

Model-based financial regulations impair the transition to net zero carbon emissions

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Abstract

Investments via the financial system are essential for fostering the green transition. However, the role of existing financial regulations in influencing investment decisions is understudied. Here we analyse data from the European Banking Authority (EBA) to show that existing financial accounting frameworks might inadvertently be creating disincentives for investments in low carbon assets. We find that differences in the provision coverage ratio (PCR) indicate that banks must account for nearly double the loan loss provisions for lending to low carbon sectors as compared to high carbon. This bias is likely the result of basing risk estimates on historical data. We show that the average historical financial risk of the oil and gas sector has been consistently estimated lower than renewable energy. These results indicate 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.

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The urgency of climate change has not always been matched by the pace of action by governments. But increasing concerns about climate-induced financial instability and stranded assets¹⁻¹⁹ has led some academics and financial regulators to advance a set of possible policy changes to help catalyse the green transition²⁰⁻²⁸. While various policies aimed at assessing climate related financial risks - which could possibly indirectly stimulate the net zero carbon transition - have become widespread in recent years (e.g., climate stress testing, climate related risk disclosure)²⁹⁻³², financial policies aimed at directly fostering green investments have not always gained traction among policymakers (e.g., differentiated capital requirements). Yet, a largely neglected question in this literature and among policymakers is whether existing financial regulations could be negatively contributing to the net zero carbon transition.

This paper assesses whether widely used model-based risk regulations might create disincentives for financial institutions to divest their portfolios from high carbon assets. Such financial regulations have 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 (e.g., Basel III/IV) aim to force banks to hold higher capital buffers for investments that are *estimated* to be riskier. Accounting rules (e.g., IFRS9) appraise the “fair value” of outstanding loans on banks' balance sheet, reducing their net value by the amount of *estimated* expected losses. These regulatory frameworks affect key metrics of financial institutions which ultimately influence management's incentives and resources allocation³³⁻³⁶.

We focus on financial accounting rules which are a key driver of the profitability of banks and leverage model-based estimates of risk. 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 of the *future expected* credit losses from outstanding loans (ECL). When there is any change in these model-based estimates of risk, banks are expected to account for any estimated financial losses before they occur. In turn, differentials in any of these estimates may influence banks' profitability, management behaviour and resources allocation (see Supplementary Information 4).

To examine the impact of such financial accounting rules 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 rev2 level 1). We combine these data with the results of the EBA risk assessment exercise, which reports the average exposure towards climate policy relevant sectors (CPRS)⁵ within each NACE level 1 section, to classify sectors as “high carbon” or “low carbon”. We classify the sectors with a share of CPRS higher than 95% as high carbon and provide a set of robustness analyses. We are particularly interested in the ratio of loan loss reserves over the value of outstanding loans, which is a proxy of banks' estimates of expected credit losses. This measure is oftentimes called provision coverage ratio (PCR).

Our empirical analysis allows us to observe that model-based estimates of risk are lower for high carbon sectors compared to low carbon ones. We then provide an assessment of what are the implications of this observation for some key financial metrics of banks if they had to divest from high carbon assets. Specifically, we utilise the accounting relationships among some of these metrics to show that an active divestment from high carbon assets could be costly for banks. We argue that this, in turn, could create perverse incentives impairing the shift of financial resources from high carbon to low carbon assets, possibly including much needed

investments in renewable energy. Finally, we provide some possible explanations as to why some of these models may lead to estimates that are negatively correlated to carbon emissions.

Results

Our analysis shows that in 2021 the average provision coverage ratio of banks in the EU was substantially lower for high carbon (1.8%) than low carbon sectors (3.4%), as reported in Table 1. Such a difference has substantial implications for banks' return on capital and profitability and therefore heavily influences management incentives and behaviours. Our analysis shows that 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, this effect is exacerbated for smaller financial institutions in absolute terms, but in relative terms there is no correlation between the difference in provision coverage ratio and the bank size. This finding is also consistent across countries, regardless of the large variation in terms of absolute provision coverage ratio between Nordic and Southern/ Eastern European regions.

