MILLIMAN WHITE PAPER

# Developing climate risk scenarios for Solvency II ORSA

## Key challenges for European insurers in the assessment of transition risks on assets

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Climate change is an emerging topic in prudential supervision as well as a standalone research area. Best practices still need to be developed, however, and we can expect that developing scenarios for climate transition risks for the Own Risk and Solvency Assessment (ORSA) will become an important challenge for the industry.

In early August 2022, EIOPA published 'Application guidance on running climate change materiality assessment and using climate change scenarios in the ORSA.'

Under the application guidance, European insurers will be required to identify material climate change risks that affect their business and integrate these risks into their system of governance, risk management and ORSA.

Focus is put on several areas:

- Integration of climate change risks within the ORSA in the short and long term
- Materiality assessment of climate change risks
- Range of climate change risk scenarios
- Lower precision and frequency of long-term scenario analyses
- Evolution of climate change risk analyses
- Supervisory reporting and consistent disclosure

Climate risk for financial institutions includes two basic risk types: physical risk and transition risk, as described in Figure 1.

**FIGURE 1: BASIC RISK TYPES**

| TYPE OF RISK | DESCRIPTION |
|---|---|
| **Physical** | Physical climate risk arises from the direct impact of climate change, which can include shorter-term impacts like increased severity for extreme events (acute physical risk), as well as longer-term impacts from modifications in climate patterns, such as sustained increases in temperature levels (chronic physical risk). |
| **Transition** | Transition climate risk can arise from the process of adjustment to a low-carbon economy. While it seems that physical risks have more impact on the liabilities of insurers, transition risk is expected to impact more the valuation of financial assets (equities, corporate and government bonds), but may have also strategic implications for insurers. |

When developing ORSA scenarios, companies will be expected to translate certain high-level narrative scenarios into the impact on liabilities and assets, and their expected materialization within different risk modules, e.g. market risks, credit risks, underwriting risks, operational risks, etc. Some companies may be more exposed to transition risks while others may have more exposure to physical risks, and this will depend to a large extent on the risk profile of the company. Companies will be required to report climate risks in their ORSA process for only those risks that are material.

The scope of this paper is restricted to transition risks. These are likely to materialize over the short to medium term on the asset side of balance sheets. We focus on explaining the regulatory context, and give an overview of possible theoretical approaches. This paper also includes an overview of the prudential stress tests that have taken place over the last few years and may be of help in constructing scenarios. We also provide a simple numerical example.

FIGURE 2: DRIVERS OF TRANSITION RISK

| POLICY | TECHNOLOGY | LITIGATION | MARKET SENTIMENT AND REPUTATION |
|---|---|---|---|
| ▪ Carbon tax<br>▪ Emission reduction targets<br>▪ Restrictions on coal usage<br>▪ Mandates on renewable energies | ▪ Advances in clean technology<br>▪ Replacement of existing products and services by lower-emission technologies<br>▪ Displacement of older technologies | ▪ Increased litigation against companies failing to adapt | ▪ Changing consumer preferences<br>▪ Business re-evaluations |

# The nature of transition risks

The term 'climate transition risk' refers essentially to uncertainty around the process of adjustment to a low-carbon economy, as part of meeting the objectives of the Paris climate agreement, i.e. limiting global warming to two degrees compared to pre-industrial levels and achieving climate neutrality by the middle of the century. The distinction between physical risks and transition risks may not always be clear cut. For example, how should the risk of not achieving the two-degree objective due to a physical event (such as a catastrophic volcano eruption) be treated? Or, how should physical damage resulting from delayed policies be considered?

Although this does not seem very clear a priori, our understanding is that transition risk should be strictly related to the path of social, economic and regulatory change that is aimed at achievement of the objective. In other words, transition risk is related to human behaviour, without judgment. For example, if certain technologies were to develop more slowly than expected, or carbon reduction policies are delayed by regulators, or if consumer preferences do not adapt to being socially responsible within the assumed timeframe, then these would all form part of transition risk. However, a catastrophic volcano eruption that sabotages achievement of the two-degree objective would not be considered within transition risk, as this would be a random event that is independent of human behaviour. In the case of physical events resulting from delayed policies, this is less clear from a risk taxonomy point of view, and we feel that it can be more logical to treat these as falling under physical risks.

Another common issue related to risk classification is the treatment of litigation risk. Litigation risk may be considered as a separate category, i.e., outside of physical and transition risks. However, in our understanding, litigation risks are mainly related to human actions or lack thereof related to managing climate risks. Such litigation risks are clearly related to transition risks. They are also similar to transition risks in terms of risk taxonomy, as they are likely to impair certain asset values. Although it does not necessarily directly impact the achievement of the two-degree objective, it can be seen as an 'expense risk' related to transition. We therefore consider this risk as part of transition risk (implying an extension of the definition of transition risk).

The transition path may lead to reassessment of a wide range of asset values, especially within climate-sensitive sectors such as fossil fuels, but also within sectors for which transition represents an opportunity (such as renewable energy). The process of adjustment to a low-carbon economy might be impacted by several factors, such as developments in climate-change policy (in particular, slowing down or accelerating the process), the emergence of new technologies, shifting sentiment and social preferences, shocks in the supply of primary energy, etc. Another category of risks which might be considered within transition risk is legal/litigation risks—for example, climate-related claims under legal-liability policies or perhaps direct claims against insurers for failing to manage climate risks.

Transition risks that impact asset values may materialize as, for example:

- Impairment of financial asset values due to the process of transition. For example, so-called 'stranded' assets, 'brown' real estate, and the direct impact of the transition on the valuation of assets within climate-sensitive sectors.
- This materializes mainly in **equity prices** and hence in ORSA climate scenarios should be reflected within the equity shock that is applied.
- Deteriorating creditworthiness of those borrowers and counterparties that fail to properly address the transition to a low-carbon economy. This risk applies to both corporations and governments. For example, countries with economies tied to exporting fossil fuels are likely to be affected by lower demand for these commodities.
- This materializes mainly in **bond prices** and yields, as well as within counterparty default probabilities.

# Designing the process

The process of application of climate risk scenario tests is generally performed using the following steps:

- **Materiality assessment** is very important from a practical perspective, as ORSA scenarios will need to be designed only for material risks. Note that EIOPA considers risks to be material[1] when *ignoring the risk could influence the decision making or the judgement of the users of the information, which in case of ORSA would be the undertaking's administrative, management or supervisory body and its relevant staff.*

  The materiality assessment could involve describing the assets and liabilities which would potentially be impacted by climate risks, investigation of the potential impact of climate change on the business via identification of specific exposures, and qualitative and quantitative assessment of the relevance to the business.

  For quantitative assessment of transition risks relating to investments, two methods are likely to prevail, at least over the first few years.

