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Climate Transition Risk and Financial Stability in France

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ABSTRACT: This study empirically investigates the impact of the climate transition on the French financial sector using a micro-macro approach to examine the long-term effects of climate mitigation and decarbonization policies on sectoral output and the effects on firm profitability and the likelihood of corporate defaults. We employ a recursive-dynamic, multi-regional, multi-sectoral computable general equilibrium (CGE) model to simulate the Fit-for-55 climate scenario and then integrate the sectoral output paths derived from the model into firm-level corporate balance sheets and risks. We then assess the extent of credit exposure of banks to energy-intensive sectors. Our findings indicate that, under the Fit-for-55 scenario, the mining, chemicals and manufacturing sectors might face notable increases in their probability of defaults, in turn creating pockets of vulnerabilities in some parts of the banking system depending on their exposure to these energy-intensive sectors. This highlights the importance for a timely and orderly transition, including integrating climate transition plans into the prudential framework.

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WORKING PAPERS

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I. Introduction

Climate change poses an unprecedented threat to our planet, as evidenced by the continued increase in the frequency and severity of extreme climate-related events and related ecological problems, such as biodiversity loss and ecosystem degradation, pollution, or scarcity of fresh water. Beyond the immediate environmental impact and infrastructure/real assets damages, climate change can have significant effects on the economy and macrofinancial stability. Accordingly, there are clear benefits from averting the adverse consequences of climate change, including in terms of reduced natural disasters, improved health outcomes, productivity gains in low carbon technologies, and energy security through reduced fossil fuel imports. At the same time, the transition towards a low-carbon economy and the structural changes associated with it are subject to a high degree of uncertainty and can pose important economic and financial challenges, if not well-managed and timed.

As discussed in Grippa et al. (2019), the financial system can be affected by climate change through both increased physical and transition risks. The physical risk arises if the financial system is directly exposed to corporates that experience damage to their assets. These exposures can lead to increased default risk of loan portfolios or lower values of assets. For insurers, physical risks can materialize on the asset side, but risks also arise from the liability side as insurance policies generate claims with a higher frequency and severity than originally expected. The transition risk results from changes in climate policy, technology, and market sentiment and the economic structural changes during the transition to a lower-carbon economy. If corporates have business models not focused on transitioning to a low-carbon economy, transition risks can materialize on the asset side of financial institutions as they could incur losses on the exposure to such corporates.

The transition to a low-carbon economy entails shifts in market dynamics. These include changes in consumer preferences, technological advancements, and shifts in investor sentiments toward sustainability. Investments in fossil fuels and other carbon-intensive industries may become less appealing, leading to potential losses for investors and financial institutions (OECD, 2023). Additionally, stranded assets, such as coal mines, oil reserves, and power plants, may lose value if they become economically unviable due to regulatory changes or declining demand for fossil fuels, resulting in financial losses for investors and lenders.[1] Direct regulatory frameworks (such as carbon pricing, emissions regulations, and renewable energy mandates) incentivize investments in clean energy and penalize carbon-intensive industries for the transition to a low-carbon economy. Regulations potentially reshape industries and impact employment patterns, as companies in carbon-intensive sectors may face increased compliance costs and regulatory scrutiny, affecting their profitability and valuation.[2]

Risks more broadly can materialize if the transition to a low-carbon economy proves abrupt as a result of policy delays or inaction, or if it is poorly designed or difficult to coordinate globally. Financial stability risks could arise when asset prices adjust rapidly to reflect unexpected realizations of transition risks. Orderly action entails implementing timely and proactive measures to mitigate the effects of the climate

[1] Please refer to Semieniuk, et. al. (2022), McGlade and Ekins (2015), Welsby et. al. (2021), Von Dulong (2023), and France: 2022 Article IV Consultation (Country Report No. 2023/056) for detailed analysis on losses from stranded assets in the transition to a low-carbon economy.

[2] For a discussion of regulatory frameworks used in environmental policies, please refer to Stavins and Aldy (2012), Goulder and Parry (2008), and Mooij, Keen, and Parry (2012).

transition. By adopting sustainable practices, investing in renewable energy sources, and enacting robust environmental policies now, countries can work towards minimizing the impact of climate-related events and transitioning towards a more resilient and sustainable future. In contrast, delayed action which defers or neglects to address climate change not only exacerbates the immediate risks associated with extreme weather events and environmental degradation but also compounds the challenges countries face in transitioning to a low-carbon economy in the future. The longer countries postpone action, the more difficult and costly it becomes to implement effective solutions, necessitating even more stringent and potentially disruptive measures in the future.

At this juncture, a growing number of central banks and global institutions increasingly acknowledge the financial stability implications of climate change. The Network of Central Banks and Supervisors for Greening the Financial System (NGFS) is working to integrate climate-related risks into supervision and financial stability monitoring. These initiatives aim to evaluate, quantify, and effectively manage the financial risks stemming from physical and transition risks.[3] They vary widely in terms of methodology, level of granularity, and jurisdictions in scope, horizon, and climate risks covered.

Understanding climate risk endogeneity is crucial for effective strategies for climate adaptation and mitigation. As highlighted by the ECB/ESRB (2023) in a study proposing macroprudential policy for managing climate risk, climate risk endogeneity challenges traditional approaches to macroeconomic and financial risk analysis. While climate-related events significantly influence financial stability risks, the reverse dynamic is equally impactful. For instance, funding of high-emitting industries by individual banks exemplifies a negative externality within the system, leading to capital misallocation and ultimately amplifying climate risk accumulation. It requires integrated approaches that consider the complex feedback loops and interactions between climate dynamics and the financial system.

The general literature on climate risk analysis within the financial sector presents a multifaceted examination of the complexities and implications associated with climate-related financial risks. Approaches outlined in reports such as those by the IMF (2022e) and FSB (2022) emphasize the necessity of integrating climate scenario analysis into financial stability assessments, highlighting the role of region-specific analyses and collaborative initiatives such as those facilitated by the NGFS. Most studies analyze historical data from developed countries using statistical methods, while some use computational modeling to estimate future climate risks. The academic review by Battiston et al. (2021) offers insights into the estimates on the impact of climate-related financial risks, finding that climate events typically reduce insurers' profitability, bank stability, market returns, and international investment. Factors such as income levels and financial regulations can mitigate these effects. Future research should focus on forward-looking computational modeling to assess the economic impact of climate risks and investigate interactions between financial institutions. Overall, the literature underscores the urgency for comprehensive frameworks and collaborative efforts to address the evolving challenges posed by climate-related financial risks and strengthen the resilience of the global financial system.

[3] See the studies and reports in De Nederlandsche Bank (2018), Bank of England (2019), Bank of Canada (2020), Bank of France/ACPR (2021), European Central Bank (2021 and 2023), Italy (Faeilla et al., 2022), the Netherlands (Caloia et al., 2022), and IMF (Ireland (IMF,2022b), Germany (IMF, 2022c), Mexico (IMF, 2022d), and, Japan (IMF 2024, forthcoming)).