[TABLE 1 HERE]

These results emerge from banks' statistical models based on historical information as required by the accounting framework. Standard backward-looking risk models can show a high carbon portfolio to be relatively low risk, even if there is a possibility of a rapid transition to green energy (see Discussion). Although it is arguably difficult to take an objective stance on the correct estimate of risk for these investments on a forward-looking basis, our analysis is sufficient to show that the structure of model-based 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, model-based financial regulations may create perverse outcomes possibly leading to more investments in polluting activities.

Simulating the effect of a divestments from high carbon activities and a re-investment in low carbon 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. Specifically, as indicated by the accounting rules, we assume that if a bank had to divest from high carbon sectors and re-invest the proceeds in low carbon sectors, the PCR of such investments would need to increase to the higher level of the latter (Table 1). This, in turn, would lead to a higher level of loan loss provisions and higher costs due to the structure of the accounting rules (see Methods).

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 substantially impacted if they were to swiftly shift their portfolio away from high carbon to other investments. Our modelling shows that if banks had to stop lending to firms in high carbon-sectors and lend only to low carbon 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 ([FIGURE 1 HERE]). This effect is consistent for most banks in our sample and across various nations, with the exception of a few institutions with low provision coverage ratio for high carbon assets. Banks in countries with the largest difference in PCR between high carbon and low carbon assets would be hit substantially 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 impacted more than others (2.35% increase compared to 0.9% simple average).

[FIGURE 1 HERE]

We estimate that a shift in investments away from high carbon to low carbon assets would require a loan-weighted average increase of 35% of LLR for banks in the European Union (**Error! Reference source not found.**). This result is consistent after controlling for bank size and country of headquarter. The decision to divest from high carbon assets could lead to more than doubling of provisions for some banks in our sample and could thus have material impacts on the bank's stock market valuations. The increase in loan loss reserves will not only depend on the difference between the estimated expected loss from lending to low carbon and high carbon activities, but also on the share of high carbon loans. The higher the share of current outstanding loans towards high carbon firms, the more pronounced the impact on LLR given a certain level of difference in provision coverage ratio. This relationship further exacerbates the potential impact of a divestment for banks more exposed to high carbon sectors creating greater hysteresis in investing in high carbon sectors and contributing further to the build-up of risk in assets that could become stranded in a green transition.

[FIGURE 2 HERE]

The increased provision coverage ratio, loan loss reserves and the resulting loan loss provision charges driven by a potential divestment strategy could weigh substantially 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. In order to simulate this effect, we take the absolute increase in loan loss provisions, and we compare it to 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 estimate that for some banks the transition could cost as much as five years of profits over the divestment horizon and, on an outstanding loan weighted average basis, 15% of the previous five years of profits due to a large increase in loan loss reserves (Figure 3). The total sum of banks' lost profits due to the increase in provisions following a divestment from high carbon assets could be of the order of 28 Euro billion (considering the 59 largest banks in the European Union). This is only a rough estimate as it does not account for how such divestment could affect other investments in a network of interconnected banks (indirect effects), whether sufficient alternative investment opportunities are available to the banks, or the impact on the costs and prices of alternative energy generation options resulting from changes in the investments in those options. However, this figure is useful to assess the materiality of our findings. [The European Central Bank \(ECB\) estimates](#) that the impact of physical risk and transition risk could be around 17 and 53 Euro billion respectively in a short-term scenario for the 41 largest banks in the Euro area.

[FIGURE 3 HERE]

Although, there are a few instances of banks who experience higher profits due to their lower estimate of risk for low carbon than high carbon sectors, our results show consistently that most banks' profits would be negatively impacted by a divestment from high carbon assets. Our

findings are also robust to the classification of specific sectors as high carbon. It is the prevalence of the lowest provision coverage ratio among the high carbon sectors, in general terms, that drives our key results. We found that relabelling some selected sectors between high carbon and low carbon clusters does not alter the main outcome of our study, although the magnitude of the impact can change (Supplementary Information 1). This sensitivity test provides us with confidence that sectors with particularly low (high) levels of PCR among the high carbon (low carbon) sectors are not driving our results.

