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The Impact of the Carbon Footprint in European Loans of the Economic Activities

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Abstract

The transition to a low-carbon economy has interested academics and policymakers recently. Our goal is to develop a preliminary analysis of the transition risk of the European financial system and individuate the importance of the environmental aspect in the loans received by statistical classification of economic activities in the European Union (NACE Sectors). The study defines two indicators that identify the transition risk the EU bears and the "carbon footprint of the loan" (CFL) that Europe presents through the loans granted to the various economic sectors. In addition, it analyzes the possible interactions that influenced the value of loans. In particular, the paper puts as the dependent variable the loans and, as independent variables, the Value Added (VA) by each NACE sector, the carbon footprint of loans, GreenHouse Gas emissions, environmental taxes, and economic growth. The groups "D. Electricity, gas, steam and air conditioning supply" plus "E. Water supply, sewerage, waste management and remediation activities" result to be, simultaneously, the sectors with the higher risk transition and CFL. Besides, the results show that the VA and CFL variables are statistically significant. The first highlights the strategic importance of having better performance and economic development, which allow for obtaining higher loans. The second variable underlines the ever-increasing importance of environmental issues and how the authorities are attentive to the provision of financing based on the polluting capacity of those "funded". From this, we can deduce the ever-increasing importance of renewable energy for reducing greenhouse gases (European objective of climate neutrality by 2050) and reducing dependence on fossil fuels.

Keywords: Climate-related financial risks; Transition risks; GreenHouse Gas; Europe; Value Added

1. Introduction

Financial authorities at the global and European levels have recognized that climate change poses new risks for individual financial institutions and financial stability (European Banking Authority, 2021; European Central Bank, 2020, 2021). According to the financial climate risk guidelines published in November 2020, the European Central Bank expects European credit institutions to integrate climate and environmental risks into their internal risk analysis and management processes. On the other side of the Atlantic, the president of the United States of

America also signed an ordinance requiring financial institutions to analyze climate risks. Climate change mitigation scenarios are essential for risk analysis and climate stress tests. These scenarios are not forecasts but projections on the trajectories of the economic sectors, conditioned by the objectives of reducing greenhouse gas emissions and the technologies available. As for Europe, the Green Deal (The European Green Deal, 2019) defines the goal of transforming Europe into the first neutral continent from a climate point of view by 2050. The Commission's strategy implements the United Nations' 2030 Agenda and sustainable development goals.

So, two main risk drivers emerge physical and transition risks. The former represents the physical impact on the economy of global warming, which may characterize some geographic locations with higher risks than others. Instead, transition risks express the risk induced by the transition to a low-carbon economy, which may lead to some activities being phased out.

Our attention is particularly focused on transition risks, for which many policies have been introduced to reduce greenhouse gases (GHG) and carbon emissions, such as adopting renewable energies, action plans, and energy efficiency and taxation. Depending on the ability of companies to implement policies, the technologies needed to assess these objectives become an additional driver of this type of risk as they can change the way companies (but not only) are affected by climate change.

In this context, the reference scenarios for the financial sector were developed by the global platform of financial authorities for green finance (NGFS – The Network of Central Banks and Supervisor for Greening the Financial System) in collaboration with scientists from the Intergovernmental Panel on Climate Change (IPCC). These scenarios are fundamental for understanding the dynamics of investments in economic activities that contribute directly or indirectly to emissions but also in activities that can support the transition. In addition, the scenarios are used to design climate policies, such as the tax on emissions. However, these scenarios do not consider the expectations of the financial system (in terms of risks and returns) nor the credibility of policies (Battiston et al., 2021). Climate-related financial risks can now be understood through the traditional risk categories: credit, liquidity, market, operational, and reputational risks (Bolton et al., 2020; NGFS, 2019, 2021). The recent literature focuses on the impacts of climate risk drivers on credit risk (Birindelli et al., 2022). Credit risk measurement efforts are mainly directed at assessing the risks associated with corporate loans and real estate exposure. For example, Breitenstein et al. (2021) and Nguyen et al. (2021, 2023), using the default model of Merton, analyze the banks' exposure to climate transition risk to loan level. The results show that the climate transition risk is also due to other sectors' carbon emissions. Stolbov and Shchepeleva (2023) examine the relationship between the bank performance indicators and the carbon footprint of bank loans. Delis et al. (2019) affirm that before 2015, the banks did not price climate policy exposure. Besides, the authors demonstrated that the "green banks" applied marginally higher loan rates to fossil fuel firms. Battiston et al. (2021) affirm that if the investors' perceptions of the risk transition are lower, they fail to trigger a reallocation of capital into low-carbon investments. The researchers have focused on advancing instruments to incorporate climate risks in tools for conventional risk management. These tools required granular data and measurement methodologies, knowledge, and availability of relevant data, both physical/transition risk drivers and computational. For example, Monasterolo (2020) affirms that the financial system could help hit the global climate goals squarely by aligning investments to sustainability. Still, the investors are much exposed to carbon-intensity assets. These could delay the low-carbon transition and raise the sources of climate financial risks. Faiella and Lavecchia (2020) analyze the climate-related transition risks for the Italian financial sector, and D'Orazio et al. (2022) for the German Banking sector. The first develops a methodology to estimate the financial sector's exposure by linking the GHG emissions and loans. In contrast, the second offers quantification of the vulnerability of the German banking sector to transition risks.

Our goal is to develop a preliminary analysis of the transition risk of the European financial system. In detail, we will define two different indicators that will allow us to identify the transition risk borne by the EU and the “carbon footprint loan” (CFL) that Europe presents through the loans granted to the various economic sectors. In addition, it will also be of interest to us to analyze the possible interactions that influenced the value of loans. In particular, the paper puts as the dependent variable the loan’s value and, as independent variables, the value added by each production sector, the carbon footprint of loans, the environmental taxes, and the economic growth. Section 2 explains the data collection procedure, the methodology applied, and the results obtained. Finally, the last paragraph will be devoted to conclusions.