Since 2020, the Banque de France (BdF) has been at the forefront of the analysis and management of climate risks, including through the French Prudential Supervision and Resolution Authority (ACPR), employing both top-down and bottom-up approaches. The ACPR's initial pilot climate exercise to assess climate transition and physical risk for the French banking sector was conducted in 2020-2021, following a bottom-up approach.[4] This was supported by the top-down analysis in BdF and ACPR (2021) employing general equilibrium models to generate sectoral output paths for assessing transition risks for the corporate sector and their impact on the banking and insurance sectors. Overall, the BdF exercise revealed a generally "moderate" exposure of French banks and insurers to climate transition risk by 2050, with larger financial risks for the financial institutions more exposed to the most impacted sectors and firms, especially under the disorderly transition scenarios. Specifically, a significant share of bank losses was concentrated in seven sensitive sectors and saw their cost of risk tripling over the analysis period. A second more recent bottom-up climate risk assessment by BdF in May 2024 focused on the insurance sector with a strong physical risk dimension. Results indicate that under the short-term scenario, the combined effect of physical and transition risks adversely affect insurers' solvency (i.e., Solvency Capital Requirement Coverage Ratios would decline by 60 percentage point between 2022 and 2027).

Building upon earlier exercises on climate stress tests (ECB, 2022), ECB (2023) adopted a new granular approach of modelling energy-related developments and sectoral dynamics relevant to the green transition with extensive coverage of economic agents and of exposures, including corporates, households, and different types of financial institutions. The new modelling framework calibrates three novel eight-year transition risk scenarios and includes bottom-up modelling of green investment to replace brown assets and investment in renewable energy. It also incorporates revenue changes for the brown energy sectors arising from decreasing demand, as well as the corresponding changes for the electricity sector. It further allows for amplifications of transition risk through the supply chain. For firms, firm-level probabilities of default (PD) are estimated, based on changes in firms' profitability and leverage, which are then mapped to granular data on corporate loan and bond instruments held by financial institutions, enabling the calculation of expected losses. The findings from the ECB study reveal that an accelerated transition would offer substantial advantages to firms, households, and the financial system when compared to a scenario where the transition is delayed.

[4] Refer to Banque de France (BdF) & Autorité de Contrôle Prudentiel et de Résolution (ACPR) (2021).

Figure 1. An Integrated Micro-Macro Framework

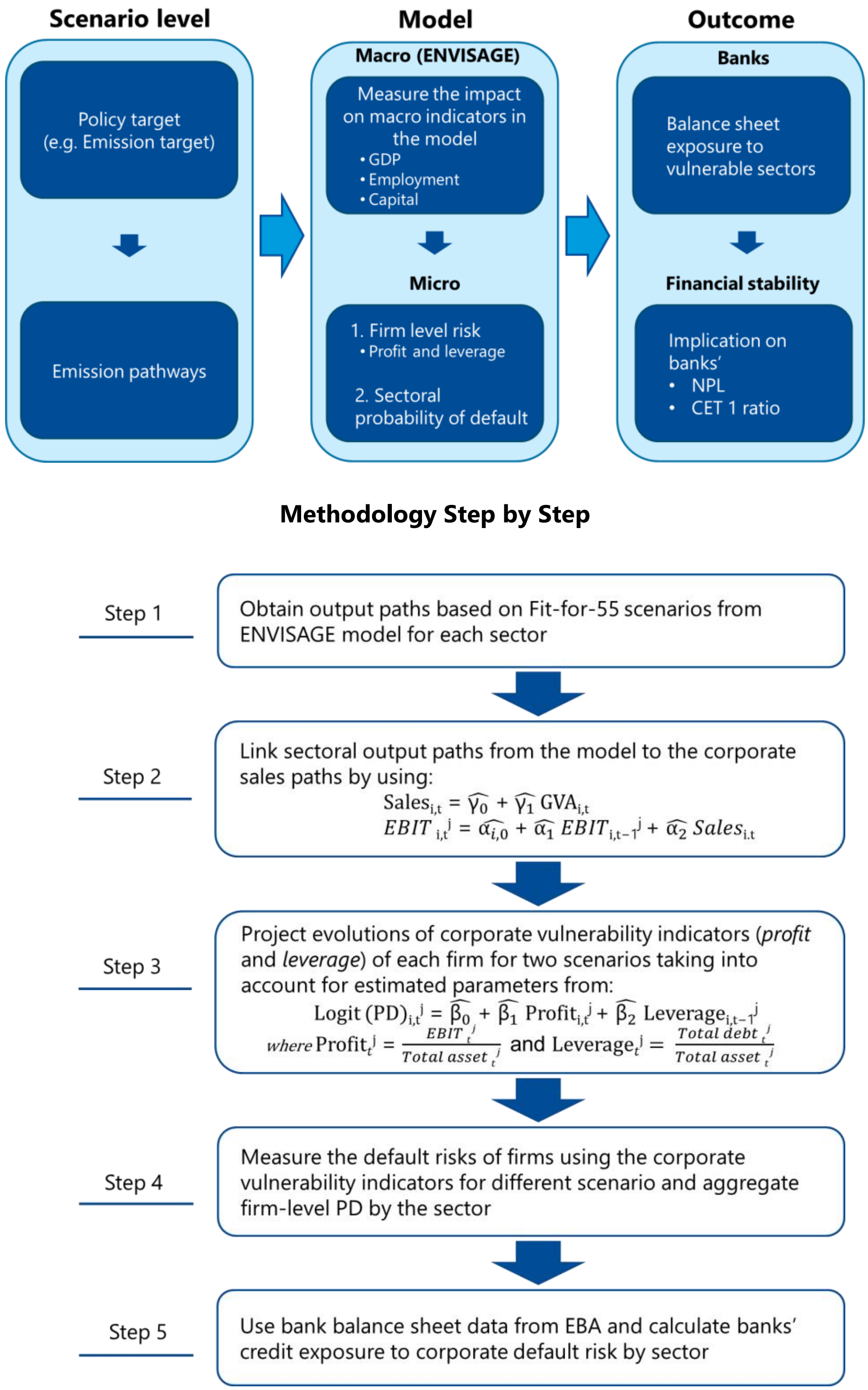


Table 1. Literature Comparison

	ECB (2023)	BdF (2021)	This paper
Approach	Top-down	Bottom-up	Top-down
Scenarios	**Three** • Accelerated (immediate start): 1.5°C compatible • Late start (3 years of lag) i. late-push (1.5°C), ii. delayed (2.6°C)	**Three** • Orderly • Disorderly • Sudden transition	**Two** • Business-as-usual (BAU) • Fit-for-55
Type of climate risk	Transition risk	Physical & transition risk	Transition risk
Horizon	2023-2030	2020-2050	2023-2030
General Equilibrium Model based	No	Yes	Yes
Sectoral analysis	11 sectors: • Agriculture, mining, utility, construction, manufacturing, metals, chemicals, transportation, wholesale/retail, ITC, real estate	20 sectors	• 8 sectors: Agriculture, mining, utility, construction, manufacturing, metals, chemicals, transportation
Balance sheet assumption	Static	Dynamic	Static
Fiscal policy choice in the model	Income tax reductions and reduction in government debt		Labor tax reductions
Impact on the economy	Corporate + Households + Financial system	Financial sector	Corporate + Financial sector
Types of financial risk	Credit exposure, market risk	Credit exposure, market risk	Credit exposure
Country in focus	Euro area	France	France

The climate risk analysis in this paper builds upon the approach undertaken in the recent FSAPs – Financial Sector Assessment Programs (e.g. Japan (2024), Ireland (2022), Mexico (2022), and Kazakhstan (2024))[5]. It supplements the existing scenario-based analyses and climate stress testing frameworks assessing climate transition risk by using a novel micro-macro approach and the most recent climate scenario in the EU—the Fit-for-55 scenario.[6] [7] Specifically, the analysis employs a recursive-dynamic, multi-regional, multi-sectoral computable general equilibrium (CGE) model to examine the long-term effects of climate mitigation and decarbonization policies on sectoral output, and simulate impacts on energy demand and supply, greenhouse gas (GHG), macroeconomic variables, sectoral outcomes and trade. The sectoral output paths derived from the model are then integrated into firm-level corporate balance sheets and risks and ultimately into bank credit risks depending on individual banks' credit exposure to energy-intensive sectors. The analysis focuses on credit transition risks, making an *exposure* assessment using firm vulnerability metrics, such as carbon emissions data, and financial institutions metrics, such as carbon footprint of bank loans. Accordingly, it is not a climate VaR, which are forward-looking and return-based valuation assessments to measure climate related risks. Figure 1 illustrates the general process outlined in the paper. Key comparisons between previous analyses by the Banque de France (BdF) and the European Central Bank (ECB) and our paper are summarized in Table 1.