  The first method is based on the classification of all equities and government bonds into Climate Policy Relevant Sectors (CRPS) as introduced in Battiston et al. (2017), which provides a classification of economic activities into European Union (NACE) codes. The CRPS sectors are agriculture, fossil fuels, utilities, energy-intensive, transport and housing. When applying this approach, one should also take into consideration the financial sector and try to assess indirect exposures to CRPS sectors. Under this approach, the materiality assessment would be based on the exposures of equities and corporate bonds within the exposed sectors.

  This approach is relatively easy to implement, as NACE codes are publicly available (and even available within QRT's). However, the codes are not free of limitations. For example, NACE codes don't allow sources of energy to be identified or any link with GHG (green house gas) emissions.

  For example, investments in renewable energy could be considered 'brown' while they are clearly not brown. A more granular analysis of the portfolio could take into account the split by technology/source of energy, or focus on GHG emissions.

  This type of approach can be applied using the Paris Agreement Capital Transition Assessment (PACTA), a public open-source tool developed by the 2 Degree Investing Initiative (2DII) and described in more detail later in this paper.
- **Scenario design** comprises defining the scenario narratives as well as considering such features as appropriate time horizons and granularity. The difficulty when considering climate change in ORSA is that the time horizons involved with climate risk are typically much longer than the business horizons typically considered within ORSA. To be clear, we do not mean that physical damage events will not be observed within the next five years, but it is perhaps more likely that the most important factors impacting the value of the business will be observable over a longer time horizon (for example, the impact on mortality rates for life insurers). However, for transition risks, the typical ORSA horizon of five years does not seem inappropriate, although something longer (for example, 10 years) might be preferable.

  While there is quite clear guidance from EIOPA on what the scenario narrative could look like (see next section), companies should consider carefully how they would prefer to apply the scenarios. For example, it could make a significant difference operationally if scenarios are applied as a multi-period projection of the

[1] Consultation paper on Application guidance on running climate change materiality assessment and using climate change scenarios in the ORSA

balance sheet (as in a traditional financial scenario analysis for ORSA), as opposed to being calculated as sensitivities. It is worth mentioning that, so far, most prudential stress tests related to climate risk have been based on single shocks rather than multi-period projections.

- **Developing scenario specifications** covers translating high-level narrative scenarios around climate factors (like pathways for temperature, carbon prices, emissions, etc.) and macroeconomic factors (like GDP, inflation, interest rates) into the impacts on economic sectors and countries, and then on the specific company or even specific activities, which can in turn be translated into specific asset shocks.

  In practice, the asset shocks could be derived per sector (e.g., based on the NACE codes) but might also be based on a more sophisticated breakdown by technologies, analysis of emissions, etc.

  Developing shocks based on a very granular analysis might be challenging at this stage, as best practices have not yet been developed. Although in their working papers EIOPA had been suggesting certain methodologies for deriving shocks (discussed later in this paper), we are not convinced that any of these methods could represent a straightforward algorithm for companies to derive shocks. EIOPA perhaps realizes this, as no reference to the technical approaches is made in the application guidance. Instead, EIOPA states the following: *The calibration of the shocks could be based on expert judgement principles, backed by relevant and updated studies, <u>or on existing stress tests which already tried to quantify the impact of transition risks on the assets</u>*(...). In reality, this means that using the shocks provided by one of the regulatory stress test exercises will be accepted by regulators, at least over the first few years.
- **Evaluating the financial impact** of the shocks on assets and liabilities, following the adopted methodology (e.g., instantaneous shocks or multi-year balance sheet projections) and on prudential indicators like Solvency Capital Requirements.
- **Assessing resilience and potential responses**, being an integral part of ORSA in which companies, following a forward-looking assessment of risks, evaluate implications for business models, investment strategy and insurability of risks and develop management actions aiming to mitigate risks as appropriate.

## How to define scenarios

In the application guidance, EIOPA suggests that the following options can be considered in the definition of scenario narratives, where the choice will depend on the results of the materiality assessment:

- **Single risk factor**: Considering only a specific asset or insurance risk factor (under a justified assumption that other factors are not material)
- **Single scenario**: Multiple risk factors but only a specific area of shock (e.g., assets or liabilities)
- **Combined scenario**: Multiple risk factors affecting both assets and liabilities

Before issuing the application guidance, EIOPA did not use this classification. For example, the EIOPA sensitivity analysis performed in 2020 used the 'single scenario' type of analysis, as only assets were stressed. On the other hand, several prudential stress test exercises performed so far were based on combined scenarios, as the value of liabilities was impacted at least via the discount rates. Although it is too early to judge it with certainty, we feel that in most cases companies will perform either single scenario or a combined scenario type of analysis, while single risk factor will be applicable only to companies with very specific outcome of materiality assessment.

In order to evaluate transition risks, it is useful to refer to the set of scenario narratives recommended by the Network for Greening and Financial Systems (NGFS) and referred to in multiple documents issued by EIOPA:

- **Orderly transition**: Emissions are reduced starting now, and the transition to a carbon-neutral economy starts early. The increase in global temperatures stays below 2°C (in line with the Paris agreement).
- **Disorderly transition**: Emissions are reduced later, and the transition to a carbon-neutral economy starts late. The increase in global temperatures stays below 2°C (in line with the Paris agreement); however, the transition path is not smooth and includes a sudden shock related to the disorderly introduction of very strict policies.
- **Too little, too late transition**: There is a delay in the starting point and, due to physical risk arising, the transition is disorderly and the global temperature goal is not met.
- **Hot house world**: Business continues as usual with no additional policy action. The global temperature goal is not met.

Note that EIOPA has been placing special emphasis on the disorderly transition scenario compared to the orderly transition scenario. EIOPA considered this scenario both in the 2020 'Sensitivity analysis of climate-change related transition risks' (EIOPA Sensitivity Analysis 2020) and in its 'Climate scenario for the European Insurance and Occupational Pensions Authority's EU-wide pension fund stress test in 2022' (EIOPA Stress Test for IORPs 2022).

So how do these scenarios impact investors and how do they impact financial assets? Each scenario gives a glimpse of future climate effects and how these can impact the price of financial portfolios. For example, to meet the global temperature goal, in the orderly transition, the global response might be to impose policies like a carbon tax on high $CO_2$ emitters. This can significantly increase the cost of carbon and reduce carbon emissions. As a result, this would likely be reflected in lower share prices and stranded assets, as there would be an increase in the cost of equity for companies that are high polluters.

Technology risk can arise, for example, when there is insufficient investment in systems and processes to measure and manage climate risks, leading to missed opportunities, strategic consequences, increased costs, and eventually leading to decreases in the value of equities or possibly even to impairments.

Under an orderly transition scenario, the implementation of a carbon tax might reduce the profitability of a carbon emitter proportionally to its emissions. Under a disorderly transition scenario, the implementation of a carbon tax is introduced late, reducing the time available for carbon-emitting companies to reduce their emissions, leading to a sudden increase in the price of carbon. This impacts companies' revenues through changes in supply and demand. As the cost of production becomes significantly higher, prices of carbon goods will increase, and demand will decrease. This effect of increased costs will be more pronounced for a disorderly transition, and hence asset volatility will be greater.

