CORE MATTERS

A climate stress test model for credit spreads

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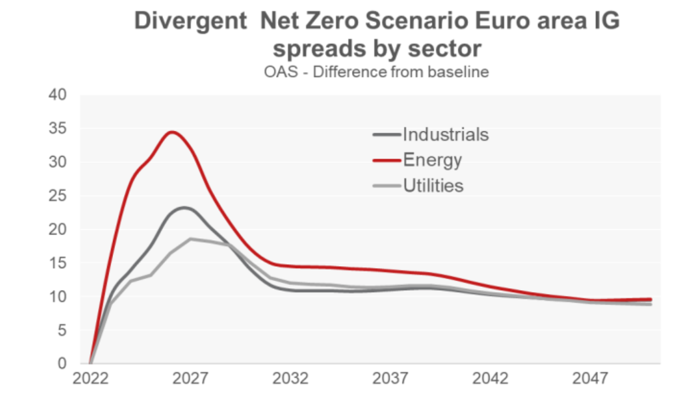
Our Core Matters series provides thematic research on macro, investment, and insurance topics



Source:GIAM

- Climate mitigation policies have varying impacts across sectors, which may not be fully accounted for in top-down scenarios. This limitation hinders the comprehensive assessment of their effects on a credit portfolio.
- In order to analyse the influence of climate scenarios on sectoral credit performance, we have developed an econometric model that establishes a link between a set of macroeconomic variables, financial market metrics, sector-specific expected and actual default probabilities, and finally credit spreads (by industry and rating class)
- This model enables us to evaluate the impact of both standard and climate-related economic scenarios on a wide range of credit spreads. The results can then be incorporated into Strategic Asset Allocation (SAA) and/or Asset and Liability management (ALM) tools. Additionally, risk management teams can leverage these findings to integrate climate stress testing capabilities.
- To illustrate the effectiveness of our approach, we simulated three macro climate scenarios using the same methodology employed by various central banks and the Network for the Greening of the Financial System (NGFS). Our findings reveal that delayed or uncoordinated climate risk mitigation policies could lead to increases of over 100 basis points in high yield (HY) spreads compared to baseline.
- The modelling approach, which follows the logic of the widely used NGFS scenarios developed by a group of central banks is based mostly on the historical relationships between variables. It has come under criticism as it may deliver too smooth, muted and in the end too reassuring responses of financial prices to the structural shift posed by climate change. We acknowledge this criticism and will tackle it in the development of our climate scenarios.
- In a companion paper, we will analyse in more detail the modelling of equities.

CONTENT

Stress tests are a key tool for assessing the risk of climate change and mitigation measures to the economy and financial markets. They were initially developed for regulatory purpose and are proving useful also to individual intermediaries willing to fine tune their asset allocation and risk management. However, the user-friendly tools used for this kind of stress normally often have a very aggregate modelling of financial assets. Typically, credit spreads, if available, are not broken down by rating class nor by sectors. Large and sophisticated bond investors should aim for a stronger approach.

In this thematic report we present our proprietary model which translates the output from a macro climate scenario into projections for sectoral credit spreads. We start by recapping the main issues involved in macro climate scenarios and sketching the global econometric model that we will use for our exercise. Then we describe in some details how our proprieraty credit model is specified. Finally, we illustrate the results of three climate scenarios, and specifically the impact on various credit spreads.

1. Macro-Financial Climate stress tests

The standard approach used by central banks[1] involves the combination of two kind of models. First, macrostructural models that use econometrically estimated parameters to establish relations between key economic variables, such as relative prices, changes in employment, unemployment, and inflation. The architecture of **macrostructural models** relies on standard economic theory (an IS-LM framework coupled with a Phillips curve relationship for inflation, on top of a classical growth model) and usually focuses on short-term disequilibrium in the economy following an initial shock. These are the same tools normally used to produce medium-term economic forecasts or to simulate the impact of fiscal policy or shocks like a rise in commodity prices.

The link between climate and economic outcomes is provided by **Integrated Assessment Models** (IAM)[2], which include feedback loops between economic outcomes and climate variables over time. This is modelled mostly through Greenhouse Gas (GHG) emissions, their impact on temperature and the consequences on long-term growth via slower productivity and a higher risk of disasters. This allows for the construction of decarbonisation trajectories as well as expected damages from climate change over time. This enables to compute the expected economic costs and benefits of climate policies.

