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Are financial regulations impairing the transition to net zero?

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Abstract

The discussions around the role of the financial system in fostering the green transition have been steadily growing. Companies are increasingly required to quantify and disclose climate risks. However, the influential role of existing accounting and financial reporting requirements, and broader financial regulation, are not commonly considered to be a significant driver in the transition. Analyzing data and classifications from the European Banking Authority, we test whether existing frameworks might inadvertently be disincentivizing divestments from brown assets. We find that a significant bias exists – differences in the provision coverage ratio (PCR) reveal banks have to account for nearly double loan loss provisions for lending to non-brown sectors as to brown. We argue that this bias could be present in other model-based regulations, such as capital requirements and possibly impact the ability of banks to fund green investments. Finally, we discuss the possible underlying drivers of this effect and some avenues for further research.

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Introduction

The urgency of climate change has not always been matched by the pace of action by governments. Increasing concerns about climate-induced financial instability and stranded assets [1–5] led academics and policymakers to advance a set of possible policies that could be used to foster the green transition [6]. Among these, greater disclosure and transparency of climate related financial risks is increasingly seen as a key tool for shifting firm and investor behaviours to foster the low carbon energy transition[v]. The foundation of sustainability disclosure proposals is that providing financial markets with information about the risks emerging from a transition to net zero carbon emissions might allow the risk-repricing needed for the reallocation of financial resources from "brown" to "green" activities [7–10]. Risk is a central tenet in many aspects of the financial system which affects prices and resources allocation.

A less discussed issue is whether existing risk regulatory frameworks may influence behaviours of financial institutions to invest in brown assets as opposed to non-brown, including green activities. Financial regulation has extensively required banks to use statistical models for assessing firms and investments' financial risk for various purposes (e.g., financial stability). For example, capital requirements (Basel III/IV) aim to internalise the social cost of banks' failures and force banks to hold higher capital buffers for investments that are *estimated* to be riskier. Accounting and reporting rules (IFRS9) based on risk models appraise the "fair value" of outstanding loans on banks' balance sheet, reducing their net value by the amount of *estimated* expected losses[vi]. These regulatory frameworks, which are generally set by international bodies and then implemented into local regulations, affect key metrics of financial institutions which ultimately influence management compensation. Previous research has shown that risk-based regulatory frameworks might structurally influence the allocation of resources by financial institutions [11–14].

This paper assesses whether such widely used risk frameworks might create disincentives for banks and other financial institutions to divest their portfolios from brown assets. Specifically, we focus on financial accounting and reporting rules which are a key driver of the profitability of banks and leverage model-based estimates of risk. The primary objective of this regulation is to ensure the valuation of banks' assets is sufficiently representative of their "fair value". A key measure in this framework is Loan Loss Reserves (LLR), which is an allowance for potential future losses from outstanding loans. Due to the structure of double-entry accounting, LLR are liabilities which net the valuation of assets by the amount of their expected losses. Any change in LLR results in Loan Loss Provision charges (LLP), which are a *present* cost for the amount of *future* expected credit losses from outstanding loans (ECL)[vii]. When there is any

[v] The first set of voluntary proposals was from the Taskforce on Climate-Related Disclosure (TCFD), which has largely been followed by the International Financial Reporting Standard Foundation (IFRS) in the creation of the International Sustainability Standards Board (ISSB) and the Sustainability Accounting Standards Board (SASB). Governments and legislators have also proposed mandatory frameworks such as the Sustainable Finance Disclosures Regulation (SFDR) in the European Union and the recent SEC consultation on climate disclosure in the United States

[vii] Importantly, the framework does not account for incurred losses but rather for expected losses which are estimated according to model-based risk regulation

change in these model-based estimates of portfolio risk, banks are expected to account for any associated financial losses before they occur[viii].

To undertake this assessment, we make use of sector level information of financial institutions' Loan Loss Reserves in the European Union (EU) to simulate the impact of banks' divestment from brown assets on several widely used financial metrics. This allows us to understand the implicit incentive structure created by the regulation. We use data from the European Banking Authority (EBA) transparency exercise which provides the amount of LLR and outstanding loans of supervised banks in the European Union by economic sector (defined as NACE rev1). We combine the results of the EBA climate risk pilot exercise, which reports the average exposure towards climate policy relevant sectors (CPRS)[ix] within each NACE label, to classify sectors as brown. We classify the sectors with a share of CPRS higher than 95% as brown[x]. We are particularly interested in the ratio of loan loss reserves over the value of outstanding loans, which represents a proxy of banks' estimate of expected credit losses. This measure is oftentimes called *provision coverage ratio* (PCR) and measures the proportion of outstanding loans that might not be repaid. Our data allows us to gauge the difference in banks' PCR for brown and non-brown investments across all major banks in the EU. With this empirical observation, we simulate the impact of a divestment from brown assets on different financial metrics impacted by the accounting regime.

Results

Our analysis shows that in 2021 the average provision coverage ratio of banks in the EU was substantially lower for brown (1.8%) than non-brown sectors (3.4%), as reported in Table 1. Such a difference has significant implications for banks return on capital and profitability and therefore influences incentives and behaviours. This result is consistent for banks of different portfolio size and across country of the banks' headquarters, with the only exception being Italy. Looking at the results by the size of banks show this effect is exacerbated for smaller and less sophisticated financial institutions in absolute terms, but in relative terms there is no correlation between the difference in provision coverage ratio and the size. The average absolute difference in PCR between non-brown and brown activities for banks in the smaller quartile is as high as 3% while it decreases to around 2% for the largest financial institutions. In relative terms the difference ranges between 65% and 125%, but with no correlation depending on the size. This finding is also consistent across countries, regardless of the significant variation in terms of absolute provision coverage ratio between Nordic and

[viii] Please refer to the supplementary material 3 for a more thorough description of the accounting framework

[ix] Climate policy relevant sectors (CPRS) are a more granular classification of climate-sensitive activities provided by Battiston et al., (2017) associated with the carbon intensity of their production. We assume that climate sensitive sectors are brown sectors or carbon intensive activities. We classify: A - Agriculture, forestry and fishing, B - Mining and quarrying, D - Electricity, gas, steam and air conditioning supply, E - Water supply, sewerage, waste management, H - Transport and storage, L - Real estate activities as brown sectors. We consider non-brown all sectors that are not brown.

[x] Climate policy relevant sectors (CPRS) are a more granular classification of climate-sensitive activities provided by Battiston et al., (2017) associated with the carbon intensity of their production. We assume that climate sensitive sectors are brown sectors or carbon intensive activities. We initially classify: A - Agriculture, forestry and fishing, B - Mining and quarrying, D - Electricity, gas, steam and air conditioning supply, E - Water supply, sewerage, waste management, H - Transport and storage, L - Real estate activities as brown sectors. We consider green all sectors that are not brown.

Southern/ Eastern European regions. In some cases, such as Greece, the difference between brown and non-brown PCR could be as high as almost 6% while in Germany as little as 1%, but the relative variation is still high. The relative difference of the PCR in Greece and Germany oscillates around 100% in both cases. The range of relative variation across the full set of countries in our sample is between -2% and 200%, although the number of banks covered in each country varies.