While it is possible to build narratives such as that above, translation of scenario narratives into real economic impacts is highly non-trivial. Significant support for companies and regulators will therefore be found in the scenarios published by the NGFS, a working group made up of a majority of global central banks and financial supervisors in collaboration with leading academic centres.

In the first phase of their project, the NGFS published scenarios with future pathways for climate and macroeconomic variables, such as energy demand, investments, electricity capacity, carbon prices, emissions, temperature trajectories, agricultural variables, GDP, etc.

Although NGFS scenarios can represent a very good reference for stress testing, at this stage supervisors or companies are still left with the difficult task of disaggregating the climate and macroeconomic variables into the specific impacts on financial assets per sector, per firm or even per activity of individual firms.

It is worth emphasizing that in a phase two update, NGFS plans to publish scenarios at a more granular level, adding more macroeconomic variables, exploring further dimensions of risk, and expanding regional and sectoral coverage. Such scenarios would likely provide a much better basis for constructing long-term transition stress tests focused on financial assets.

However, so far, the NGFS scenarios did not provide any indication how to quantify shocks, e.g., per individual asset/sector, etc. The application guidance makes it clear that no sophisticated approaches will be required, at least not at the start. Assessing the impact of climate risk on the financial sector is very new, both as an area of academic research and as industry practice. It also seems clear that smaller companies especially may face issues of limited expertise in this area and limited data with which to calibrate meaningful shocks. Taking this into account, EIOPA explicitly suggests using previously calibrated shocks (e.g., those of prudential stress tests exercises) as the basis for stress testing.

For financial supervisors, the primary objective of this stress testing exercise is to increase awareness of the potential impacts of climate risk on the balance sheet and to integrate these within the risk management system and the system of governance, even if quantification methods will be initially high-level and based on best effort.

Nevertheless, in its 'Methodological principles of insurance stress testing—climate change component' published in early 2022, EIOPA investigated four possible modelling approaches which could be used for the process of calibrating shocks for assets: CLIMAFIN, CARIMA, NIGEM and PACTA. In the application guidance, EIOPA does not refer to these methods however, perhaps because none of these methods may be applied without significant research and/or elements of expert judgement. This seems to confirm our own findings in considering these methods, though there is the possibility that some may evolve in the future.

Nevertheless, we believe that learning the basic principles of these methods could be very useful in terms of understanding transition risks, and we describe each method briefly in the appendix.

Going forward, EIOPA intends to liaise with the academic community, practitioners and model vendors on the exact calibration of shocks.

# Past prudential stress tests

### DE NEDERLANDSCHE BANK (DNB) 2018 STRESS TEST

In 2018, De Nederlandsche Bank (DNB) published a research paper, 'An energy transition risk stress test for the financial system of the Netherlands' (DNB stress test). which included a stress test on financial assets exposed to transition risk The stress test was conducted on EUR 2,256 billion of assets held by banks, insurers and pension funds located in the Netherlands, with most assets belonging to banks (EUR 970 billion) and pension funds (EUR 1,067 billion).

The shocks were calibrated by the supervisor, and the DNB calculated balance sheet sensitivities disaggregated by type of financial institution (banks, pension funds and insurers) and type of asset (bonds versus equities), as well as by type of industry and scenario specifically for the transition risk.

DNB applied the NIGEM macroeconomic model to assess the Global Stock Price Index (level) by scenario for a five-year projection based on stressing carbon variables like price of coal, gas, and oil per policy scenario.

The Global Stock Price Index (level) from the NIGEM model was disaggregated to industry level by applying so-called transition vulnerability factors (TVFs), calculated for each scenario. These were applied to the global stock price index (level) to yield equity shocks by industry and by scenario. TVFs were constructed using the Capital Asset Pricing Model (CAPM) and were based on the embodied emissions of the final goods and services in each industry by considering emissions of the firms upstream in the value chain.

To assess the impact on bonds, the regulator used the projected changes in 10-year government bond yields as a proxy for the change in the risk-free rate for all maturities. Also, the impact of credit spreads was applied in the recalculated bond prices per scenario. The movement in the credit spread reflected the estimated changes in the probability of default, based on changes in GDP at the macroeconomic level obtained by the NIGEM model, equity returns obtained through the disaggregated model calculated by sector and scenario, bond ratings and the remaining maturity of the bond.

DNB used the four scenarios as defined below, all of which are used to assess the impact on the global stock price index and TVFs:

- **Policy shock scenario:** Carbon price increase by USD 100 per ton of $CO_2$ emissions. The shock runs through the macroeconomic model yielding lower GDP growth, higher inflation, a decrease in stock prices and higher interest rates. Higher energy costs increase the cost of production, resulting in lower profitability. This in turn can bring down investment as well as equity prices
- **Technology shock scenario:** Unanticipated technological breakthroughs allow the share of renewable energy in the energy mix to double in five years. Two macroeconomic shocks are used: (i) adjusting the production function such that fewer fossil fuels are used to produce a given amount of output, and (ii) increasing the speed of depreciation of fossil fuel intensive fixed capital (from 1 to 1.25). As a result of this shock, the share of fossil fuels required to produce a given amount of energy falls by 20% at the end of the five-year horizon. An additional 6% of depreciation of the capital stock in the first year is imposed, and an additional 4% of depreciation of the capital stock in the second year. In total, 10% of the current capital stock is written off because of the technological breakthrough.

- **Double shock scenario:** The shocks from the policy and technology shock scenarios occur simultaneously. Due to this combination of shocks, losses in this scenario are higher than in the policy or technology shock scenario alone. The distribution of these losses, however, is likely to be identical to the distribution of losses in the technology shock scenario.
- **Confidence shock scenario:** Uncertainty regarding government policies to combat climate change causes a sudden drop in the confidence of consumers, producers and investors. Specifically, it is assumed that policy uncertainty triggers a sudden drop in confidence, such that consumers delay their purchases, producers invest more cautiously, and investors demand higher risk premiums. As a result, there is a setback in GDP, stock prices fall, and lower inflation leads to lower interest rates.

This stress test should be seen as an attempt to determine the impact of a disruptive energy transition for the Netherlands. The stress test results suggest that losses for financial institutions could be sizeable in the transition to a green economy but can be manageable.

Losses for insurers ranged from 2% of total stressed assets in the technology shock scenario to 11% in the double shock scenario, with the interest rate having the most impact in three out of the four scenarios. The bond portfolio of insurers is typically characterized by high durations, which leads to significant asset value decreases when interest rates rise. For example, in the double shock scenario, 9% out of a total 11% loss is driven by interest rates.

We note that in the case of insurers the effect of rising interest rates on the asset side is offset by the effect on liabilities. In some cases it may even happen that the overall impact on Solvency II own funds might be positive.

#### PRUDENTIAL REGULATION AUTHORITY (PRA)/BANK OF ENGLAND 2019 INSURANCE STRESS TEST

Between July and September 2019 the Prudential Regulation Authority (PRA) conducted stress testing exercises for life insurers including an exploratory exercise for managing difficult-to-assess risks—in this case, climate risk. This bottom-up exercise was designed to capture information on how different firms are managing climate-change-related risks.

