Prepared by

Juan Licari
Juan.Licari@moodys.com
Managing Director

Petr Zemcik
Petr.Zemcik@moodys.com
Senior Director

Chris Lafakis
Chris.Lafakis@moodys.com
Director

Janet Lee
Janet.Lee@moodys.com
Director

Climate Risk Macroeconomic Forecasting

INTRODUCTION

As early as 2021, many regulators across the world will require financial institutions to provide a self-assessment or to stress-test their balance sheets with respect to climate change risk. Constructing climate change scenarios starts with a trajectory for carbon dioxide emissions, the necessary policies to reduce these emissions, and the corresponding change in global temperatures. Moody's Analytics is expanding its capabilities to enable institutions to assess risks posed by climate change. The physical and transition impacts on the economy of temperature change are determined using our model of the global economy. Our scenarios are consistent with Orderly, Disorderly, and Hot House World scenarios by the Network of Central Banks and Supervisors for Greening the Financial System. We employ our modelling framework to generate climate change scenarios for the U.S. and the U.K.

Climate Risk Macroeconomic Forecasting

BY JUAN LICARI, PETR ZEMCIK, CHRIS LAFAKIS, AND JANET LEE

As early as 2021, many regulators across the world will require financial institutions to provide a self-assessment or to stress-test their balance sheets with respect to climate change risk. Constructing climate change scenarios starts with a trajectory for carbon dioxide emissions, the necessary policies to reduce these emissions, and the corresponding change in global temperatures. Moody's Analytics is expanding its capabilities to enable institutions to assess risks posed by climate change. The physical and transition impacts on the economy of temperature change are determined using our model of the global economy. Our scenarios are consistent with Orderly, Disorderly, and Hot House World scenarios by the Network of Central Banks and Supervisors for Greening the Financial System. We employ our modelling framework to generate climate change scenarios for the U.S. and the U.K.

More specifically, we first provide an overview of the relevant regulatory landscape, focusing on the U.K. and the U.S. We then summarize our methodological approach, which is complementary to scenarios produced by Integrated Assessment Models (see Table 1 for the list of acronyms). The approach leverages our modelling framework initially designed for standard macroeconomic forecasting and for producing stress-testing scenarios for various regulatory purposes. We then discuss how the framework is employed to account for the long-term physical risk associated with climate change and then altered to incorporate risks linked to the transition to a carbon-neutral economy. The newly constructed transition mechanism block includes a carbon dioxide tax in the system of simultaneous equations. Finally, we generate climate change scenarios for the U.K. and the U.S. consistent with published NGFS scenarios using the updated modelling setup.

Regulatory landscape

The Network for Greening the Financial System and the Task Force on Climate-Related Financial Disclosures are key organizations leading the global effort to assess the financial impact of climate risk. The NGFS is a group of central banks and regulatory agencies worldwide established at the Paris One Planet

Table 1: List of Acronyms

Acronym	Full title
BoE	Bank of England
BES	Biennial Exploratory Scenario
ECB	European Central Bank
GCAM	Global Change Analysis Model
IAM	Integrated Assessment Model
IPCC	Intergovernmental Panel for Climate Change
JFSA	Japanese Financial Services Agency
MAgPIE	Model of Agricultural Production and Its Impacts on the Environment
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
ORSA	Own Risk and Solvency Assessment
RCP	Reactive Concentration Pathways
REMIND	Regional Model for Investment and Development
TCFD	Task Force on Climate-Related Financial Disclosures

Source: Moody's Analytics

Summit in December 2017.[1] Members include the Bank of England, Banque De France, the European Central Bank and the European Banking Authority, The People's Bank of China, and the European Insurance and Occupational Pensions Authority.[2] In December 2020, the Federal Reserve joined the NGFS as well. The TCFD is a taskforce set up by the Financial Stability Board, composed of over 785 influential organizations from around the world. They have been urging businesses across industries to voluntarily measure and disclose their vulnerabilities to climate risk. Scenario-based risk analysis is an integral part to both the NGFS and TCFD's action plans.

The U.K. government has made significant steps towards assessment of the financial impact of climate risk. It has committed to ending coal sales, taxing carbon, and reducing emissions to net zero by 2050. It also closely follows recommendations of the U.K. Climate Change Committee and sets up five-year carbon budgets required by the Climate Change Act. In addition, the country will host the 26th United Nations Climate Change conference in Glasgow in November 2021. The key financial

---

1   See https://www.oneplanetsummit.fr/en.
2   The full list of members and observers is at https://www.ngfs.net/en/about-us/membership.

regulator, the Prudential Regulatory Authority (a part of the Bank of England), already published the contours of climate risk scenarios in its Insurance Stress Test guidelines in 2019. The climate change scenarios contain elements of both physical and transition climate change risks.[3] Following the Insurance Stress Test, the PRA announced its intention to test the U.K. financial system's resilience to the financial risks from climate change as part of the 2021 Biennial Exploratory Scenario. The plan was outlined in the July 2019 Financial Stability Report.[4] Finally, the U.K. Financial Conduct Authority has announced premium-listed companies to be subject to more detailed disclosures regarding how climate risk affects their business from January 2021. This announcement is consistent with the recommendations of TCDF. These are linked to environmental, social and governance factors for individual companies. The environmental factor reflects the vulnerability of companies to climate risk.[5]

The Bank of England indicated that it will use NGFS scenarios as the foundation for the Biennial Exploratory Scenario. In December 2020, it published an updated methodology of a 2019 discussion paper describing its intended approach.[6] The BoE will supply integrated climate and macrofinancial variables. These will include projections for temperature, emissions and climate policies that incorporate the underlying physical and transition risks. The macrofinancial variables should be used to assess the impact of climate change. There will be NGFS scenarios characterizing outcomes under assumptions of the earlier and later policy actions, as well as the scenario with no policy change. These scenarios are discussed in detail in the subsequent sections of this paper.

While the U.S. has not been very active in terms of climate risk regulation in the last decade, Fed Chair Jerome Powell indicated the Fed would like to engage with NGFS in November

2020. The point man for financial regulation, Randal Quarles, echoed these comments later. On 15 December 2020, the Federal Reserve formally joined NGFS. The Financial Stability Report from November 2020 already listed climate risk as one of the risks to financial stability in the near future. It mentioned both chronic and acute physical hazards affecting the value of financial and nonfinancial assets, as well as volatility in sentiment.[7] Earlier in September 2020, an advisory panel to the Commodity Futures Trading Commission released a report entitled "Managing Climate Risk in the U.S. Financial System." It is the first of its kind from a federal financial regulator and implies that proper pricing of carbon emissions in the U.S. will be required.

Other financial regulators across the globe have been active in climate risk regulation as well. The European Central Bank published its guide on climate-related and environmental risks for banks on 27 November 2020. In 2021, the banks regulated by the ECB will be required to conduct a self-assessment of climate risk exposure and formulate action plans reflecting the outcome of this assessment. A full supervisory review of banks' practices will be conducted in 2022. The European Insurance and Occupational Pensions Authority started a consultation process regarding the use of climate change risk scenarios in the Own Risk and Solvency Assessment in October 2020. Elsewhere, the Japanese regulator Financial Services Agency plans to include climate risk scenarios in a stress-test pilot for the country's five biggest banks. Similarly, the Monetary Authority of Singapore intends to include climate change scenarios in its stress-testing exercise within the next two years.

Climate risk scenarios

The climate change scenarios are similar in principle to the classical stress-testing ones

Chart 1: Economic vs. Climate Risk Scenarios
Differentiation btw standard forecasts and climate risk scenarios

Economic scenarios	Climate risk scenarios
• 5- to 30-yr forecast horizon	• 30- to 80-yr forecast horizon
• Used to measure capital and assess risk	• Used to assess risk
• Shock inputs are provided by Moody's Analytics, clients or regulators	• Impact channels must be translated into shock inputs
• Stable economic relationships	• Increased uncertainty over how impact channels translate into economic inputs
• Shock inputs do not depend on carbon dioxide trajectory	• Increased uncertainty over how the economy transitions from fossil fuels to renewables
	• Shock inputs depend on carbon dioxide trajectory
	• Requires new forecast variables and model equations

Source: Moody's Analytics

(see Chart 1). They leverage existing macroeconomic models to generate projections of economic variables of interest. Following the Global Financial Crisis, the stress-test scenarios have now been fully embedded in the methodology toolkits of financial institutions across the world. The macroeconomic scenarios have been embraced by regulators, including central banks such as the Federal Reserve, the Bank of England, and the European Central Bank together with the European Banking Authority, and countless others. The stress scenarios have also been used for accounting standards for the Current Expected Credit Losses by the Financial Accounting Standards, and for the International Financial Reporting Standard by the International Accounting Standards Board. Due to the extensive employment of these scenarios, they have been standardized to some extent. The forecast horizon ranges from five years for the standard stress scenarios to 30 years for accounting standards, although most of the stress typically occurs during the first one to three years of the scenario.

However, there are several differences and corresponding challenges. First, the time horizon needs to be extended by decades. Moody's Analytics Global Macroeconomic Model, hosted on the web-based platform Scenario Studio, already generated projections for 30 years to accommodate accounting standards. However, the time horizon needs to be extended to 2100, which involves extending the projections of potential GDP paths and paying close attention to long-term demographic trends. A key attribute of climate risk modelling is the inclusion of the trajectory for carbon dioxide emissions. This projection is translated into a temperature path. Different temperature paths generate different physical risk and

3   SS3/19: Enhancing banks' and insurers' approaches to managing the financial risks from climate change April 2019.
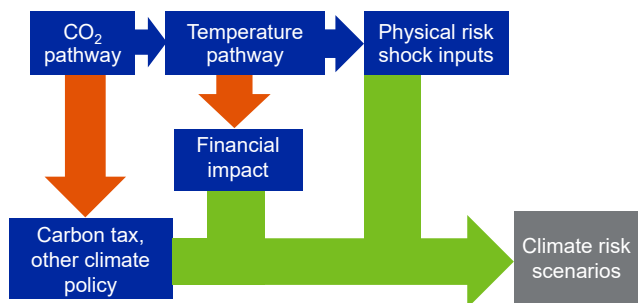
4   https://www.bankofengland.co.uk/financial-stability-report/2019/july-2019.

5   Moody's Analytics has acquired Vigeo-Eiris, a company that provides ratings for the ESG for some 5,000 companies. This will be enlarged to over 10,000 in 2021. Moody's Analytics will leverage on the existing ratings to estimate ESG scores for 100,000 non-rate companies.