We then simulate the impact of allocating each sector partially to the low carbon and to the high carbon cluster depending on their median share of climate policy relevant sectors (CPRS) found among banks in the European Union taking part in the EBA risk assessment exercise. This robustness analysis simulates a partial divestment of only the high carbon portion of investments in each NACE level 1 and allows us to better investigate the heterogeneity of high carbon/low carbon sectors within each NACE level 1 section. This is because the underlying CPRS classification leverages a much more granular sectorial classification (NACE level 4) which better captures whether economic activities are high carbon or low carbon. Once again, we find that our main results persist. Moreover, our results are robust after controlling for different time periods. If we use quarterly average levels from March 2020 to June 2022 (maximum temporal depth of the data) the impacts are similar (100% increase in PCR, 33% increase in provisions, 14% impact on previous 5 years profits).

The robustness of our results highlights that our findings are not a function of the specific high carbon/low carbon classification used but driven by a lower average estimated risk for high carbon sectors compared to low carbon ones. As long as the structure of the regulation foresees that *i.* losses are costs that are accounted for as expected as opposed to incurred and *ii.* provision coverage ratios are proportional to model-based estimates of risk, then divesting from an *estimated* low-risk asset and re-investing in an *estimated* high-risk asset mechanically leads to higher costs in the income statement. Indeed, despite not being able to use carbon emissions data directly, in our Discussion and Methods sections, we provide strong evidence for a negative correlation between CPRS / emission intensity of assets and risk estimates (Figure S1). This in turn leads to a confirmation of our conclusion that there likely exists an implicit incentive structure which might inadvertently favour assets involved in high carbon activities.

Discussion

The bias shown toward high carbon assets identified in this paper likely emerges from the backward-looking nature of risk estimates. That is, it is the outcome of using models that rely on the historical relationship between a firm's financial performance and past risk as a predictor of future risk. As discussed in the literature and by policymakers, such models are useful but may not be well suited to capturing uncertain macro-economic outcomes when there are structural breaks or non-marginal changes in the system – such as the clean energy transition. In these risk-based models, the creditworthiness of firms is oftentimes estimated through financial ratios measuring 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 high carbon firms, as previous research has highlighted³⁷, risk models will likely produce favourable outcomes for this type of investment. This phenomenon might arguably limit investments in green assets if their past risk estimates have been relatively high.

To illustrate this, we use a simple analysis based on a dataset of 228 oil & gas and 235 renewable energy firms worldwide and financial information between 2010-2021, retrieved from Bloomberg (Supplementary information 2). We use this dataset as a representative sample of some of the most relevant sectors in the high carbon and low carbon 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. 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%) (Figure 4a). Similarly, the outcome of one such models retrieved from Bloomberg shows consistently higher average estimates of risk (expressed in terms of probability of default) for renewable energy than oil & gas between 2010 and 2021 (Figure 4b). This highlights how 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 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, following a change in the probability distribution of losses³⁸. 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 (or climate policies with an equivalent shadow carbon price), 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 31% to 86% against 42% for renewable energy). In such case, financial ratios, and the resulting risk estimates, might become lower for renewable energy investments. A more forward-looking framework including scenario analysis or the consideration of climate related risks in such assessments might be better suited to capturing such unprecedented emerging risks.

[FIGURE 4 HERE]

In conclusion, our results suggest that model-based financial regulations, and in particular accounting rules, might disincentivise banks to divest from high carbon sectors by directly impacting their profitability. This side effect of the rules might impair the transition towards net zero carbon emissions and in turn contribute to increasing the build-up of transition risk in the financial system. Our comparison of financial ratios between oil & gas and renewable energy firms indicates that this effect might penalise investments in clean energy. Current financial accounting practices might unintentionally hinder the shift of funds required for the green transition, especially in Europe where these investments are oftentimes provided by the banking sector. While the desire to promote a green transition may be based on broader social objectives that lie beyond the remit of financial regulators the deeper problem for regulators is that this transition could represent a potential source of systemic risk. Broader research is needed to determine whether the existing regulations sufficiently account for any such emerging sources of systemic risks that might accompany the green transition. More research is needed to shed light on whether this bias might be present in other similar model-based frameworks (e.g., capital requirements). Finally, regulators and investors should investigate

risk models that include forward looking assessments of climate and energy transition risk to ensure those risks are appropriately incorporated in decisions and remove any inadvertent bias.