Firms were requested to consider the impact of three hypothetical greenhouse emission scenarios on selected metrics of their business models and asset values. These scenarios were expressed in terms of physical risks as well as financial impacts related mainly to transition risk:

- **Scenario A:** A sudden transition (a Minsky moment), ensuing from rapid global action and policies, and materialising over the medium-term business planning horizon that results in achieving a temperature increase below 2º C (relative to pre-industrial levels), but only following a disorderly transition. In this scenario, transition risk is maximized.
- **Scenario B:** A long-term orderly transition scenario that is broadly in line with the Paris Agreement. This involves a maximum temperature increase well below 2º C (relative to pre-industrial levels), with the economy transitioning over the next three decades to achieve carbon neutrality by 2050 and greenhouse-gas neutrality in the decades thereafter.
- **Scenario C:** A scenario with failed future improvements in climate policy, leading to a temperature increase of more than 4° C (relative to pre-industrial levels) by 2100, assuming no transition and continuation of current policy trends. Physical climate change risk is high under this scenario, with climate impacts reflecting the riskier (higher) end of current estimates.

The PRA provided shocks on investments by sector, by scenario and by type of asset, for both physical and transition risk. The PRA calibrated these assumptions based on its own research.

The equity shock varied between sectors, with the harshest impact ranging from 40% to 65% for climate-exposed industries (fuel extraction, power generation, food, agriculture), depending on scenario. Due to the complexity of the calculation for corporate bonds, the shock was defined as 15% of the equity shock. Sovereign and municipal bonds were not assessed for transition risk.

### PRA/BANK OF ENGLAND 2021 CLIMATE BIENNIAL EXPLORATORY SCENARIO (CBES)

The objective of the 2021 BES bottom-up stress test is to test the resilience of the current business models of the largest banks, insurers and the financial system to physical and transition risks from climate change. Participating institutions were required to calculate the impact on their exposures for three detailed climate scenarios provided by the Bank of England over an extended time horizon of 30 years. The three scenarios followed broadly similar narratives to those of the 2019 exercise, and were described as:

- Early policy action scenario
- Late policy action scenario
- No additional policy action scenario

Participants were required to calibrate the model on their own, based on the above scenario narratives and the evolution of macroeconomic factors from NGFS scenarios (provided by the regulator).

The Bank of England published aggregate results in May 2022. From the analysis it seems that insurers' asset values fell by 15% in the No Additional Action (NAA) scenario, compared with 8% and 11% in the early and late action scenarios. The losses were driven mainly by falls in the value of equity holdings and falls in bond prices due to increases in interest rates and increases in credit downgrades/defaults for corporate bonds. Investment losses were the highest for the early action scenario, as the impact of transition policies on corporate profits starts to come through earlier compared to the late action scenario.

### BANQUE DE FRANCE 2020 CLIMATE PILOT EXERCISE

This pilot stress test exercise in France took place in 2020 and involved nine banking groups and fifteen insurance groups, covering 85% of the total balance sheet of banks and 75% of the total balance sheet of insurers. The analysis was performed using a bottom-up approach and covered the impact of physical as well as transition risks.

The Banque de France relied on the guidelines published by the NGFS and gave three transition scenarios: a baseline scenario and two disorderly scenarios:

- Baseline orderly scenario
- Late transition
- 'Sudden transition'

Banks were required to perform full balance sheet projections while insurers performed balance sheet shocks for different asset classes and business sectors. The calibration was done in accordance with the NGFS guidelines on the construction of climate change scenarios and was based on two of the scenarios published by the NGFS in June 2020.

The impact of asset shocks was measured as a deviation from the initial market value in 2025 and 2050 for the late and sudden transition scenarios, so that both short and longer perspectives were taken into account.

The report summarized the impact of transition risk and physical risk for banks and insurers per asset class and sector and for the entire industry. This pilot exercise revealed a generally moderate exposure of French banks and insurers to climate transition risk. One of the reasons is that French financial institutions already have quite a low exposure to 'brown' sectors, as a result of significant commitments already made within the French market in terms of climate-related investment policies.

### EIOPA SENSITIVITY ANALYSIS 2020

EIOPA's top-down climate stress test was performed in 2020. EIOPA used data reported under Solvency II, combined with external sources, to assess the impact of climate-change-related transition risks within the portfolios of European insurers.

In their sensitivity analysis, EIOPA considered only one scenario, corresponding to the case of late policy/disorderly transition.

The report provides balance sheet sensitivities for the entire market, with some key figures split by EU countries. The calibration of equity shocks was done in cooperation with PACTA. The derivation of equity shocks assumes that the production shock is a function of the difference in capacity between the late transition and the International Energy Agency's (IEA) Sustainable Development Scenario (SDS, referred to as a 'two-degree scenario'). The impact on equity prices is then a function of the required changes in production and the misalignment with the two-degree scenario. The report uses a carbon budget accounting method where greenhouse gas (GHG) emissions are targeted to reach the outcome.

The shock on corporate bonds was assumed to be equal to 15% of the equity shock for the same counterparty. Here EIOPA used the assumption of the PRA 2019 stress test exercise.

For government bonds, EIOPA calculated per-issuer shocks following the approach of Battiston and Monasterolo (2019), based on the CLIMAFIN framework developed by Battiston et al. (2019). In their work, the authors considered a scenario which was defined to be broadly consistently with the disorderly transition scenario used by EIOPA, so in effect the results from the paper were replicated by EIOPA for the purpose of the sensitivity analysis.

It should be noted that this sensitivity analysis did not take into account macroeconomic impacts on, e.g., interest rates, but was limited to shocks on equities and corporate and government bond spreads.

The impact the of equity shock on the total balance sheet reported by solo undertakings in Q4 2019 was almost 20% (17% of non-linked and 19% for unit linked), while for corporate bonds the impact was nearly 2.5% for non-linked and 4% for unit-linked of their total market values. It should be noted that this is the net impact, including considerable gains from the transition through investments in, e.g., renewable power generation and nuclear industry.

The impact on the aggregated portfolios of equities, corporate bonds and government bonds was limited to about 0.3% for non-linked and 0.7% for unit-linked business, while the impact on the excess of assets and liabilities (directly impacting the solvency ratio) was about 0.8%. This impact varied a lot across countries, from a 0.1% impact on Own Funds for Iceland to 2.1% for the UK.

In general however, the total impact of the disorderly transition scenarios on the balance sheet of insurers was rather mild based on the output of this analysis, although of course for companies which are more exposed to risky assets in sensitive sectors the impact could be considerable.

### EIOPA 2022 STRESS TEST FOR INSTITUTIONS FOR OCCUPATIONAL RETIREMENT PROVISION (IORPS)

EIOPA has initiated in 2022 an EU-wide stress test to assess the resilience of IORPs to adverse developments in climate risk.

