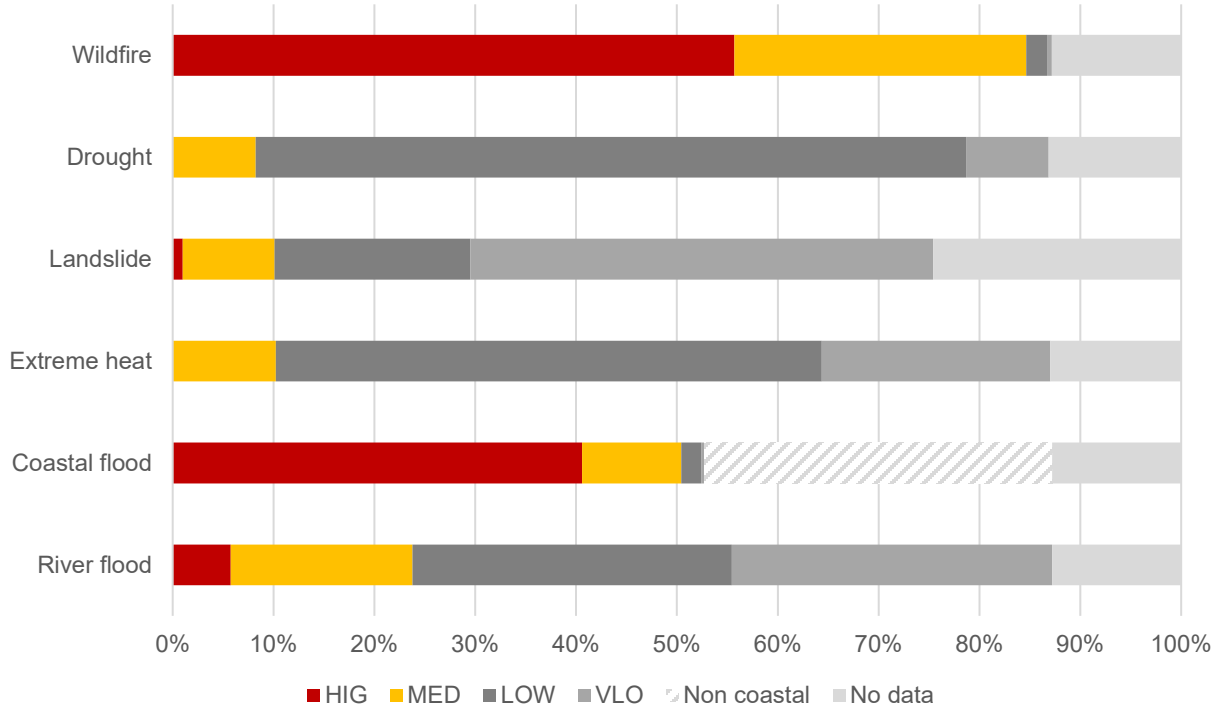
Source: Authors based on AECM survey; Eurostat.

There are large differences in individual transition risk scores between CGSs. For each individual CGS we calculate the sum of their transition risk scores for each sector *i*. We find that within our NACE2 sample, the mean transition risk score is 0.03 with a standard deviation of 0.04. The highest scoring CGS has a transition risk score of 0.17 compared to 0.01 for the lowest scoring CGS. The highest scoring CGSs tend to be highly exposed to, and specialized in, crop and animal production. The lowest scoring CGSs have their highest exposures in retail and wholesale trade and financial service activities.

4.2 Physical risk vulnerability

Using the vulnerability data by Think Hazard, CGSs in Europe are exposed to a broad range of climate-related risks. Our main results are provided in Figure 4. We find the main high-risk exposures to be for wildfire (56 percent of aggregate CGSs' portfolios in our sample), coastal flood (41 percent), and river flood (6 percent). There are also some exposures to high landslide risk (1 percent). The high risk for wildfires is mainly driven by regions in Greece, Portugal, Spain and the United Kingdom, while the high risk for coastal flood is primarily driven by the United Kingdom. High risk for river flood is driven by regions in Germany, Hungary, Poland the United Kingdom.