The remainder of the paper is organized as follows. Section II presents the methodology, including the model and scenario assumptions as well as the corporate data calibration; Section III discusses the climate risk analysis results both in terms of corporate and banking impact; and Section IV concludes and offers policy considerations.

[5] See also the accompanying working paper on Mexico by Laliotis et al. (2023).

[6] The scenario considered om this working paper differs from the scenario of the EBA "One-off Fit-for-55 climate risk scenario analysis".

[7] We do not incorporate physical risks in our analysis because damages from chronic and acute physical risks are expected to be less significant by 2030 than over the long-term and they are difficult to predict and to calibrate into overall GDP and sector-specific losses.

II. Methodology

ENVISAGE Model and Scenario Assumptions

The climate risk analysis presented in this paper employs the ENVISAGE model to examine the long-term effects of climate mitigation and decarbonization policies in France.[8] The model allows for a detailed analysis of how the Fit-for-55 scenario impacts sectoral output in France.

The ENVISAGE model is a standard global CGE model that employs a neo-classical framework, which optimizes consumption and production decisions by households and firms.[9] It follows the circular flow of an economy based on the activities of the key agents: firms, households, and markets. Firms purchase inputs and primary factors to produce goods and services. Households receive the factor incomes and in turn demand the goods and services produced by firms. Markets determine equilibrium prices for factors, goods, and services. Countries also exchange commodities and capital on international markets. Factors of production are almost perfectly mobile across sectors but not across countries. Production follows a series of nested constant-elasticity-of-substitution (CES) functions to capture the different substitution possibilities across all inputs. Demand is non-homothetic and international trade is modeled using the so-called Armington specification where demand for goods is differentiated by region of origin. This specification uses a full set of bilateral flows, prices and trade costs by commodity. The model is recursive dynamic: it is solved as a sequence of comparative static equilibria where the factors of production are exogenous for each year and linked between years with accumulation expressions. Agents, however, are not forward looking and investment levels are driven by savings, which in turn is a combination of assumptions on household savings, the government budget balance and the current account balance.

The model creates direct linkages between all economic activities and emissions of different greenhouse gases (GHGs), and a detailed representation of electricity generation by power source. This allows the introduction of mitigation policies that can be GHG- and activity-specific. Hence, the model allows for broad or very detailed carbon taxation schemes and multi-country emission trading systems (ETS)[10] as well as modeling energy efficiency, emission intensity and mitigation regulations on different activities, commodities, and energy sources.

We employ a stylized modeling of the Fit-for-55 policy package, where the individual policy instruments are calibrated based on the magnitudes in the Fit-for-55 proposals to reach the target of an EU-wide 55 reduction of the 1990 GHG emission levels by 2030. We use both carbon pricing through the EU-ETS and additional non-pricing policies to simulate the Fit-for-55 scenario. This implies an increase in the implicit

[8] The model encompasses 12 European countries/regions and other major global economies as well as other regional aggregates, across 36 distinct sectors. See Appendix for further details.

[9] Van den Mensbrugghe (2024) provides the full documentation of the ENVISAGE model.

[10] As a caveat, ENVISAGE is a real economy model with almost perfect markets for commodities. Therefore, it does not account for adjustment costs when factors of production reallocate across economic activities. Hence, the model is not well suited to analyze short-term dynamics nor transition paths –as the model dynamics move from one general equilibrium to another. Nominal values are also not well represented since the model does not have money nor interest rates, and thus, monetary policy assessments are not possible.

carbon price under the current EU-ETS and UK ETS to US$185 per ton in 2030.[11] [12] Three additional policies are further considered:

- Energy efficiency improvements in transportation and buildings to reduce the related emissions by households, transportation services and other services sectors (which includes most non-residential buildings). The costs of the necessary regulations are calibrated to be 5.8 percent of gross annual fixed investment in each European country.
- Increased use of heat pumps, calibrated to reduce household energy demand by 11 percent, by switching away from natural gas and coal energy demand to increased electricity demand. The associated costs are calibrated to be 0.6 percent of gross annual fixed investment.
- Easing of permits for investments in renewable energy, which are assumed to increase total factor productivity of wind and solar power and leads to 10 percent more renewable generation compared to baseline values in 2030.[13]

Furthermore, we assume that only the EU, UK and EFTA are achieving their Nationally Determined Contributions (NDC) targets, while the rest of the world has no mitigation policies with a view to be more conservative in terms of outcomes. The pathways of emissions and carbon pricing assumptions under two scenarios, namely business-as-usual (BAU, serving as our baseline) and Fit-for-55 (FF55), are illustrated in Figure 2. BAU assumes no changes in climate policy and does not account for the impact of temperature increases and physical risks.

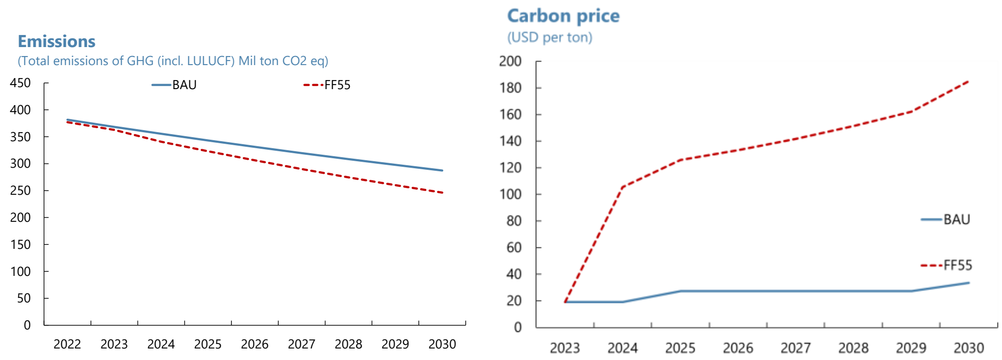
The model has a detailed energy bundle whereby capital and energy are complementary in the short-run (elasticity < 1) and substitutes in the long-run (elasticity > 1), i.e. new capital is more energy efficient than old capital, and substitution possibilities exist between different energy sources and between electricity and non-electricity energy. The carbon tax acts as a shock to both production and consumption, so the energy intensity changes across sectors. Under the FF55 scenario, France's energy intensity is reduced much more than in the baseline scenario (Figure 3). In the model, firms minimize production costs, which also includes optimization across energy sources at different nests. The cost effectiveness of energy sources will depend on the cost structure, trade options and demand. If there is no green production alternative, emissions can only go down if activity levels (production and consumption) are reduced.

[11] The value of the implicit carbon price is endogenously determined by the model to achieve emission reduction in the EU-ETS sectors that are 7 percent higher than baseline values. See Dolphin et al. (2024) for all the details related to the calibration of the ETS and non-pricing policies. Note that we model the same policy shocks for EFTA countries and similar policies (but with the higher emission reduction targets) for the United Kingdom.