		Provision coverage ratio (PCR) non-brown sectors	**Provision coverage ratio (PCR) brown sectors**	**Number of Banks**
Total sample		3.40%	1.80%	59
Loan book size (quartile)	0-25	7.29%	3.28%	14
	25-50	3.68%	2.01%	15
	50-75	2.82%	1.13%	15
	75-100	3.20%	1.94%	15
Country	Austria	2.98%	2.12%	3
	Belgium	3.70%	2.27%	2
	Denmark	1.92%	0.60%	3
	Finland	1.46%	1.17%	2
	France	3.24%	1.98%	9
	Germany	2.08%	1.00%	12
	Greece	12.49%	6.52%	4
	Hungary	4.85%	3.53%	1
	Ireland	5.02%	4.95%	2
	Italy	4.75%	4.87%	7
	Netherlands	2.42%	1.04%	4
	Portugal	6.73%	3.25%	1
	Spain	3.48%	2.42%	5
	Sweden	0.71%	0.44%	4

Table 1 – Provision coverage ratio for brown and non-brown investments for European Banks

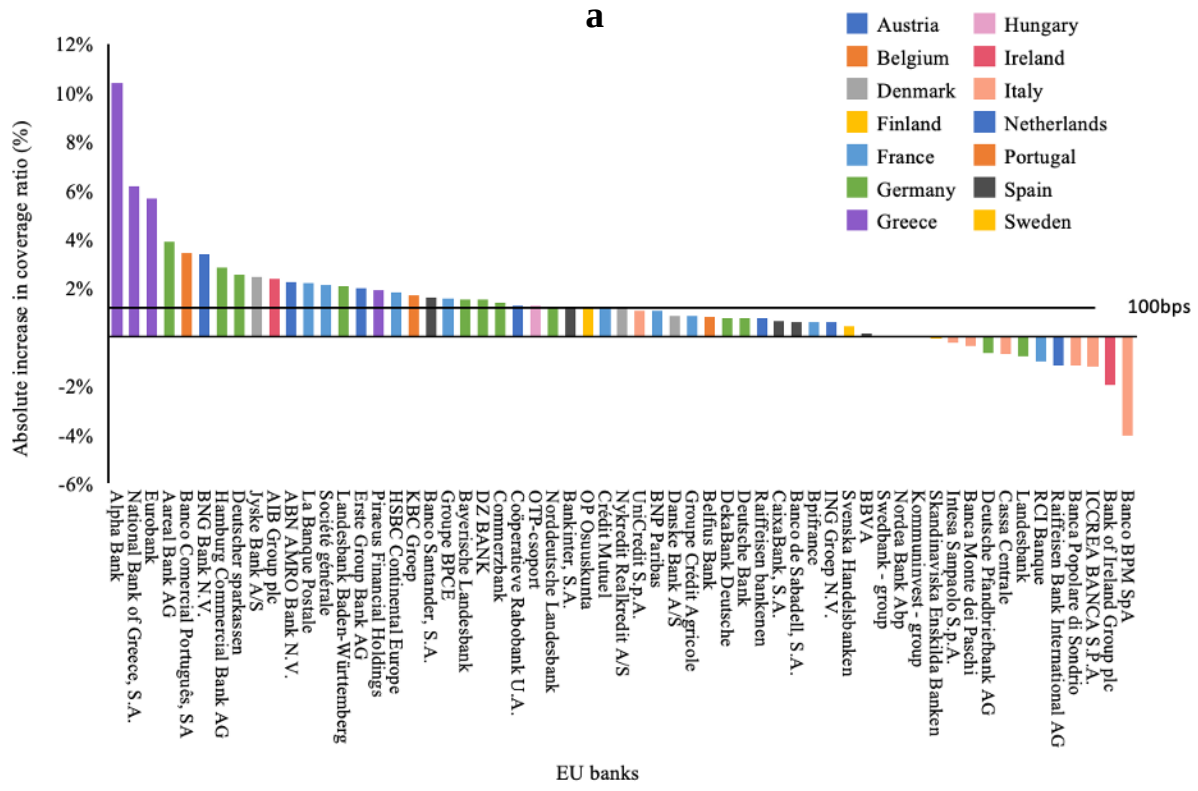
Exposure weighted average provision coverage ratio (PCR) for sectors classified as brown and non-brown for the 59 largest European banks participating in the EBA transparency exercise, representing 93% of total banking exposure as of June 2021. PCR defined as the ratio of loan loss reserves over value of outstanding loans. The table reports the breakdown by bank size (quartile of total loan outstanding) and country of the bank headquarters

The results shown in Table 1 emerge from individual banks statistical models based on historical information as required by the framework. Standard backward-looking risk methods can show a brown portfolio to be relatively low risk, even if there is a possibility of a rapid transition to green energy. Although it is arguably difficult to take an objective stance on the correct level of estimate of risk for these investments on a forward-looking basis, our analysis is sufficient to show that the structure of risk frameworks may have an unintended side effect that is potentially in conflict with the purpose of the regulations or other societal goals. By

affecting financial institutions incentives some financial regulations may create perverse incentives possibly leading to more polluting businesses, and increase the potential for financial instability from transition risks. Simulating the effect of a divestments from brown activities and a re-investment in non-brown sectors allows us to better understand the effects of such action on banks financial metrics and the linked management incentives which ultimately affect behaviours and resources allocation.

Simulation of a divestment strategy

Due to the model-based risk estimates of PCR required by the accounting regulation, the performance of financial institutions would be significantly impacted if they were to swiftly shift their portfolio from brown to other investments. Our modelling shows that if banks had to stop lending to brown-sector firms and lend only to non-brown ones, the portfolio average provision coverage ratio would need to increase by more than 100 basis points (1%) across most institutions in the European banking sector (Fig. 1). This is because the PCR would need to increase to the level of expected losses of non-brown firms (Tab. 1). This effect is consistent for most banks in our sample and across various nations, except for few institutions with low provision coverage ratio for brown assets. Banks in countries with the largest difference in PCR between non-brown and brown assets would be hit significantly more according to our analysis. Most financial institutions would be affected by this shift regardless of their size, but, in line with our empirical observations, banks in the smaller size quartile would be more impacted than others (2.35% increase compared to 0.9% simple average).