6   The updated information is at https://www.bankofengland.co.uk/climate-change and the 2019 discussion paper can be found at https://www.bankofengland.co.uk/paper/2019/biennial-exploratory-scenario-climate-change-discussion-paper.
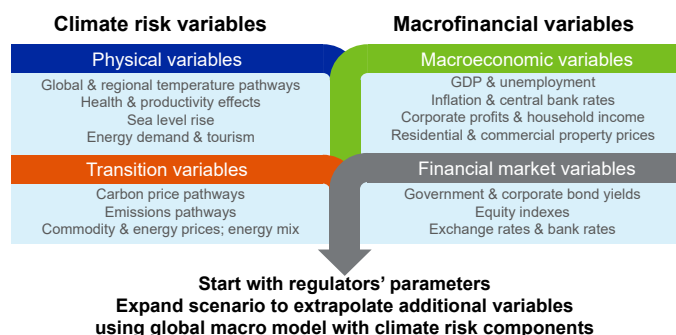
7   See the statement by Governor Lael Brainard at https://www.federalreserve.gov/publications/brainard-comment-20201109.htm.

Chart 2: Transition and Physical Risk

Source: Moody's Analytics

Chart 3: Constructing Climate Risk Scenarios

Source: Moody's Analytics

the subsequent impact on economic drivers. In addition, various government policies such as a carbon tax affect the speed with which the carbon dioxide paths are altered. These generate transition risks associated with each path.

Chart 2 illustrates how the transition and physical risks associated with climate change are incorporated into the macroeconomic modelling. The pathway for carbon dioxide determines the temperature pathway. Physical risk refers to the physical consequences of changing climate patterns, including rising sea levels, changing precipitation patterns, and changes in the magnitude and frequency of extreme weather events. These climate changes are the consequence of rising carbon dioxide emissions driving up global temperature. Transition risk associated with climate

change mitigation policies is embedded in the path for carbon taxes and other policies. This is combined with a financial impact linked to the timeline, according to which asset markets incorporate the climate risk in asset prices. This is often referred to as the Minsky moment[8] as it can lead to instability and crisis. Once the physical, transition and financial impact is considered, we can generate the climate risk scenarios.

Note that the Moody's approach does not explicitly model either the conversion of the carbon dioxide pathway into the temperature pathway or the conversion of the temperature path into physical risks. These steps are typically addressed via a climate

___

8   According to economist Hyman Philip Minsky, who studied the stability of financial systems.

module that is part of the Integrated Assessment Models. For example, one of the scenarios generated by NGFS is produced by the Global Change Analysis Model that uses an Earth System Module – Hector v2.0. The Moody's approach differs from the IAM, as the objective is to provide a projection of the carbon tax consistent with a particular pathway of the carbon dioxide emissions. Moody's aims to construct forecasts of standard economic drivers consistent with various climate risk assumptions and the corresponding temperature pathways, using its Global Macroeconomic Model. Box 1 discusses in some detail the IAMs and elaborates on how the Moody's approach to climate risk complements the IAM modelling philosophy.

Box 1: Integrated Assessment Models

Our approach to constructing climate scenarios shares some features of the commonly used IAMs. For example, the GCAM employed by NGFS spans across socioeconomics; energy; agriculture, land use and bioenergy; water; climate; emissions; economic choice; trade and technology; and policies and costs.[9] Another example of IAM is the Regional Model for Investment and Development, a Ramsey-type macroeconomic general equilibrium growth energy-economy model. It is combined with the Model of Agricultural Production and Its Impacts on the Environment.

These topics are captured by modules connected to describe how greenhouse gas emissions affect climate and how climate change affects the economy. The energy system serves as the conduit through which environmental and economic variables interact. Most IAM energy systems are detailed representations of the sources of energy supply, which subsequently determine emissions. Assumptions regarding population, labor productivity, technology characteristics and policies are used to provide outputs on emissions, prices, energy supply and demand, temperature, agricultural production, land use, and water use, among others. IAMs produce forecasts for these outputs in five-year intervals. Moody's Analytics uses output from these IAMs as an input into its scenario construction process. The main IAM inputs are fossil fuel consumption by source, temperature pathways and carbon prices.

___

9   See http://jgcri.github.io/gcam-doc/toc.html.

Chart 3 provides an overview of the construction of climate risk scenarios. The climate risk variables consist of physical variables such as the temperature pathways and the transition variables, including carbon dioxide emissions. The macroeconomic variables include core economic drivers such as GDP components, labor market metrics, and key interest rates and prices. These are then used to produce projections of a wide range of financial market variables. In the Moody's approach, we assess the impact of the chronic physical risk separately, mainly via its impact on productivity and other variables. Newly, we have constructed variables to model and quantify the transition risk. The macroeconomic variables are generated by the Moody's Macroeconomic Model hosted on the web platform Scenario Studio (see Box 2). The macroeconomic variables are used as inputs together with additional assumptions regarding the timing of the Minsky moment to produce projections of a wide range of financial market variables.

Box 2: Moody's Global Macroeconomic Model

Generation of the climate risk scenarios relies on the Moody's Analytics Global Macroeconomic Model hosted on the web-based platform Scenario Studio. The model forecasts more than 15,000+ time series across 100 countries that collectively constitute more than 95% of global GDP. Model equations are specified based on economic theory, and they feature shock properties that are essential in scenario construction, including the creation of economic forecasts consistent with different climate change assumptions. The model captures both short-term business cycle dynamics and long-run trends. Short-term forecasts are determined by fluctuations in aggregate demand, whereas long-term forecasts are determined by an economy's labor force and labor force productivity growth. The model captures both interconnectedness among economic regions and country-specific idiosyncracies. The linkages among countries and regions are characterized by trade and financial flows. The cross-country linkages include the impact of global prices and exchange rates on economic performance.

Chart 4: Our Global Macroeconomic Model
100+ country modules linked via trade and finance

Specification choice
» Theoretical reasoning versus statistical properties

In-sample equation fit
» R-squared, RMSE, information criteria
» Fitted values and residuals

Forecasting performance
» Back-testing: Conditional and unconditional evaluation
» Benchmarking during important past episodes

Sensitivity to shocks
» Forecasts across scenarios
» Response to individual shocks

Source: Moody's Analytics

While the model structure is similar across countries, the framework allows for country-specific variations of key equations and for the inclusion of tailpipe equations for variables important for some countries (see Chart 4).[10]

10 For more details please see "Moody's Analytics Global Macroeconomic Model Methodology", M. Hopkins, Moody's Analytics March 2018. https://tinyurl.com/y2ao8jga

Physical risk

Climate change poses both physical and transition risks. Physical risk refers to the physical consequences of changing climate patterns, including rising sea levels, changing precipitation patterns, and changes in the magnitude and frequency of extreme weather events. Physical risks can be separated into chronic and acute. There are six primary components of chronic physical risk:

» Sea level rise

» Human health effects

» Heat effect on labor productivity

» Agricultural productivity effects

» Tourism effects

» Energy demand effects

Moody's Analytics already provides chronic physical risk scenarios that are available for all countries in the Global Macroeconomic Model through 2048 for four Reactive Concentration Pathways (RCP) by the Intergovernmental Panel for Climate Change (IPCC) (see Chart 5).[11]

We create three new scenarios that are consistent with NGFS projections and modify our framework to incorporate chronic physical risk into our new scenarios. The most recent NGFS projections[12] are available for three scenarios: Orderly, Disorderly, and Hot House World. The Orderly and Disorderly scenarios assume that climate change policies

11 For narratives for these scenarios, see "The Economic Implications of Climate Change", Chris Lafakis, Laura Ratz, Emily Fazio, and Maria Cosma, Moody's Analytics June 2019. https://www.moodysanalytics.com/-/media/article/2019/economic-implications-of-climate-change.pdf

12 NGFS Climate Scenarios for central banks and supervisors, NGFS, June 2020.

are adopted to limit the global warming to below 2°C. In the case of the Disorderly scenario, the transition starts only after 2030. The Hot House World scenario ssumes no adaptation occurs. Stylized world-level carbon prices and emissions are iluustrated in Charts 6 and 7. The corresponding temperature pathways are depicted in Chart 8.

Acute physical risk refers to weather events that could become increasingly likely or severe because of climate change. There are four primary components of acute physical risk:
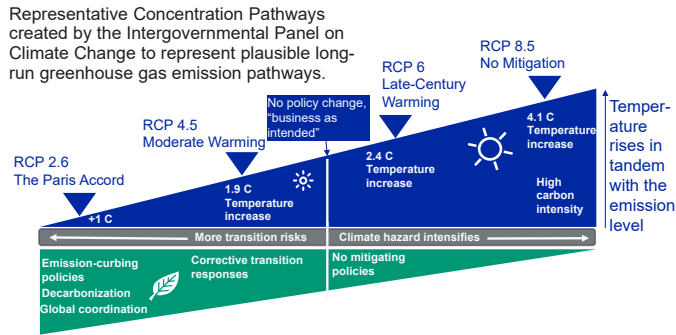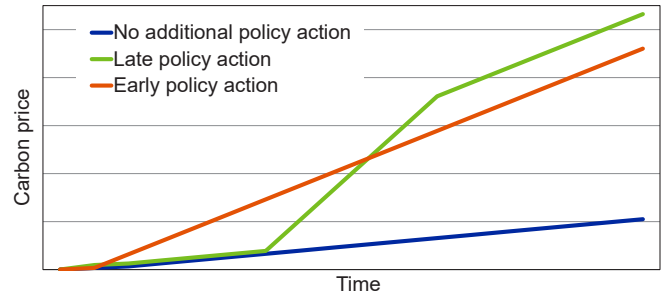
» Heat waves and cold snaps

» Droughts and wildfires

» Flooding

» Tropical cyclones

Chart 5: IPCC Scenarios

Greenhouse gas concentration levels define four distinct scenarios

Representative Concentration Pathways
created by the Intergovernmental Panel on
Climate Change to represent plausible long-
run greenhouse gas emission pathways.

RCP 8.5
No Mitigation

RCP 6
Late-Century
Warming

RCP 4.5
Moderate Warming

RCP 2.6
The Paris Accord

4.1 C
Temperature
increase

High
carbon
intensity

Temper-
ature
rises in
tandem
with the
emission
level

No policy change,
"business as
intended"

2.4 C
Temperature
increase

1.9 C
Temperature
increase

+1 C

More transition risks   Climate hazard intensifies

Emission-curbing
policies
Decarbonization
Global coordination

Corrective transition
responses

No mitigating
policies

Source: Moody's Analytics

Chart 6: Carbon Price (World)

Carbon price, US$2010/metric ton CO_2

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

Carbon price

Time

Sources: Network for Greening the Financial System, Moody's Analytics

Two approaches could be taken to model acute physical risk. The first is to quantify the link between rising temperatures and the economic cost of natural disasters by country. These costs could then be modelled over time as global temperatures rise in the upcoming BoE scenarios. This approach does not model an explicit natural disaster, but rather smoothes their cost over the forecast horizon. The BoE (as mentioned in its discussion paper) will also provide characterization of a distribution of key physical variables to capture changes in the frequency and severity of climate events at a granular regional level. The second approach is to model an explicit natural disaster occurring in a specific geography at a specific time that carries a specific intensity. Explicit modelling of the propensity towards acute physical risk requires climate risk data at a regional and postcode level. Moody's acquired a majority stake in Four Twenty Seven Inc., a provider of data,
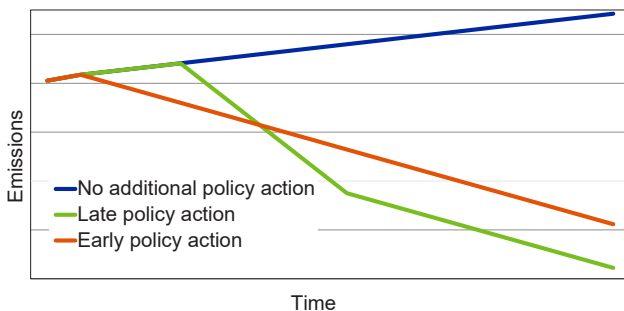
intelligence and analysis related to physical climate risks. Four Twenty Seven Inc. translates climate models into actionable intelligence for clients that include some of the world's largest investors, asset managers, commercial banks, development finance institutions, corporations, and government agencies. The "427" analytics engine leverages a wide range of data from various sources to generate climate risk impact data. This information will be incorporated in downstream models for regional drivers and credit risk assessment.