Yet most available macro-econometric models do not have the sufficient level of detail as far as financial assets are concerned. Then for stress test purposes they are complemented by **satellite models** that link a measure of financial prices or returns to macroeconomic variables[3]. In this core matter we present our satellite model focused on corporate credit.

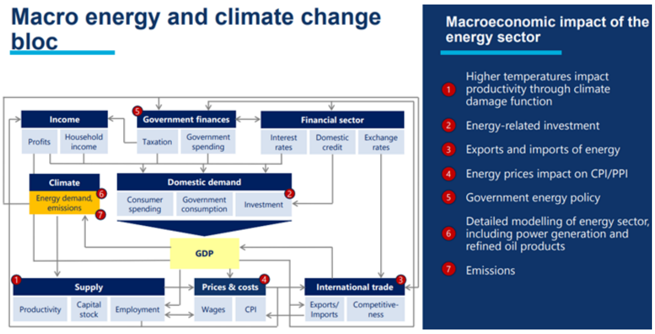
Our aim is to replicate, and build beyond, the core of the stress test procedure used by NGFS and several other central banks. This process entails beginning with a long-term database (in our case, extending up to 2050) that incorporates the impact of climate change, primarily the rise in temperatures, on economic growth, inflation, and other key macroeconomic and financial variables. Then the assumptions on climate policies are introduced: they feed though the economy and the financial system and *interact* with monetary and fiscal policy, determining the path for, say, GDP, employment, rates, sovereign yields and equity prices. At the same time, they determine a projection for GHG emission and temperature level, which feeds back to long term growth. Our satellite model then takes the projections for a few macro/financial variables and computes those for credit spreads.

The tool we use to compute the climate and macro projection is a widely used commercial model produced by Oxford

1 The reference for this kind of exercises is the work conducted carried out by several European central banks within the Network for Greening the Financial System. Its web portal provides a detailed explanation of the scenarios and the path for several macroeconomic and financial variables.

2 The pioneering work is Nordhaus, W. D. (1992). An optimal transition path for controlling greenhouse gases. Science, 258(5086), 1315–1319, another important reference is Tol, R. S. J. (2002). Estimates of the Damage Costs of Climate Change - Part I: Benchmark Estimates. Environmental and Resource Economics 211: 47–73.

3 They are called "satellites" because they treat macroeconomic variables as exogenous. This means that the feedback from distress in the parts of the financial market described in the satellite mode to the economy are not considered. This may lower the economic impact of the stress and may be a drawback of this approach. However, this must be weighed against the flexibility and user friendliness of this approach. Moreover, the macro model we use embeds already quite a lot of financial variables, so the second-round effect via markets is well considered.



Source: Oxford Economics

Economics. On top of the standard setting for the macro variables, it features a detailed model of the energy sector, which drives energy demand and a linkage between temperature and productivity – the so-called Climate Damage Function – which contributes to long-term growth. In this setup, climate policies are modelled by a shadow price of carbon (or a carbon tax), proportional to the CO2 content, that governments apply to the domestic price of fuels to steer demand away from the more polluting forms of energy. In the short term this affects the economy much like an increase in oil prices, by raising prices and lowering demand; the model allows to study the outcome of the shock and the possible different options for monetary policy (raise or not raise the policy rate in response to higher inflation) and for the fiscal authority (how to redistribute the extra revenue from the carbon tax).

As a result, changes in climate policies are translated into macro variables and key financial indicators, such as equity prices and sovereign yields (including the full yield curve for the largest economies). However, the model has limited coverage of credit variables. Nonetheless, it does provide a detailed breakdown of sectoral value added, which responds to industry-specific costs of energy influenced by their energy mix. Typically, the implementation of a carbon tax would lead to a greater increase in coal prices compared to gas prices, impacting the Gross Value Added (GVA) of sectors more reliant on coal or "dirty" fuels in general.

This is crucial in case of climate policy having a very diverse impact across sectors. For example, the table below shows the impact on GVA for several industries in the euro area induced by a series of policy actions that raise the cost of the most polluting fuels to reach net zero CO2 emission by 2050.

The impact is clearly stronger for the extraction industry, which faces a severe curb in demand, and energy intensive manufacturing, where the increase in the fuel bill lowers production. The financial industry contracts too following the decrease in demand for financial services. On the opposite, value added in utilities is higher than in the baseline, which assumes no additional decarbonisation policies on top of those already implemented. This is mostly due to the increase in electricity demand following the reduction in the consumption of fossil fuels.