Figure 4 – Exposures to climate-related physical risks in the CGSs' portfolios (NUTS 2 sample, 2020)



Source: Authors based on AECM survey; Think Hazard.

Within CGSs' portfolios we estimate that 24-31 percent of guarantees are towards sectors that have elevated exposure to climate change and weather variability. Since our classifications are both at a NACE 1 level, we use our largest sample covering 84 percent of total guarantees. For the classification by Lazo et al. (2011) based on US weather variability impact, we find that the combined exposures of CGSs in our sample to these sectors is EUR 65 billion (24 percent of total guarantees in the sample). This is driven primarily by manufacturing (EUR 29 billion) and agriculture (EUR 28 billion). For the classification obtained from Skougaard et al. (2017) on relevant sectors from a climate change perspective in Europe, we find that the combined exposure of CGSs in our sample to these sectors is EUR 83 billion (31 percent of total guarantees in the sample). This is driven primarily by agriculture (EUR 28 billion) and accommodation and food services (EUR 27 billion).

4.3 Potential losses in adverse scenarios

We find that for transition and physical risk scenarios the annual expected loss on the guarantee portfolio could increase by EUR 181 million and EUR 128 million, respectively. For our transition scenario the outcome is calculated for 2025, which represents the time horizon for which the ECB (2022) obtained the highest increases in default rates. After 2025 the annual expected loss declines. For our physical risk scenario ("hot house world"), the highest increase in default rates is observed in 2050, with the expectation that financial losses would keep increasing afterwards. Comparing our results to baseline expected losses, the transition scenario represents a peak 8.9 percent increase in the annual expected losses on the guarantee portfolios of CGSs in

2025. Transition losses are driven primarily by utilities (EUR 54 million), wholesale and retail trade (EUR 29 million), and transport (EUR 19 million). The physical risk scenario is expected to lead to gradually increasing losses culminating in an increase in expected annual loss of 6.3 percent by 2050. Physical risk losses are driven primarily by wholesale and retail trade (EUR 28 million), agriculture (EUR 23 billion), and accommodation and food (EUR 14 million). Results are presented in Table 3.

5. Conclusions and recommendations

This paper presents an assessment of the vulnerability to climate-relate financial risks for a sample of European CGSs. Based on unique sectoral and spatial data collected through a survey of AECM members, to the best of our knowledge this paper represents the first attempt to measure climate-related financial risks for CGSs, both transition risks and physical risks. In particular, this paper links CGSs' guarantee portfolio data to a set of sectoral and spatially disaggregated transition and physical risk vulnerability indicators, which allows us to identify the portfolio shares at risk per indicator. We also identify sectors that are most relevant for CGSs to focus on by creating a transition risk score which combines exposure with GHG intensity. Finally, we conduct a stylized stress test to assess potential financial losses that CGSs could incur under adverse climate-related scenarios.

CGSs in Europe are exposed to transition risks in a broad range of sectors as well as to physical risks in vulnerable sectors and regions. Our results show that about one-third of CGSs' guarantee portfolios is towards sectors that have high exposure to a disorderly energy transition. The most relevant sectors for CGSs from a transition perspective include crop and animal production, land transport, and wholesale trade. European CGSs are also exposed to a broad range of climate-related physical risks, especially wildfire, coastal flood, and river flood, with 24-31 percent of outstanding guarantees towards sectors that have elevated exposure to climate change and weather variability. The annual expected losses on the aggregate guarantee portfolios could increase by EUR 181 million and EUR 128 million for transition and physical risk scenarios, respectively. These figures represent specific future scenarios as investigated by the ECB and we note that other, more severe, scenarios are possible. This is especially the case for physical risks, for which there are large and deep uncertainties regarding the underlying climate science.