The physical risk impact estimates are synthesized by Roson and Sartori (2016),[13] who report the impact on GDP for the six components of physical risk by country for increases in °C of +1, +2, +3, +4, and +5 for years 2050 and 2100. The sea level

impact is reflected in private real consumption FC$_GEO; agricultural and labor productivity, jointly with human health effects, impact real potential productivity FPROD$_POT_IGEO; tourism demand affects net exports FNETEX$_I_GEO; and energy demand impacts the Brent oil price FCPIFICEBOIU_US. Charts 9 and 10 summarize the impact channels for the physical risk as well as the remaining climate risk modelling components. Real consumption and net exports are expenditure components of GDP. Potential GDP and real average wage depend on real potential productivity, and many energy prices take oil prices into account. There are several options for incorporating the impact of the physical risk using the Moody's Global Macroeconomic Model. Two key ones are creating a series for add factors and exogenizing the series. As the physical impact is long term, we opt for the latter approach in this case.
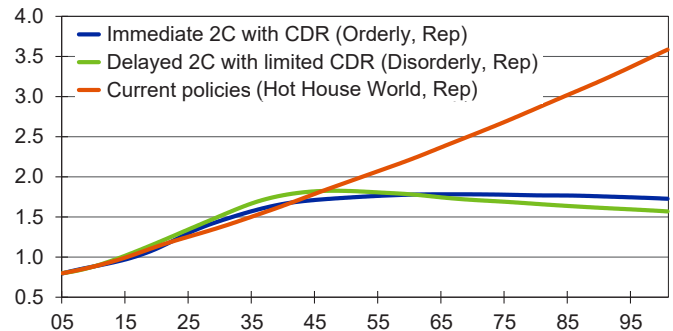
---

13 Roberto Roson and Martina Sartori, Estimation of Climate Change Damage Functions for 140 Regions in the GTAP9 Database, World Bank Group Policy Research Working paper 7728, June 2016.

Chart 7: CO_2 Emissions (World)

Emissions

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

Time

Sources: Network for Greening the Financial System, Moody's Analytics

Chart 8: NGFS Scenarios

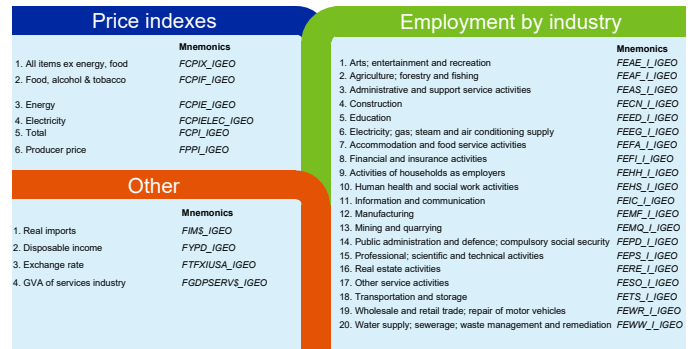World temperature pathway (°C relative to 1850-1900)

- Immediate 2C with CDR (Orderly, Rep)
- Delayed 2C with limited CDR (Disorderly, Rep)
- Current policies (Hot House World, Rep)

4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5

05 15 25 35 45 55 65 75 85 95

Sources: Network for Greening the Financial System, Moody's Analytics

Chart 9: Modelling Framework 1/2

Impact channel

	Mnemonics
1. Sea level rise	FCS_GEO
2. Agricultural productivity	FPROD$_POT_GEO
3. Heat stress effect on labor productivity	FPROD$_POT_GEO
4. Human health effects	FNETEX$_I_GEO
5. Tourism	FNETEX$_I_GEO
6. Energy demand	FCPIFICEBOIU_US

CO2 taxes

	Mnemonics
1. Dividend dummy	DUM_CARBONDIV_IGEO
2. Carbon tax dummy	DUM_CARBONTAX_IGEO
3. Carbon tax rate	FCARBONTAX_IGEO
4. Carbon tax revenue	FCARBONREV_IGEO
4-i. Carbon tax revenue: Coal	FCOALREV_IGEO
4-i. Carbon tax revenue: Natural gas	FNGASREV_IGEO
4-i. Carbon tax revenue: Petroleum	FPETREV_IGEO

Energy prices

	Mnemonics
1. Coal	FPCCOALDOM_IGEO
2. Natural gas	FPCNGASDOM_IGEO
3. Oil	FPCOILDOM_IGEO

Energy consumption

	Mnemonics
1. Coal	FCOALCONQ_IGEO
2. Natural gas	FNGASCONQ_IGEO
3. Petroleum and othe liquid	FPETCONQ_IGEO

CO2 emissions

	Mnemonics
1. Coal	FCOALCO2EQ_IGEO
2. Natural gas	FNGASCO2EQ_IGEO
3. Oil and petroleum products	FPETCO2EQ_IGEO

Government finances

	Mnemonics
1. Total revenue	FGGREV_IGEO
2. Total expense	FGGEXP_IGEO
3. Expenditure intermediate term	FGGEXP_I_IGEO
4. Expenditure residual	FGGEXP_RESID_IGEO

Source: Moody's Analytics

Chart 10: Modelling Framework 2/2

Price indexes

	Mnemonics
1. All items ex energy, food	FCPIX_IGEO
2. Food, alcohol & tobacco	FCPIF_IGEO
3. Energy	FCPIE_IGEO
4. Electricity	FCPIELEC_IGEO
5. Total	FCPI_IGEO
6. Producer price	FPPI_IGEO

Other

	Mnemonics
1. Real imports	FIMS_IGEO
2. Disposable income	FYPD_IGEO
3. Exchange rate	FTFXIUSA_IGEO
4. GVA of services industry	FGDPSERV$_IGEO

Employment by industry

	Mnemonics
1. Arts; entertainment and recreation	FEAE_I_IGEO
2. Agriculture; forestry and fishing	FEAF_I_IGEO
3. Administrative and support service activities	FEAS_I_IGEO
4. Construction	FECN_I_IGEO
5. Education	FEED_I_IGEO
6. Electricity; gas; steam and air conditioning supply	FEEG_I_IGEO
7. Accommodation and food service activities	FEFA_I_IGEO
8. Financial and insurance activities	FEFI_I_IGEO
9. Activities of households as employers	FEHH_I_IGEO
10. Human health and social work activities	FEHS_I_IGEO
11. Information and communication	FEIC_I_IGEO
12. Manufacturing	FEMF_I_IGEO
13. Mining and quarrying	FEMQ_I_IGEO
14. Public administration and defence; compulsory social security	FEPD_I_IGEO
15. Professional; scientific and technical activities	FEPS_I_IGEO
16. Real estate activities	FERE_I_IGEO
17. Other service activities	FESO_I_IGEO
18. Transportation and storage	FETS_I_IGEO
19. Wholesale and retail trade; repair of motor vehicles	FEWR_I_IGEO
20. Water supply; sewerage; waste management and remediation	FEWW_I_IGEO

Source: Moody's Analytics

Transition risk

Charts 9 and 10 include the key components of the transition risk modelling, in addition to the previously described approach, to take account of the aggregate physical risk. The first step in determining the impact of introducing the carbon tax in an economy is setting dummy variables for the carbon dividend and carbon tax in a country model embedded in the Moody's Global Macroeconomic Model. Using the U.K. model as an example, Appendix Table provides additional information for the blocks of equations described in the Modelling Framework in Charts 9 and 10. The table includes the mnemonics for these and other carbon tax-related variables. Following the standard employed in the Scenario Studio platform, which hosts the Moody's Global Macroeconomic Model, equations are stochastic, exogenous or identities. Stochastic equations contain an error term to capture randomness, and the projections are endogenously solved for in the system of all simultaneous equations in the Moody's Global Macroeconomic Model. Identities characterize basic relationships, and exogenous variables enable the user to set up a path based on information outside of the model.

Appendix Table also includes the relevant units and upstream and downstream dependence. For example, government expenditures and household disposable income depend on the dividend dummy variable. The impact of the transition is triggered by imposing taxes on carbon dioxide for the key sources of energy such as coal, natural gas and petroleum. The usage of the tax rate is indicated via the carbon tax dummy and the corresponding tax rate. Prices of coal, natural gas and petroleum depend on the carbon tax rate and so does government revenue for the three fossil fuels. The carbon tax rate is imposed exogenously based on assumptions regarding a government's climate change policy. Imposing the carbon tax rate results in the corresponding revenue. The equation for the revenue is a simple identity, where the revenue equals the dummy variable multiplied by the tax rate and the amount of emissions. This revenue is also added to the government budget.

The subsequent block of transition risk equations characterizes energy prices. Specifically, these include the average price of coal, the effective domestic natural gas price, and the effective domestic oil price. All three energy prices depend on the dummy variable for the carbon tax rate as well as the carbon tax rate. The price of natural gas also depends on the exchange rate, and the price of oil on the price of Brent crude. Consumption of all three fossil fuels and consumer prices for energy and electricity reflect the energy prices. The price of oil also affects gross value added in industries such as electricity, gas, steam and air-conditioning, and mining and quarrying. Imports and the producer price index depend on oil prices as well. Besides energy prices, energy consumption depends on industrial production for natural gas, and household disposable income and motor vehicle registration for passenger cars. Energy consumption mainly determines the emissions for each of the fossil fuels plus global demand for petroleum. There is essentially a one-to-one correspondence between the growth rates of energy consumption and emissions. These are captured by a simple regression equation which also includes autocorrelation in error terms.