The individual risk factors of the climate scenario presented were calibrated based on the scenarios developed by the NGFS. The EIOPA stress tests looked at the disorderly transition only, where climate policies are assumed to be introduced by 2030.

EIOPA provided the calibrated shock values, derived from the NIGEM model. For example, in a disorderly scenario, the impact on equities per industry ranged from 10% to 38% depending on sector (the most severe shock is applied for the sector of mining and quarrying). For corporate bonds, the impact on credit spreads ranged from 121 to 467 bps, depending on sector by NACE code. The stresses also included a change in interest rates (with the increase ranging from 0.6% to 0.8% for the EUR, based on maturity) and the aggregate impact on government bond yields (per country and maturity, with an impact of 111 bps for bonds with 10-year+ maturities in the Eurozone).

EIOPA created an easy-to-use helper tool in Excel which provided all stresses per asset class, sector, country and maturity.

# Practical illustration

In this final section we present a simple numerical example to illustrate a possible order of magnitude for a climate risk stress test on the balance sheet of an insurance company. We base the example on the shocks defined in the IORP stress test described above. We used the shocks for

- The risk-free EIOPA curve
- Government bond yields (Eurozone)
- Equities and corporate bond spreads (per sector)

We summarize the shocks in the following figures.

**FIGURE 3: RISK-FREE CURVES (BASED VS. SHOCKED) AND GOVERNMENT BOND YIELD SHOCKS**

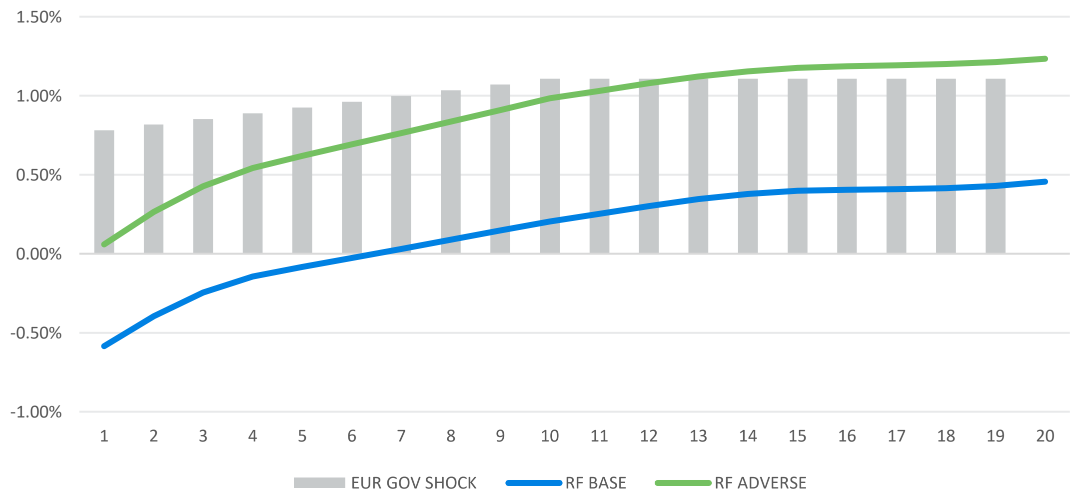
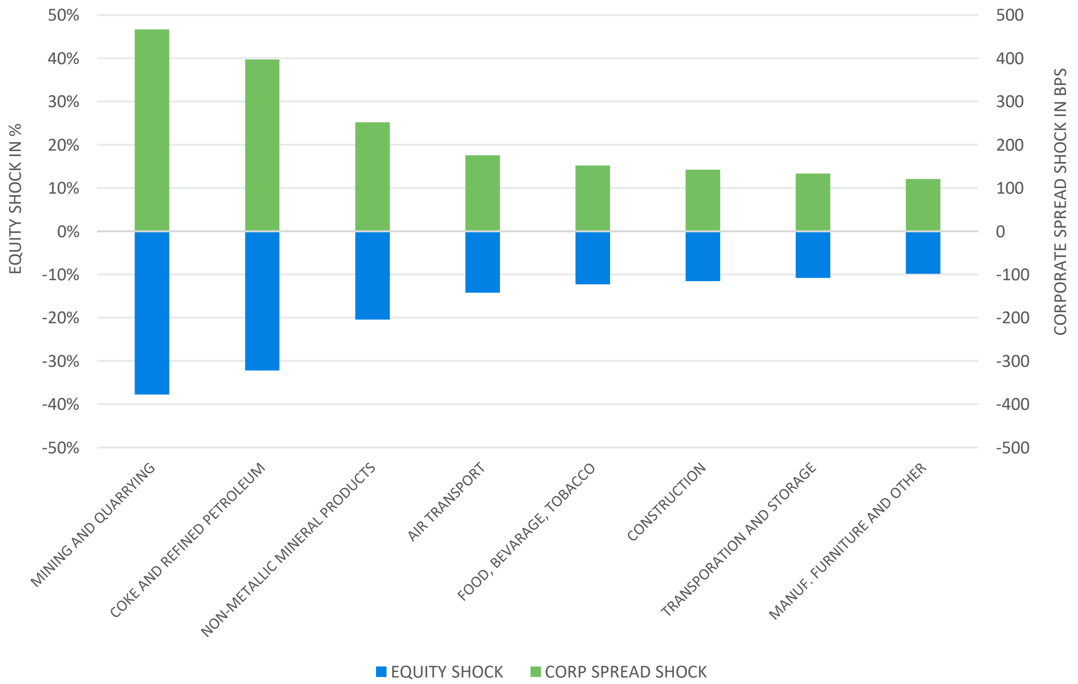


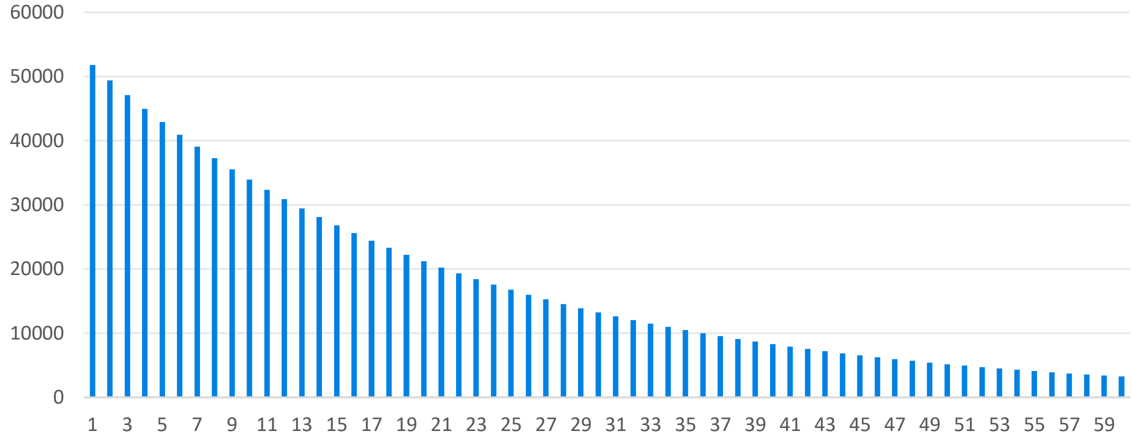

**FIGURE 4: EQUITY AND CORPORATE SPREAD SHOCKS FOR SELECTED SECTORS**



We consider two asset portfolios (high-risk portfolio and low-risk portfolio) where the risk is related both to the composition of the asset classes (exposure in equities and corporate bonds) and to the split of sectoral exposures within those asset classes. We assume also that these asset portfolios cover certain liabilities, with the same cash flows in all calculations. In particular, we assume in this illustration that the liabilities do not have any participation features (or these are immaterial) so that the asset mix and interest rates do not impact liability cash flows.