Euro area: Gross Value added. Net Zero shock

(% dev. From baseline)

	2023	2030	2035	2040
Manufacturing	-0.2	-1.2	-2.0	-2.7
Coal, Oil & Gas	-0.4	-10.2	-14.1	-17.2
Financial services	0.0	-0.8	-1.5	-2.1
Utilities	0.5	2.7	1.4	-0.1
Total	0.0	-0.4	-1.0	-1.4

Source: Oxford Economics, GIAM

2.The satellite model for credit

From this sectoral breakdown we build our proprietary credit model. It aims to project the path of several sectoral and rating-based Option Adjusted Spreads (see table for the coverage) under the different scenarios, in a way that is consistent with the outcome for the main macro and financial variables. The model has two blocs: the first relates sectoral value added and other sector specific variables to a measure of expected default probabilities; the second translates these into projections for Option-Adjusted Spreads (OAS).

> *Our model projects the path for OAS under different scenarios using detailes sectoral information*

The key ingredient of the fist bloc is the probability of default (PD). Following an approach suggested by the Banque of France study[4] we use PD indexes developed by the National University of Singapore. Based on a statistical model, the 12mth ahead expected PD for each listed firm is computed using mostly firms' fundamentals and few aggregate variables. The individual default probabilities are then aggregated by sector and countries[5].

4 See Allen et. Al (2020)„ Climate-Related Scenarios for Financial Stability Assessment: an Application to France" – Banque de France Working Paper 774

5 For a technical exposure of the methodology, see Duan, J. et al. (2012). "Multiperiod Corporate Default Prediction – A Forward Intensity Approach", Journal of Econometrics, 179, pages 191-209. A nontechnical explanation and the series (up to one year ago) are available on the NUS Credit Research Initiative.

We use PDs aggregated by sector and estimate equations linking them to the evolution of value added in the relevant industries, plus measures of borrowing costs and other sector-specific drivers. PDs follow a non-normal distribution, so the estimated equations (on quarterly data) have the following specification[6]

$$PD_{c,i,t}^{12} = \frac{exp(\alpha+\beta_1 dlog(GVA_{c,i,t})+\sum_{q=1}^{N}\beta_q X_{q,t})}{1+exp(\alpha+\beta_1 dlog(GVA_{c,i,t})+\sum_{q=1}^{N}\beta_q X_{q,t})} + \varepsilon_{c.,i,t}$$

The 12-month ahead expected PD at time t for sector c in country y is a nonlinear function of the annual growth rate of the sector value added plus sector specific variables (like oil prices for energy or house prices for real estate) and/or borrowing costs (long term rates). Inserting a path for GVA and the other variables, the approach renders a projection for expected PD. In the second step, we then convert PDs into "theoretical" spreads, assuming a 40% recovery rate and using a formula commonly used in risk management

$$CS_{c,i,t}^{12} = -\frac{1}{12} log\left[1-(1-0.4)N\left[N^{-1}(PD_{c,i,t}^{12}) + \theta_{c,i}\sqrt{12}\right]\right]$$

where N() is a normal distribution function and $\theta(c,i)$ is calibrated to maximise the correlation between credit spreads and the corresponding one-year CDS.

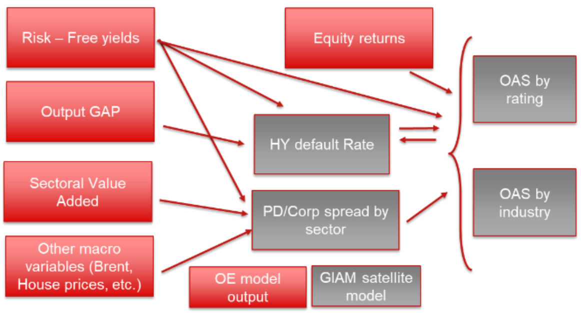
Then, we map the industry-specific credit spreads derived from default probabilities into observed sector market spreads[7] We model observed market spreads as a function of the following drivers: the fundamental-based credit spread just illustrated, a proxy for financial markets volatility (proxied by the square of the quarterly % change in the stock prices), the overall risk in the bond markets, measured by the actual HY default rate (see below); finally for the euro area we use the spread between core and peripheral 10 year government bond yields.