Including the carbon dioxide tax has implications for government finances. Overall tax revenue depends on tax income reflecting the GDP level and the revenue from the carbon tax. Expenditures depend on the carbon dividend dummy as well as the carbon tax revenue. Many other factors have an impact on government finances, including the current interest expense on existing government debt and the debt-to-GDP ratio. The government budgetary metrics determine government spending as a part of GDP, which completes the endogenous loop for the simultaneous equations model.
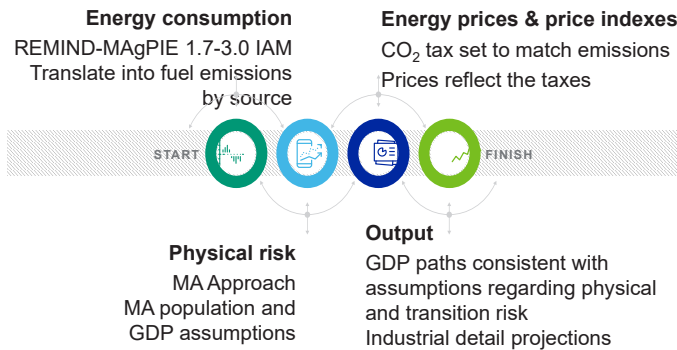
The consumer energy price index depends on the prices of oil, natural gas and electricity. The electricity price depends on the price of gas and coal. The overall price index depends on energy prices as well as on a variety of other factors such as the unemployment rate and inflation expectations. The producer price index depends on the oil price.

The key variables that are impacted by the block of climate transition risk equations are real imports via the effective domestic oil price; disposable income via the carbon dioxide tax revenue and indirectly via government expenditures; indirectly the exchange rate and gross value added for industries. The GVA is one of the drivers of employment in each of the 20 industries.

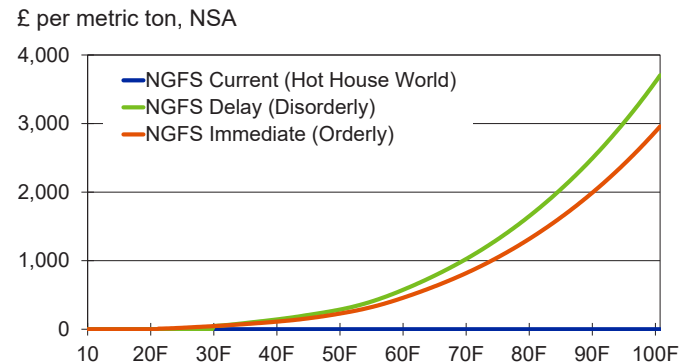## Moody's Analytics NGFS scenarios

In this section, we show how we are calibrating to the NGFS scenarios and discuss the key results generated by the Moody's Analytics

Chart 11: NGFS Consistent Scenarios

Energy consumption
REMIND-MAgPIE 1.7-3.0 IAM
Translate into fuel emissions
by source

Energy prices & price indexes
CO_2 tax set to match emissions
Prices reflect the taxes

START ⬤⬤⬤⬤ FINISH

Physical risk
MA Approach
MA population and
GDP assumptions

Output
GDP paths consistent with
assumptions regarding physical
and transition risk
Industrial detail projections

Source: Moody's Analytics

Chart 12: U.K. Carbon Dioxide Tax Rate

£ per metric ton, NSA

- NGFS Current (Hot House World)
- NGFS Delay (Disorderly)
- NGFS Immediate (Orderly)

Sources: Network for Greening the Financial System, Moody's Analytics

Global Macro Model. In general, we also follow guidelines by the BoE in its BES discussion paper mentioned above, although we go beyond these in a number of ways. For example, the BoE forecast horizon is 2050 while it is 2100 in our case. The BoE leverages on the NGFS projections at a five-year frequency, while we have produced datapoints at quarterly frequency to allow time series analysis with standard macrofinancial variables.

The forecasted series shown here all include the impacts from both transition and chronic physical risk, derived using the methodology discussed in detail in the earlier sections. The NGFS publishes results for three representative scenarios and five alternative scenarios using three different IAMs: GCAM 5.2, REMIND-MAgPIE 1.7-3.0, and MEASSAGE ix-GLOBIOM 1.0. This creates a challenge in the calibration process. First, the population and GDP figures are different in the historical period of 2005 to 2020 for different models. Therefore, the

starting point across scenarios will not be the same if we calibrate to the NGFS marker scenarios. Second, NGFS suggested calculating the mitigation cost expressed as a loss of GDP between two scenarios by subtracting GDP in one scenario from the other for REMIND-MAgPIE and MESSAGEix-GLOBIOM. Calibrating to the marker scenarios will not allow us to calculate the mitigation cost as suggested by NGFS. Finally, only for the REMIND-MAgPIE 1.7-3.0 IAM model does the NGFS publish results for all three of its representative scenarios—Hot House World, Disorderly, and Orderly. The NGFS therefore recommends that all scenario analysis exercises be conducted using the same model. Following this recommendation, and for the sake of consistency across scenarios, we have used the NGFS-provided output from REMIND-MAgPIE 1.7-3.0 to construct our climate risk scenarios.

Chart 11 summarizes the adopted process to produce scenarios consistent with NGFS.

We match energy consumption translated into fuel emissions by source. For the physical risk, we apply the Moody's Analytics approach including the assumptions with respect to projections of population and GDP. For transition risk, we have opted to match energy consumption and emissions, as they are well defined, while the GDP paths published by NGFS depend on assumptions with respect to population and other variables that are inconsistent with ours. We also use the NGFS carbon price trajectories and our model to produce forecasts for domestic energy prices, which simultaneously interact with other model variables to produce our full set of macroeconomic forecasts. Ultimately, the ranking of our GDP paths is similar to those of the NGFS, though there are differences in absolute levels. The end product is a set of macroeconomic scenarios consistent with NGFS assumptions on fossil fuel usage, carbon emissions, and carbon prices.

Chart 13: U.S. Carbon Dioxide Tax Rate

$ per metric ton, NSA

- NGFS Current (Hot House World)
- NGFS Delay (Disorderly)
- NGFS Immediate (Orderly)
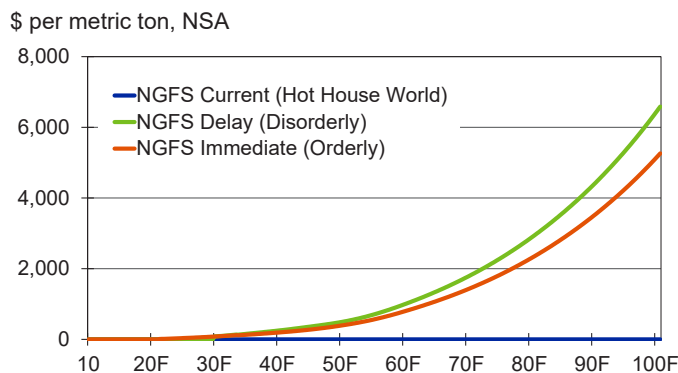
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 14: U.K. Effective Domestic Price: Coal

1/100 £ per #, log scale, NSA

- NGFS Current (Hot House World)
- NGFS Delay (Disorderly)
- NGFS Immediate (Orderly)
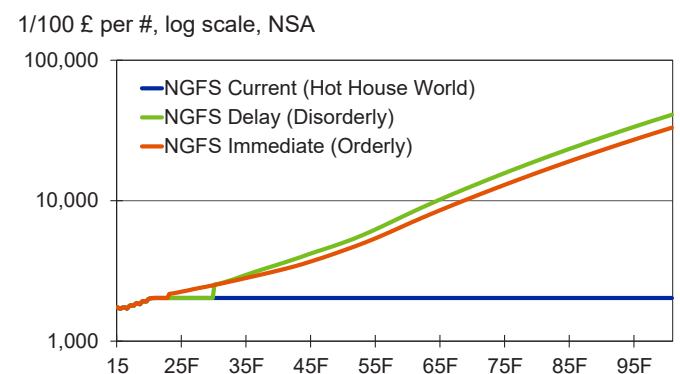
Sources: U.K. Department for Business, Energy & Industrial Strategy, Moody's Analytics

Chart 15: U.S. Effective Domestic Price: NG

$ per mmBTU, log scale, SA
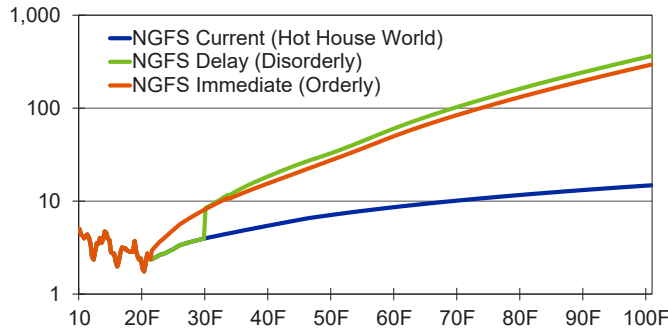
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 16: U.K. Energy Consumption: Coal

BTU, tril, log scale, SAAR
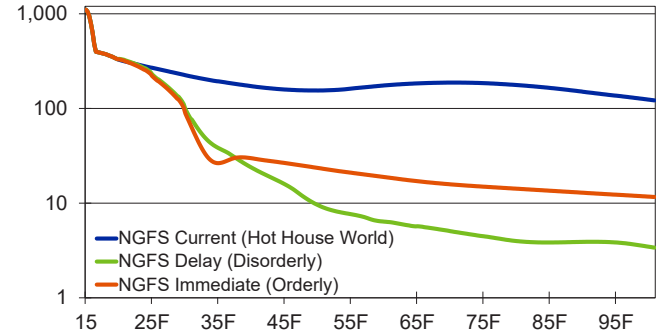
Sources: U.S. Energy Information Administration, Moody's Analytics

Charts 12 and 13 summarize the U.K. and U.S. carbon tax rate until 2100 for the three NGFS representative scenarios. For each scenario, we calibrate the carbon tax pathway to match the carbon tax trajectory generated by the REMIND-MAgPie IAM model used by NGFS. In the Orderly scenario, the carbon tax is put into effect starting in the third quarter of 2021, and the carbon tax rate rises overtime, with the increase significantly intensifying in the second half of the century. In the Disorderly scenario, the carbon tax is not implemented until the first quarter of 2030, and because of the late start, the carbon tax rate needs to be higher than the immediate scenario in order to make up for the lost time. In the Hot House World scenario, the carbon tax rate is zero since no additional future action will be taken to mitigate climate risks.

The carbon tax will raise the effective domestic energy prices of fossil fuels tremendously. Charts 14 and 15 show that prior to 2030, energy prices for U.K. coal and U.S.

natural gas in the Disorderly scenario are the same as in the Hot House World scenario, but they will rise rapidly and exceed the Orderly scenario starting in 2030. By 2100, the U.K. effective domestic coal price in the Orderly and Disorderly scenarios will be more than 15 times the Hot House World scenario, and a similar pattern holds for the U.S. effective domestic natural gas price. Since the carbon tax is levied per metric ton of emission, it will have a larger impact on coal than on natural gas because coal has a higher CO_2 emission factor.

As a result of the very large carbon tax rate imposed in the Orderly and Disorderly scenarios, fossil fuels consumption will fall dramatically. Chart 16 shows that U.K. coal consumption will be driven to near zero in the Orderly and Disorderly scenarios, and without the carbon tax, U.K. coal consumption will continue its long-term decline, but will not fall to zero by 2100 in the Hot House World scenario. U.S. natural gas

consumption in Chart 17 is projected to rise steadily in the Hot House World scenario, but in the the Orderly and Disorderly scenarios it is projected to decline by over 50% in 2100.