2. Methodology

2.1 Data

This analysis needs to recuperate data on the European financial system to estimate climate-related transition risk adequately. To this scope, we retrieve annual GHG emission data[1] on the Eurostat for 2008-2021. In particular, we have extracted the data relating to the Air emission accounts (AEAs) and industry affiliations based on the NACE Rev. 2 classification. A major advantage of the methodology of the AEA is that it can be applied to other scales, like linking emission data with National Accounts data on the sectoral level. Figure 1 shows that greenhouse gas emissions in the EU are decreasing. The GHG emission reduced by 31% between the 90s and 2020, improving the EU’s 2020 goal by 11 percentage points. This result was achieved through the emission cuts in 2008-2021 (Fig. 1). This phenomenon is the consequence of the effects of fossil fuel prices and European policy measures; the decline in 2020 is certainly due to the COVID-19 pandemic. By 2030, EU greenhouse gas emissions should continue to decline. However, the 2030 target has not yet been aligned with the state’s ambitions. Furthermore, implementing more impactful policies and measures will be essential to achieving the new goal.

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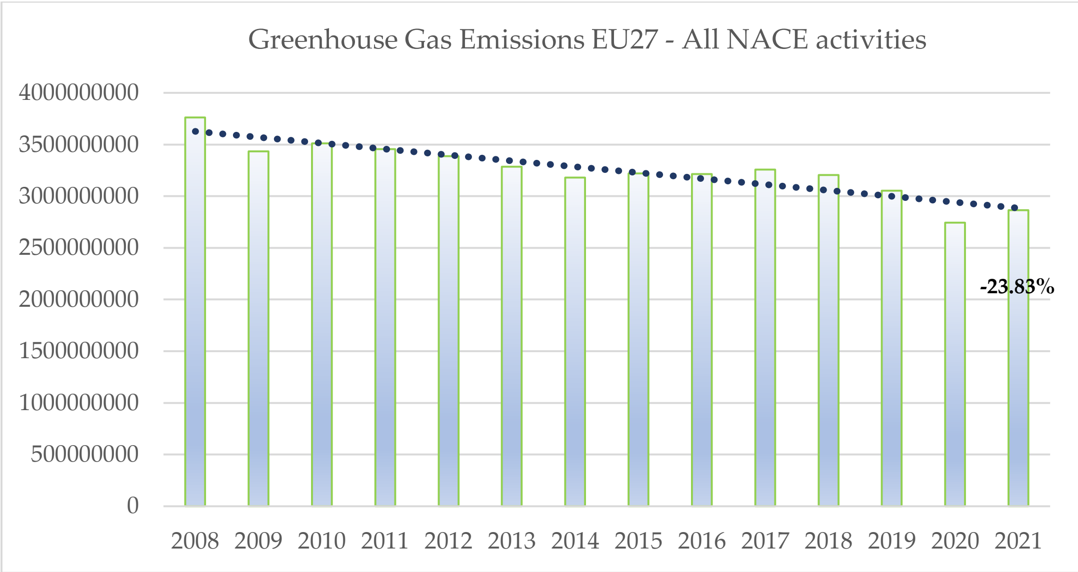
[1]Greenhouse gases (CO2, N2O in CO2 equivalent, CH4 in CO2 equivalent, HFC in CO2 equivalent, PFC in CO2 equivalent, SF6 in CO2 equivalent, NF3 in CO2 equivalent)

Fig. 1 GHG emission data for 2008 -2021 of All Nace activities



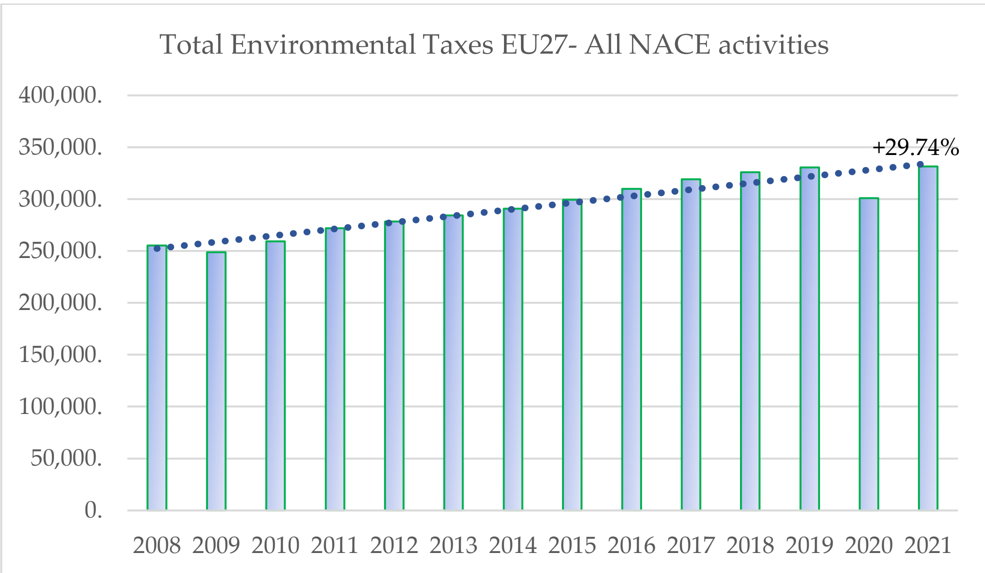
Source: Elaboration data Eurostat

It is evident from Figure 1 that the European Union's way is to reduce greenhouse gas emissions. From 2008 to 2021, it has been circa twenty-four point percentage.

Another instrument to describe the impact of greenhouse gas emissions is the total environmental taxes expressed in millions of euros. The source is Eurostat annually, by economic activity from 2008 to 2021, and by EU27 geo-localization.

At the level of the 27 EU Member States, the environmental tax increased by 29.74%% (Fig. 2). However, several transition processes have fiscal implications for taxpayers and the public budget (European Environment Agency, 2019, 2021). Moreover, not transitioning towards sustainability would also have fiscal implications; for example, there would be costs of "inaction" (Guo et al., 2021; Sanderson & O'Neill, 2020).