$$Spread_{c,i,t} = \alpha + \beta CS_{c,i,t}^{12} + \gamma dlog(P\_STOCKS_{c,t})^2 + \theta PDHY_{c,t-1} + \mu(10Y\_Periph_t - 10Y\_Core_t) + \varepsilon_{c,i,t}$$

Our satellite model also contains two equations for the actual default rate of HY bonds. They are function of the output gap and of the lagged yield on HY securities, computed as the sum of the credit spread and a medium-term sovereign interest rate.

$$PDHY_{c,t} = \frac{exp\left(\alpha + \beta GAP_{c,t-1} + \gamma\left(SHY_{c,t-1} + Y5YR_{c,t-1}\right)\right)}{1 + exp\left(\alpha + \beta GAP_{c,t-1} + \gamma\left(SHY_{c,t-1} + Y5YR_{c,t-1}\right)\right)} + \varepsilon_{c.t}$$

An important aspect to consider is the bidirectional relationship between credit spreads and default probabilities, which enables us to account for the second-round effects resulting from shocks to interest rates. The chart below summarises the connections between the Global macro model and our satellite.



The existing coverage in terms of sectoral default probabilities and credit spreads is presented in the table below. It is worth noting that the model can be readily expanded to encompass additional sectors or rating classes.

Satellite model: Coverage

Probability of Default	
Industrials	
Materials	
Real Estate	
Durables	
Financials	
Energy	
Utilities	
Spreads	
Euro Area	**US**
Financials - AA	IG
Financials - BBB	HY
Financials - HY	
Nonfin - AA	
Nonfin - BBB	
Nonfin - HY	
Covered Bonds	
Energy	
Industrials	
Utilities	
Durables	

3.The model at work: climate scenarios

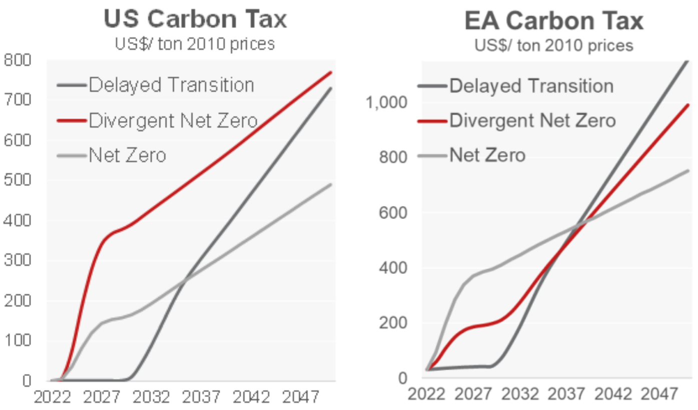
To illustrate the output of the model we present the results from three climate stress tests generated with the macro model and provided by Oxford Economics. They share with the similarly labelled NGFS scenarios the assumption on carbon taxes and investment in decarbonisation. The three scenarios are:

6 See Simons, D. and F. Rolwes (2009) "Macroeconomic Default Modelling and Stress Testing", International Journal of Central Banking, September, pages 177-204.

7 In the application presented here, we model Option Adjusted Spreads, but the framework can be used for other measures.

- **Net Zero:** restrictions on the usage of fossil fuels are introduced smoothly from 2023 on and in a coordinated fashion across countries and sectors. Together with heavy investment on decarbonisation and – later on – carbon capture, they bring net CO2 emission to zero by 2050 and give at least a 50% chance to limit global temperature rise to 1.5°C.
- **Divergent Net zero:** The outcome is the same as in the Net Zero but the scenario assumes that fossil fuels are phased out more quickly in developed economies. Policies are more stringent in transportation and construction, and less so in industry and power generation, due to coordination failure. This results in much higher inflation and more broadly higher economic costs of decarbonisation.
- **Delayed transition:** measures are implemented only from 2030 onwards, managing to keep temperature rise to below 2°C but imposing a big cost to the economy in terms of inflation and stranded assets, and causing financial instability.