After calibrating to the NGFS carbon tax and fossil fuels consumption pathway, and adjusting for the effects of chronic physical risk for the U.K.[14] and the U.S., we use the Moody's Analytics Global Macro Model to generate the full scenario pathway for the U.K., U.S., and the rest of the global economy. The scenario outputs are the entire suite of economic and financial variables currently in the Moody's Analytics Global Macro Model universe. Charts 18 and 19 show the projected percentage loss in real GDP between scenarios. Since the impacts of chronic physical risk are small and almost negligible for the U.K. and

---

14 Since the U.K. is not a separate region in the NGFS scenarios, we calibrate the U.K. using the carbon tax rate and fossil fuels consumption pathway for the EU as a proxy.

Chart 17: U.S. Energy Consumption: NG

Ths, short tons, SAAR
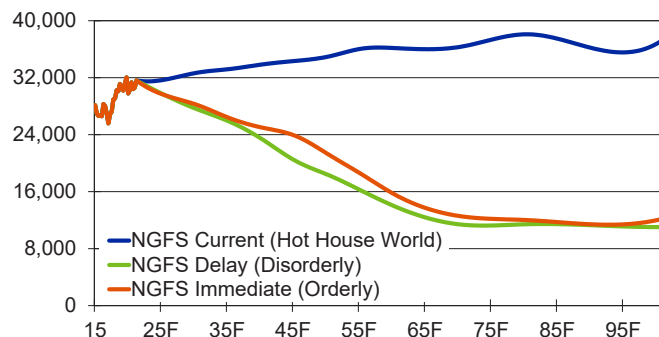
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 18: U.K. Real GDP Scen Comparison

% deviation from NGFS current
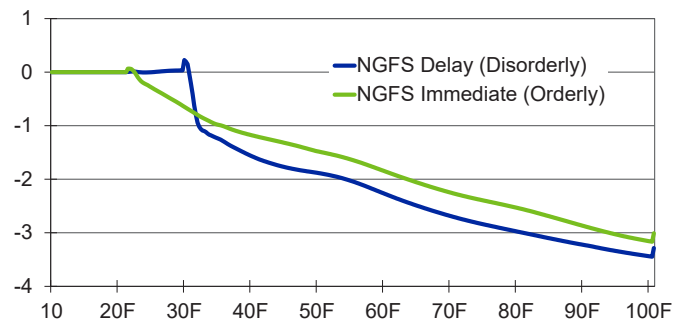
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 19: U.S. Real GDP Scen Comparison

% deviation from NGFS current
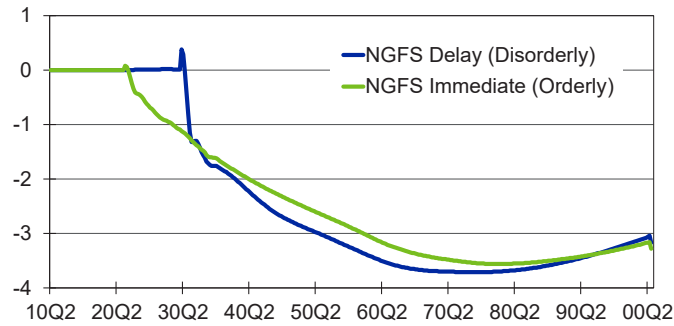
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 20: U.K. GVA Svcs Industry Scenario

% deviation from NGFS current
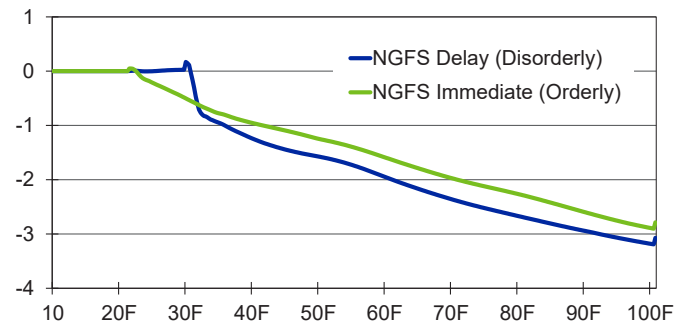
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 21: U.S. GPO Mining Industry Scenario

% deviation from NGFS current
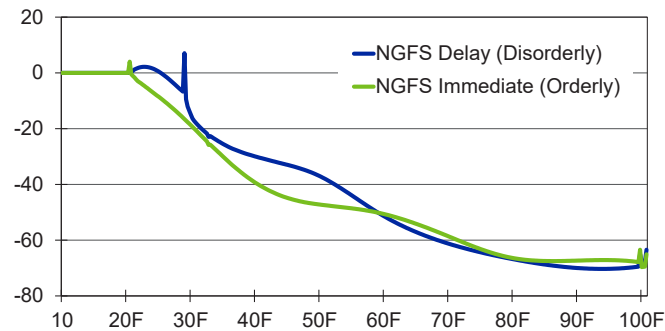
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 22: U.K. Employment Services Industry

% deviation from NGFS current
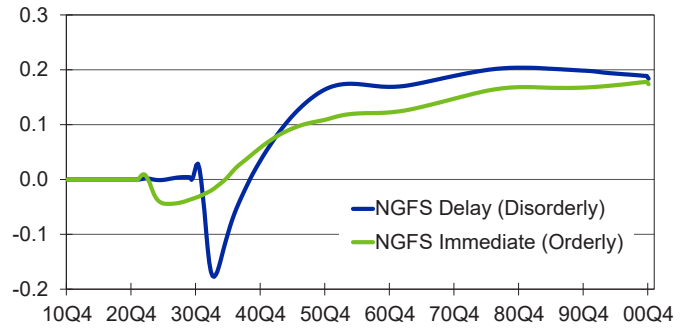
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 23: U.S. Employment Mining Industry

% deviation from NGFS current
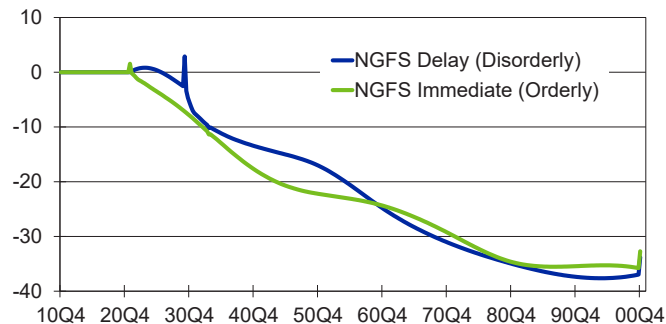
Sources: Network for Greening the Financial System, Moody's Analytics

Chart 24: Climate Risk Sensitivities

Climate change and credit risk
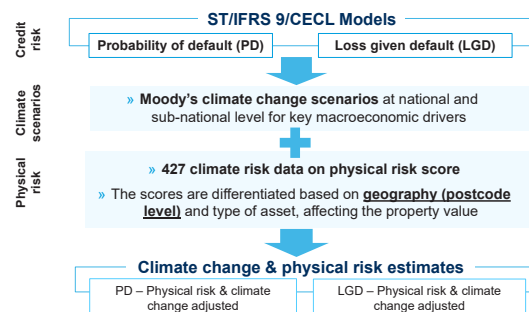
Sources: Network for Greening the Financial System, Moody's Analytics

the U.S., losses in real GDP for these two countries are mostly due to transition risk alone. The percentage losses calculated from the Moody's Analytics Global Macro Model are similar to the estimates from RE-MIND-MAgPie. For the U.K., the peak loss occurs at around 3% in 2100, and for the U.S., the peak loss occurs earlier in 2070 at almost 5%, and the loss becomes smaller after that. Other than the initial period in which the carbon tax is put into effect, real GDP is consistently lower in both the Orderly and Disorderly scenarios when compared with the Hot House World scenario. In the initial period, the economy gets an immediate boost due to the collection and distribution of the carbon tax revenue, which raises real GDP. In the Orderly scenario, GDP loss occurs right away in 2021, and in the Disorderly, GDP loss occurs in 2030 after the carbon tax is implemented and exceeds the loss level in the Orderly scenario throughout the forecast period.

GDP loss at the aggregate level may give a false impression of the full impact from transition risk for individual industries. In transitioning to a low carbon economy, there needs to be a substantial reallocation of resources, and the inflation pressures from energy prices will affect industries and sectors differently. High-risk industries such as mining and utilities will be hit much harder than low-risk industries such as professional services. Charts 20 and 21 show the projected percentage losses in gross value added for the U.K. service-providing industry and the gross

product originating for the U.S. mining industry. Not surprisingly, the difference between industries is huge. The U.K. service-providing industry is expected to incur a peak loss in output of 3% by 2100, slightly lower than the percentage loss in aggregate GDP, whereas the U.S. mining industry is expected to suffer a peak loss of well over 60% when compared with the Hot House World scenario. Industry employment tells a similar story. The U.K. service-providing industry is virtually unaffected, with employment loss hovering around 0%, while the U.S. mining industry is projected to experience a nearly 40% reduction in employment in both the Orderly and Disorderly scenarios (see Charts 22 and 23).

Summary

The financial industry has been gearing up to address the challenges of assessing climate risk. The starting point of this assessment is the generation of climate change scenarios. Moody's Analytics has developed a framework to complement and expand scenarios provided by various regulators and often produced using IAMs or other types of models with heavy emphasis on climate modelling. The Moody's framework leverages its well-tested Global Macroeconomic Model, which has been used to produce macroeconomic scenarios for stress-testing and other regulatory purposes. We have presented a methodology that enables us to include the long-term physical climate change risk in the scenario generation process. The Global Macroeco-nomic Model has been enhanced by several blocks of equations at the country and industry levels to incorporate transition risk to a zero-carbon economy. The transition risk approach is based on a path of the carbon dioxide tax that affects energy prices and subsequently the overall price level. The simultaneous equations model of the global economy is then solved for all standard macrofinancial variables, including the newly added transition drivers. We use this upgraded framework to produce NGFS consistent scenarios for the U.S. and the U.K. These scenarios are also in general consistent with the BoE BES that also employ NGFS climate change scenarios.

The climate change scenarios are used as input and the first step in the credit risk assessment of portfolios of financial institutions. They are further combined with facility-level data such as the previously discussed physical risk scores by 427 (see Chart 24). The data requirements are similar to standard stress-testing and/or IFRS 9/CECL type calculations. These data inputs are used to generate projections of risk parameters such as probability of default, loss given default, and the corresponding expected credit losses. The analysis of instrument-level performance based on the portfolio data snapshots, combined with facility-level climate risk score from 427, will result in adjustment factors for PDs and LGDs to account for the climate change risk. The output includes a variety of instrument-level metrics combined with the adjustment factors.