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This paper only reflects the views of the authors. Any organisations they may be affiliated with do not accept any liability for opinions expressed in it.

Authors contribution statement

MG contributed to conceptualising the study, carrying out the analyses, and writing the paper.
MI, BC, SF, and EB contributed to the writing of the paper.

Competing interests

The authors declare no competing interests

Tables

		Provision coverage ratio (PCR) low carbon sectors	Provision coverage ratio (PCR) high carbon 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 high carbon and low carbon investments for European Banks

Exposure weighted average provision coverage ratio (PCR) for sectors classified as high carbon and low carbon for 59 of the 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 headquarter

Figures legends

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 high carbon assets and corresponding re-investment in low carbon 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 low carbon as opposed to high carbon assets, for each bank in our sample. Horizontal line represents average in basis points (bps). **a)** show the banks ranked by absolute increase in PCR. **b)** is the same information ranked by gross loan exposure (from largest on left hand side to smallest).*

Figure 2: Relative increase in loan loss reserves

Relative increase in loan loss reserves (LLR) following a divestment from high carbon assets and corresponding re-investment in low carbon assets, maintaining a constant level of outstanding loans. Horizontal axis represents current share of high carbon sector outstanding loans (June 2021). Bubbles represent banks in our sample, colour coded based on the country of headquarter. Bubble size represents the total value of outstanding loans. 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%).

Figure 3: Impact on average 5 years net profits. *Impact on net profits following a divestment from high carbon assets and corresponding re-investment in low carbon assets, maintaining a constant level of outstanding loans by banks. Bars represent the share of cumulative 2016-2020 profits lost due to the required increase in LLR. The impact represents the ratio of absolute increase in LLR over the cumulative profits between 2016-2020. The horizontal line represents the average loss of profits (-15%).*

Figure 4: Comparison of financial ratios between oil and gas and renewable energy industries

a) *Average of 5 years Bloomberg Probability of Default (PD), 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).* **b):** *Average Bloomberg PD estimate through time for the companies in the sample.*