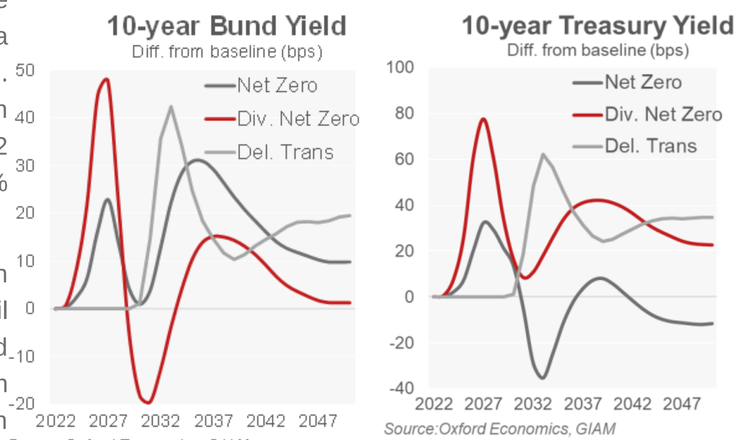
The three scenarios imply different paths for the carbon tax, which interacts with other non-price measures to curb emissions, like investment and technological progress.



Source:Oxford Economics, GIAM

Source:Oxford Economics, GIAM

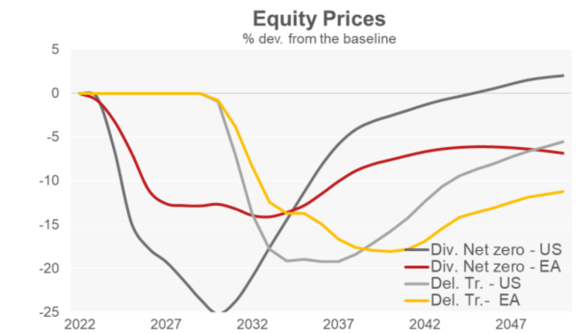
Moreover, different levels of policy commitment and decarbonisation across regions are assumed. This explains, for example, the expected steeper path of the Euro area carbon tax with respect to the US, whose economy is currently more carbon intensive. Importantly, while NGFS assumes that **central banks react to higher inflation** by tightening policy, the scenarios that we use to test the model hypothesise that they recognise the supply side nature of the shock and keep rates unchanged, and accommodate and mitigate the impact on growth.



Source:Oxford Economics, GIAM

Source:Oxford Economics, GIAM

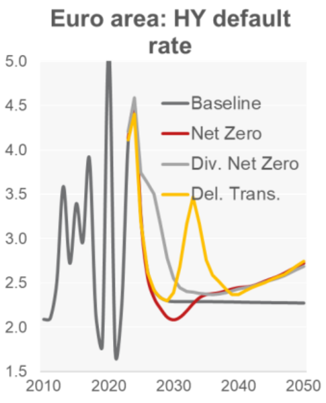
The impact on sectors varies widely, depending on their current energy mix and on the different composition of domestic demand (i.e. changes in household consumption affect manufacturing and financial services GVA to a different extent). At the same time, the impact on financial markets varies widely also across countries. The US equity market is worse off than the euro area one. This is mostly due to the US economy being relatively more reliant on fossil fuels and therefore, the rise in their price having a deeper and more widespread impact on the economy.



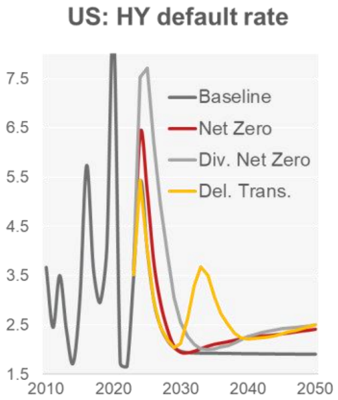
Source:Oxford Economics, GIAM

Higher costs and uncertainty depress demand and the initial fall in output triggers an increase in HY defaults. Depending on the scenario, demand follows different paths. The smooth transition implied by the Net zero scenario allows for a rather quick reduction in defaults.

> *Almost all climate scenarios impy a marked riske in HY defaults*



Source:Moody's, Ox. Econ. GIAM



Source:Moody's, Ox.Econ., GIAM

The detailed results for credit are shown at the end of the paper. A few remarks:

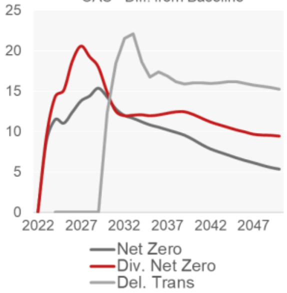
- Consistent with the impact on equity markets, the stress is higher in the US than the Euro area.
- Most of the stress is front-loaded. Contingent on the intensity of the scenario, however, a persistent effect remains, the magnitude of which is determined by the smoothness and timeliness of decarbonisation efforts.
- Lower-rated indices or assets experience more significant and pronounced impacts during stressful periods compared to higher-rated ones. This reflects the higher vulnerability and sensitivity of lower-rated assets to adverse market conditions, economic shocks, and changes in investor sentiment. The asymmetric response highlights the importance of considering credit ratings when assessing the potential impact of stress events on investment portfolios or credit markets.
- The energy sector is more sensitive than non-financial sectors. This is hardly surprising and can be attributed to the energy sector's inherent reliance on fossil fuels; this results in a drop in prices and marginality. As a result, the energy sector bears a heavier burden and faces greater challenges in adapting to the changing landscape of climate policies and shifting market dynamics.
- It is interesting to compare the stress to financials with the negative but more contained impact on Industrials and, especially utilities. Their ability to diversify away from fossil fuels results in a lower sensitivity of profits to carbon taxation, and a lower probability of default.
- Financial sector spreads are initially very sensitive to the volatility triggered by the policy shock, then the impact decreases. It is important to notice the large persistent impact in the Delayed Transition scenario, where the need to act fast has a destabilising impact on financial markets.

4.Conclusions

Raising taxes on carbon fuels to reduce meaningfully GHG emissions has large economic costs, which are not evenly distributed across sectors. This has important implications for large and sophisticated bond investors as it entails a possibly meaningful divergence of spreads, according to sectors or rating classes. To tackle this issue, we develop a small-scale econometric model, which uses as inputs the outcome of simulations from an integrated macro and climate model and produces long term credit spread projections. Testing the model on a series of climate scenarios highlights the risks posed by delayed and uncoordinated action. At the industry level, energy companies could see credit spreads jump by more than one fifth, complicating the task of funding the decarbonisation of their activities. Moreover, tackling climate change by means of higher taxes on emissions may result in permanently higher spreads and lower asset prices, as the trend growth of the economy slows down and default risk increases. Of course the impact will depend also on the evolution of the cost of producing energy from non-fossil fuels: the continuation of the current trend of sharp decrease in the price of solar panels, for example, would quicken the reduction in the share of taxed fossil fuels in the mix, reducing the negative impact on the economy and the financial system.

The response of spreads to the shock may look a bit small given with the structural shift implied by climate change. What we show in this paper are the results based on past correlations: this is an inherent feature of this kind of modelling. This approach is being increasing challenged as the response in terms of asset prices are too smooth, as they do not fully account for the sudden repricing of assets. This may lead to complacency about the cost of limiting climate change. Moreover, the smooth response to physical risk likely leads to an underestimation of the costs of not doing enough. We concur that the kind of modelling we present in this paper is more suitable for transition risk. The doubts about the size of the response must be weighed against the transparent set up and the possibility to analyse a wide range of assets. Moreover, it is technical possible in this kind of setup to calibrate and impose the confidence shocks that are likely to be triggered by tax-based climate policies. We will tackle this issue when designing our own climate scenarios.

Euro area - AA Financials spreads
OAS - Diff. from Baseline



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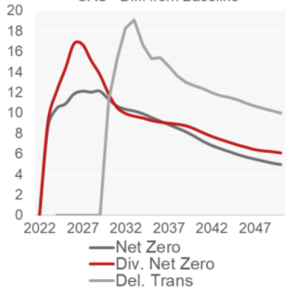
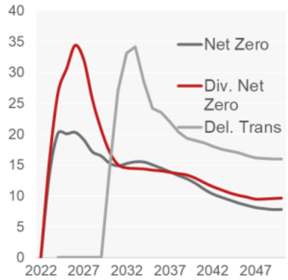
Euro area - AA Nonfin. spreads
OAS - Diff. from Baseline



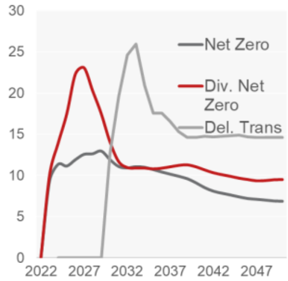
Source:GIAM

Euro area - Energy sector spreads
OAS - Diff. from Baseline



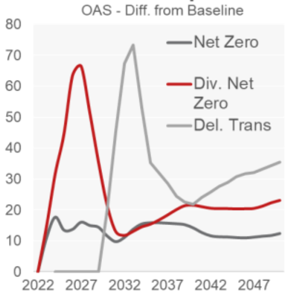
Source:GIAM

Euro area - Ind. sector spreads
OAS - Diff. from Baseline



Source:GIAM

Euro area - BBB Financials spreads
OAS - Diff. from Baseline



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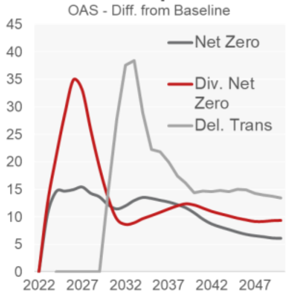
Euro area - BBB Nonfin. spreads
OAS - Diff. from Baseline