Table 3 – Expected annual credit losses on CGS portfolios per sector, under baseline and stressed scenarios (NACE 1 sample, 2020, EUR million)

		(A) Orderly transition (2025)		(B) Hot house world (2050)	
Sector	**Baseline**	**Stressed**	**Difference**	**Stressed**	**Difference**
A - Agriculture, forestry and fishing	208	213	5	231	23
B - Mining and quarrying	3	15	11	3	0
C - Manufacturing	220	235	15	233	13
D - Electricity, gas, steam, and A/C	19	73	54	21	2

E - Water supply, sewerage, and waste	16	17	1	17	1
F - Construction	195	198	3	203	9
G - Wholesale and retail trade	402	431	29	430	28
H - Transportation and storage	86	94	9	89	4
I - Accommodation and food services	202	204	2	215	14
J - Information and communication	51	51	0	53	2
L - Real estate activities	60	61	1	64	4
M - Professional, scientific, and technical	108	127	19	112	4
R - Arts, entertainment, and recreation	47	48	1	51	5
Other	416	446	30	437	21
Total	**2,032**	**2,213**	**181**	**2,160**	**128**

Source: Authors based on AECM survey; European Central Bank.

Our analysis has several limitations. With respect to the transition risk assessment, our transition risk score is based on direct GHG emission in the respective sectors. This data does not encompass effects along the supply chain, such as cost pass-through (see Fabra and Reguant 2013). With respect to our physical risk assessment, the main drawback of our analysis is that not all CGSs in our survey were able to provide exposure data at the NUTS 2 level. This could lead to an overall bias in our spatial assessment, given that 90 percent of the exposures in our NUTS 2 sample are obtained from CGSs in Germany, Poland, Portugal, Spain and the United Kingdom. The latter alone accounts for 63 percent of total NUTS2 exposures in our sample. Results however do not change significantly when we exclude the United Kingdom from the analysis. See annex 5. Finally, our stress test uses values for credit risk parameters that are applied across the sample but may differ between regions and CGSs depending among others on their business model and risk appetite.

Despite its limitations, this paper points to important policy implications for CGSs. SMEs are instrumental to the ambitious decarbonization policies of European countries, yet they need to access bank finance to finance their green projects. European CGSs can play an important role in supporting SME investment in climate change mitigation and adaptation. This will require mainstreaming climate action within CGSs. To facilitate this process, the World Bank, in partnership with the industry and stakeholders, including AECM, recently developed the "Guidelines for Integrating Climate Change Mitigation and Adaptation into Public CGSs for SMEs" (World Bank 2022), a set of good practices to help CGSs integrate climate change considerations in their strategies and operations. Supported by their shareholders, CGSs could develop an internal roadmap to help organize the work. Central to these efforts, as the findings of this paper suggest, could be the explicit integration of climate-related financial risks in their respective risk management frameworks, if they have not done so already.

Future research could include case studies on sectors that are highly relevant for CGSs and investigate the role that CGSs can play to support an energy transition. Our results point to the importance of specific sectors that are highly relevant for CGSs, including agriculture and transportation. Future studies could provide deep dives on transition and physical risks in those

sectors and how best to address them. Additionally, future research could focus on the desirability of differentiating guarantee conditions and pricing based on climate-related risk considerations. It could also go further and ask what types of supporting roles CGSs can play in achieving climate targets in their jurisdiction.