Fig. 2 Total Environmental Taxes (millions €) for all activities from 2008-2021



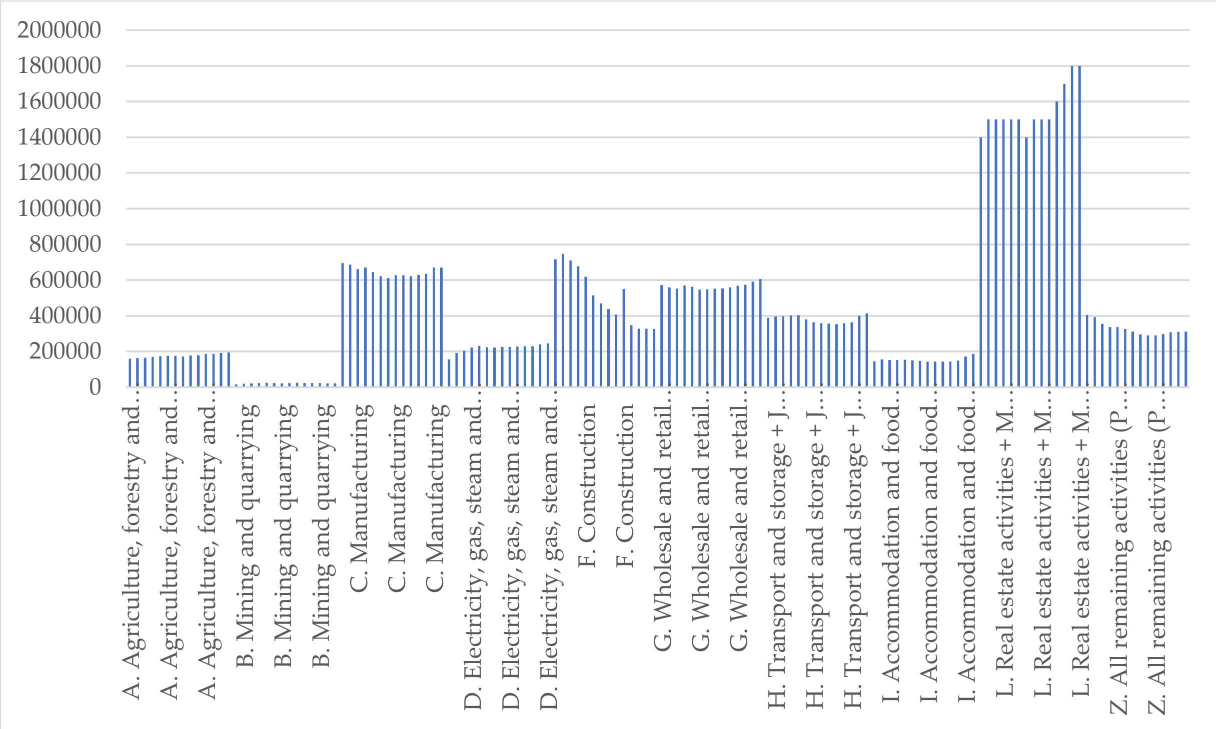
Source: Elaboration data Eurostat

Finally, further interest data are the loans divided for activity from the European Central Bank Datawarehouse. The time frequency is quarterly from Q1 2008 to Q4 2021, but following the timeframe of the period analysis, we transformed the frequency annually for the period 2008 – 2021 (Fig. 3).

A classification system must be used to distinguish European banks’ assets and understand the financial system’s exposure. Battiston et al. (2017) mapped economic activities in five climate-policy-relevant sectors (CPRS):

- energy-intensive (mining of metal ores and most of the manufacturing activities);
- fossil fuel (mining and extraction of coal and petroleum, manufacturing of coke, refined petroleum products and chemicals, and specialized construction activities);
- housing (construction of buildings, including manufacturing of non-metallic mineral products and furniture);
- utilities (electric power generation, transmission, and distribution, including the construction of utility projects);
- transport (land, water, air transport, and some supporting activities).

Fig. 3 Loans of European Member States divided by sector’s activity from 2008 - 2021



Source: Elaboration data ECB Data Warehouse (Loans, ECB estimate based on national contributions vis-a-vis euro area NFCs reported by MFIs excl. ESCB in the euro area (stocks) (BSI.Q.U2.N.A.A20EST.A.1.U2.2240A.Z01.E)

This analysis will, however, follow the classification of NACE Rev 2.0 as indicated in the table (Table 1).

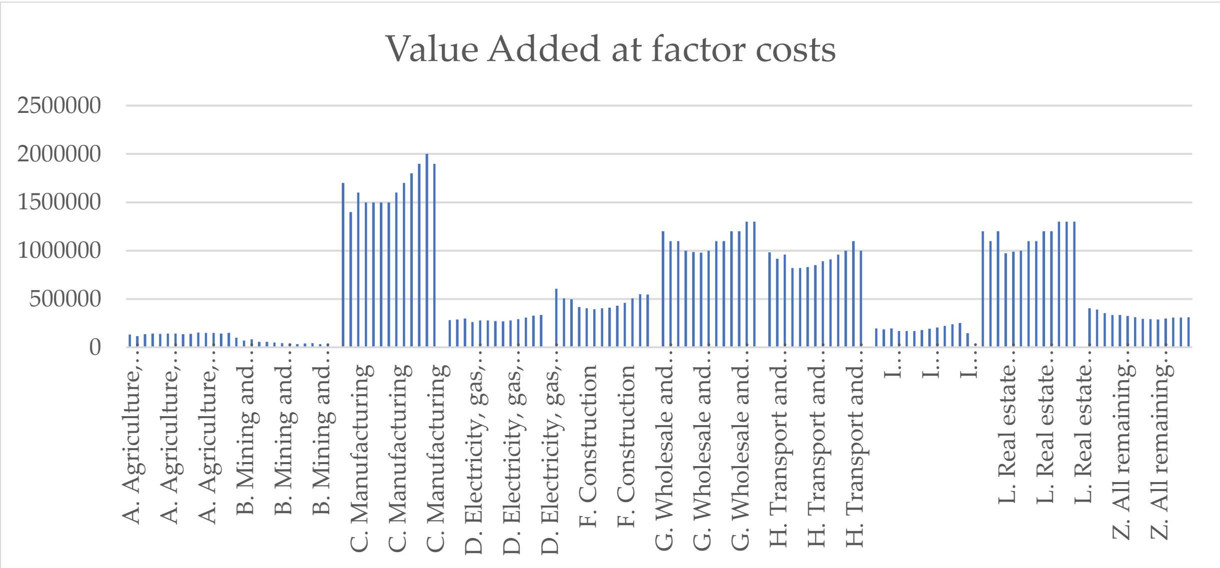
Table 1 Legend of the sectors NACE Rev 2.0

Sections	**Description**
A	Agriculture, forestry, and fishing
B	Mining and quarrying
C	Manufacturing
D+E	D. Electricity, gas, steam, and air conditioning supply + E. Water supply, sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H+J	H. Transport and storage + J. Information and communication
L+M+N	L. Real estate activities + M. Professional, scientific, and technical activities + N. Administrative and support service activities
I	Accommodation and food service activities
Z	All remaining activities (P. Education; Q. Human health and social work activities; R. Arts, entertainment and recreation; S. Other service activities; T. Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use; U. Activities of extraterritorial organizations and bodies)

Source: Elaboration data ECB Data Warehouse

Another independent variable of our interest is the value added at factor cost. It is "the gross income from operating activities after adjusting for operating subsidies and indirect taxes (Eurostat, 2021)". The data has been downloaded by Eurostat with annual frequency from 2008 to 2020. Fig. 4 highlights that the manufacturing sector, wholesale and retail trade, and the repair of motor vehicles and motorcycles are the NACE sectors with the higher value-added. It implies that the sectors are contributing more to the overall economic output.