We assumed certain life insurance liability cash flow profile as provided in Figure 5 below.

**FIGURE 5: LIABILITY CASH FLOW PROFILE**

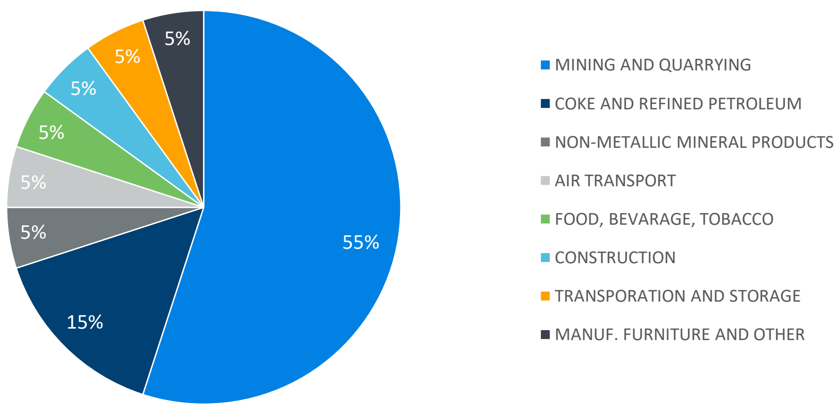



We consider two asset mixes. The high-risk portfolio has the following composition of assets:

- 55% in government bonds
- 35% in corporate bonds
- 10% in equities

For corporate bonds and equities we assumed the same distribution between sectors as in Figure 6 below.

**FIGURE 6: SECTOR COMPOSITION OF THE HIGH-RISK PORTFOLIO**

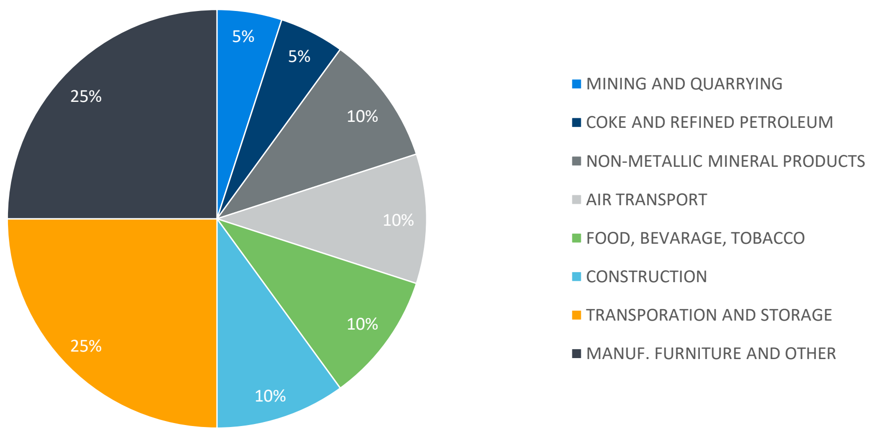



The low-risk portfolio has the following composition of assets:

- 70% in government bonds
- 25% in corporate bonds
- 5% in equities

Again, we did not differentiate the composition between sectors for equities and corporate bonds, as shown in the figure below.

FIGURE 7: SECTOR COMPOSITION OF THE LOW-RISK PORTFOLIO




Moreover, for both portfolios we assumed the same composition of fixed income instruments in terms of duration:

- 30% in bonds of each type of duration two years
- 40% in bonds of each type of duration of six years
- 30% in bonds of each type of duration of 10 years

We calculated the results of the shocks obtaining the results shown in Figure 8.

FIGURE 8: THE RESULTS OF CLIMATE RISK STRESS FOR A HIGH-RISK AND LOW-RISK PORTFOLIO

| | HIGH-RISK PORTFOLIO | LOW-RISK PORTFOLIO |
|---|---|---|
| **BASE MV ASSETS** | 1,000,000 | 1,000,000 |
| **BASE BEL** | 918,606 | 918,606 |
| **OWN FUNDS** | 81,394 | 81,394 |
| **SHOCKED MV ASSETS** | 845,804 | 911,899 |
| **SHOCKED BEL** | 838,600 | 838,600 |
| **SHOCKED OWN,FUNDS** | 7,203 | 73,299 |
| **% IMPACT ASSETS** | -15.4% | -8.8% |
| **% IMPACT BEL** | -8.7% | -8.7% |
| **% IMPACT OWN FUNDS** | -91.2% | -9.9% |

As we observe in the table, in the case of the low-risk portfolio, the assets fall by 8.8% but the fall of Own Funds is limited to less than 10% because of the offsetting impact of the increase in interest rates on the long-dated liabilities.

On the other hand, for the high-risk portfolio, the impact on assets (in particular on corporate bonds and equities) is significant and is not offset by the fall in BEL. As a result, Own Funds fall to very low levels.

For avoidance of doubts, the high-risk portfolio is not very likely to appear on an insurer's balance sheet. The 2020 sensitivity analysis by EIOPA shows that the exposure of insurers to climate-sensitive sectors is not very high. The purpose of this illustration is mostly to illustrate how such extreme asset allocation could be reflected in the stress test.

## Summary and conclusions

EIOPA has very recently issued the application guidance for running materiality assessment and scenarios for ORSA. This application guidance, together with a few earlier documents issued by EIOPA, present a lot of interesting material on how such scenarios could be constructed. However, while in earlier documents EIOPA suggested certain quantitative techniques for calibrating the shocks, in the application guidance it is explicitly stated that companies could simply reuse the shocks from other climate-risk-related stress testing exercises (taking into account the assessment of materiality).

In reality. the latter is an explicit acknowledgement that 'scientific' calibration of asset shocks could be a big challenge for all insurance companies (not just smaller companies). It seems that regulators are aware of this, and the overall expectation is that, especially at the beginning, the ORSA stress tests will be explorative by nature while market best practice emerges.

This paper provides a numerical illustration with shocks calibrated to the most recent EIOPA stress test for Institutions for Occupational Retirement Pensions (IORP's), which we understand should represent a fully legitimate approach for ORSA reporting.