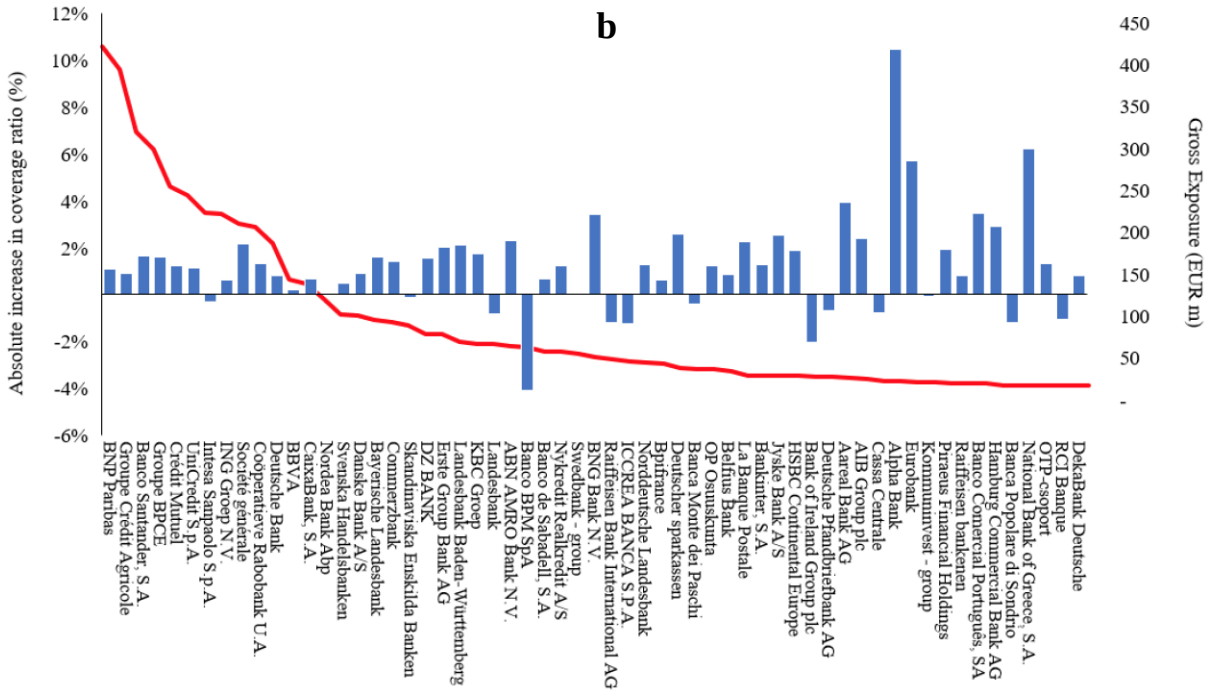


Figure 1 – Change in provision coverage ratio increase for 59 largest European banks
Absolute percentage increase in provision coverage ratio (PCR) following a divestment from brown assets and corresponding re-investment in non-brown assets, maintaining a constant level of outstanding loans by bank. Colours represent the country of bank's headquarters. The increase in PCR represents the difference between PCR required for non-brown as opposed to brown assets, for each bank in our sample. Horizontal line represents average in basis points (bps). Figure **a** *show the banks ranked by absolute increase in PCR. Figure* **b** *is ranked by gross loan exposure (from largest on left hand side to smallest).*

The increase in the provision coverage ratio is caused by the increase in loan loss reserves (LLR) required due to the higher estimated risk of non-brown firms' loans. According to the accounting regulations, if a bank is investing in an activity which is expected to bear more risk, it should carry higher loan loss reserves, due to higher *expected* losses. This in turn leads to a higher PCR. We estimate that the impact of shifting investments from brown to non-brown sectors would require an exposure-weighted average increase of 35% of LLR for banks in the European Union (Fig. 2). This result is consistent after controlling for bank size and country. The decision to divest could lead to more than doubling of provisions for some banks in our sample and could have material effects on the bank's stock market valuations. Further, the increase in loan loss reserves depends on the difference between the estimated expected loss from lending to non-brown and brown activities, but also on the share of brown loans. The higher the share of current outstanding loans towards brown firms, the more pronounced the impact on LLR given a certain level of difference in provision coverage ratio. This relationship further exacerbates the impact of this bias for banks more exposed to brown sectors creating a negative feedback loop which leads to more investments in the brown sectors and might contribute to the build-up of risk in assets that could become stranded.

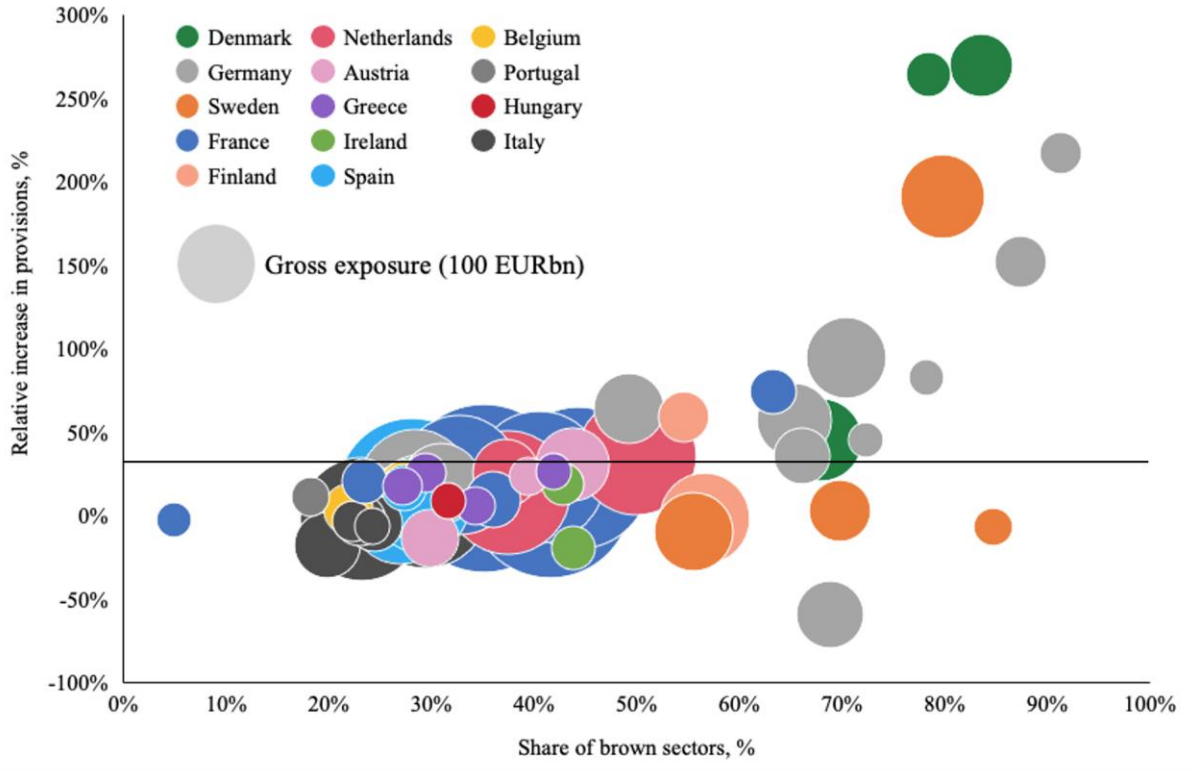


Figure 2 – Relative increase in loan loss reserves

Relative increase in loan loss reserves (LLR) following a divestment from brown assets and corresponding re-investment in non-brown assets, maintaining a constant level of outstanding loans by bank. Horizontal axis represents current share of brown sector outstanding loans as of June 2021 (starting point of simulation). Dots represent banks in our sample and are colour coded based on the country of headquarter. Bubble size represents the total value of outstanding loans of the respective bank. Relative increase in LLR represents the absolute increase in LLR over the level of LLR as of June 2021. Results are gross exposure weighted. Horizontal line is weighted average by gross exposure across banks (35%).

The increased provision coverage ratio, loan loss reserves and the resulting loan loss provision charges driven by a potential divestment strategy could weigh significantly on banks' net profits. An increase in loan loss reserves not only impacts the liability side of the balance sheet, but also the income statement through decreased profits[xi]. In order to simulate this effect, we take the absolute increase in provisions and we compare it with each bank's cumulative profits from 2016 to 2020. We select 5 years of profits to smooth possible bad years or extraordinary items in the financial reporting and to provide a stable baseline for our counterfactual analysis. We find that, at system level, the increase in provision following a divestment from brown assets could hit the European banking sector with an aggregated loss in profits of around €28 billion (considering the 59 largest European banks). To put this number in perspective, in its climate stress test the European Central Bank (ECB) estimated the impact for physical risk and transition risk for the largest European banks taking part in the exercise, would be between 17 and 53 Euro billion [xii]. For some banks the transition could cost as much as five years of profits over the divestment horizon and, on average, 13% of the past five years of profits due to a large

[xi] Any change in LLR results in a loan loss provisions charge which represents a cost and decreases profits

[xii] https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.climate_stress_test_report.20220708~2e3cc0999f.en.pdf

increase in loan loss reserves. On an exposure weighted average basis, losses could amount to as much as 15% of the previous 5 years profits. For some banks, we estimate that the impact could be higher than the previous 5 years profits given a combination of low profitability, high share of brown outstanding loans, and significantly higher estimated provision coverage ratio of non-brown sectors.