[12] The GDP impacts of mitigation policies in our CGE model are not conditional on static price change assumptions and the values of synthesized elasticities, but rather depend on a larger set of demand and supply elasticities, on country-specific consumption and production structures, trade patterns, substitution between different energy sources, between energy and capital, and between production factors, and the interactions of sector-specific mitigation policies in a larger set of economic activities (impacted simultaneously in several countries) that result in indirect GE effects. In the case of France, the estimated GDP costs for the Fit-for-55 scenario are not related to changes in the energy sector, which is mostly decarbonized in France already, but largely to the costs of switching to heat pumps and the investments associated with the energy efficiency targets for transport and buildings. These are effects that are not directly transmitted through price changes, but through relocation of productive investments, changes in energy demand (more electricity and less fossil fuels) and energy efficiency parameters.

[13] See Dolphin et al. (2024) for a detailed explanation of this calibration procedure. In particular, Annex 2.B provides a detailed explanation of the price and non-price measures modelled.

Figure 2. Trajectory for Emissions and EU-Wide Carbon Tax in France

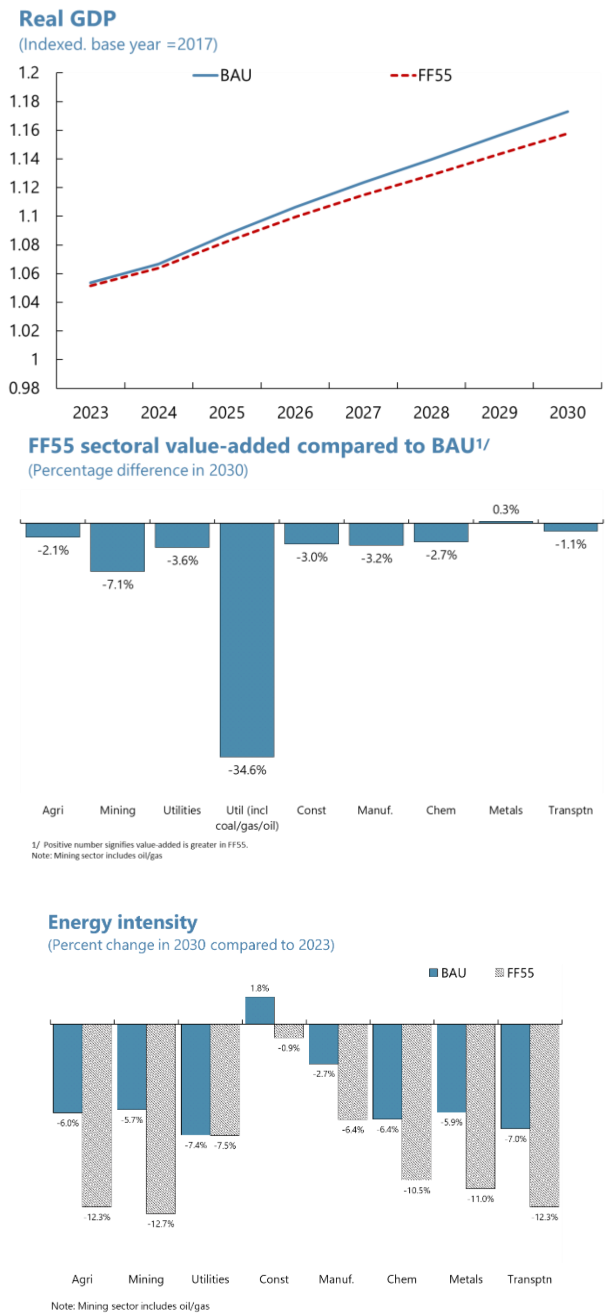


Sources: IMF staff estimates.

With an increasingly green electricity generation mix and higher energy efficiency for transport and buildings by 2030, the impact in terms of France's real output mostly arises from the energy-intensive sectors. The electricity mix is exogenously adjusted to follow closely the projections of the European Commission using the PRIMES energy model. By 2030, France has no energy powered by coal or oil, while it has lower gas and nuclear power and higher wind generation (Figure 4). Note, however, that France is expected to have a largely decarbonized electricity generation already under the baseline.

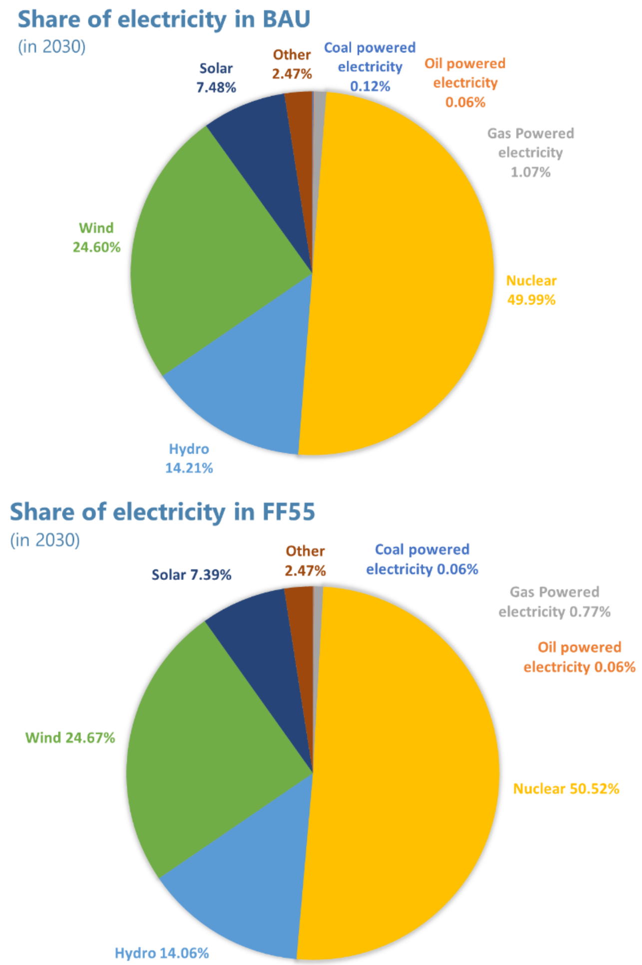
Abatement costs are implicitly determined by the energy-intensity of each sector and the substitution possibilities between energy sources, with lower abatement costs for the energy sector, given renewable electricity generation, and higher abatement costs for other emission sources such as agriculture, transport, and industrial processes. GDP costs are linked to both the carbon pricing and additional non-pricing policies, with a large share related to the costs of switching to heat pumps and the investments associated with the energy efficiency targets for transport and buildings. These are effects that are not directly transmitted through price changes, but through relocation of productive investments, changes in energy demand (more electricity and less fossil fuels) and energy efficiency parameters. As illustrated in Figure 3, the real GDP level in 2030 for the FF55 scenario is 1.3 percent below the baseline scenario, with most affected sectors being the energy-intensive sectors such as mining, oil & gas, manufacturing, chemicals, and utilities (coal, gas, and oil).

Figure 3. Real GDP, Sectoral VA and Energy Intensity Under the Baseline and Fit-for-55 Scenario



Sources: IMF staff estimates.