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# Appendix: Modelling approaches to transition risk

### CLIMAFIN

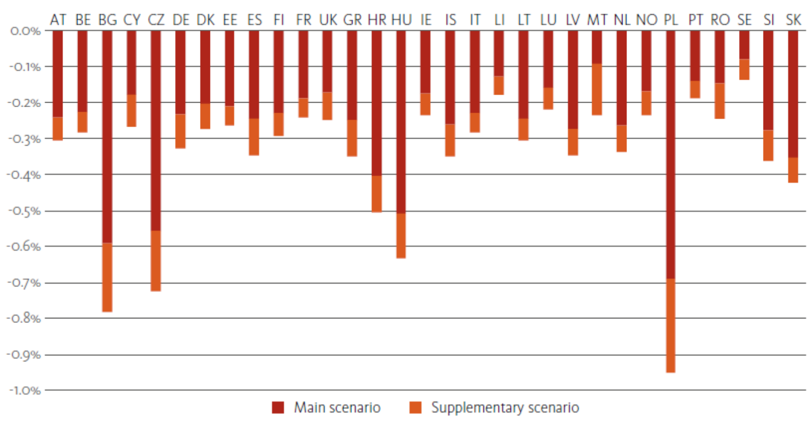
The Climafin model has been developed by Battiston et al. (2019). Under this approach, financial pricing models are adjusted to allow for the effect of climate scenarios and forward-looking transition risk shocks. Theoretically, the Climafin model can be used for different asset classes (equities, corporate bonds, government bonds); however, this approach gained particular popularity for its development of shocks on government bonds, following Battiston and Monasterolo (2019). EIOPA applied this model for government bonds in their Sensitivity Analysis 2020.

The Climafin model is a bottom-up approach which is based on estimating the contribution of firms' profitability to the Gross Value Added (GVA) of different sectors. Based on assumed transition scenarios corresponding to the concentration of certain greenhouse gas emissions in the atmosphere, the authors calculate economic trajectories for the fossil-fuel and renewable-energy sectors.

The impact of the shocks on market share and GVA of firms and sectors is calculated using two so-called Integrated Assessment Models (IAMs): the Global Change Analysis Model[2] (GCAM) and the World Induced Technical Change Hybrid[3] (WITCH). These are (partial or general) equilibrium models, calibrated on the recent state of the economy and climate targets, and provide trajectories in which the economy remains in equilibrium along any given trajectory. The output of these models is used subsequently for calculating the impact on fiscal revenues of the sovereigns and finally on the sovereign fiscal asset, default probability and related 'climate spread.'

Battiston and Monasterolo (2019) applied the methodology to the portfolio of sovereign bonds issued by OECD countries and included in the Austrian National Bank's (OeNB) non-monetary policy portfolio, and Battiston et al. (2019) analyses the impact of a climate policy shock on the sovereign holdings of European insurers based on Solvency II reporting. The latter results were replicated by EIOPA in the Sensitivity Analysis published in 2020, which led to the shocks per issuer country shown in the figure below.

**FIGURE 9: SHOCKS OF SOVEREIGN SPREADS PER ISSUER COUNTRY**




Source : EIOPA Sensitivity analysis of climate-change related transition risks

### CARIMA

Carbon Risk Management (CARIMA) is based on measuring the 'carbon risk' beta of an asset/portfolio by the so-called carbon risk factor BMG (brown-minus-green) with reference to the Capital Asset Pricing model (for example, Fama and French (1993)).

The idea behind evaluating an investment or asset portfolio's carbon risk is to assess and finally reduce the portfolio's carbon footprint. The way to achieve this is to be more exposed to green, low-carbon, companies than to brown, high-carbon, companies. Overall, the carbon beta is a market-based relative risk measure that quantifies the risk of losses, as well as the chance of profits, resulting from the uncertainties of the transition process towards a green economy.

[2] http://www.globalchange.umd.edu/gcam/

[3] https://www.witchmodel.org/

Estimation of the carbon beta in the CARIMA model is based on a two-step approach. First, the BMG risk factor is created, e.g., based on information from different ESG databases. The BMG factor corresponds to a time series of returns of a benchmark portfolio built on a long position in 'brown' assets and short positions in 'green' assets.

Second, a statistical CAPM-like model is considered. It can take different forms depending, for example, on the type of underlying assets—the authors explicitly consider models for equities, corporate bonds, loans and funds. For example, for equities the equation can take the following form, which was derived as an extension of the Fama and French (1993) 3-factor model:

$$r_t = \alpha + \beta_M r_{M,t} + \beta_{SMB} SMB_t + \beta_{SMB} HML_t + \beta_{BMG} BMG_t + \varepsilon_t,$$

where

- $r_t$ – return of an equity share
- $r_{M,t}$– return of a market portfolio
- $SMB_t$– the global size factor (small minus big)
- $HML_t$– the global value factor (high minus low), where high / low are related to book to market value ratio
- $BMG_t$ – global climate factor (brown minus green), introduced by the CARIMA model and calculated in step 1.

Note that for all the factors involved (market factor, cap factor small minus big and value factor high minus low), for many economies the relevant time series are available and updated regularly. These time series can be downloaded from Kenneth French's website.[4]

From a practical point of view, it is perhaps important to note also that the CARIMA model can be applied top-down as well, to obtain the carbon beta of an entire portfolio.

The resulting carbon betas have a relatively simple interpretation: if the carbon beta is greater than zero, then the portfolio is exposed more to 'brown industries,' while when it is negative the portfolio is biased towards 'green industries.' Depending on the climate transition path, in the short term green assets may outperform brown assets (e.g., if restrictive climate polices are implemented very early on) and in such cases portfolios with low carbon beta will perform better. On the other hand, in the case of delayed transition policies, brown assets could outperform green assets in the short term, giving preference to portfolios with higher carbon beta.

Carbon betas can easily be aggregated from the level of single assets up to an entire portfolio, sector and even country level, due to their additive properties. Equally weighted carbon betas correspond to the average of the carbon betas of the individual financial assets. It is also possible to derive appropriate measures using a value-weighted basis, i.e., weighting individual assets by market capitalization. In practice, carbon beta provides a consistent approach to quantifying carbon risks and allows for managing a wide range of asset classes.

The potential advantage of this approach for stress testing is related to the independence of the BMG risk factor from the actual portfolio. Hypothetically, this risk factor could be calculated for different economies and updated in subsequent years by a certain index provider or research centre (e.g., in a similar way to the indices published on Kenneth French's website), and end users could then start their analysis from the second step, i.e., relatively straightforward statistical analysis based on linear regression. We understand, however, that this is currently not the case—the BMG risk factor was calculated by the authors as part of their research project for the US market for the years 2010 – 2019; however, we have not found any publicly available updates of this factor.

The CARIMA approach could become an interesting alterative for the development of stress scenarios, as in reality this approach could greatly simplify the process. Instead of generating multiple asset shocks per industry, per company or per activity, it can be sufficient to define the impact of specific shocks on the BMG factor. The shock would then be propagated to the entire portfolio in line with the calculated beta factor.

This would be especially attractive if the BMG factor were publicly available and hence not required to be calculated.