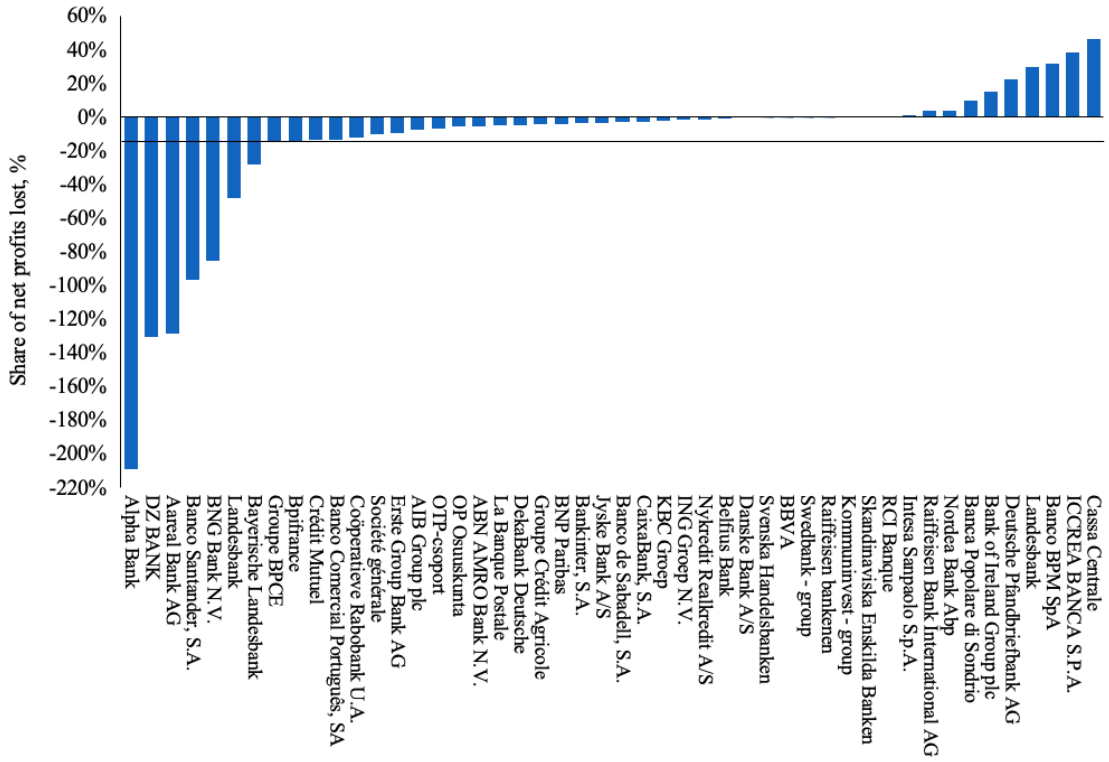


Figure 3 – Impact on average 5 years net profits
Impact on net profits following a divestment from brown assets and corresponding re-investment in non-brown assets, maintaining a constant level of outstanding loans by banks. Bars represent the share of cumulative 2016-2020 profits loss due to the required increase in LLR. Impact represents the ratio of absolute increase in LLR over the cumulative profits between 2016-2020. Horizontal line represents average (13%).

Although, there are a few instances of banks who experience higher profits due to their lower estimate of risk for non-brown than brown sectors, our results show consistently that most banks profits would be negatively impacted by a divestment from brown activities. Our findings are also not substantially sensitive to the classification of specific sectors as brown. On the contrary, the prevalence of the lowest provision coverage ratio among the brown sectors, in general terms, drives the key output of our results. Firstly, relabelling some selected sectors between the brown and non-brown clusters provides some confirmation that the main outcome of our study is not sensitive to the classification used, although the magnitude of the impact changes (for details see the Supplementary Information). Secondly, we simulate the impact of allocating each sector partially to the non-brown and to the brown cluster depending on their median share of climate policy relevant sectors (CPRS) found among banks in the European Union taking part in the EBA climate risk pilot exercise. Once again, we find that

our main results persist. The robustness of our results highlights the fact that our findings are not a function of the specific non-brown/brown classification used but driven by a general lower estimated risk for brown sectors compared to non-brown ones. Finally, our results are robust controlling for different time periods. If we use quarterly average levels from March 2020 to June 2022 (maximum depth of the data) the impacts are roughly similar[xiii]. This in turn leads to the conclusion that there exists an implicit incentive structure which might inadvertently favour brown activities (Supplementary Information 1).

Discussion

The *"carbon bias"* shown in this paper might emerge from the backward-looking nature of risk estimates. That is, the use of models that rely on the historical relationship between firm's financial performance and risk. Such models may not be well suited to capturing uncertain future outcomes when there are structural breaks in the system, or a major transition – such as the clean energy transition. Financial performance is oftentimes measured through financial ratios that summarise the creditworthiness of firms through their profitability (e.g., EBIT/ Revenue), solvency (e.g., Debt/ Asset, Interest/EBITDA) and liquidity (e.g., short term debt/working capital). If these ratios have been historically favourable for brown firms, as previous research has highlighted[15], risk models will likely produce favourable outcomes for this type of activities. This phenomenon might also arguably limit investments in green assets, if their past risk estimates are relatively high.

To illustrate this, we use a dataset of 228 Oil & Gas and 235 renewable energy firms worldwide and financial information between 2010-2021, retrieved from Bloomberg. We use this dataset as a representative sample of some of the most relevant sectors in the brown and non-brown clusters. We construct some financial ratios that are commonly used in risk assessment to investigate the origins of risk estimates differentials. We then contrast them to infer the likely relative magnitude between these two important sectors in the net zero carbon transition. As reported in Figure 4, the average share of interest expenses over Earnings Before Interest, Taxes, Depreciations and Amortizations (EBITDA) for the period 2010-2021 is lower for Oil & Gas (16%) than renewable energy firms (32%) and the average debt over asset ratio lower for Oil & Gas (31%) than renewable energy (42%). This shows that historically investing in the former might have been less risky compared to the latter, due to the higher solvency and lower indebtedness.

These ratios have been arguably a good proxy of the historical creditworthiness of firms and have been used extensively by financial analysts. However, problems arise if these historical metrics are not representative of the future, leading to a change in the distribution of losses [16]. For example, we estimate that if there were an increase in the average global level of carbon tax enforced on Scope 1 and 2 emissions to USD $100, the ratio of interest expenses over EBITDA for Oil & Gas firms might increase substantially above the ratio of renewable energy companies (from 16% to 46% against 32% for renewable energy). Similarly, a partial write-off of oil reserves valuations in the balance sheet of Oil & Gas companies of USD $20 per barrel, might result in an increase in the debt to asset ratio of these firms, much higher than the average value observed among renewable energy companies (from 16% to 86% against 32% for renewable energy). In such case, financial ratios, and the resulting risk estimates, might

[xiii] 100% increase in PCR, 33% increase in provisions, 14% impact on previous 5 years profits

become lower for renewable energy investments. A more forward-looking framework including scenario analysis might simulate the effects of various climate related risks capturing these unprecedented emerging risks.