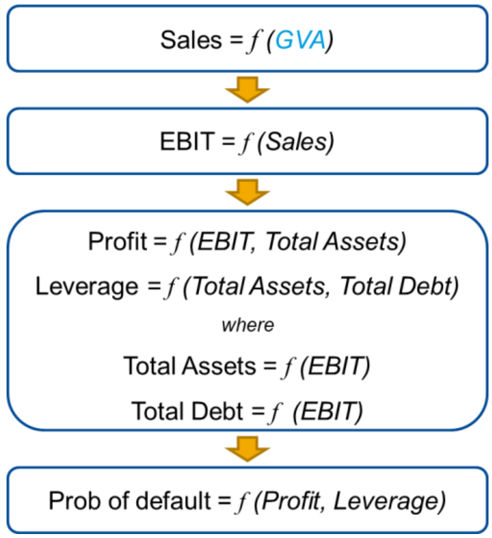
Figure 4. Electricity Generation



Sources: IMF staff estimates.

Structural Link: Model Sectoral Output and Corporate Earnings

Figure 5. Linking Model Output to Firms' Probability of Default



Our modelling framework integrates the sectoral output paths derived from the model into firm-level corporate balance sheets and risks, which are used to evaluate implications for financial stability based on banks' exposure to energy-intensive sectors. Figure 5 illustrates how the results of the ENVISAGE model are connected to firm vulnerability, which is subsequently used to evaluate the implications for financial stability through banks' exposure to more vulnerable firms. First, we estimate five equations using historical data: (1) sales as a function of aggregate GVA; (2) Earnings Before Interest and Taxes (EBIT) as a function of Sales; (3) profit as a function of EBIT and total assets; (4) leverage as a function of total assets and total debt; and (5) the probability of default in logit form as a function of Profit and Leverage. Subsequently, with sectoral value-added (VA) results from the model under two scenarios, we generate sectoral sales paths using the estimated equations. These sectoral sales paths are then utilized to derive EBIT paths, which in turn generate paths for profit and leverage. Finally, the paths of profit and leverage are employed to determine the probability of default. One caveat of the analysis is that the mapping of the sectoral GVA from the macro model into the sectoral corporate balance sheets and later into the banks' sectoral exposures are subject to approximation errors since sectoral classification used can differ at the macro and micro levels due to data availability.

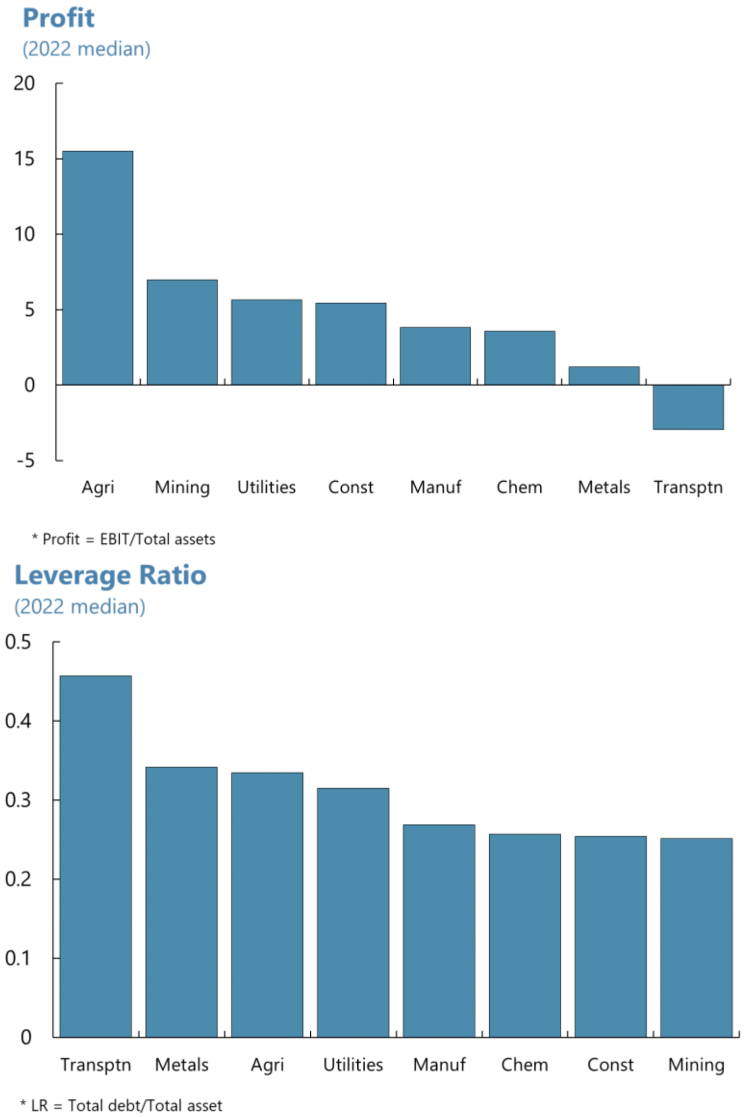
Corporate Vulnerability and Bank Exposure Data

The corporate microdata we use covers a large sample of 667 large, medium-sized, and small firms and contains key balance sheet and profit and loss (P&L) items.[14] The data sample was sourced from Datastream, with the sample period covering balance sheet data from 2013 to 2022. Energy-intensive companies, including sensitive manufacturing, chemicals and metal companies represent about 27 percent of all companies in the sample, and in terms of size of assets, most companies are medium-sized.

[14] Details can be found in the Appendix.

[15] [16] Figure 6 illustrates firm balance sheet indicators, where "profit" pertains to short-term financial stability and the "leverage ratio" reflects long-term solvency conditions.