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

1 - Impact channel

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
Sea level rise	FC$_GEO	Real private consumption expenditure	Stochastic	Bil. 2018 GBP, SAAR	FC$_I_IGBR (National Accounts: Private Consumption [Intermediate term]) FGDP$_I_IGBR (National Accounts: Gross Domestic Product [Intermediate term]) FIF$_I_IGBR (National Accounts: Gross Fixed Capital Formation [Intermediate term]) FG$_IGBR (National Accounts: Real Government Consumption Expenditure FNETEX$_IGBR (National Accounts: Real Net Exports of Goods and Services) FGDP$_RESID_IGBR (National Accounts: GDP Discrepancy)	FGDPFA$_I_IGBR (FGDPFA$_I_IGBR(Gross Value Added [GVA] - Accommodation and food service activities [Intermediate term])) FGDPAS$_I_IGBR (FGDPAS$_I_IGBR(Gross Value Added [GVA] - Administrative and support service activities [Intermediate term]) FGDPAE$_I_IGBR (FGDPAE$_I_IGBR(Gross Value Added [GVA] - Arts; entertainment and recreation [Intermediate term])) FGDPEG$_I_IGBR (FGDPEG$_I_IGBR(Gross Value Added [GVA] - Electricity; gas; steam and air conditioning supply [Intermediate term])) FGDPIC$_I_IGBR (FGDPIC$_I_IGBR(Gross Value Added [GVA] - Information and communication [Intermediate term])) FGDPPS$_I_IGBR (FGDPPS$_I_IGBR(Gross Value Added [GVA] - Professional; scientific and technical activities [Intermediate term])) FGDPTS$_I_IGBR (FGDPTS$_I_IGBR(Gross Value Added [GVA] - Transportation and storage [Intermediate term])) FGDPWR$_I_IGBR (FGDPWR$_I_IGBR(Gross Value Added [GVA] - Wholesale and retail trade; repair of motor vehicles [Intermediate term])) FRVEHLQ_IGBR (FRVEHLQ_IGBR(Motor vehicles: Sales - New - Light vehicles)) FII$_IGBR (FII$_IGBR(National Accounts: Change in Inventories)) FC_IGBR (FC_IGBR(National Accounts: Nominal Private Consumption Expenditure)) FDDEMAND$_IGBR (FDDEMAND$_IGBR(National Accounts: Real Domestic Demand)) FIF$_IGBR(FIF$_IGBR (National Accounts: Real Gross Fixed Capital Formation [GFCF])) FC$_D_IGBR (FC$_D_IGBR(National Accounts: Real Private Consumption Expenditure))
Agricultural productivity						FGDP$_POT_IGBR (National Accounts: Potential Real Gross Domestic Product)
Heat stress effect on labor productivity	FPROD$_POT_GEO	Real potential productivity	Stochastic	Ths. 2018 GBP, SAAR	FPROD$_POT_IGBR (Real potential productivity)	FYPEWAVG$_I_IGBR (Real average wage [Intermediate term])
Human health effects						FPROD$_POT_IGBR (Real potential productivity)

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
Tourism	FNETEX$_L_GEO	Real net exports of goods and services	Identity	Bil. 2018 GBP, SAAR	FIM$_IGBR (National Accounts: Real Imports of Goods and Services); FEX$_IGBR (National Accounts: Real Exports of Goods and Services)	FII$_IGBR (National Accounts: Change in Inventories); FGDP$_L_IGBR (National Accounts: Gross Domestic Product [Intermediate term]); FGDP$_IGBR (National Accounts: Real Gross Domestic Product [GDP]); FIF$_IGBR (National Accounts: Real Gross Fixed Capital Formation [GFCF]); FIM$_IGBR (National Accounts: Real Imports of Goods and Services); FC$_IGBR (National Accounts: Real Private Consumption Expenditure)
						FPCOIL_IWRLD (Commodity prices: Crude oil: simple average of three spot prices: Dated Brent; West Texas Intermediate; Dubai Fateh); FMEPPAPRPQ_US (Crude Oil Production); FPCOILDOM_ICHN (Effective domestic oil price); FPCOILDOM_IDEU (Effective domestic oil price); FPCOILDOM_IGBR (Effective domestic oil price); FPCOILDOM_ITHA (Effective domestic oil price); FPCOILDOM_US (Effective domestic oil price); FCPIFICEBOIU_US (Futures Price: Brent crude oil 1-month forward [fob]); FCPWTI_US (Futures Price: NYMEX Light Sweet Crude Oil - Contract 1); FCPPOIL$Q_IWRLD (Real Global Price of Oil)
Energy demand	FCPIFICEBOIU_US	Futures price: Brent crude oil 1-mo forward [fob]	Stochastic	USD per bbl, NSA	FCPIFICEBOIU_US (Futures Price: Brent crude oil 1-month forward [fob]); FEIAPDGQ_US (EIA: Petroleum- Global Demand); FTWDBRD$_US (Weighted Average Exchange Value of U.S. Dollar: Broad Index - Real); FCPIFICEBOIUT_US (Equilibrium Price: Brent crude oil 1-month forward [fob])	

2 - CO2 taxes

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
1. Dividend dummy	DUM_CARBON-DIV_IGBR	Dummy variable for U.K. carbon dividend: 1=dividend; 0=no dividend	Exogenous	Boolean, NSA	NA	FGGEXP_L_IGBR (Government Finance: Expenditure - Total [Intermediate term]); FYPD_IGBR (Household Disposable Income - Gross)

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
2. Carbon tax dummy	DUM_CARBONTAX_IGBR	Dummy variable for carbon tax: 1=tax applied; 0=no tax applied	Exogenous	Boolean, NSA	NA	FPCCOALDOM_IGBR (Average price in Pence - Coal) FCOALREV_IGBR (Carbon dioxide tax revenue from coal) FNGASREV_IGBR (Carbon dioxide tax revenue from natural gas) FPETREV_IGBR (Carbon dioxide tax revenue from petroleum) FPCNGASDOM_IGBR (Effective Domestic natural gas price) FPCOILDOM_IGBR (Effective domestic oil price)
3. Carbon tax rate	FCARBONTAX_IGBR	Carbon dioxide tax rate	Exogenous	GBP per metric ton, NSA	NA	FPCCOALDOM_IGBR (Average price in Pence - Coal) FCOALREV_IGBR (Carbon dioxide tax revenue from coal) FNGASREV_IGBR (Carbon dioxide tax revenue from natural gas) FPETREV_IGBR (Carbon dioxide tax revenue from petroleum) FPCNGASDOM_IGBR (Effective Domestic natural gas price) FPCOILDOM_IGBR (Effective domestic oil price)
4. Carbon tax revenue	FCARBONREV_IGBR	Carbon dioxide tax revenue - Total	Identity	Bil. GBP, SAAR	FCOALREV_IGBR (Carbon dioxide tax revenue from coal) FNGASREV_IGBR (Carbon dioxide tax revenue from natural gas) FPETREV_IGBR (Carbon dioxide tax revenue from petroleum)	FGGEXP_L_IGBR (Government Finance: Expenditure - Total [Intermediate term]) FGGREV_IGBR (Government finance: General government - Total revenue) FYPD_IGBR (Household Disposable Income - Gross)
4-i. Carbon tax revenue: coal	FCOALREV_IGBR	Carbon dioxide tax revenue from coal	Identity	Bil. GBP, SAAR	DUM_CARBONTAX_IGBR (Dummy variable for carbon tax: 1=tax applied; 0=no tax applied) FCARBONTAX_IGBR (Carbon dioxide tax rate) FCOALCO2EQ_IGBR (Carbon dioxide emissions - Coal and coke)	FCARBONREV_IGBR (Carbon dioxide tax revenue - Total)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
4-i. Carbon tax revenue: natural gas	FNGASREV_IGBR	Carbon dioxide tax revenue from natural gas	Identity	Bil. GBP, SAAR	DUM_CARBONTAX_IGBR (Dummy variable for carbon tax: 1=tax applied; 0=no tax applied); FCARBONTAX_IGBR (Carbon dioxide tax rate); FNGASCO2EQ_IGBR (Carbon dioxide emissions - Natural Gas)	FCARBONREV_IGBR (Carbon dioxide tax revenue - Total)
4-i. Carbon tax revenue: petroleum	FPETREV_IGBR	Carbon dioxide tax revenue from petroleum	Identity	Bil. GBP, SAAR	DUM_CARBONTAX_IGBR (Dummy variable for carbon tax: 1=tax applied; 0=no tax applied); FCARBONTAX_IGBR (Carbon dioxide tax rate); FPETCO2EQ_IGBR (Carbon dioxide emissions - Petroleum and other liquids)	FCARBONREV_IGBR (Carbon dioxide tax revenue - Total)
3 - Energy prices						
1. Coal	FPCCOALDOM_ IGBR	Average price in Pence - Coal	Stochastic	1/100 GBP per #, NSA	FPCCOALDOM_IGBR (Average price in Pence - Coal); DUM_CARBONTAX_IGBR (Dummy variable for carbon tax: 1=tax applied; 0=no tax applied); FCARBONTAX_IGBR (Carbon dioxide tax rate)	FPCCOALDOM_IGBR (Average price in Pence - Coal); FCOALCONQ_IGBR (Coal consumption); FCPIE_IGBR (Consumer Price Index: Goods - Energy); FCPIELEC_IGBR (Consumer price index: Electricity)
2. Natural gas	FPCNGASDOM_ IGBR	Effective domestic natural gas price	Stochastic	Index 2010=100, SA	FPCNGASDOM_IGBR (Effective Domestic natural gas price); DUM_CARBONTAX_IGBR (Dummy variable for carbon tax: 1=tax applied; 0=no tax applied); FCARBONTAX_IGBR (Carbon dioxide tax rate); FTFXIUSA_IGBR (Nominal Bilateral Exchange Rate)	FCPIE_IGBR (Consumer Price Index: Goods - Energy); FCPIELEC_IGBR (Consumer price index: Electricity); FPCNGASDOM_IGBR (Effective Domestic natural gas price); FNGASCONQ_IGBR (Natural gas consumption)