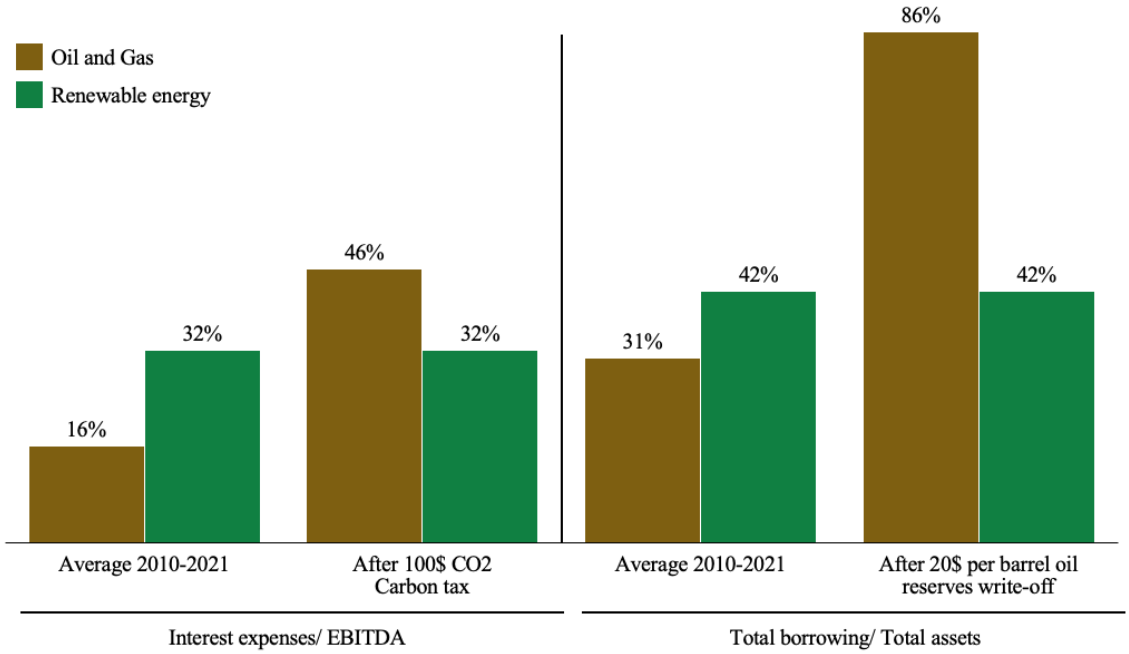


Figure 4 – Comparison of financial ratios between oil and gas and renewable energy industries *Average interest expenses over EBITDA and Total Borrowing over Total assets of 228 Oil & Gas and 235 renewable energy firms in our sample between 2010-2021. Simulation of the impact of USD $100 carbon tax on EBITDA expressed in terms of average interest expenses over EBITDA ratio (left-hand side). Impact of USD $20 per barrel write-off of oil reserves on total assets expressed in terms of average Total Borrowing over Total Assets (right-hand side).*

In conclusion, our results suggest that the reporting framework and the related accounting rules might be *"carbon biased"* and disincentivise banks to divest from brown sectors by directly impacting their profitability. This side effect might impair the transition towards net zero carbon emissions and might contribute to increasing climate risk build-up in the financial system. Our comparison of financial ratios between Oil & Gas and renewable energy firms indicates that this bias might penalise investments in the green energy. Current financial accounting practices might unintendedly impair the shift of funds required for the green transition, especially in Europe where these investments are oftentimes provided by the banking sector. While the motivations for not wanting to impede the green transition may be based on broader social objectives that lie beyond the remit of financial regulators the deeper problem for such regulators is that this transition, and in particular the rapid diffusion of green energy technologies, might represent a source of systemic risk for brown investments and by extension, the banking sector. Broader research is needed to determine whether the existing regulation sufficiently accounts for the emerging systemic risks that might accompany the green transition. More research would also be needed to shed light on whether this bias might be present in other similar policy frameworks (e.g., capital requirements).

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Methods

Data

We use data from the 2021 European Banking Authority (EBA) transparency exercise which provides granular portfolio level information of banks' gross exposure and accumulated provisions (Loan loss reserves) by NACE[xiv] sector level 1 at end of June 2021. The Nomenclature of Economic Activities is a standard classification of sectors in the European Union. It has various levels of granularity from 1 (least granular) to 4 (most granular) and the EBA transparency exercise relies on this classification. The exercise is an annual data collection to foster transparency, and to complement banks' own disclosures, publicly available online[xv]. The information published includes 111 EU banks across 25 countries and provides information regarding banks' assets, liabilities, loan loss provisions, and other financial information for each bank. The data is submitted every year by individual banks to the EBA which also uses it to carry out its own analysis

We use the Legal Entity Identifier (LEI) code in the EBA dataset to complement this information with the historical net profit data from Bloomberg. The data identifiers have been matched with each LEI code in our sample through manual research on the Bloomberg terminal. We start from the largest 60 banks in our sample representing 95% of the total banking exposure, but we exclude one bank because of name and LEI code missing which would have not allowed us to retrieve income information. This bank represents around 2% of total EU banking assets. After this manipulation our dataset covers more than 93% of total banking exposure in the European Union and provides us with loan loss reserves, total lending exposure for all NACE sectors (level 1) and cumulative net profits from 2016 to 2021 for the largest 59 banks in the EU.

NACE Sector	Gross exposure	Loan loss Reserve / Outstanding loans
A Agriculture, forestry and fishing	213,318	2.55%
B Mining and quarrying	81,359	3.98%
C Manufacturing	815,066	3.32%
D Electricity, gas, steam and air conditioning supply	259,135	1.23%
E Water supply, sewerage, waste management	48,423	1.57%
F Construction	268,833	5.95%
G Wholesale and retail trade	680,038	3.54%
H Transport and storage	317,979	2.78%
I Accommodation and food service activities	156,017	5.74%
J Information and communication	147,902	1.75%
K Financial and insurance activities	223,718	1.99%
L Real estate activities	1,383,779	1.45%
M Professional, scientific and technical activities	251,711	2.74%
N Administrative and support service activities	213,488	2.28%

[xiv] Nomenclature Statistique des Activités économiques dans la Communauté Européenne. https://ec.europa.eu/competition/mergers/cases/index/nace_all.html

[xv] https://www.eba.europa.eu/risk-analysis-and-data/eu-wide-transparency-exercise/2021

O Public administration and defence, compulsory social security	13,119	1.53%
P Education	17,098	2.52%
Q Human health services and social work activities	101,754	1.71%
R Arts, entertainment and recreation	33,059	5.13%
S Other services	170,396	3.78%

Table 2 – System wide exposure distribution and provision coverage ratio by sector
Summary of EU baking system exposure (Euro millions) and provision coverage ratio (PCR) by NACE sectors for banks in our sample. PCR expressed as ratio of Loan Loss Reserves over total outstanding loans by sector.

Brown sectors classification

We then add to the dataset information to classify sectors as brown. Specifically, we complement the data with the results of the EBA Climate risk pilot exercises which provides median values of Climate policy relevant sectors (CPRS) as defined by Battiston et al., (2017). CPRS is a classification used to assess the exposure of investments to transition risks, including carbon taxation, and is a proxy of how polluting an investment in an economic activity is. The exercise was carried out in 2021 by the EBA and a sample of 29 volunteer banks from 10 countries representing 50% of the total EU banking assets with the objective to have a preliminary quantification of the exposure of banks to climate relate risks, with particular focus on transition risk[xvi]. The data annex provided publicly available discloses the share of CPRS sectors in each high-level NACE lev 1 label according to banks' classification of their own clients in CPRS. This information is particularly useful because it allows us to have a more granular labelling of non-brown and brown sectors than the high-level NACE level 1. The CPRS rely on NACE level 2 which provides a better discrimination between climate sensitive sectors and others (additional information provided in Supplementary information 2). In fact, the NACE level 2 has 88 divisions as opposed to the 21 in the NACE level 1.

The information at bank level of gross exposure and loan loss reserves by NACE code has been labelled in brown and non-brown sectors. We define as "brown" sectors with a median share of CPRS higher than 95%[xvii] as reported by banks in the climate risk pilot exercise. This gives us the following brown sectors and their respective code: A - Agriculture, forestry and fishing, B - Mining and quarrying, D - Electricity, gas, steam and air conditioning supply, E - Water supply, sewerage, waste management, H - Transport and storage, L - Real estate activities. This approach has limitations, but we ensure our results are not sensitive to the assumption used to classify non-brown and brown by performing an extensive robustness analysis. Furthermore, we use as a proxy of the share of brown activities within each sector the percentage of CPRS within each NACE code reported by the EBA Climate risk pilot exercise. We do so, in order to prevent the concern of heterogenous sectors. In fact, in some cases (e.g., power generation), sectors might have an heterogenous mix of non-brown and brown activities.