Figure 6. Sectoral Balance Sheet Data

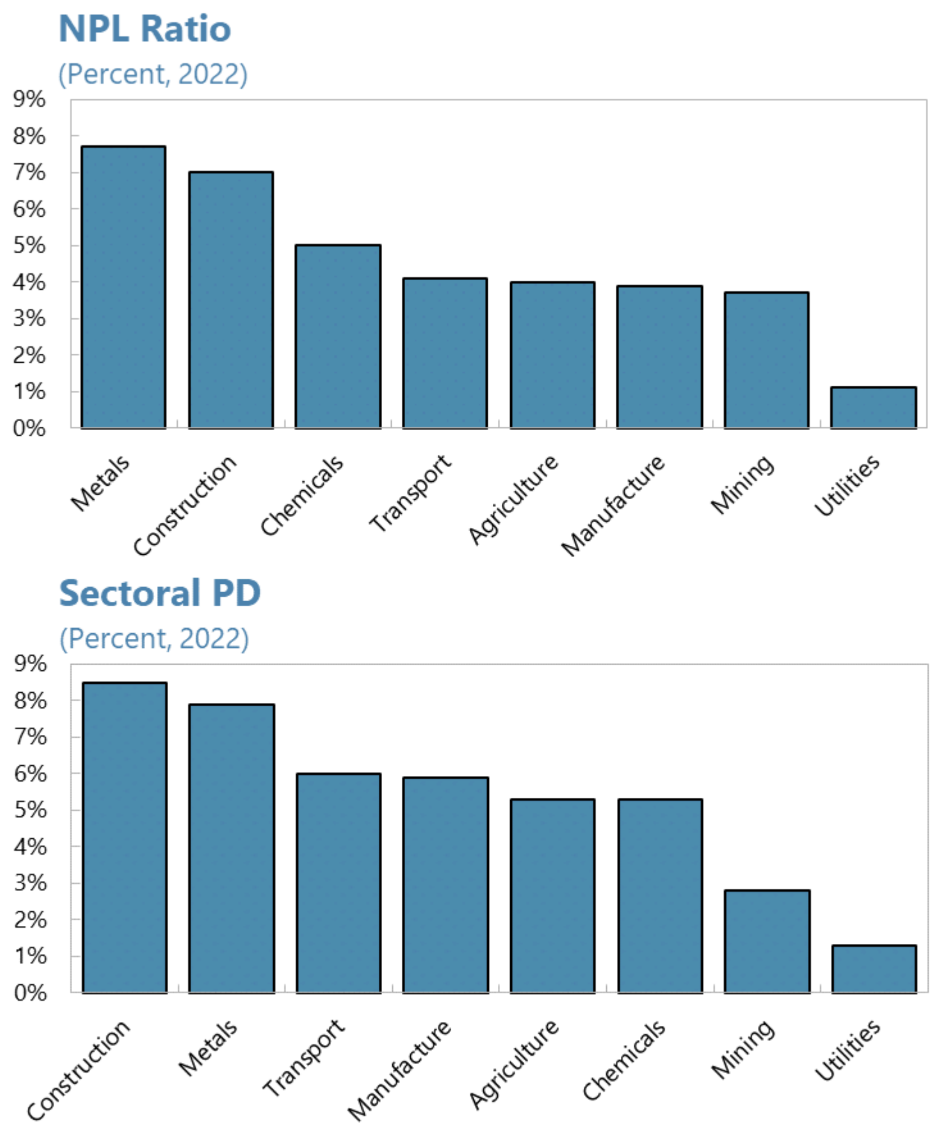


Source: Datastream.

[15] The following sectors are represented: chemicals, metals, and other sensitive manufacturing (27 percent), construction (7 percent), utilities (7 percent), mining (6 percent), transportation (5 percent), metals (2 percent), and agriculture (1 percent). In terms of asset distribution, the bulk of companies, amounting to 75.9 percent, are categorized as medium-sized, with total assets ranging from 10 million to 1 billion euros. Large-sized companies, possessing assets exceeding 1 billion euros, account for 19.2 percent of the total, while small-sized companies, with assets less than 10 million euros, make up 4.9 percent.

[16] We focus on transition-sensitive sub-sectors within the manufacturing sector, including the manufacture of coke and refined petroleum products (NACE code C19), manufacture of chemicals and chemical products (C20), manufacture of other non-metallic mineral products (C23), and manufacture of basic metals (C24). The classification of sectors sensitive to transition risk is borrowed from Annex B of BdF and ACPR (2021).

Figure 7. Corporate PDs and NPL Ratios, 2022



Sources: Banque de France, and IMF staff estimates.

Meanwhile, for a forward-looking default risk measure, we employ Moody's EDF in 2022 tailored to France as a proxy for initial probability of default (PD), consolidating corporate data into sectoral levels using total assets as the weighting factor.[17] As a caveat, using assets as a weighting factor may underestimate risks if firms with relatively high levels of assets have consistently lower debt/leverage ratios. Figure 7 illustrates the weighted average of sectoral PDs and non-performing loans (NPLs). These sectoral PDs serve as the initial points for our PD projection later. We summed all gross carrying amounts and NPLs from all banks for each sector to calculate the NPL ratios. We have coverage of the 9 largest French banks which represent 90 percent of total banking assets. To examine bank exposures, we used data from the

[17] Expected Default Frequency (EDF) is a metric that quantifies the likelihood of a borrower defaulting on its debt commitments within a specified time frame, which we have set at one year.

BdF on credit exposures by sectors as of December 2022. Our climate risk analysis is based on a static balance sheet assumption. On an aggregate level, the French banking system faces credit risks from some more energy-intensive sectors such as manufacturing as well as from less energy-intensive sectors such as construction.

Estimation

This section links the ENVISAGE model output results to the firms' probability of default, by first connecting sectoral GVA to sectoral sales and then to firm-level profits, and second by establishing a structural relation between corporate-level vulnerability indicators and default risks. This methodology was first introduced in IMF (2022b and 2022d).

Sales: We connect the output level to corporate sales revenues and subsequently connect sales revenue to earnings. Equation (1) displays how we estimate sales as a function of a proxy of output, namely GVA.

$$Sales_{i,t} = \gamma_0 + \gamma_1 \, GVA_{i,t} + \varepsilon_{i,t} \qquad \text{where } i = 1,\dots I \text{ for sectors} \qquad (1)$$

where γ_1 reflects the sensitivity of sales to the paths of gross output/gross value added (GVA). We estimate γ_1 at the aggregate sectoral level using historical data. Table 2.1 shows the results for $\widehat{\gamma_1}$.

EBIT: Equation (2) represents the relationship between EBIT, its lagged variable, and sales with a firm fixed effect whose estimation results are displayed in Table 2.2. One of the key distinctions of our paper compared to other work in this field is how we connect the output (GVA) from the macro model to assess a firm's profitability and, consequently, their vulnerability.

$$\mathrm{EBIT}^{j}_{i,t} = \alpha_{i,0} + \alpha_1 \, \mathrm{EBIT}^{j}_{i,t-1} + \alpha_2 \, Sales_{i,t} + \upsilon^{j}_{i,t} \qquad \text{where } j = 1,2,\dots,J \text{ for firms} \qquad (2)$$

$\widehat{\alpha_1} > 0$ and $\widehat{\alpha_2} > 0$ indicate a positive correlation between last period's EBIT and Sales with current EBIT.

Probability of default: We establish a structural connection between corporate vulnerability indicators and default risks. Two vulnerability indicators are employed: profit and leverage, defined respectively as the ratio of EBIT to total assets ($\mathrm{Profit}_t = \frac{\mathrm{EBIT}_t}{\mathrm{Total\ Assets}_t}$) and the ratio of total debt to total assets ($\mathrm{Leverage}_t = \frac{\mathrm{Total\ Debts}_t}{\mathrm{Total\ Assets}_t}$).

$$\mathrm{Logit(PD)}^{j}_{i,t} = \beta_{i,0} + \beta_1 \, Profit^{\,j}_{i,t} + + \beta_2 \, Leverage^{\,j}_{i,t} + \eta^{j}_{i,t} \qquad (3)$$

Table 2.3 shows the estimated result of equation (3). The estimation results are straightforward: A negative estimate for $\widehat{\beta_1}$ implies that firms with higher profitability have a lower probability of default. Conversely, a positive estimate for $\widehat{\beta_2}$ indicates that firms with a higher leverage ratio in the previous period (i.e., higher debt relative to their assets) have a higher probability of default. [18]

[18] We include the lagged leverage ratio in our analysis, despite finding that the coefficient is not statistically significant. This decision is based on both economic rationale and the need for comparability with other studies, such as those conducted by the ECB. Here we control for firm fixed effects.