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
3. Oil	FPCOILDOM_IGBR	Effective domestic oil price	Identity	GBP per bbl, NSA	FCPIFICEBOIU_US (Futures Price: Brent crude oil 1-month forward [fob]); FTFXIUSA_IGBR (Nominal Bilateral Exchange Rate); DUM_CARBONTAX_IGBR (Dummy variable for carbon tax: 1=tax applied; 0=no tax applied); FCARBONTAX_IGBR (Carbon dioxide tax rate)	FCPIE_IGBR (Consumer Price Index: Goods - Energy); FGDPEG$_I_IGBR (Gross Value Added [GVA] - Electricity; gas; steam and air conditioning supply [Intermediate term]); FGDPMQ$_I_IGBR (Gross Value Added [GVA] - Mining and quarrying [Intermediate term]); FIM$_IGBR (National Accounts: Real Imports of Goods and Services); FPETCONQ_IGBR (Petroleum consumption); FPPI_IGBR (Producer Price Index: Input Prices [materials and fuel])
4 - Energy consumption						
1. Coal	FCOALCONQ_IGBR	Coal consumption	Stochastic	Tril. BTU, SAAR	FPCCOALDOM_IGBR (Average price in Pence - Coal)	FCOALCO2EQ_IGBR (Carbon dioxide emissions - Coal and coke)
2. Natural gas	FNGASCONQ_IGBR	Natural gas consumption	Stochastic	Tril. BTU, SAAR	FPCNGASDOM_IGBR (Effective Domestic natural gas price); FIP_IGBR (Industrial Production: Total)	FNGASCO2EQ_IGBR (Carbon dioxide emissions - Natural Gas)
3. Petroleum and other liquid	FPETCONQ_IGBR	Petroleum consumption	Stochastic	Tril. BTU, SAAR	FPCOILDOM_IGBR (Effective domestic oil price); FYPD$_IGBR (Household Disposable Income - Gross); FREG_IGBR (New Motor Vehicle Registrations: Passenger Cars)	FPETCO2EQ_IGBR (Carbon dioxide emissions - Petroleum and other liquids); FEIAPDGQ_US (EIA: Petroleum- Global Demand)
5 - CO2 emissions						
1. Coal	FCOALCO2EQ_IGBR	Carbon dioxide emissions - Coal and coke	Stochastic	Mil. Metric Tons, SAAR	FCOALCONQ_IGBR (Coal consumption)	FFFCO2EQ_IGBR (Carbon dioxide emissions - Fossil fuels); FCOALREV_IGBR (Carbon dioxide tax revenue from coal)
2. Natural gas	FNGASCO2EQ_IGBR	Carbon dioxide emissions - Natural gas	Stochastic	Mil. Metric Tons, SAAR	FNGASCONQ_IGBR (Natural gas consumption)	FFFCO2EQ_IGBR (Carbon dioxide emissions - Fossil fuels); FNGASREV_IGBR (Carbon dioxide tax revenue from natural gas)

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
3. Oil and petroleum products	FPETCO2EQ_IGBR	Carbon dioxide emissions - Petroleum and other liquids	Stochastic	Mil. Metric Tons, SAAR	FPETCONQ_IGBR (Petroleum consumption)	FFFCO2EQ_IGBR (Carbon dioxide emissions - Fossil fuels); FPETREV_IGBR (Carbon dioxide tax revenue from petroleum)
6 - Govt finances						
1. Total revenue	FGGREV_IGBR	Government finance: General government - Total revenue	Identity	Bil. GBP, SAAR	FGDP_IGBR (National Accounts: Nominal Gross Domestic Product [GDP]); FGGTAXR_I_IGBR (Effective tax rate [Intermediate term]); FCARBONREV_IGBR (Carbon dioxide tax revenue - Total)	FGGBAL_IGBR (Government finance: General government - Budget balance)
2. Total expense	FGGEXP_IGBR	Government finance: General government - Total expense	Identity	Bil. GBP, SAAR	FGGEXP_RESID_IGBR (Government expenditure residual [Intermediate term]); FGGEXPINT_IGBR (Government finance: General government - Interest expense); FG_IGBR (National Accounts: Nominal Government Consumption Expenditure)	FGGBAL_IGBR (Government finance: General government - Budget balance)
3. Expenditure intermediate term	FGGEXP_I_IGBR	Government finance: Expenditure - Total [Intermediate term]	Stochastic	Bil. GBP, SAAR	FGGEXP_I_IGBR (Government Finance: Expenditure - Total [Intermediate term]); FCARBONREV_IGBR (Carbon dioxide tax revenue - Total); DUM_CARBONDIV_IGBR (Dummy variable for U.K. carbon dividend: 1=dividend; 0=no dividend); FGDP_POT_IGBR (National Accounts: Potential Nominal Gross Domestic Product); FGGDEBTGDP_IGBR (General government debt to GDP ratio)	FGGEXP_I_IGBR (Government Finance: Expenditure - Total [Intermediate term]); FGGEXP_RESID_IGBR (Government expenditure residual [Intermediate term])
4. Expenditure residual	FGGEXP_RESID_IGBR	Government expenditure residual [Intermediate term]	Identity	Bil. EUR, SAAR	FGGEXP_I_IGBR (Government Finance: Expenditure - Total [Intermediate term]); FGGEXPINT_IGBR (Government finance: General government - Interest expense); FG_IGBR (National Accounts: Nominal Government Consumption Expenditure)	FGGEXP_IGBR (Government finance: General government - Total expense); FYPD_IGBR (Household Disposable Income - Gross)

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

7 - Price indexes

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
1. All items ex energy, food, alcohol, tobacco	FCPIX_IGBR	CPIH: Index - Special aggregates - All items; ex energy; food; alcohol; tobacco	Stochastic	Index 2015=100, SA	FCPIX_IGBR (CPIH: Index - Special aggregates - All items; excluding energy; food; alcohol & tobacco); FEINFLAT_IGBR (Inflation expectations); FTFXIEUZN_IGBR (Nominal Bilateral Exchange Rate); FCPIE_IGBR (Consumer Price Index: Goods - Energy); FCPIF_IGBR (Consumer Price Index: Goods - Food; alcoholic beverages & tobacco); FLBR_IGBR (Labor Force Survey: Unemployment Rate); FNAIRU_IGBR (Non-accelerating inflation rate of unemployment [NAIRU]); FYPEWS_IGBR (Personal Income: Nominal Wages and Salaries); FGDP_IGBR (National Accounts: Nominal Gross Domestic Product [GDP])	FCPIXUQ_IGBR (CPIH: Index - Special aggregates - All items; excluding energy; food; alcohol & tobacco); FCPIX_IGBR (CPIH: Index - Special aggregates - All items; excluding energy; food; alcohol & tobacco); FCPI_IGBR (Consumer Price Index: EU Harmonized - Total)
2. Food, alcohol, tobacco	FCPIF_IGBR	Consumer price index: Goods - Food; alcohol; tobacco	Stochastic	Index 2015=100, SA	FCPIF_IGBR (Consumer Price Index: Goods - Food; alcoholic beverages & tobacco); FPCIF_IWRLD (Commodity prices: Agriculture - Food); FTFXIEUZN_IGBR (Nominal Bilateral Exchange Rate); FCPIE_IGBR (Consumer Price Index: Goods - Energy)	FCPIX_IGBR (CPIH: Index - Special aggregates - All items; excluding energy; food; alcohol & tobacco); FCPI_IGBR (Consumer Price Index: EU Harmonized - Total); FCPIF_IGBR (Consumer Price Index: Goods - Food; alcoholic beverages & tobacco)
3. Energy	FCPIE_IGBR	Consumer price index: Goods - Energy	Stochastic	Index 2015=100, SA	FPCOILDOM_IGBR (Effective domestic oil price); FPCNGASDOM_IGBR (Effective Domestic natural gas price); FPCCOALDOM_IGBR (Average price in Pence - Coal); FCPIELEC_IGBR (Consumer price index: Electricity)	FCPIX_IGBR (CPIH: Index - Special aggregates - All items; excluding energy; food; alcohol & tobacco); FCPI_IGBR (Consumer Price Index: EU Harmonized - Total); FCPIF_IGBR (Consumer Price Index: Goods - Food; alcoholic beverages & tobacco)

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
4. Electricity	FCPIELEC_IGBR	Consumer price index: Electricity	Stochastic	Index 2015=100, SA	FPCNGASDOM_IGBR (Effective Domestic natural gas price); FPCCOALDOM_IGBR (Average price in Pence - Coal)	FCPIE_IGBR (Consumer Price Index: Goods - Energy)
5. Total	FCPI_IGBR	Consumer price index: EU Harmonized - Total	Stochastic	Index 2015=100, SA	FCPIE_IGBR (Consumer Price Index: Goods - Energy); FCPIF_IGBR (Consumer Price Index: Goods - Food; alcoholic beverages & tobacco); FCPIX_IGBR (CPIH: Index - Special aggregates - All items; excluding energy; food; alcohol & tobacco); FCPI_IGBR (Consumer Price Index: EU Harmonized - Total)	Almost all countries in the global model
6. Producer price	FPPI_IGBR	Producer price index: Input prices [materials and fuel]	Stochastic	Index 2010=100, NSA	FPDIIM_IGBR (Implicit Price Deflator: Imports of Goods and Services); FPCOILDOM_IGBR (Effective domestic oil price)	
8 - Other						
1. Real imports	FIM$_IGBR	National accounts: Real imports of goods and services	Stochastic	Bil. 2018 GBP; SAAR	FNETEX$_IGBR (National Accounts: Real Net Exports of Goods and Services); FC$_I_IGBR (National Accounts: Private Consumption [Intermediate term]); FIF$_I_IGBR (National Accounts: Gross Fixed Capital Formation [Intermediate term]); FEX$_IGBR (National Accounts: Real Exports of Goods and Services); FTFXIUSA_IGBR (Nominal Bilateral Exchange Rate); FCPI_IGBR (Consumer Price Index: EU Harmonized - Total); FCPIU_US (CPI: Urban Consumer - All Items); FGDP$_POT_IGBR (National Accounts: Potential Real Gross Domestic Product); FPCOILDOM_IGBR (Effective domestic oil price)	

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
2. Disposable income	FYPD_IGBR	Household disposable income - Gross	Stochastic	Bil. GBP, SAAR	FYPD$_IGBR (Household Disposable Income - Gross); FYPEW$_IGBR (Personal Income: Nominal Wages and Salaries); FCARBONREV_IGBR (Carbon dioxide tax revenue - Total); DUM_CARBONDIV_IGBR (Dummy variable for U.K. carbon dividend: 1=dividend; 0=no dividend); FRMP_IGBR (Interest rate: Bank of England Base Rate); FPDIC_IGBR (Implicit Price Deflator: Private Consumption Expenditure); FGDP$_IGBR (National Accounts: Real Gross Domestic Product [GDP]); FGGTAXR_I_IGBR (Effective tax rate [Intermediate term]); FSPI_IGBR (Stock Market: FTSE-100 Index); FGGEXP_RESID_IGBR (Government expenditure residual [Intermediate term])	FHHDEBTCCSR_IGBR (Debt Service Ratio - Nominal Credit Card Debt to Nominal Disposable Income); FHHDEBTMSR_IGBR (Debt Service Ratio - Nominal Mortgage Debt to Nominal Disposable Income); FHHDEBTOTHSR_IGBR (Debt Service Ratio - Other Nominal Consumer Debt to Nominal Disposable Income); FHHDEBTMLNN_IGBR (Household Debt: Net mortgage lending to individuals); FYPD$_IGBR (Household Disposable Income - Gross); FHHDPDOM_IGBR (Households and non-profit institutions serving households - Deposits with UK MFIs [AF221])
3. Exchange rate	FTFXIUSA_IGBR	Nominal bilateral exchange rate	Stochastic	USD per GBP; NSA	FTFXTW$_L_IGBR (Effective Exchange Rate - Real Broad Index [Intermediate term]); FTWDBRD_US (Weighted Average Exchange Value of U.S. Dollar: Broad Index - Nominal); FTFXIUSAQ_IEUZN (Nominal Bilateral Exchange Rate)	All countries in the global model
4. GVA of services industry	FGDPSERV$_IGBR	Gross value added [GVA] - Service-providing industries	Stochastic	Bil. Ch. 2018 GBP, SAAR	FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries); FGDPTOT$_IGBR (Gross Value Added [GVA] - Total); FGDP$_IGBR (National Accounts: Real Gross Domestic Product [GDP])	GVA and employment in all other sectors