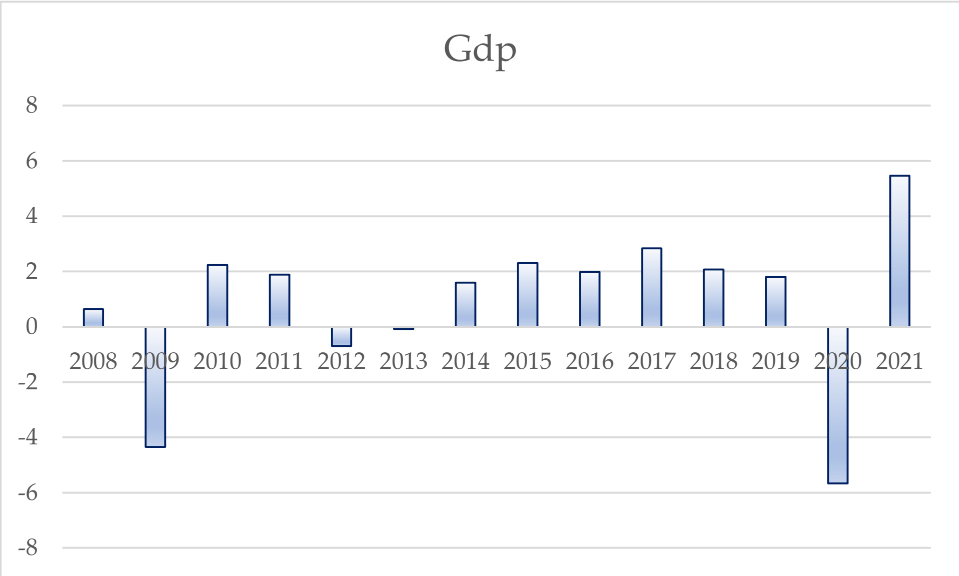
Fig. 4 The Value Added at factor costs for all NACE sectors.



Source: Our elaboration on the Eurostat database.

The last variable of our interest is the GDP (in volume and growth rate) of the European Union. The data was downloaded from the World Bank Group. Figure 5 graphically shows the 2009 crisis and the profound COVID-19 impact on economic growth in Europe and worldwide.

Fig. 5 GDP of the European Union 27 from 2008-2021



Source: Elaboration World Bank Data

We will define two indicators that will allow us to identify the cost of the transition risks supported by the EU and the carbon footprint of European loans through the amount of these to the various economic sectors. It will also be interesting for us to analyze any relationships between CO2 emissions and economic growth.

2.2 Description of data and scenario

It is necessary to rely on the loan granular data from the European Central Bank to know the exposure "environmental" of the European financial system. The simple way is to link the information on Greenhouse Gas emissions with the distributions of loans based on NACE classification.

The information on loans $L_{s,t}$ are expressed in euro, for sector "s" and years "t". The loans were processed and expressed annually, while the Greenhouse Gas emissions. $GHG_{s,t}$ is expressed in tonnes and for all ten sectors precedently individuated. Following, define the "Carbon Footprint Loan ($CFL_{s,t)}$ that represents how many GHG tonnes are emitted by sectors in a year for every borrowed million euros.

$$CFL_{s,t} = \frac{GHG_{s,t}}{\sum_{i=1}^{n} {L_{s,t}}/{n}} \qquad \text{for each sector and year} \qquad (1)$$

What distinguishes this indicator from Faiella's Loan Carbon Intensity is the composition of the loans. Non-performing loans are not considered here, but only loans are still on the balance sheet and not suffering.

Through the total emissions and carbon footprints, it will be possible to identify which sectors pose the highest overall transition risk (as expressed by total emissions) and which sectors have the most discrepancy between current levels and their economic importance (as represented by carbon footprint). In this way, it is possible to identify the sectors that will potentially pose the highest threats to financial stability in low-carbon transitions.

Fig. 6 shows that the major GreenHouse Gas emissions sector is the "D+E_Electricity, gas, steam, air conditioning supply, water supply, sewerage, waste management, and remediation activities"; successively, the "C. Manufacturing", the sector "A. Agriculture, forestry and fishing” and the sectors “H. Transport and storage” plus ”J. Information and communication”. Also, Fig.7 on the carbon footprint of the loans shows that the same sectors have a major impact. The index indicates how many grams of GreenHouse Gas emissions are produced for each euro of loan. An aspect that deserves attention is the carbon footprint loans of the sectors “B. Mining and quarrying” and “C. Manufacturing”. At the environmental level, the manufacturing sector is certainly the more impacted, but the footprint of the mining sector is decidedly more important.