References

1. Semieniuk, G. *et al.* Stranded fossil-fuel assets translate to major losses for investors in advanced economies. *Nat Clim Chang* **12**, 532–538 (2022).
2. Lamperti, F., Bosetti, V., Roventini, A. & Tavoni, M. The public costs of climate-induced financial instability. *Nat Clim Chang* **9**, 829–833 (2019).
3. Mercure, J. F. *et al.* Macroeconomic impact of stranded fossil fuel assets. *Nat Clim Chang* **8**, 588–593 (2018).
4. Dietz, S., Bowen, A., Dixon, C. & Gradwell, P. Climate value at risk' of global financial assets. *Nat Clim Chang* **6**, 676–679 (2016).
5. Battiston, S., Mandel, A., Monasterolo, I., Schütze, F. & Visentin, G. A climate stress-test of the financial system. *Nat Clim Chang* **7**, 283–288 (2017).
6. Weyzig, F., Kuepper, B., Willem Van Gelder, J. & Van Tilburg, R. *The Price of Doing Too Little Too Late* (2014).
7. D'Orazio, P., Hertel, T. & Kasbrink, F. No need to worry? Estimating the exposure of the German banking sector to climate-related transition risks. *Working paper* (2022).
8. Battiston, S., Guth, M., Monasterolo, I., Neudorfer, B. & Pointner, W. *Austrian banks' exposure to climate-related transition risk* (2020).
9. Campiglio, E. & van der Ploeg, R. Macrofinancial Risks of the Transition to a Low-Carbon Economy. *Rev Environ Econ Policy* **16** (2022)
10. Campiglio, E., Monnin, P. & Jagow, A. von. Climate risks in financial assets. *Working paper* (2019).
11. BIS. *Climate-related financial risks a survey on current initiatives*. (2020).
12. Virgilio, S. Di, Faiella, I., Mistretta, A. & Narizzano, S. *Assessing credit risk sensitivity to climate and energy shocks* (2023).
13. Caldecott, B., Clark, A., Koskelo, K., Mulholland, E. & Hickey, C. Stranded Assets: Environmental Drivers, Societal Challenges, and Supervisory Responses. *Annu Rev Environ Resour* **46**, 417–447 (2021).
14. Alogoskoufis, S. *et al.* ECB's Economy-Wide Climate Stress Test. *Working paper* (2021)
15. Monasterolo, I. Climate change and the financial system. *Annu Rev Resour Economics* **12**, 299–320 (2020).
16. Roncoroni, A., Battiston, S., Escobar-Farfán, L. O. L. & Martinez-Jaramillo, S. Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability* **52** (2021).
17. Sen, S. & von Schickfus, M. T. Climate policy, stranded assets, and investors' expectations. *J Environ Econ Manage* **100** (2020)
18. Vermeulen, R. *et al.* The heat is on: A framework for measuring financial stress under disruptive energy transition scenarios. *Ecological Economics* **190** (2021)
19. Gasparini, M., Baer, M. & Ives, M. C. A re-evaluation of the financial risks of the net zero transition. *Working paper* (2023).
20. Campiglio, E. *et al.* Climate change challenges for central banks and financial regulators. *Nat Clim Chang* **8**, 462–468 (2018).
21. Dafermos, Y. & Nikolaidi, M. *Greening capital requirements*. (2022).
22. Philipponnat, T. *Breaking the climate-finance doom loop*. (2020).
23. Bolton, P., Despres, M., Pereira da Silva, L. A., Svartzman, R. & Samama, F. *The green swan*. (2020).
24. Campiglio, E. Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological Economics* **121**, 220–230 (2016).
25. Alessi, L. Di, Girolamo, F. E., Pagano, A. & Petracco, M. *Accounting for climate transition risk in banks' capital requirements*.

26. Dafermos, Y. & Nikolaidi, M. How can green differentiated capital requirements affect climate risks? A dynamic macrofinancial analysis. *Journal of Financial Stability* **54**, (2021).
27. Diluiso, F., Annicchiarico, B., Kalkuhl, M. & Minx, J. C. Climate actions and macro-financial stability: The role of central banks. *J Environ Econ Manage* **110**, (2021).
28. Dunz, N., Naqvi, A. & Monasterolo, I. Climate sentiments, transition risk, and financial stability in a stock-flow consistent model. *Journal of Financial Stability* **54**, 100872 (2021).
29. Ameli, N., Kothari, S. & Grubb, M. Misplaced expectations from climate disclosure initiatives. *Nat Clim Chang* **11**, 917-924 (2021)
30. Ameli, N., Drummond, P., Bisaro, A., Grubb, M. & Chenet, H. Climate finance and disclosure for institutional investors: why transparency is not enough. *Clim Change* **160**, 565–589 (2020).
31. Goldstein, A., Turner, W. R., Gladstone, J. & Hole, D. G. The private sector's climate change risk and adaptation blind spots. *Nat Clim Chang* (2019)
32. Edwards, I., Yapp, K., Mackay, S. & Mackey, B. Climate-related financial disclosures in the public sector. *Nat Clim Chang* **10**, 588-591 (2020)
33. Gropp, R., Mosk, T., Ongena, S. & Wix, C. Banks response to higher capital requirements: Evidence from a quasi-natural experiment. *Review of Financial Studies* **32**, 266–299 (2019).
34. Glancy, D. & Kurtzman, R. How Do Capital Requirements Affect Loan Rates? Evidence from High Volatility Commercial Real Estate. *Review of Corporate Finance Studies* **11**, 88–127 (2022).
35. Beatty, A. & Liao, S. Financial accounting in the banking industry: A review of the empirical literature. *Journal of Accounting and Economics* **58**, 339–383 (2014).
36. Aymanns, C., Caccioli, F., Farmer, J. D. & Tan, V. W. C. Taming the Basel leverage cycle. *Journal of Financial Stability* **27**, 263–277 (2016).
37. Schmidt, To. Low-carbon investment risks and de-risking. *Nat Clim Chang* **4**, 237–239 (2014).
38. Holscher, M., Ignell, D., Lewis, M. & Stiroh, K. Climate Change and the Role of Regulatory Capital: A Stylized Framework for Policy Assessment. *Working paper* (2022)