Table 2.1 Linking Sectoral GVA to Sales

	Sales
Sector GVA	**1.101*** **
	(0.0783)
Constant	19.89
	(14.11)
Observations	64
R-squared	0.761
Sectors	8

Table 2.2 EBIT Evolution Estimation

	EBIT
Lagged EBIT	**0.561*** **
	(0.02)
Sales	**0.0459*** **
	(0.002)
Observations	2210
R-squared	0.583

Table 2.3 Default Probability Estimation

	EDF
Profitability	**-2.18*** **
	(0.58)
Lagged LR	**0.192**
	(0.32)
Observations	2244

Standard errors in parentheses: p<0.1, ** p<0.05, *** p<0.01

Projection of Probability of Default

When calculating the EBIT path, we add one more component that is *carbon tax expenditure*, which accounts for the direct additional operating cost resulting from firm-level emission projections and scenario-specific carbon prices. It is calculated as the product of the carbon price and emissions (in tCO2eq). We gather firm-level emissions data from Urgentem, encompassing historical and future emission projections and integrate these with our set of corporate balance sheet variables. Under two scenarios, BAU and Fit-for-55, carbon taxes are imposed differently in different sectors, thereby influencing the variability of EBIT sectoral paths. This represents a direct pathway through which EBITs differ across scenarios. Another pathway is through sales, which is dependent on GVAs under different scenarios. While sales paths are inherently sectoral, as they were directly derived from sectoral GVAs, therefore, we can calculate the evolution of EBIT at the firm level using initial firm-level EBIT and emission values.

$$EBIT_{i,t}^{j} = \widehat{\alpha_{i,0}} + \widehat{\alpha_1}\, EBIT_{i,t-1}^{j} + \widehat{\alpha_2} Sales_{i,t} \text{ - } Carbon\ Tax\ Expenditure_{\ i,t}^{\ j} \qquad for\ t = 2023,\ldots,2030 \qquad (4)$$

We utilize the estimated coefficients derived in the previous step to forecast firm-level PDs under the two transition scenarios. The methodology for constructing corporate vulnerability indicators is detailed in Table 3. We project the vulnerability indicators, profit and leverage, at the firm level for each scenario from 2023 to 2030, using projected EBIT, firm-specific balance sheet information, and carbon emissions, with carbon tax expenditure being scenario-dependent. This process facilitates dynamic projections, enabling the determination of balance sheet components using a dynamic accounting identity. Subsequently, the projected vulnerability indicators are multiplied by the estimated coefficients from the probability of default equation (equation (3)) to derive the PD paths. These forward-looking projections assume a constant firm interest rate on debt (R_t) at the level observed in 2022. Upon obtaining corporate-level PD paths derived from scenario-dependent corporate-level EBIT paths, we aggregate these paths at the sectoral level, using total firm assets as weights for aggregation.

Table 3. Projection of Corporate Balance Sheet and Vulnerability Indicators

Vulnerability Indicators	Projection formula based on accounting identity
$\text{Profit}_t = \dfrac{\text{EBIT}_t}{\text{Total Assets}_t}$	1) $\text{EBIT}_t = \widehat{\alpha_{1,0}} + \widehat{\alpha_1}\,\text{EBIT}_{t-1} + \widehat{\alpha_2}\text{Sales}_t$ - Carbon Tax Expenditure $_t$ 2) $\text{Carbon Tax Expenditure}_t = \text{Emission}_t * \text{Carbon Price}_t$ 3) $\text{Total Assets}_t = \text{Total Assets}_{t-1} + \text{Cash and Equivalents}_t - \text{Cash and Equivalents}_{t-1}$
$\text{Leverage}_t = \dfrac{\text{Total Debts}_t}{\text{Total Assets}_t}$	1) $\text{Total Assets}_t = \text{Total Assets}_{t-1} + \text{Cash and Equivalents}_t - \text{Cash and Equivalents}_{t-1}$ 2) $\text{Interest Expense}_t = \text{R}_{t-1} * \text{Total Debt}_{t-1}$ 3) $\text{Cash and Equivalents}_t = \max(0,\ \text{Cash and Equivalents}_{t-1} + \text{EBIT}_t - \text{Carbon Tax Expenditure}_t - \text{Interest Expense}_t)$ 4) $\text{Total Debt}_t = \text{Total Debt}_{t-1} - \min(0, \text{Cash and Equivalents}_{t-1} + \text{EBIT}_t - \text{Carbon tax Expenditure}_t - \text{Interest Expense}_t$ 5) $\text{Interest Expense}_t = \text{R}_{t-1} * \text{Total Debt}_{t-1}$

III. Climate Risk Analysis Results

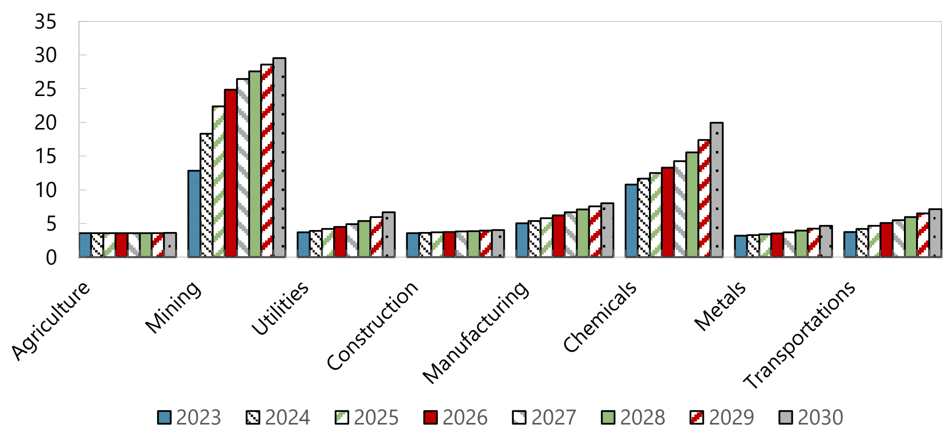
Impact on Corporate and Banking Sectors

There are heterogeneous drivers that affect the impact of the climate transition on firms, corporate sectors, and eventually the banking system. First, the energy intensity of firms in different sectors and the initial risk characteristics and financial health of firms in each sector (Figures 6 and 7) are quite diverse. Second, the heterogeneous sectoral impact shown in Figure 3 from the CGE model maps into firms' sales revenues and consequently into the vulnerability indicators differently. Third, the sensitivity of firm-level PDs, the coefficient betas in the bridge equation used to project climate scenario dependent PD paths and later aggregated to weighted sectoral PDs are themselves different. Lastly, the credit exposure of the banking system to more energy-intensive sectors, which is directly responsible for the materiality of bank capital impact, is also quite diverse across sectors.

Under the Fit-for-55 scenario, some sectors face a larger impact in terms of output and in turn PDs (Figure 8). For example, PDs for the mining, chemicals, and manufacturing sectors more than double over the analysis horizon, while PD increases remain contained for utilities (notably coal, gas, and oil-powered electricity) and transport sectors despite an upward path. The reason for rising PDs in these sectors is not only significantly higher emission profile, but also lower profits and higher leverage (Figure 6). As such, transition risks might mainly exacerbate existing weaknesses in financial standing in some firms and sectors.

Figure 8. Sectoral Corporate PDs under FF55

(Percent, 2023-2030)



Sources: IMF staff estimates.

The change in PDs across banks, weighted by their exposures to the energy-intensive sectors,[19] show a significant rise in risks in the corporate credit portfolio under the Fit-for-55 scenario in the absence of a timely and well-managed climate transition. Figure 8 displays the ENVISAGE model projections of sectoral PDs from 2023 to 2030. The mining sector shows the most significant projected increase in PDs by 2030, followed by the chemicals sector. Other sectors like other sensitive manufacturing and metals exhibit moderate increases in PD. The impacts of climate policy on each sector affect banks asymmetrically, as their exposure to energy-intensive sectors, such as mining and chemicals, tends to vary (1.7 percent for mining, and 0.8 percent for chemicals, on average). Estimates for capital impairment are not reported given high sensitivity to underlying assumptions, lacking more granular data on banks' exposures to energy-intensive sectors and bank-by-bank loss-given-default rates (LGDs).

We use NPLs as a proxy for the transition risk that banks are facing. The ENVISAGE model generates distinctive GVA paths for each sector under FF55, which are then converted to corporate PD projections. We apply sectoral PD trajectories to NPLs, using 2022 data as the basis. We first calculate NPL trajectories for all sectors, then average NPLs for each year by weighting each sector according to the banks' loan amounts in 2022. According to our model and data, NPLs could increase by about 1.5 percentage points by 2030 under the Fit-for-55 transition central scenario which focuses on the impact on the energy-intensive sectors (ie, chemicals, metals, and other sensitive manufacturing). Nevertheless, NPLs could increase by about 3 percent in a more severe scenario with a broader impact to all sectors of interest rather than only the energy-intensive ones.