Simulation of a divestment strategy

Starting from the data collected, we calculate the impact of a divestment from brown assets on banks financials. The primary assumption in this simulation is that the total exposure of each

[xvi] https://www.eba.europa.eu/risk-analysis-and-data/eu-wide-pilot-exercise-climate-risk
[xvii] As reported in figure 8 of EBA Climate risk exercise data annex

bank is left unvaried. In other words, the simulation assumes that banks would shift their lending portfolio from brown to non-brown investments rather than only exiting brown firms. The labelling in our data allows us to calculate the average risk estimate (provision coverage ratio) of non-brown and brown sectors for all banks in our sample. We make use of the accounting relationship between provisions coverage ratio, loan loss provision charges and net profits to assess the impact of a divestment from brown assets on these metrics.

We first define the provision coverage ratio (PCR) as the loan loss reserves (or accumulated provisions in EBA terminology) divided by the gross exposure for the brown and non-brown sectors *i* for each bank *j*. The provision coverage ratio represents the expected credit loss (of non-default counterparties) and the corresponding loan loss provisions which banks must allocate to lending activities in each sector. This measure is assumed to be the model-based output from each institution risk model, in line with the accounting regulation.

$$PCR_{i,j} = \frac{Loan\ loss\ reserves_{i,j}}{Gross\ exposure_{i,j}}$$

We then calculate the change in the level of loan loss reserves following a divestment from brown assets. This is performed by assuming that all non-brown exposures replacing the brown ones would require the average provision coverage ratio of existing non-brown assets. More formally, the increase/decrease in provision for bank *j* is defined as follows:

$$\begin{aligned} Loan\ Loss\ Provision\ charges_j &= \Delta\ Loan\ Loss\ Reserves_j \\ &= \left(PCR_{green,j} - PCR_{brown,j}\right) * Gross\ exposure_{brown,j} \end{aligned}$$

This result provides the expected increase/ decrease in provisions if a bank had to shift the totality of its assets from brown to non-brown investments. This relationship is an accounting identity defined by the framework. The impact of additional loan loss provisions on the bank's income statement is a loan loss provision charge (i.e., additional costs) with direct effect on the net profit. In particular, the increase in provisions (i.e., the loan loss provision charges) is directly deducted from the net profit being an additional cost for the bank in the fiscal year of the divestment giving us the change in net profits following a divestment from brown assets. More formally:

$$Net\ profit_{j,t+1} = Net\ profit_{j,t} - Loan\ Loss\ Provision\ \ charges_j$$

Where *j* refers to each bank in our sample, *t* is the starting point period and *t+1* is the period post divestments. Importantly, in order to simulate the effect of the divestment we assume it occurs entirely in one fiscal year. This result would likely occur spread across multiple years, but frontloading the entire impact allows us to better investigate the implicit incentive structure created by the regulation. This simple approach allows us to simulate what would be the impact of a divestment from brown assets on banks' balance sheet and income statements. In

particular, this approach allows us to test the hypothesis that a potential divestment strategy might be costly disincentivizing banks in taking such action.

Supplementary information 1 - Sensitivity of results

Our analysis provides evidence of the potential negative effects of model-based regulation on the green transition, but it leaves room to a possible subjective interpretation of what should be classified as brown and non-brown. This has been, for example, highly controversial in the case of the EU green taxonomy. The classification of climate policy relevant sectors (CPRS) provided by Battiston et al. (2017) has been used in the literature and by policy makers but is only one of the multiple possible alternatives available. To ensure that our findings are not affected by the labelling used, we perform a sensitivity analysis and provide evidence that our results are driven primarily by the prevalence of high provision coverage ratio estimates among non-brown sectors. We discuss this regarding some key sectors and provide transparency on how the results would change were we to reclassify industries among the two clusters.

We first investigate the sensitivity of our results to the reclassification of sectors from brown to non-brown activities. The real estate sector is one of the largest exposures of banks in our sample. Carbon emissions are only an imperfect proxy of the exposure of some specific sectors to climate transition risk, but it is probably one of the most relevant drivers. Real estate is also one of the sectors with the lowest PCR in the brown cluster and it is relevant in shifting the average results. For this reason, we recalculate the system level impact relabelling the real estate sector as non-brown. As expected, in this case the effect of a divestment from brown sectors is still substantial (44bps PCR increase). Similarly, the power generation sector is particularly difficult to classify using NACE labels because of its sub-industry heterogeneity. Our sensitivity analysis provides reassuring results for this sector, as relabelling the power generation sector as non-brown or partially brown would still impact the profits of banks willing to divest (74bps PCR increase)[xviii].

We then relabel some non-brown sectors which could be controversial due to their relatively high level of carbon emissions to the brown cluster. In contrast to the approach set out in the previous paragraph, we select a sector based on its relative high coverage ratio and emissions. The construction sector in this case could significantly impact our results. In fact, relabelling it as brown would lead to an overall lower increase in the coverage ratio following a divestment strategy (44bps coverage ratio increase), but still high enough to generate the bias discussed in our main results. The manufacturing sector has different NACE activities within it and could include firms with various levels of carbon intensity, but it is not characterised by a particularly high coverage ratio. For this reason, it is worth investigating the impact of including it in the brown cluster. In this case, the impact of a divestment strategy would still lead to an increase in the overall coverage ratio among the banks in our sample (89bps).

The relabelling of some selected sectors between the non-brown and brown clusters provides some comfort that the main outcome of our study is not sensitive to the classification applied, although the impact on the financial system varies. To further understand the effect of the classification of some specific sectors in driving the overall results, we carry out a similar analysis for all NACE labels (Table 2). Recursively re-classifying sectors to the opposite cluster (e.g., brown to non-brown clusters) shows us that our main results are not sensitive to the classification of individual industries as brown. Thus, we conclude that the prevalence of

the highest provision coverage ratios among the predominantly non-brown sectors is a key driver of our results.

NACE Sector	Impact on 2016-2020 cumulative years profits	Percentage increase loan loss reserves	Provision coverage ratio increase (bps)
Baseline model	-14.66%	34.86%	104
A Agriculture, forestry and fishing	-14.1%	32.9%	106
B Mining and quarrying	-16.8%	38.9%	114
C Manufacturing	-14.8%	33.3%	89
D Electricity, gas, steam and air conditioning supply	-9.8%	26.7%	74
E Water supply, sewerage, waste management	-13.5%	31.5%	100
F Construction	-6.8%	32.1%	44
G Wholesale and retail trade	-14.9%	27.6%	77
H Transport and storage	-14.9%	34.8%	104
I Accommodation and food service activities	-14.0%	33.6%	82
J Information and communication	-17.5%	37.0%	116
K Financial and insurance activities	-16.7%	38.4%	111
L Real estate activities	-2.6%	1.9%	55
M Professional, scientific and technical activities	-17.7%	40.5%	112
N Administrative and support service activities	-18.6%	41.2%	115
O Public administration and defence	-17.1%	38.7%	112
P Education	-16.9%	38.9%	112
Q Human health services and social work activities	-19.7%	50.9%	124
R Arts, entertainment and recreation	-16.3%	38.1%	106
S Other services	-17.9%	38.7%	97

Table 3 – Sensitivity analysis
Sensitivity analysis of the impact of a divestment from brown assets and corresponding re-investment in non-brown assets, maintaining a constant level of outstanding loans by bank, on the system level provision coverage ratio (PCR), loan loss reserves (LLR) and net profit. Values refer to the impact of a reclassification of the sector represented in the row to the opposite cluster. Shaded sectors classified as brown in the baseline setting of the model. The sensitivity analysis tests the impact of a reclassification of the sector in the non-brown cluster. Non-shaded sectors classified as non-brown in the baseline setting of the model. The sensitivity analysis tests the impact of a reclassification of the sector in the brown cluster.