Fig. 6 Percentage of GreenHouse Gas emissions by all NACE sectors

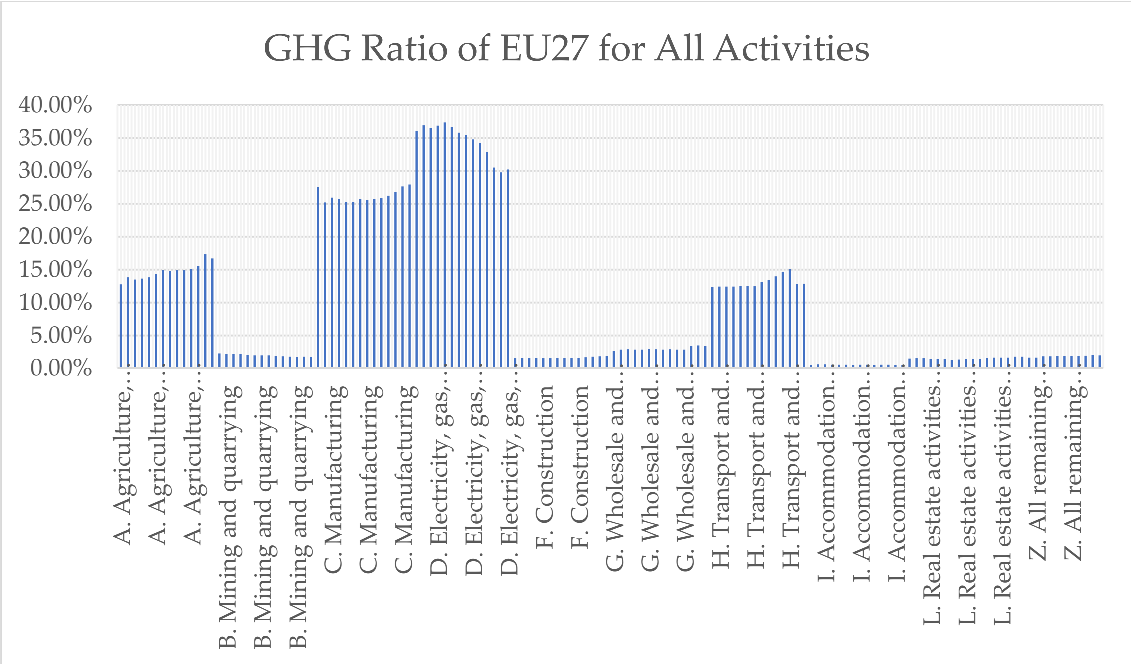
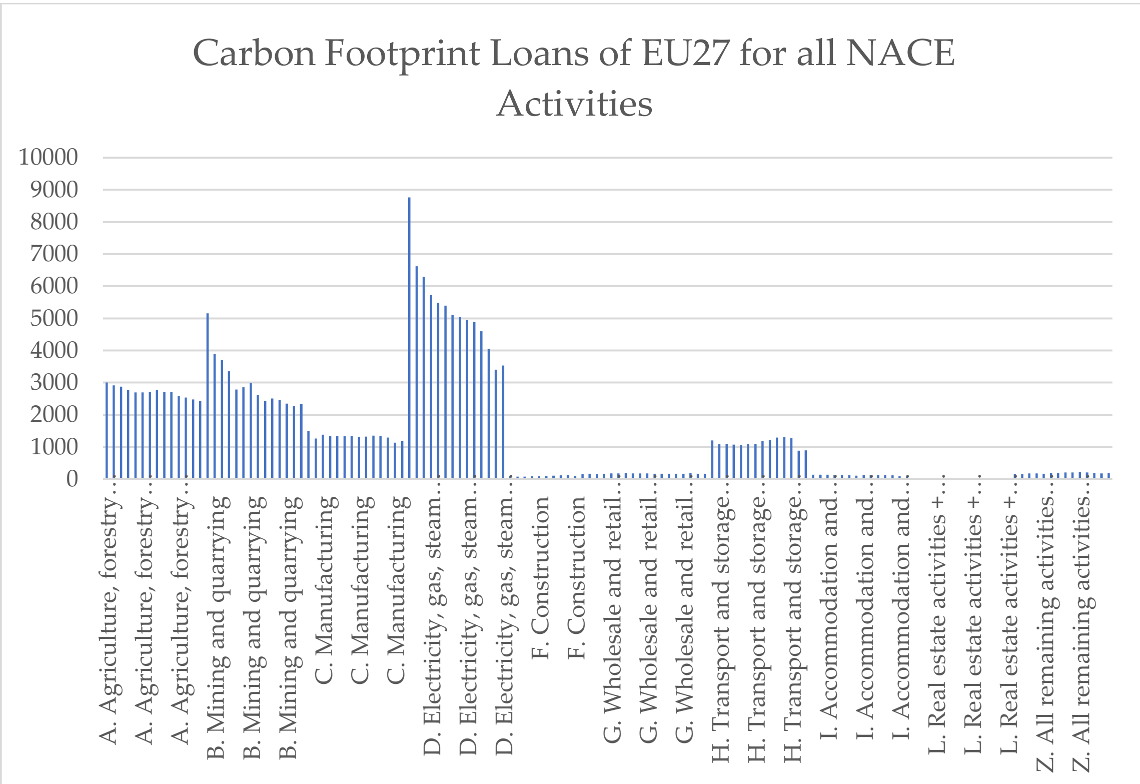


Fig. 7 The Carbon Footprint of the Europen’s Loan.



This aspect highlights how, proportionally, the mining sector could threaten financial stability toward a low-carbon transition. However, it should be underlined that in recent years, the carbon footprint has had a downward trend, with an increase in 2021, but most probably, it is a consequence of the effect of the post-COVID recovery (Table 2). The data show how the energy policies the sector implements by moving toward renewable energy produce its effects. In Table 3, the evidence shows us how GHG emissions of the "D+E" decreased by 6% (in absolute terms) in 2008-2021. This is a straightforward example of how financial development might significantly impact carbon dioxide emissions ((Buhari et al., 2020; Di Febo et al., 2021; Nguyen, Diaz-Rainey et al., 2021).

Table 2:Carboon Footprint Loan Growth Rate 2009-2021

	A. Agriculture, forestry, and fishing	B. Mining and quarrying	C. Manufacturing	D. Electricity, gas, steam, and air conditioning supply + E. Water supply, sewerage, waste management and remediation activities	F. Construction	G. Wholesale and retail trade; repair of motor vehicles and motorcycles	H. Transport and storage + J. Information and communication	I. Accommodation and food service activities	L. Real estate activities + M. Professional, scientific, and technical activities + N. Administrative and support service activities	Z. All remaining activities
2009	-3%	-24.57%	-15.66%	-24.39%	-10.86%	1.31%	-10.18%	-3.64%	-4.29%	1.20%
2010	-1.59%	-4.63%	9.66%	-5.00%	3.40%	4.25%	1.47%	6.45%	-0.01%	15.70%
2011	-3.75%	-9.68%	-3.74%	-8.95%	8.06%	-6.38%	-2.12%	-8.56%	-8.91%	-4.54%
2012	-2.50%	-16.94%	0.11%	-4.34%	4.12%	0.14%	-1.70%	-1.34%	-6.31%	-2.24%
2013	-0.12%	2.41%	0.19%	-1.57%	17.85%	3.12%	3.12%	-3.90%	1.12%	10.10%
2014	0.47%	4.83%	0.44%	-5.30%	7.75%	-4.97%	0.58%	-10.00%	-10.12%	1.21%
2015	2.54%	-12.36%	-2.16%	-1.34%	8.95%	-0.93%	8.07%	12.31%	3.99%	9.09%
2016	-2.19%	-6.88%	0.44%	-1.86%	8.77%	0.32%	2.42%	1.32%	0.91%	3.84%
2017	0.08%	2.89%	2.94%	-1.25%	-25.10%	-0.17%	6.81%	-2.38%	0.41%	0.40%
2018	-4.63%	-1.75%	-1.13%	-5.79%	61.77%	-3.60%	1.55%	0.17%	-3.30%	-4.92%
2019	-1.99%	-5.06%	-3.62%	-11.92%	6.51%	11.82%	-3.25%	-5.94%	1.55%	-4.60%
2020	-2.58%	-3.18%	-12.32%	15.99%	-6.19%	-11.17%	-30.48%	-28.43%	-13.63%	-6.80%
2021	-1.27%	3.04%	5.53%	3.73%	7.57%	0.35%	0.85%	-1.99%	3.31%	2.17%