[4] French, Kenneth. http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

**NIGEM**

The National Institute Global Econometric Model (NIGEM)[5] is a leading global macroeconomic model used since 1987 by policy-makers and the private sector for economic forecasting, scenario building and stress testing. The model includes individual country models for major economies, linked together through trade in goods and services and integrated capital markets. NIGEM is an econometric model and represents a closed world, where outflows from one country or region are matched by inflows into other countries and regions.

The model is based on a broadly New Keynesian structure with many of the characteristics of Dynamic Stochastic General Equilibrium models. The country models are grounded in macroeconomic foundations, with features such as sticky prices, rational or model-consistent expectations, endogenous monetary policy based on a Taylor rule or other standard specifications, and long-run fiscal solvency. A key feature of the model is its flexibility, allowing users to define the scenario space, including policy regimes and the formation of expectations by consumers, firms, wage setters and/or financial markets, together with other assumptions and judgements. The model considers a wide range of global macroeconomic variables as well as variables driving global asset prices like equities and interest rates.

Climate risk scenarios are created by observing how all macroeconomic variables (linked together via a network of econometric formulas) respond to certain shocks—for example, a shock to the price of fossil fuels as defined within a high-level narrative scenario.

The NIGEM is also the model underlying the climate transition scenarios published by NGFS. The NIGEM model has also been used for calibrating the prudential stress tests for energy transition by De Nederlandsche Bank, as well as for the Banque de France stress test and most recently the EIOPA stress test for IORPs. For example, in the pilot climate risk exercise performed by Banque de France and published in May 2021, three scenarios were considered (orderly transition, delayed transition and accelerated transition), with the main driving factor being based on a carbon tax schedule. From this, certain paths for the price of carbon were then used as an input to the NIGEM model, which was in turn used to produce macroeconomic scenarios for the entire world.

From a practical point of view, the most relevant outputs from the NIGEM model for insurers performing stress tests are those variables directly impacting asset prices, e.g., interest rates, equity prices or real estate prices. The process of transition can have a significant impact on asset prices as it can result in economic slowdown, with falling equity prices, increasing inflation and rising interest rates (due to the attempts of central banks to curb inflation). Rising interest rates will of course result in falling bond prices. The impact on credit spreads requires additional analysis, and could be done by assessing the probability of default based on changes in GDP at the macroeconomic level (which can be obtained from the NIGEM model) or equity returns. This may need to be done at a disaggregated level (e.g., sectoral) and, generally, credit spread is not a standard output from the NIGEM model.

Nor does the NIGEM model provide an answer as to how global economic impacts can be translated into the effect on individual assets (or at least on sectors). For this reason, additional modelling approaches will need to be considered to obtain shocks that can be applied to individual assets.

An analogous disaggregation exercise has been performed by Banque de France in their 2020 climate risk stress testing exercise. Aside from a similar CAPM-like model, Banque de France also applied different models based on projections of industry-specific value-added and dividend flows, which are linked to sector-level stock returns using a Dividend Discount Model. Banque de France combines different approaches, including their proprietary credit rating model.

In conclusion, the NIGEM model could be very helpful in developing shocks for climate ORSA scenarios; however, considerable additional (and challenging) work would need to be done to obtain results at a more granular/disaggregated level. Nevertheless, it is the NIGEM model which is currently at the foundation of most calibrations used for prudential stress tests.

[5] A proprietary model by National Institute of Economic and Social Research in UK

**PACTA**

The Paris Agreement Capital Transition Assessment (PACTA) is a public and open-source tool developed by the 2 Degree Investing Initiative (2DII) that aims to measure the alignment of various financial portfolios with climate scenarios.

The goal of the Paris Agreement treaty is to limit global warming to well below two degrees Celsius (and preferably to below 1.5 degrees). This objective translates into greenhouse gas (GHG) emission reduction pathways and then into a carbon budget. As various climate scenarios can give insight into possible decarbonisation pathways, but do not necessarily achieve the same goals via the same pathways, the PACTA often works with sets of scenarios.

As the requirements for meeting the goal of the Paris Agreement vary by sector and technology, so does the PACTA. The methodology distinguishes climate-relevant sectors such as power, fossil fuels, coal mining, auto manufacturing, cement, steel, aviation, shipping and heavy-duty vehicles, which together account for 75% of global GHG emissions. Based on the five-year production plans of companies in these sectors, and how they are linked to financial assets (equities, fixed income, corporate bond portfolios; PACTA for investors and loan books; PACTA for banks), the PACTA measures the exposure of investors' portfolios to climate-related sectors and identifies which sectors/companies (and ultimately asset classes) within the portfolio are the most significant for the results. This allows for comparison between the performance of the portfolio and market benchmarks.

The analysis is based on actual production figures for the real economy. Vast business intelligence databases (covering 40,000+ companies and 230,000+ energy-related physical assets) provide current as well as forward-looking production figures.

The PACTA provides three metrics at sector and technology level, projected up to five years into the future:

- For sectors with well-defined technology decarbonisation pathways (e.g., power, fossil fuels and automobiles) the alignment of the portfolio with different climate scenarios is derived, as well as a view of how the portfolio's technology mix within those sectors is expected to look in the future (based on current investment plans) and how it compares to the market.

  For these sectors, we also obtain the Production Volume Trajectories metric. This index aims to measure the alignment of production volumes, based on the five-year capital plans of the underlying companies, with the production volumes given by the climate scenarios.
- For sectors without technology roadmaps, for which there are no zero-carbon or low-carbon alternatives, or for which forecasting the growth of 'green' technologies may be difficult for other reasons (e.g, cement and steel, shipping, aviation), the PACTA provides the emission intensity metric. This compares the GHG emissions from production against industry targets (as $CO_2$/economic unit of output). These values are then compared to emission intensity reference values given by climate scenarios.

  The PACTA methodology assumes constant exposure/structure (i.e., buy-and-hold strategy) over the entire five-year period, and therefore the portfolio projections depend only on the underlying production plans of the companies and are not on any changes in the structure of the assets. The user describes the portfolio using just three inputs: ISIN24 code, market value and currency. An automatic report is then generated, covering geographical and sectoral split, analysis of technology and emissions and the estimated financial loss on assets (being the difference between stressed market value and baseline initial market value), and can be tailored by selecting two different transition scenarios.

  The estimated financial loss can be considered as a stress test on the asset side of the balance sheet. It should be noted, however, that the PACTA methodology has several practical limitations:

  - The time horizon of five years may be considered short for climate risk scenarios (although this is not necessarily too short in the case of transition risk).
  - Although there are several predefined scenarios usefully incorporated within the PACTA these cannot be customized.
  - The PACTA is a form of black-box solution, and the underlying data used for computations (e.g., sourced by Bloomberg) are not available to end users.
  - Last but not least, for confidentiality reasons it may be problematic to upload the actual asset portfolios of insurance companies to an open-source tool.

With these limitations in mind, it is worth noting that the PACTA is still developing and that in the future the functionality may align much better with the needs of insurers.

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