Finally, we simulate the impact of allocating each sector partially to the brown cluster depending on their median share of climate policy relevant sectors (CPRS) found among banks in the European Union that took part in the EBA climate risk pilot exercise. For example, considering the median share of CPRS in the Manufacturing sector reported by banks is 73%, we can allocate only this portion to the brown bucket. In this case, the increase in the provision coverage ratio is still positive (30bps) including the effect on loan loss reserves (+25%). The average impact of a divestment strategy on profits in this case is lower (-4%) but still negative and with high variance among the banks in our sample (minimum -187%, maximum 287%).

Supplementary information 2 - Descriptive statistics

Sector	Median share of CPRS
A - Agriculture	100%
B - Mining and Quarrying	96%
C - Manufacturing	73%
D - Electricity, Gas, Steam	100%
E - Water supply, sewerage, waste management	100%
F - Construction	85%
G - Wholesale and Retail	18%
H - Transportation and Storage	97%
I - Accommodation and Food	62%
L - Real Estate	100%
M - Professional	1%
N - Administrative	23%

Table 4 – Percentage of climate policy relevant sector by NACE code
Percentage of climate policy relevant sector by NACE code according to EBA 2021 climate risk pilot exercise (Data annex, figure 8) and classification provided in Battiston et al. (2017)

Sector	Co2 Emissions (Tonnes)	Banks' Exposure (EURm)
Electricity, gas, steam and air conditioning supply	695,249,449	259,135
Manufacturing	694,258,047	815,066
Transportation and storage	369,796,104	317,979
Agriculture, forestry and fishing	98,943,702	213,318
Wholesale and retail trade; repair of motor vehicles and motorcycles	62,106,757	680,038
Construction	49,379,561	268,833
Water supply; sewerage, waste management and remediation activities	34,943,731	48,423
Public administration and defence; compulsory social security	24,925,976	13,119
Mining and quarrying	22,464,410	81,359
Human health and social work activities	20,966,844	101,754
Professional, scientific and technical activities	17,028,217	251,711
Administrative and support service activities	17,018,320	213,488
Accommodation and food service activities	12,980,932	156,017
Other service activities	11,247,794	170,396
Education	10,880,959	17,098
Information and communication	7,957,810	147,902
Arts, entertainment and recreation	6,937,446	33,059
Financial and insurance activities	6,260,460	223,718
Real estate activities	5,070,313	1,383,779
Activities of households as employers	97,717	0
Activities of extraterritorial organisations and bodies	324	0

Table 5 – Carbon emissions by sector Eurostat Total European Union (EU27) and Banks' exposure
Carbon emissions in 2020 as reported by Eurostat and gross loans in our sample (EURm).

Bank Name	Loan Loss Reserves	Gross carrying amount	Net profit 2016-2020
BNP Paribas	11,066	421,891	38,227
Groupe Crédit Agricole	12,313	394,656	30,092
Banco Santander, S.A.	9,937	319,748	1,491
Groupe BPCE	9,327	299,819	14,678
Crédit Mutuel	5,518	255,114	8,854
UniCredit S.p.A.	10,782	245,051	- 1,622
Intesa Sanpaolo S.p.A.	9,040	223,446	21,936
ING Groep N.V.	3,511	222,912	21,525
Société générale	6,046	210,263	13,791
Coöperatieve Rabobank U.A.	3,848	206,993	10,732
Deutsche Bank	2,430	186,866	- 6,781
BBVA	6,007	143,871	17,211
CaixaBank, S.A.	3,664	139,159	7,802
Nordea Bank Abp	1,644	121,268	609
Svenska Handelsbanken	194	102,424	82,204
Danske Bank A/S	1,335	101,321	75,281
Bayerische Landesbank	833	96,126	2,738
Commerzbank	1,986	92,976	- 1,016
Skandinaviska Enskilda Banken	734	88,963	85,872
DZ BANK	1,363	78,961	593
Erste Group Bank AG	2,262	78,455	6,628
Landesbank Baden-Württemberg	1,101	69,962	1,460
KBC Groep	2,354	67,731	11,501
Landesbank	778	67,337	1,537
ABN AMRO Bank N.V.	2,098	64,024	8,891
Banco BPM SpA	3,176	63,358	1,765
Banco de Sabadell, S.A.	1,749	58,132	2,610
Nykredit Realkredit A/S	217	57,516	31,997
Swedbank Group	470	55,278	92,677
BNG Bank N.V.	203	52,116	1,483
Raiffeisen Bank International AG	1,358	48,278	4,880
ICCREA Banca S.p.a	3,941	46,531	490
Norddeutsche Landesbank	957	44,923	- 4,011
Bpifrance	1,019	44,250	687
Deutscher sparkassen	488	38,140	-
Banca Monte dei Paschi	1,839	37,514	- 9,187
OP Osuuskunta	407	36,665	3,768
Belfius Bank	1,040	34,751	2,989
La Banque Postale	550	29,709	7,119
Bankinter, S.A.	623	29,243	2,380
Jyske Bank A/S	212	28,957	12,808

HSBC Continental Europe	616	28,921	- 591
Bank of Ireland Group plc	1,359	28,140	1,727
Deutsche Pfandbriefbank AG	259	27,896	854
Aareal Bank AG	435	26,479	733
AIB Group plc	1,303	25,202	3,120
Cassa Centrale	1,714	23,141	116
Alpha Bank	2,674	22,266	325
Eurobank	1,833	21,187	- 654
Kommuninvest - group	0	20,978	2,392
Piraeus Financial Holdings	2,388	20,825	- 776
Raiffeisen bankenen	282	20,700	1,214,096
Banco Comercial Português, SA	1,248	20,596	996
Hamburg Commercial Bank AG	486	18,052	- 284
Banca Popolare di Sondrio	963	17,667	613
National Bank of Greece, S.A.	1,726	17,647	- 3,631
OTP-csoport	773	17,476	919
RCI Banque	352	17,358	3,871
DekaBank Deutsche	149	16,962	1,236

Table 6 – List of banks in database and key statistics

List of banks in data sample including key summary statistics in Euro millions. Variables reported are Loan Loss Reserves, Outstanding loans and sum of 2016-2020 profits.