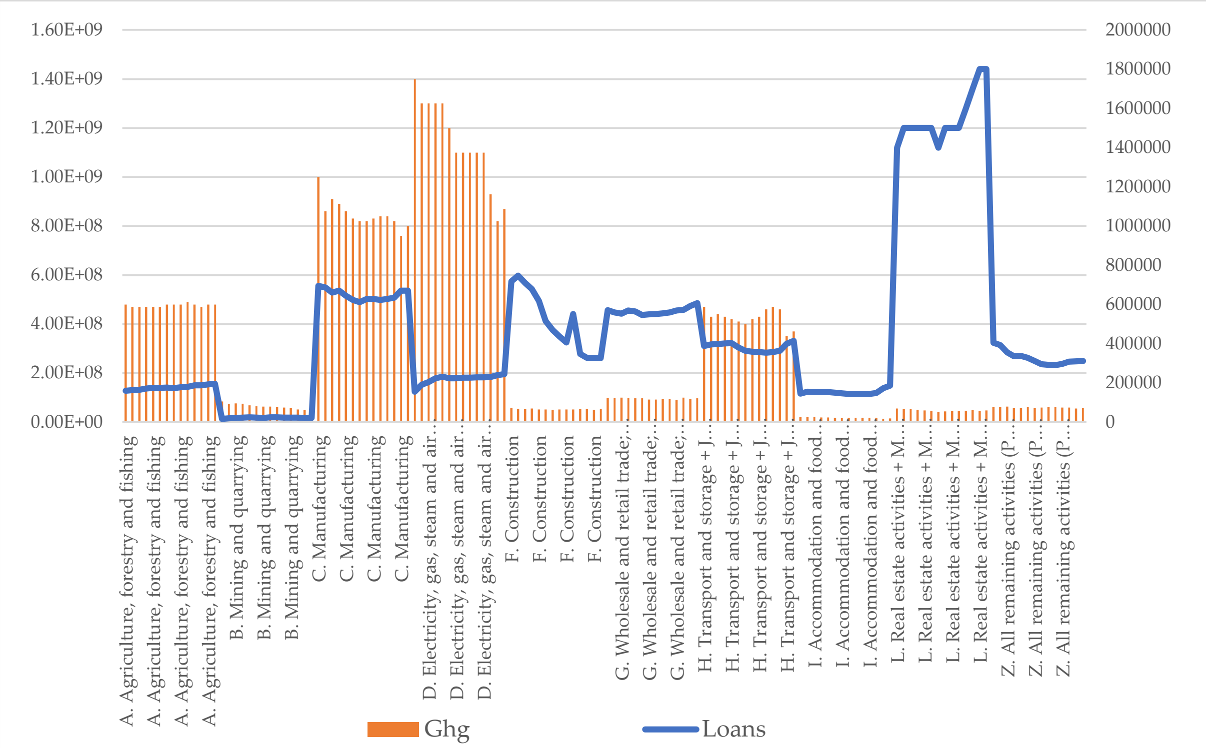
Note I: Z. All remaining activities (P. Education; Q. Human health and social work activities; R. Arts, entertainment and recreation; S. Other service activities; T. Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use; U. Activities of extraterritorial organizations and bodies)

Table 3: Ratio of the Greenhouse Gas Emissions 2008-2014-2020

	2008	**2014**	**2021**
A. Agriculture, forestry, and fishing	12.78%	14.97%	16.68%
B. Mining and quarrying	2.24%	1.97%	1.72%
C. Manufacturing	27.58%	25.73%	27.90%
D. Electricity, gas, steam, and air conditioning supply + E. Water supply, sewerage, waste management and remediation activities	36.12%	35.79%	30.20%
F. Construction	1.54%	1.57%	1.88%
G. Wholesale and retail trade; repair of motor vehicles and motorcycles	2.63%	2.91%	3.39%
H. Transport and storage + J. Information and communication	12.38%	12.46%	12.83%
I. Accommodation and food service activities	0.52%	0.50%	0.51%
L. Real estate activities + M. Professional, scientific, and technical activities + N. Administrative and support service activities	1.47%	1.28%	1.64%
Z. All remaining activities	1.63%	1.80%	1.97%

From Figure 8, it is evident that the NACE sector with the worst relationship between green emissions and loans is sector "D" because the production of electricity, gas, steam, and air conditioning supply, and sector "E" Water supply, sewerage, waste management, and remediation activities" remain the sectors most polluting.

Fig. 8 Comparison between greenhouse gas emissions and loans received



2.3 The Impact of the Environment on the EU 27 Loans

This paragraph analyzes the impact of different variables on the environment and the loans the NACE sectors received. In particular, this goal demonstrates that all discussions of sustainability and the environment are important for policymakers. The methodology used is a panel model estimator because it is one of the most widespread statistical tools, especially in economics. It allows you to draw information from multiple NACE sectors for numerous periods.

The following model is formed to achieve this objective:

$$Loans_{s,t} = \beta_0 + \beta_1 \mathrm{Ghg}_{s,t} + \beta_2 VA_{s,t} + \beta_3 CFL_{s,t} + \beta_4 Env\_T_{s,t} + \beta_5 Gdp_t + u_{s,t} \quad (1)$$

$s = 1, \ldots, n$ are the NACE sectors;

$t = 1, \ldots, T$ are the years from 2008-2021 and β_0 is the intercept and u_{st} an error term.