Methods

Data

We use data from the 2021 European Banking Authority (EBA) transparency exercise which provides portfolio level information of banks' gross exposure and accumulated provisions (Loan loss reserves) by NACE sector level 1 at end of June 2021. We use the most recent data, but we ensure with additional robustness analysis that the results do not change using different years (the reader should note that due to the structure of this modelling the provision coverage ratios oscillate with time in level but the relative difference across sectors is generally preserved). The Nomenclature of Economic Activities (NACE) 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. The data 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.

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 its name and LEI code are missing, which does not allow us to retrieve their income information. This bank represents around 2% of total EU banking assets. After this manipulation our dataset covers more than 93% of total banking loans in the European Union and provide us with loan loss reserves, total lending amount for all NACE sectors (level 1) and cumulative net profits from 2016 to 2021 for the largest 59 banks in the EU. A summary of the sector-level statistics is reported in Table S1.

High carbon sectors classification

We add to this dataset the information necessary to classify sectors as high carbon (i.e., sectors with high levels of emission intensity). Specifically, we complement the data with the results of the EBA Risk Assessment exercise which provides median values of Climate Policy Relevant Sectors (CPRS) as defined by Battiston et al., (2017) [5] within each NACE level 1. CPRS is a classification used to assess the exposure of investments to transition risks, including carbon taxation, and is a proxy of the level of pollution associated with an investment. The exercise was carried out 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 related risks, with a particular focus on transition risk. The data annex provided (publicly available) discloses the share of CPRS sectors in each NACE level 1 section 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 low carbon and high carbon sectors than the NACE level 1 (which would not be sufficient to address the heterogeneity of some sectors). The CPRS rely on NACE level 4 which provides a better discrimination between climate sensitive sectors and others (additional information provided in Supplementary information 2).

The information at bank level of total gross loan amount and loan loss reserves by NACE code has been grouped into high carbon and low carbon sectors. We define as "high carbon" sectors

that have a median share of CPRS higher than 95%, as reported by banks in the EBA Risk Assessment exercise. This gives us the following high carbon 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, and L - Real estate activities. We acknowledge that our approach has limitations, but we extensively test the robustness of our results to a change in the methodology used to classify low carbon and high carbon sectors (Supplementary information 1). Moreover, we compare our classification to more granular data reporting emission intensity to provide transparency about their level of correlation. It should be noted that the banks participating in the climate risk exercise did not include Sweden, Denmark, and Norway, but results do not change if those countries are excluded due to their relatively low materiality in the overall EU banking system.

Data availability prevented us from assigning carbon emissions to loans directly. However, the CPRS classification we use is highly correlated with GHG emissions intensity (Figure S1). The EBA Risk Assessment provides a breakdown of emission intensity by percentiles for CPRS and non-CPRS. They use individual firms' GHG emissions from the data provider Trucost (representing 30% of total banks' loan amount) and a proxy based on the average GHG emission intensity at NACE rev 2 level 4 for the remaining loan amount. Each bank loan is classified in percentiles of emission intensity in a range from very low to very high (More details could be found in the EBA 2020 Risk Assessment Report – Table 19). We use these data to test the correlation between the share of loan amount in the CPRS/non-CPRS and its emission intensity. There is a clear correlation between the share of loan amount of CPRS and the clusters of emission intensity (Figure S1). Around 85% of loan amount classified as having “very high” emission intensity are in CPRS. On the opposite end of the spectrum, only 8% of loan amount of CPRS are in the very low emission intensity bucket. The correlation between the share of loan amount in CPRS (non CPRS) is therefore strongly positive (negative), and around 90% (-90%). In Supplementary Information 1 we show that this correlation is very unlikely to change with different classifications using a set of robustness analyses.