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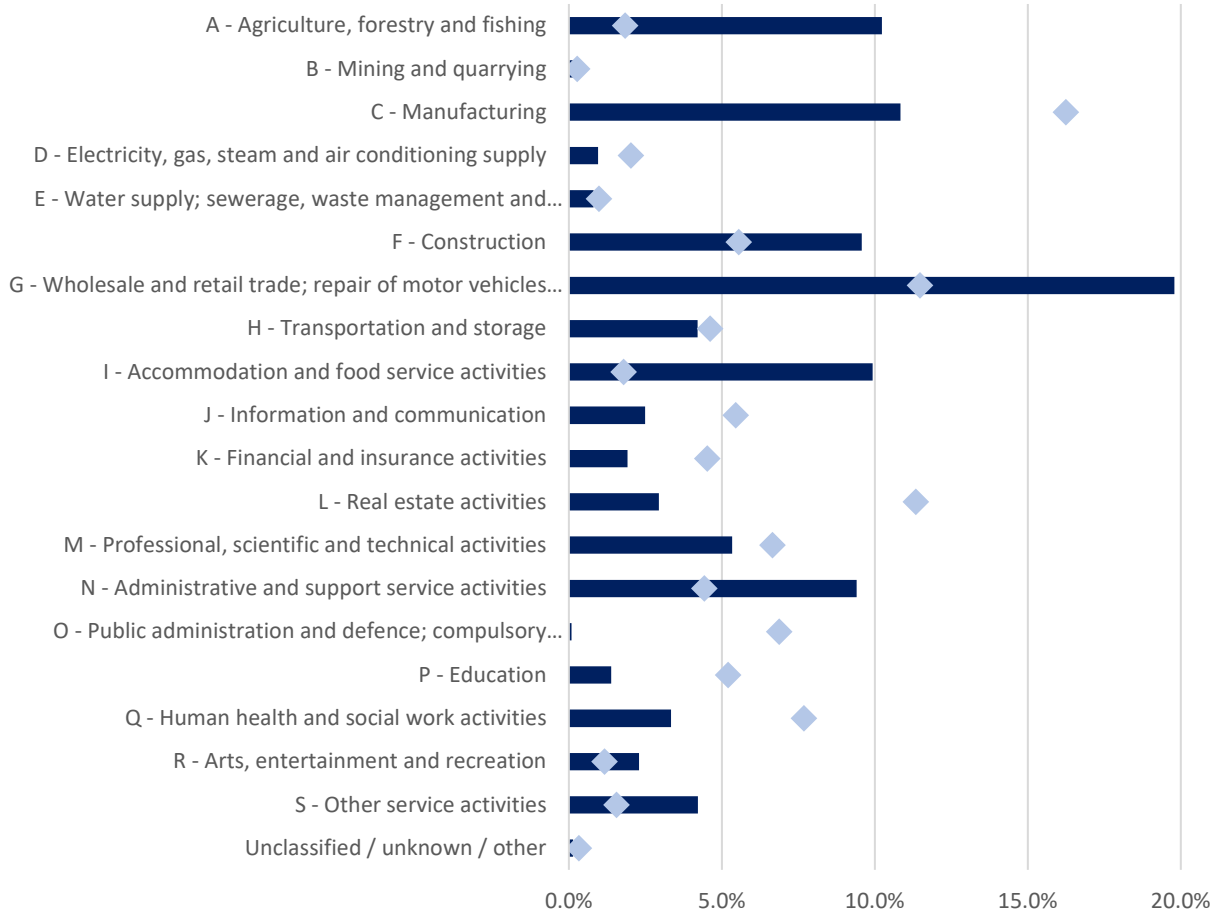
Annexes

Annex 1: CGSs' exposure share (dark blue) versus value added share (light blue marker), in 2020



Source: Authors based on AECM survey; Eurostat.

Annex 2: Classification of transition risk sensitive sectors (NACE 2)

NACE1	NACE2	Sector	Transition risk factor
A	1	Crop and animal production, hunting and related service activities	1
A	2	Forestry and logging	1
A	3	Fishing and aquaculture	1
B	5	Mining of coal and lignite	1
B	6	Extraction of crude petroleum and natural gas	1
B	7	Mining of metal ores	0.5
B	8	Other mining and quarrying	0.5
B	9	Mining support service activities	0.5
C	10	Manufacture of food products	0.5
C	11	Manufacture of beverages	0.5
C	12	Manufacture of tobacco products	0
C	13	Manufacture of textiles	1
C	14	Manufacture of wearing apparel	1
C	15	Manufacture of leather and related products	1
C	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0
C	17	Manufacture of paper and paper products	0.5
C	18	Printing and reproduction of recorded media	0
C	19	Manufacture of coke and refined petroleum products	1
C	20	Manufacture of chemicals and chemical products	0.5
C	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1
C	22	Manufacture of rubber and plastic products	0
C	23	Manufacture of other non-metallic mineral products	0.5
C	24	Manufacture of basic metals	0.5
C	25	Manufacture of fabricated metal products, except machinery and equipment	0.5
C	26	Manufacture of computer, electronic and optical products	1
C	27	Manufacture of electrical equipment	1
C	28	Manufacture of machinery and equipment n.e.c.	1
C	29	Manufacture of motor vehicles, trailers and semi-trailers	1
C	30	Manufacture of other transport equipment	1
C	31	Manufacture of furniture	0
C	32	Other manufacturing	1
C	33	Repair and installation of machinery and equipment	0.5
D	35	Electricity, gas, steam and air conditioning supply	1
E	36	Water collection, treatment and supply	0
E	37	Sewerage	1
E	38	Waste collection, treatment and disposal activities; materials recovery	1