The variables of the analysis are, respectively:

- $Loans_{s,t}$ represents the financing received from European countries, respectively, by the individual NACE sector for each year between 2008 and 2021;
- $\mathrm{Ghg}_{s,t}$ represents the Greenhouse Gas Emissions expressed in tonnes for each NACE sector between 2008 and 2021.
- $VA_{s,t}$ represents the value added at factor cost for each NACE sector. It is the gross income from operating activities.

- $CFL_{s,t}$ represents the index calculated through the ratio between the Greenhouse Gas and loans for each NACE sector.
- $Env\_T_{s,t}$ represents the total environmental taxes attributed to each NACE sector.
- Gdp_t represents the economic growth of the twenty-seven European countries.

Table 4 shows the descriptive statistics of the analysis variables, and the correlation test (Tab.5) was performed to avoid subsequent problems of distortion of the results and multicollinearity.

Table 4: Descriptive statistics of the variables

2008-2021					
Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max**
Loans	140	454754.8	415210.7	16368.5	1800690
Ghg	140	3.22e+08	3.79e+08	1.39e+07	1.36e+09
VA	132	626670.5	521344.9	27087.1	1998859
CFL	140	1400.726	1734.11	25.273	8759.28
Env_T	140	11802.84	11031.8	826.07	60.124
Gdp	140	0.86	2.78	-5.67	5.47

Note: In the table reports only the overall value

Table 5: Correlation matrix

Variables	Loans	Ghg	VA	CFL	Env_T	Gdp
Loans	1					
Ghg	-0.1574	1				
VA	0.6679	0.1840	1			
CFL	-0.4438	0.5336	-0.3561	1		
Env_T	0.0084	0.4752	0.6068	0.0194	1	
Gdp	-0.0358	0.0140	-0.0226	0.0092	0.0378	1

The Breusch Pagan and Hausman tests were also carried out, allowing us to choose the fixed effects model (Tab. 6).

Table 6: The results of the analysis

Loans	**(Fixed Effects) Coef.**
Ghg	0.00019
VA	0.128***
CFL	-31.384**
Env_T	0.4722
Gdp	-3611.061
_cons	358050.8***
R-sq:	
Overall	0.3062
Hausman test	0.0184
Breusch-Pagan	0.000

The results show that the Value Added at factor costs and the Carbon Footprint Loans are statistically significant with the opposite sign, the first positive and the second negative. The positive relationship between VA and loans depends on several factors:

- Investments in productive resources: financing can allow sectors to invest in productive resources, such as advanced technologies or staff training, thus contributing to increased value added to the cost factor.
- Innovation and efficiency: investments could drive innovation, improving operational efficiency and allowing sectors to obtain greater value from the costs incurred.
- Production growth: financing can support the expansion of production, leading to increased added value without a proportional cost increase.
- Skills development: funding can be used to develop specialized skills within sectors, creating a more skilled environment capable of generating greater value.

Carbon Footprint Loans negatively influence the loans received. This depends, for example, on Corporate Social Responsibility (CSR) pressures, growing ecological awareness, government incentives for green investment, and consumer demands.

- Corporate Social Responsibility (CSR) pressures: companies or sectors receiving funding may be sensitive to environmental issues and consider reducing carbon emissions as part of their CSR. This could be a key element in choosing investments.
- Growing ecological awareness: increasing environmental awareness and public concerns could push companies to seek financing that aligns with sustainable practices, positively influencing investment decisions.
- Government incentives for green investment: in many jurisdictions, there are government incentives in the form of tax breaks or other benefits for companies that make environmentally friendly investments. These incentives could influence investment choices.
- Consumer demands: if there is growing consumer demand for environmentally friendly products and services, companies could respond by adapting their operations through financing that supports such initiatives.

3. Conclusion

In recent decades, there has been a noticeable surge in social demand concerning environmental issues. This has prompted public authorities to respond, including establishing climate targets and sparking discussions about the role the financial system should play in transitioning towards more sustainable economic growth models. There are various studies on the argument in the literature. For example, Maza's analysis (2023), focusing on the Spanish territory, illustrates a notable reduction in the carbon footprint associated with loans from Spanish credit institutions. This decline aligns with the broader trend of decreasing polluting emissions intensity observed in the Spanish economy in recent years. Additionally, it reflects a slight adjustment in the composition of loan portfolios towards activities with lower environmental impact. Kacperczyk et al. (2022) study how carbon emissions can affect bank lending, and your results show that the firms with higher footprints that previously received larger loans currently receive less bank credit.

Our objective is to conduct a preliminary analysis of the transition risk within the European financial system. Specifically, we aim to establish two indicators for identifying the transition risk associated with the European Union and the 'carbon footprint loan' (CFL) evident in loans extended to various economic sectors. Additionally, we are interested in examining potential interactions influencing loan values. The paper designates the loan value as the dependent variable, with independent variables including value added by each production sector, the carbon footprint of loans, environmental taxes, and economic growth.

The findings reveal that the sectors comprising 'D. Electricity, gas, steam, and air conditioning supply" plus "E. Water supply, sewerage, waste management, and remediation activities" concurrently pose the highest transition risk and carbon footprint loans. Moreover, the results demonstrate the statistical significance of variables representing value-added and carbon-footprint loans. The former underscores the strategic relevance of achieving better performance and economic development, enabling access to larger loans. The latter emphasizes the escalating importance of environmental considerations and how authorities prioritize financing based on the pollution impact of the recipients.

Consequently, we can infer the growing significance of renewable energy in mitigating greenhouse gases (aligned with the European objective of climate neutrality by 2050) and reducing reliance on fossil fuels.

It should be noted that the results are in line with the recent literature. Also, Hasan & Othman (2023) investigate the correlation between the carbon footprint intensity of bank lending and CO2 emissions from advanced economies, aiming to evaluate whether financial institutions' lending practices contribute to addressing climate change risks. The study's findings indicate an inverse relationship between the intensity of carbon footprint loans in advanced economies and CO2 emissions from most economic activities, accounting for approximately 86.36%.

Certainly, the results suggest that banks' lending portfolio strategies in advanced economies lean towards sustainability, promoting transitions towards low-carbon alternatives and aiding in mitigating climate change risks. Moreover, there are many policy suggestions: educate consumers about the importance of environmental factors in lending decisions, explore the policy implications of the findings, consider how regulatory frameworks and government policies might influence transition risk and loan allocation, and promote green finance. Future developments of this research may involve several avenues for deeper exploration and understanding. Some potential directions include sector-specific investigations. Conduct more granular investigations into sectors with significant transition risk to better understand sector-specific challenges and opportunities. Conduct comparative studies with other regions or global financial systems to identify commonalities or distinctions in transition risk and carbon footprint considerations. These future developments could improve the robustness and relevance of the research, providing valuable insights into the ongoing debate on sustainable finance and climate resilience in the European financial system.