Supplementary information 3 – Additional results

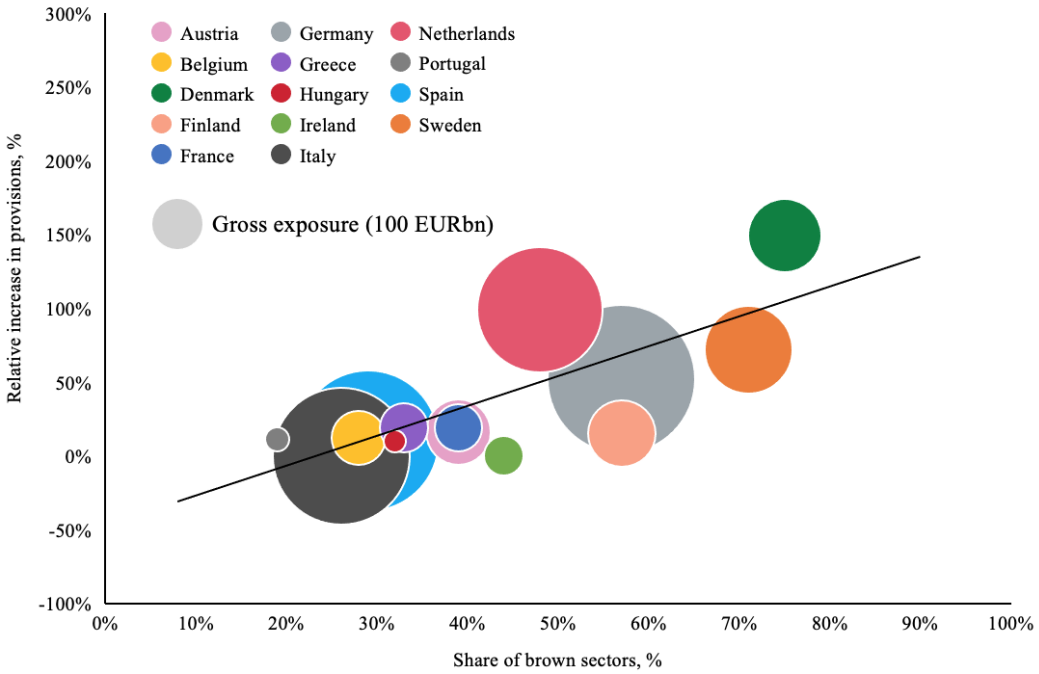

Figure 6 – Relative increase in loan loss reserves by country
Relative increase in loan loss reserves (LLR) following a divestment from brown assets and corresponding re-investment in other non-brown assets, maintaining a constant level of outstanding loans by country. Horizontal axis represents current share of brown sector outstanding loans as of June 2021 (starting point of simulation). Dots represent weighted average of individual banks results by country in our sample and are colour coded based on the country of headquarter. Bubble size represents the total value of outstanding loans of banks in the respective country. Relative increase in LLR represents the absolute increase in LLR over the level of LLR as of June 2021.

Supplementary information 4 - Accounting framework regulation

The primary objective of the model-based regulation which emerged following the global financial crisis is to better discriminate investments depending on their level of risk. This differentiation mostly occurs through the use of risk models by financial institutions which assess the creditworthiness of the borrower depending on its financial situation or on the specific terms of the deal. The outcome of these assessments is usually a quantitative measure of risk which can be used for various purposes. For example, these measures could be used for setting capital requirements or for calculating the value of a financial claim for accounting purposes. In simple terms, the risker the investment the higher the potential losses and the higher the capital requirements or the lower the value of an investment given the same net present value. A key measure of the accounting framework of financial institutions is Loan Loss Reserves (LLR), which is an allowance for potential future losses from outstanding loans. Any change in LLR results in Loan Loss Provisions (LLP) which are an actual cost for the amount of future expected losses from financial claims. Banks should calculate on a recurring basis the expected credit losses (ECL) from loans and allocate LLR accordingly. Consider the following situation where risk models foresee that non-brown investments bear more risk than brown ones. In such case, if a bank had to replace one euro of lending to brown sectors (assumed with lower estimated expected loss) with one euro to non-brown ones (assumed with higher estimated expected loss), it would result in an increase in loan loss reserves proportional to the difference in provision coverage ratio between the two lending activities in the balance sheet (valuation effect) and a corresponding loan loss provision charge in the income statement (income effect). On one side, an increase in loan loss provisions would lead to an increase in the loan loss reserves which in turn decreases the equity value of a bank. On the other side, loan loss provisions are reported as a cost in the income statement, leading to lower profits. Suppose a bank has on its balance sheet 1000 Euro exposure to a brown company with cost or risk of 1%. At maturity the bank does not refinance the loan but lends 1000 Euro to a non-brown company with provision coverage ratio of 2%. The instantaneous impact of this action would lead to a higher level of loan loss reserves (valuation effect) in the balance sheet (from 10 to 20) and an additional 10 (1%*1000) of loan loss provisions (cost) in the income statement (income effect). Under the requirements of the accounting regime, shifting investments from an estimated low-risk portfolio to an estimated high-risk portfolio leads to an increase in loan loss provisions and to the two effects described above

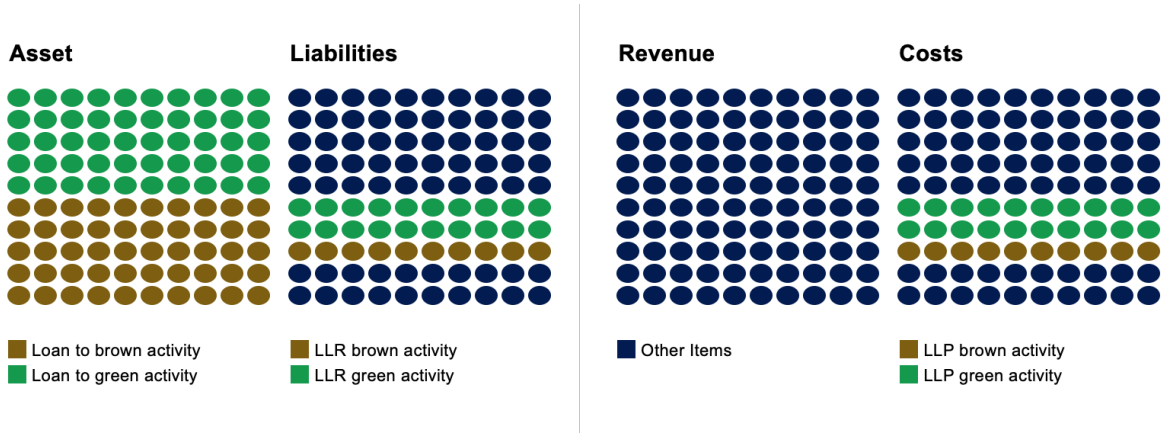

Figure 5 – Stylised representation of a bank balance sheet (left) and income statement (right)

Representation of illustrative bank balance sheet and income statement providing and exemplification of the accounting framework

Supplementary information 5 – Acronyms

Acronym	Name	Description
IFRS9	International Financial Reporting Standard Number 9	IFRS 9 is an International Financial Reporting Standard published by the International Accounting Standards Board (IASB). It addresses the accounting for financial instruments.
Basel III/IV	NA	Basel III (and its revision Basel IV) is an internationally agreed set of measures developed by the Basel Committee on Banking Supervision in response to the financial crisis of 2008/9
ECL	Expected credit loss	Expected credit loss is the amount of losses estimated or expected on a specific loan or a group of homogenous loans
LLP	Loan Loss Provisions	A loan loss provision is an actual cost a bank incurs to set aside loan loss reserves for future expected losses on a portion of loans that are unlikely to be repaid
LLR	Loan Loss Reserves	Loan loss reserves are the funds that banks set aside to cover against losses that they reasonably expect will occur in the future from a portion of loans that are unlikely to be repaid
PCR	Provision Coverage Ratio	Provision coverage ratio is the ratio between the loan loss reserves and the outstanding loan
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne	The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE (for the French term "nomenclature statistique des activités économiques dans la Communauté européenne"), is the industry standard classification system used in the European Union. The current version is revision 2 and was established by Regulation (EC) No 1893/2006
CPRS	Climate policy relevant sectors	Classifications of economic sectors that are particularly vulnerable to changes in carbon policy such as the introduction or rapid increase of a carbon tax, or regulations prohibiting extraction or use of certain resources provided by Battiston et al. (2017)
EBITDA	Earnings Before Interest, Taxes, Depreciations and Amortizations	A company's earnings before interest, taxes, depreciation, and amortization is a measure of a company's profitability of the operating business only, thus before any effects of indebtedness, state-mandated payments, and costs required to maintain its asset base