E	39	Remediation activities and other waste management services	1
F	41	Construction of buildings	0.5
F	42	Civil engineering	0
F	43	Specialised construction activities	0.5
G	45	Wholesale and retail trade and repair of motor vehicles and motorcycles	1
G	46	Wholesale trade, except of motor vehicles and motorcycles	0
G	47	Retail trade, except of motor vehicles and motorcycles	0
H	49	Land transport and transport via pipelines	1
H	50	Water transport	1
H	51	Air transport	1
H	52	Warehousing and support activities for transportation	1
H	53	Postal and courier activities	1
I	55	Accommodation	1
I	56	Food and beverage service activities	0
J	58	Publishing activities	0
J	59	Motion picture, video and television programme production, sound recording and music publishing activities	0
J	60	Programming and broadcasting activities	0
J	61	Telecommunications	0
J	62	Computer programming, consultancy and related activities	0
J	63	Information service activities	0
K	64	Financial service activities, except insurance and pension funding	0
K	65	Insurance, reinsurance and pension funding, except compulsory social security	0
K	66	Activities auxiliary to financial services and insurance activities	0
L	68	Real estate activities	1
M	69	Legal and accounting activities	0
M	70	Activities of head offices; management consultancy activities	0
M	71	Architectural and engineering activities; technical testing and analysis	0
M	72	Scientific research and development	0
M	73	Advertising and market research	0
M	74	Other professional, scientific and technical activities	0
M	75	Veterinary activities	0
N	77	Rental and leasing activities	0.5
N	78	Employment activities	0
N	79	Travel agency, tour operator and other reservation service and related activities	0
N	80	Security and investigation activities	0
N	81	Services to buildings and landscape activities	0
N	82	Office administrative, office support and other business support activities	0
O	84	Public administration and defence; compulsory social security	0

P	85	Education	0
Q	86	Human health activities	0
Q	87	Residential care activities	0
Q	88	Social work activities without accommodation	0
R	90	Creative, arts and entertainment activities	0
R	91	Libraries, archives, museums and other cultural activities	0
R	92	Gambling and betting activities	0
R	93	Sports activities and amusement and recreation activities	0
S	94	Activities of membership organisations	0
S	95	Repair of computers and personal and household goods	0
S	96	Other personal service activities	0
T	97	Activities of households as employers of domestic personnel	0
T	98	Undifferentiated goods- and services-producing activities of private households for own use	0
U	99	Activities of extraterritorial organizations and bodies	0

Source: Adapted from Battiston et al. (2017). To map our 2-digit exposures to the 4-digit CPRS we weigh 2-digit sectors using a factor 1.0 if all the subsectors are in CPRS, a factor 0.5 if two or more subsectors are in CPRS, and 0 if one or no subsectors are in CPRS.

Annex 3: Classification of transition and physical risk sensitive sectors (NACE 1)