Simulation of a divestment strategy

Using the data available, we can provide an estimate of the potential impact of a divestment from high carbon assets on EU bank's financials. The primary assumption in this estimation is that the total amount of loans of each bank is left unvaried. In other words, the simulation assumes that banks shift their lending portfolio directly from high carbon to low carbon investments. We also assume that sufficient low carbon investments are available for these transactions. The labelling in our data allows us to calculate the average risk estimate (provision coverage ratio) of low carbon and high carbon 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 high carbon assets on these metrics (all else being equal). Importantly, we do not rely on an explicit economic model, but on the accounting relationship among these metrics. In turn our results are generated by the structure of the regulation as long as a bank divests from a low PCR asset and re-invests in a high PCR asset.

It should be noted that Loan Loss Provision changes are only the direct effect of this divestment on bank's net profit changes at the time they make the investment. This is an expected loss, not necessarily a loss that will occur in the future. More specifically, three conditions need to be satisfied to generate an increase in costs from a divestment by banks:

1. Losses are costs that must be accounted for as *expected* as opposed to *incurred*. That is financial firms must account for any change in the portfolio expected losses not the actual incurred losses;
2. Provision coverage ratios must be equal to model-based estimates of *expected losses*. That is, expected losses are proportional to measures of risk;
3. Risk estimates of the asset in which a bank is divesting are *lower* than the asset in which it is making a new investment;

Point 1) and 2) are provided by the structure of the regulation and replicated in the stylized analysis proposed in this paper (see Supplementary information 4). Evidence supporting condition 3) is provided in our empirical analysis and further corroborated in the analyses described in the Discussion and the Supplementary information 2 sections. In particular, from the three conditions above, it emerges that the results of the simulation are grounded on PCR differentials. For this reason, we pay particular attention in demonstrating a negative correlation between high carbon sectors and risk measures.

More formally, we define the provision coverage ratio (PCR) as the loan loss reserves (or accumulated provisions in EBA terminology) divided by the gross exposure for the high carbon and low carbon 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:

$$PCR_{i,j} = \frac{\text{Loan loss reserves}_{i,j}}{\text{Gross exposure}_{i,j}}$$

We then calculate the change in the level of loan loss reserves following a divestment from high carbon assets. This is performed by assuming that all low carbon loans replacing the high carbon ones would require the average provision coverage ratio of existing low carbon assets. In other words, a divestment from low PCR assets and re-investment in high PCR assets would lead to an increase in the overall average PCR. More formally, the increase/decrease in provision for bank j is defined as follows:

$$\begin{aligned} \text{Loan Loss Provision charges}_j &= \Delta \text{Loan Loss Reserves}_j \\ &= (PCR_{green,j} - PCR_{brown,j}) * \text{Gross exposure}_{brown,j} \end{aligned}$$

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

$$\text{Net profit}_{j,t+1} = \text{Net profit}_{j,t} - \text{Loan Loss Provision charges}_j$$

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 divestment would likely be 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 high carbon assets on banks' balance sheet and income statements testing the hypothesis that a potential divestment strategy might be costly disincentivizing banks in taking such action.

Data availability

The data used for the analyses and the results have been deposited in a public persistent repository in comma separated files accessible [39]

Loan data, including loan loss reserves and gross exposure, were extracted from the EBA transparency exercise website available at this [link](#). Financial information, including banks' profits, and oil and gas and renewable energy companies' financials were retrieved from the dataset Bloomberg and can be shared only with Bloomberg's permission.

Methods only reference list

39. Gasparini, M., Ives, M., Carr, B., Fry, S. & Beinhocker, E. (2024) Supplementary data. Zenodo. DOI: [10.5281/zenodo.10632853](https://doi.org/10.5281/zenodo.10632853)