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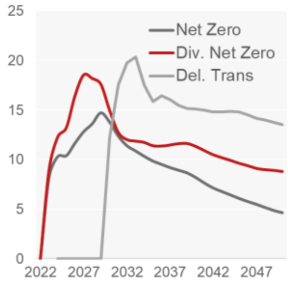
Euro area - Utilities sector spreads
OAS - Diff. from Baseline



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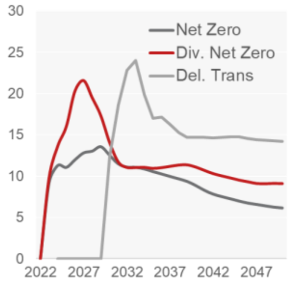
Euro area - Durables sector spreads
OAS - Diff. from Baseline



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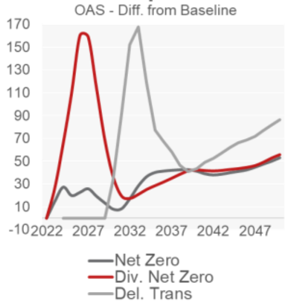
Euro area - HY Fin. spreads
OAS - Diff. from Baseline



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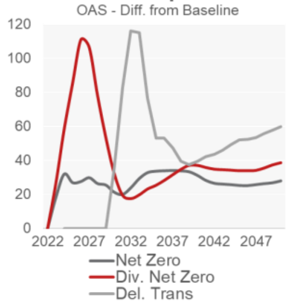
Euro area - HY Nonfin. spreads
OAS - Diff. from Baseline



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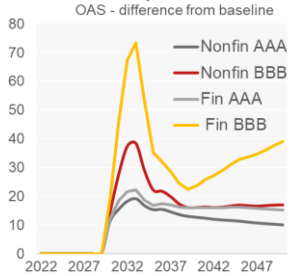
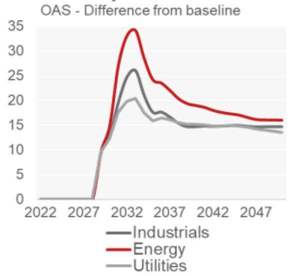
Delayed Transition Scenario - Euro area spreads
OAS - difference from baseline



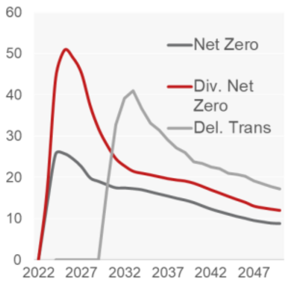
Source:GIAM

Delayed Transition Scenario - Euro area spreads
OAS - Difference from baseline



Source:GIAM

US - IG spreads
OAS - Diff. from Baseline



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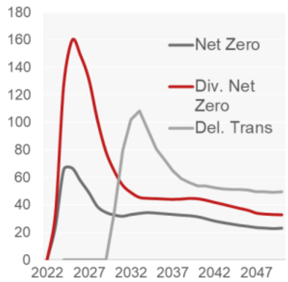
US - HY spreads
OAS - Diff. from Baseline



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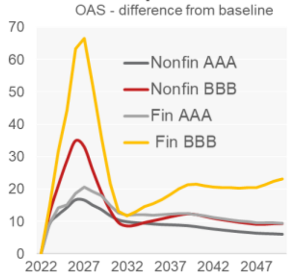
Divergent Net Zero Scenario - Euro area spreads
OAS - difference from baseline



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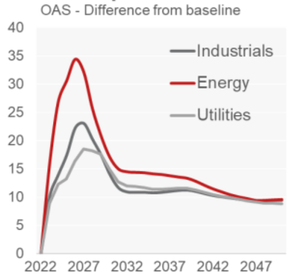
Divergent Net Zero Scenario - Euro area spreads
OAS - Difference from baseline



Source:GIAM

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