Acknowledgement

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References

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. *Nature Climate Change*, *7*(4), 283–288. https://doi.org/10.1038/nclimate3255

Battiston, S., Monasterolo, I., Riahi, K., & Van Ruijven, B. J. (2021). Accountng for finance is key for climate mitigation pathways. *Science*, *372*(6545), 918–920. https://doi.org/10.1126/science.abf3877

Birindelli, G., Bonanno, G., Dell'Atti, S., & Iannuzzi, A. P. (2022). Climate change commitment, credit risk and the country's environmental performance: Empirical evidence from a sample of international banks. *Business Strategy and the Environment*, *31*(4), 1641–1655. https://doi.org/10.1002/BSE.2974

Bolton, P., Despres, M., Pereira da Silva, L. A., Svartzman, R., & Samama, F. (2020). *The green swan* (Issue January).

Breitenstein, M., Nguyen, D. K., & Walther, T. (2021). ENVIRONMENTAL HAZARDS AND RISK MANAGEMENT IN THE FINANCIAL SECTOR: A SYSTEMATIC LITERATURE REVIEW. *Journal of Economic Surveys*, *35*(2), 512–538. https://doi.org/10.1111/JOES.12411

Buhari, D., Lorente, D. B., & Ali Nasir, M. (2020). European commitment to COP21 and the role of energy consumption, FDI, trade and economic complexity in sustaining economic growth. *Journal of Environmental Management*, *273*, 111146. https://doi.org/10.1016/j.jenvman.2020.111146

Delis, M. D., de Greiff, K., & Ongena, S. R. G. (2019). Being Stranded with Fossil Fuel Reserves? Climate Policy Risk and the Pricing of Bank loans. *SSRN Electronic Journal*, *2018*. https://doi.org/10.2139/ssrn.3451335

Di Febo, E., Ortolano, A., Foglia, M., Leone, M., & Angelini, E. (2021). From Bitcoin to carbon allowances: An asymmetric extreme risk spillover. *Journal of Environmental Management*, *298*(July). https://doi.org/10.1016/j.jenvman.2021.113384

D'Orazio, P., Hertel, T., & Kasbrink, F. (2022). *No need to worry? Estimating the exposure of the German banking sector to climate-related transition risks* (946). https://doi.org/https://doi.org/10.4419/96973108

European Banking Authority. (2021). *Eba Report on Management and Supervision of Esg Risks for Credit Institutions and Investment Firms Eba/Rep/2021/18 Eba Report on Management and Supervision of Esg Risks for Credit Institutions and Investment Firms 2*.

European Central Bank. (2020). Guide on climate-related and environmental risks risk management and disclosure. *European Central Bank*, *November*, 1–54.

European Central Bank. (2021). Climate-related risk and financial stability. *ECB/ESRB Project Team on Climate Risk Monitoring*, *July*, 111.

The European Green Deal- COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, (2019).

European Environment Agency. (2019). *The sustainability transition in Europe in an age of demographic and technological change* (Issue 23).

European Environment Agency. (2021). *The role of (environmental) taxation in supporting sustainability transitions*. https://doi.org/10.2800/24487

Eurostat. (2021). *Grossary: value added at factor cost*. https://ec.europa.eu/eurostat/statisticsexplained/

Faiella, I., & Lavecchia, L. (2020). Questioni di economia e finanza (Occasional papers)- The carbon footprint of Italian loans. *Banca d'Italia*, *557*(4).

Guo, J., Kubli, D., & Saner, P. (2021). The economics of climate change: no action not an option. *Swiss Re Institute*, *April*, 34.

Hasan, A., & Othman, A. (2023). *Carbon Footprints of Bank Loans and Economic Activities' Carbon Dioxide Emissions: Insights from Advanced Economics*. https://doi.org/10.21203/rs.3.rs-3035490/v1

Kacperczyk, M., Peydró, J.-L., Berger, A., Bolton, P., Habib, M., Iyer, R., Karolyi, A., Rajan, R., Roberts, M., Sautner, Z., Strahan, P., & Zhu, Q. (2022). *Carbon Emissions and the Bank-Lending Channel*.

Maza, L. Á. (2023). *An estimation of the carbon footprint in Spanish credit institutions' business lending portfolio. Documentos Ocasionales N.º 2220*.

Monasterolo, I. (2020). Climate Change and the Financial System. *Https://Doi.Org/10.1146/Annurev-Resource-110119-031134*, *12*, 299–320. https://doi.org/10.1146/ANNUREV-RESOURCE-110119-031134

NGFS. (2019). A Call for Action: Climate Change as a Source of Financial Risk. *NGFS Report*, *April*, 1–40.

NGFS. (2021). A Call for Action: Climate Scenarios for central banks and supervisors. *NGFS Network for Greening the Financial System*, *June*, ix. https://doi.org/10.1017/cbo9781316795873.002

Nguyen, D. K., Huynh, T. L. D., & Nasir, M. A. (2021). Carbon emissions determinants and forecasting: Evidence from G6 countries. *Journal of Environmental Management*, *285*(October 2020), 111988. https://doi.org/10.1016/j.jenvman.2021.111988

Nguyen, Q., Diaz-Rainey, I., & Kuruppuarachchi, D. (2021). Predicting corporate carbon footprints for climate finance risk analyses: A machine learning approach. *Energy Economics*, *95*, 105129. https://doi.org/10.1016/J.ENECO.2021.105129

Nguyen, Q., Diaz-Rainey, I., Kuruppuarachchi, D., McCarten, M., & Tan, E. K. M. (2023). Climate transition risk in U.S. loan portfolios: Are all banks the same? *International Review of Financial Analysis*, *85*(October 2022), 102401. https://doi.org/10.1016/j.irfa.2022.102401

Sanderson, B. M., & O'Neill, B. C. (2020). Assessing the costs of historical inaction on climate change. *Scientific Reports*, *10*(1), 1–12. https://doi.org/10.1038/s41598-020-66275-4

Stolbov, M., & Shchepeleva, M. (2023). Carbon footprints of lending and bank performance: international evidence from panel data. *Environmental Science and Pollution Research*, *30*, 91466–91477. https://doi.org/10.1007/s11356-023-28848-4