The paper results are broadly consistent with previous exercises by the BdF and ECB, although not directly comparable given differences in coverage, scenarios, assumptions, and time horizons. First, under the orderly scenario in BdF (2021), which is less stringent than the Fit-for-55 scenario considered in this paper although over a longer time horizon, the cost of risk (i.e., the provision for expected losses) is overall 1.2 times higher in 2050 compared to its 2025 level for all sectors. For the energy-intensive sectors, the cost of risk is 2.5 times as high. Under the disorderly scenarios (delayed or sudden), the GDP loss could be between 2 and 5.5 percent—a larger impact than in our scenario but over a longer time horizon—and the cost of risk is 3 times higher for energy-intensive sectors in 2050, compared to up to twice as high in our exercise although within a shorter time horizon. Under the accelerated scenario in ECB (2023), which is the closest to our scenario, the average percentage point increase in corporate PDs for the Euro Area between 2022 and 2030 would be around 0.2 and 1.2 percentage points for the lower and upper risk quartiles, which closely aligns with our estimates of the PD increase. The increases in the median corporate loan portfolio PD range from 1.6 times to 2 times in 2030 for orderly and disorderly transition, respectively.

[19] We focus on transition-sensitive sub-sectors within the manufacturing sector, including the manufacture of coke and refined petroleum products (NACE code C19), manufacture of chemicals and chemical products (C20), manufacture of other non-metallic mineral products (C23), and manufacture of basic metals (C24). The classification of sectors sensitive to transition risk is borrowed from Annex B of BdF and ACPR (2021).

IV. Conclusion and Policy Considerations

The climate risk analysis presented in this paper applies an integrated macro-micro framework to assess the impact of the Fit-for-55 scenario on financial stability in France, focusing on the top-9 banks by asset size. The framework combines sectoral output results from the ENVISAGE model with a micro-level approach. This approach enables a comprehensive evaluation of corporate financial weaknesses, analyzes banks' credit exposure to energy-intensive sectors, and assesses the effect of increasing corporate vulnerability on banks' asset quality.

There are certain limitations to our study that need to be acknowledged. We exclusively assess the impact of climate transition on sectors included in the ENVISAGE model, which primarily focuses on primary and secondary industries, rather than encompassing the entirety of the corporate sector in France. Additionally, due to lack of granular data on banks' exposures to energy-intensive sectors and loss given default (LGD) rates for each bank, potential capital impairments are subject to high uncertainty and are not reported in this paper. Furthermore, due to lack of data on the extent of climate transition already undertaken in each sector, including mitigating factors, the transition for each sector is assumed to only start in 2023, potentially resulting in an overestimation of the country's risk exposure.

Our climate risk analysis is a top-down approach which builds on existing literature, including state of the art exercises by the BdF, the ECB, and recent IMF FSAPs. Key results of our analysis are rising corporate and bank PDs by 2030, largely driven by energy-intensive sectors. This calls for increased efforts to ensure a timely and orderly transition to smooth adjustment and output costs for firms and in turn mitigate the credit risk impact on banks. These results further underscore the importance of continuing to update and expand climate risk analysis, including by combining top-down with more granular bottom-up approaches, to provide the most accurate assessments of risk.

In parallel, the ECB is requiring banks to progressively reach full alignment with supervisory expectations on climate and environment-related risks by end 2024 (ECB, 2023). In this context, greater efforts will be needed to increase banks compliance with the Corporate Sustainability Reporting Directive (CSRD), EU taxonomy regulatory requirements and Pillar 3/ESG risks reporting and disclosures and integrate climate-related risks into their governance, strategy, and risk management processes. Given the sizable concentration of energy-intensive corporates in the banking sector portfolio, disclosure should be enhanced to collect granular data for understanding the carbon footprint of the entire spectrum of firms—from the larger and listed ones to SMEs as well (ECB, 2024). Banks would need to publish information based on the CSRD, the EU Taxonomy regulation, and the EBA's Pillar 3 rules.

Furthermore, ECB supervisors are already including bank-specific climate and environmental findings in their Supervisory Review and Evaluation Process (SREP) (ECB, 2023, Priority 2). This includes the largest banks in France (G-SIBs). They have imposed binding qualitative requirements on more than 30 banks in their annual SREP (some of which in France too). In turn, SREP scores will impact banks' Pillar 2 capital requirements which will need to be boosted if banks' exposures to energy-intensive corporates are high. Thus, banks will need to accelerate the effective remediation of shortcomings in internal governance and the management of climate-related risks.

Integrating climate transition plans into the prudential framework will encourage diversification of investments by financial institutions (IMF GFSR, 2023, and NGFS, 2024a and 2024b). In this context, the revised Capital Requirements Directive includes a new legal requirement for banks to prepare prudential plans to address climate-related and environmental risks arising from the process of adjustment towards climate neutrality by 2050. Supervisors are now empowered to check these plans and assess banks' progress in addressing their climate-related and environmental risks. Supervisors are also empowered to require banks to reduce their exposure to these risks and to reinforce targets, measures and actions included in their plans. Sustained efforts are needed in France to publish reliable and comparable data on exposures of banks to energy-intensive firms and on firms' and banks' transition plans.

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Annex

List of the countries in ENVISAGE Model (24)

1. Australia
2. China
3. Japan and Korea
4. India
5. Canada
6. United States of America
7. France
8. Germany
9. Italy
10. Bulgaria, Croatia and Romania
11. Belgium and The Netherlands
12. Czechia, Slovakia and Hungary
13. Poland
14. Rest of EU and EFTA
15. United Kingdom
16. Norway
17. Turkiye
18. Russian Federation
19. Saudi Arabia
20. Rest OPEC, other Middle East and North African countries
21. Other East Asia & Oceania countries
22. Other African countries
23. Other Eurasian countries
24. Other Latin American countries

List of the sectors in ENVISAGE Model (36) and Climate Stress Test Aggregation (8)

CGE Sector Codes	CGE Sector Names	Aggregated Sector Names
cro-a	All Crops	Agriculture
lvs-a	Livestock	
frs-a	Forestry	
fsh-a	Fisheries	
coa-a	Coal extraction	Mining
oil-a	Crude Oil extraction	
p_c-a	Petroleum and coal products	
gas-a	Natural gas: extraction, manufacture & distribution	
clp-a	Coal powered electricity	Utilities
olp-a	Oil powered electricity	
gsp-a	Gas Powered electricity	
nuc-a	Nuclear power	
hyd-a	Hydro power	
wnd-a	Wind power	
sol-a	Solar power	
xel-a	Other power	
etd-a	Electricity transmission and distribution	
wts-a	Water supply; sewerage; waste management and remediation activities	
cns-a	Construction	Construction
fdp-a	Food Products	Manufacturing
mvh-a	Transport Equipment	
oma-a	Fabricated metal products	
OMN-a	Minerals n.e.s.	Chemicals
nmm-a	Non-metallic minerals	
crp-a	Chemical products	
i_s-a	Iron and Steel	Metals
nfm-a	Non-ferrous metals	
wtp-a	Water Transport	Transportation
atp-a	Air Transport	
otp-a	Transport n.e.s.: Land transport and transport via pipelines	

PUBLICATIONS

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