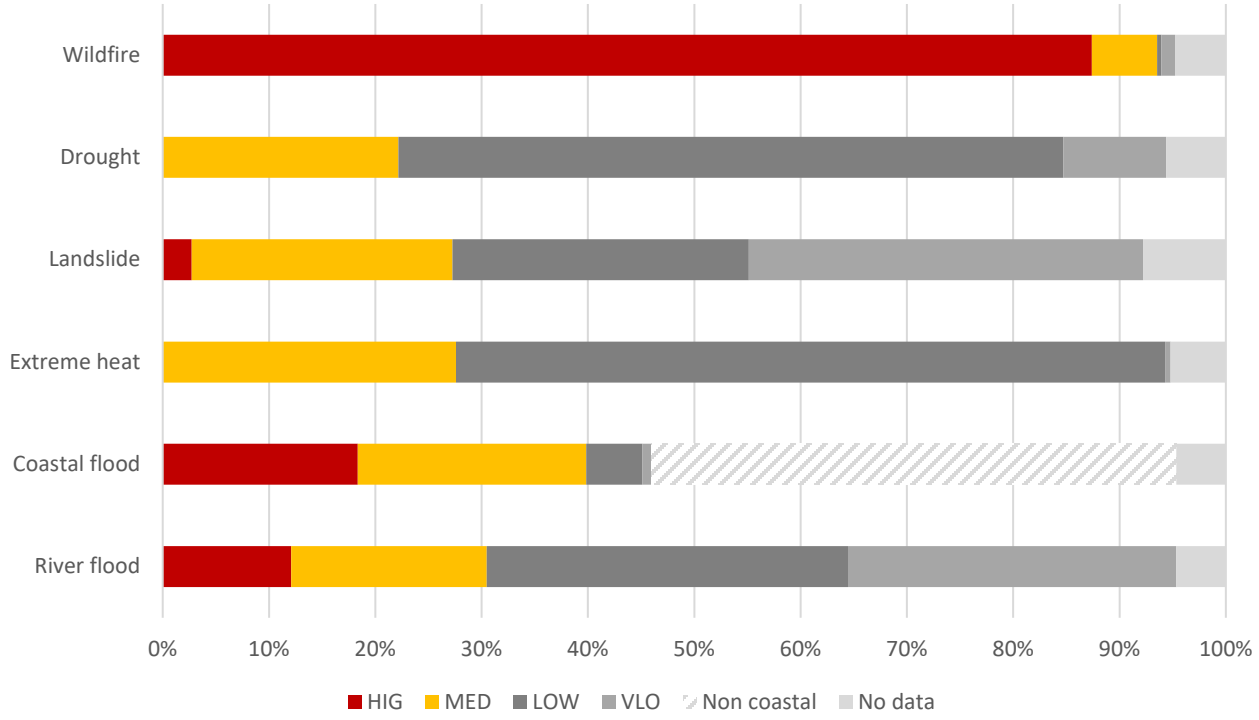
	(A)	(B)	(C)
	Battiston et al. (2017)	Lazo et al. (2011)	Skougaard et al. (2017)
	Transition risk	*Physical risk*	*Physical risk*
A - Agriculture, forestry and fishing	1	1	1
B - Mining and quarrying	1	1	1
C - Manufacturing	0.5	1	
D - Electricity, gas, steam and air conditioning supply	1		1
E - Water supply; sewerage, waste management and remediation activities	1		
F - Construction	1		
G - Wholesale and retail trade; repair of motor vehicles and motorcycles			
H - Transportation and storage	1		1
I - Accommodation and food service activities			1
J - Information and communication			
K - Financial and insurance activities		1	
L - Real estate activities	1	1	
M - Professional, scientific and technical activities			1
N - Administrative and support service activities			
O - Public administration and defence; compulsory social security			
P - Education			
Q - Human health and social work activities			1
R - Arts, entertainment and recreation			
S - Other service activities			
Unclassified / unknown / other			

Annex 4: ECB stress test factors

	(A) Orderly transition (2025)	(B) Hot house world (2050)
Accommodation & Food	0.01	0.07
Agriculture	0.02	0.11
Arts & Entertainment	0.03	0.10
Construction	0.02	0.05
Electricity & Gas	0.26	0.08
Information & Communication	0.01	0.04
Manufacturing	0.07	0.06
Mining	0.56	0.07
Other services	0.07	0.05
Real Estate	0.02	0.07
Scientific & Technical	0.17	0.04
Transport	0.10	0.04
Water Supply & Waste	0.04	0.06
Wholesale & Retail	0.07	0.07

Source: ECB (2021)

Annex 5: Exposures to climate-related physical risks in the CGSs' portfolios (NUTS 2 sample, 2020) excluding the United Kingdom



Source: Authors based on AECM survey; Think Hazard.