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
9 - Employment						
1. Arts; entertainment and recreation [Intermediate term]	FEAE_I_IGBR	Employment - Arts; entertainment and recreation [Intermediate term]	Stochastic	Mil. #, SA	FEAE_I_IGBR (Employment - Arts; entertainment and recreation [Intermediate term]); FESERV_IGBR (Employment - Services producing industries); FGDPAE$_IGBR (Gross Value Added [GVA] - Arts; entertainment and recreation); FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEAE_IGBR (Employment - Arts; entertainment and recreation); FEAE_I_IGBR (Employment - Arts; entertainment and recreation [Intermediate term]); FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
2. Agriculture; forestry and fishing [Intermediate term]	FEAF_I_IGBR	Employment - Agriculture; forestry and fishing [Intermediate term]	Stochastic	Mil. #, SA	FEAF_I_IGBR (Employment - Agriculture; forestry and fishing [Intermediate term]); FEGOOD_IGBR (Employment - Goods producing industries); FGDPAF$_IGBR (Gross Value Added [GVA] - Agriculture; forestry and fishing); FGDPGOOD$_IGBR (Gross Value Added [GVA] - Goods producing industries)	FEAF_IGBR (Employment - Agriculture; forestry and fishing); FEAF_I_IGBR (Employment - Agriculture; forestry and fishing [Intermediate term]); FEGOOD_I_IGBR (Employment - Goods producing industries [Intermediate term])
3. Administrative and support service activities [Intermediate term]	FEAS_I_IGBR	Employment - Administrative and support service activities [Intermediate term]	Stochastic	Mil. #, SA	FEAS_I_IGBR (Employment - Administrative and support service activities [Intermediate term]); FESERV_IGBR (Employment - Services producing industries); FGDPAS$_IGBR (Gross Value Added [GVA] - Administrative and support service activities); FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEAS_IGBR (Employment - Administrative and support service activities); FEAS_I_IGBR (Employment - Administrative and support service activities [Intermediate term]); FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
4. Construction [Intermediate term]	FECN_I_IGBR	Employment - Construction [Intermediate term]	Stochastic	Mil. #, SA	FECN_I_IGBR (Employment - Construction [Intermediate term]); FEGOOD_IGBR (Employment - Goods producing industries); FGDPCN$_IGBR (Gross Value Added [GVA] - Construction); FGDPGOOD$_IGBR (Gross Value Added [GVA] - Goods producing industries)	FECN_IGBR (Employment - Construction); FECN_I_IGBR (Employment - Construction [Intermediate term]); FEGOOD_I_IGBR (Employment - Goods producing industries [Intermediate term])

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
5. Education [Intermediate term]	FEED_I_IGBR	Employment - Education [Intermediate term]	Stochastic	Mil. #, SA	FEED_I_IGBR (Employment - Education [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPED$_IGBR (Gross Value Added [GVA] - Education) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEED_IGBR (Employment - Education) FEED_I_IGBR (Employment - Education [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
6. Electricity; gas; steam and air conditioning supply [Intermediate term]	FEEG_I_IGBR	Employment - Electricity; gas; steam and air conditioning supply [Intermediate term]	Stochastic	Mil. #, SA	FEEG_I_IGBR (Employment - Electricity; gas; steam and air conditioning supply [Intermediate term]) FEGOOD_IGBR (Employment - Goods producing industries) FGDPEG$_IGBR (Gross Value Added [GVA] - Electricity; gas; steam and air conditioning supply) FGDPGOOD$_IGBR (Gross Value Added [GVA] - Goods producing industries)	FEEG_IGBR (Employment - Electricity; gas; steam and air conditioning supply) FEEG_I_IGBR (Employment - Electricity; gas; steam and air conditioning supply [Intermediate term]) FEGOOD_I_IGBR (Employment - Goods producing industries [Intermediate term])
7. Accommodation and food service activities [Intermediate term]	FEFA_I_IGBR	Employment - Accommodation and food service activities [Intermediate term]	Stochastic	Mil. #, SA	FEFA_I_IGBR (Employment - Accommodation and food service activities [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPFA$_IGBR (Gross Value Added [GVA] - Accommodation and food service activities) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEFA_IGBR (Employment - Accommodation and food service activities) FEFA_I_IGBR (Employment - Accommodation and food service activities [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
8. Financial and insurance activities [Intermediate term]	FEFI_I_IGBR	Employment - Financial and insurance activities [Intermediate term]	Stochastic	Mil. #, SA	FEFI_I_IGBR (Employment - Financial and insurance activities [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPFI$_IGBR (Gross Value Added [GVA] - Financial and insurance activities) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEFI_IGBR (Employment - Financial and insurance activities) FEFI_I_IGBR (Employment - Financial and insurance activities [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
9. Activities of households as employers [Intermediate term]	FEHH_I_IGBR	Employment - Activities of households as employers [Intermediate term]	Stochastic	Mil. #, SA	FEHH_I_IGBR (Employment - Activities of households as employers [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPHH$_IGBR (Gross Value Added [GVA] - Activities of households as employers) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEHH_IGBR (Employment - Activities of households as employers) FEHH_I_IGBR (Employment - Activities of households as employers [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
10. Human health and social work activities [Intermediate term]	FEHS_I_IGBR	Employment - Human health and social work activities [Intermediate term]	Stochastic	Mil. #, SA	FEHS_I_IGBR (Employment - Human health and social work activities [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPHS$_IGBR (Gross Value Added [GVA] - Human health and social work activities) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEHS_IGBR (Employment - Human health and social work activities) FEHS_I_IGBR (Employment - Human health and social work activities [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
11. Information and communication [Intermediate term]	FEIC_I_IGBR	Employment - Information and communication [Intermediate term]	Stochastic	Mil. #, SA	FEIC_I_IGBR (Employment - Information and communication [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPIC$_IGBR (Gross Value Added [GVA] - Information and communication) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEIC_IGBR (Employment - Information and communication) FEIC_I_IGBR (Employment - Information and communication [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
12. Manufacturing [Intermediate term]	FEMF_I_IGBR	Employment - Manufacturing [Intermediate term]	Stochastic	Mil. #, SA	FEMF_I_IGBR (Employment - Manufacturing [Intermediate term]) FEGOOD_IGBR (Employment - Goods producing industries) FGDPMF$_IGBR (Gross Value Added [GVA] - Manufacturing) FGDPGOOD$_IGBR (Gross Value Added [GVA] - Goods producing industries)	FEMF_IGBR (Employment - Manufacturing) FEMF_I_IGBR (Employment - Manufacturing [Intermediate term]) FEGOOD_I_IGBR (Employment - Goods producing industries [Intermediate term])

Appendix Table: Selected U.K. Variables Capturing the Physical and Transition Risk (Cont.)

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
13. Mining and quarrying [Intermediate term]	FEMQ_I_IGBR	Employment - Mining and quarrying [Intermediate term]	Stochastic	Mil. #, SA	FEMQ_I_IGBR (Employment - Mining and quarrying [Intermediate term]); FEGOOD_IGBR (Employment - Goods producing industries); FGDPMQ$_IGBR (Gross Value Added [GVA] - Mining and quarrying); FGDPGOOD$_IGBR (Gross Value Added [GVA] - Goods producing industries)	FEMQ_IGBR (Employment - Mining and quarrying); FEMQ_I_IGBR (Employment - Mining and quarrying [Intermediate term]); FEGOOD_I_IGBR (Employment - Goods producing industries [Intermediate term])
14. Public administration and defence; compulsory social security [Intermediate term]	FEPD_I_IGBR	Employment - Public administration and defence; compulsory social security [Intermediate term]	Stochastic	Mil. #, SA	FEPD_I_IGBR (Employment - Public administration and defence; compulsory social security [Intermediate term]); FESERV_IGBR (Employment - Services producing industries); FGDPPD$_IGBR (Gross Value Added [GVA] - Public administration and defence; compulsory social security); FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEPD_IGBR (Employment - Public administration and defence; compulsory social security); FEPD_I_IGBR (Employment - Public administration and defence; compulsory social security [Intermediate term]); FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
15. Professional; scientific and technical activities [Intermediate term]	FEPS_I_IGBR	Employment - Professional; scientific and technical activities [Intermediate term]	Stochastic	Mil. #, SA	FEPS_I_IGBR (Employment - Professional; scientific and technical activities [Intermediate term]); FESERV_IGBR (Employment - Services producing industries); FGDPPS$_IGBR (Gross Value Added [GVA] - Professional; scientific and technical activities); FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEPS_IGBR (Employment - Professional; scientific and technical activities); FEPS_I_IGBR (Employment - Professional; scientific and technical activities [Intermediate term]); FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
16. Real estate activities [Intermediate term]	FERE_I_IGBR	Employment - Real estate activities [Intermediate term]	Stochastic	Mil. #, SA	FERE_I_IGBR (Employment - Real estate activities [Intermediate term]); FESERV_IGBR (Employment - Services producing industries); FGDPRE$_IGBR (Gross Value Added [GVA] - Real estate activities); FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FERE_IGBR (Employment - Real estate activities); FERE_I_IGBR (Employment - Real estate activities [Intermediate term]); FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])

Description	Mnemonic	Series description	State	Units	Variable depends on	Depend on variable
17. Other service activities [Intermediate term]	FESO_I_IGBR	Employment - Other service activities [Intermediate term]	Stochastic	Mil. #, SA	FESO_I_IGBR (Employment - Other service activities [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPSO$_IGBR (Gross Value Added [GVA] - Other service activities) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FESO_IGBR (Employment - Other service activities) FESO_I_IGBR (Employment - Other service activities [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
18. Transportation and storage [Intermediate term]	FETS_I_IGBR	Employment - Transportation and storage [Intermediate term]	Stochastic	Mil. #, SA	FETS_I_IGBR (Employment - Transportation and storage [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPTS$_IGBR (Gross Value Added [GVA] - Transportation and storage) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FETS_IGBR (Employment - Transportation and storage) FETS_I_IGBR (Employment - Transportation and storage [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
19. Wholesale and retail trade; repair of motor vehicles [Intermediate term]	FEWR_I_IGBR	Employment - Wholesale and retail trade; repair of motor vehicles [Intermediate term]	Stochastic	Mil. #, SA	FEWR_I_IGBR (Employment - Wholesale and retail trade; repair of motor vehicles [Intermediate term]) FESERV_IGBR (Employment - Services producing industries) FGDPWR$_IGBR (Gross Value Added [GVA] - Wholesale and retail trade; repair of motor vehicles) FGDPSERV$_IGBR (Gross Value Added [GVA] - Services producing industries)	FEWR_IGBR (Employment - Wholesale and retail trade; repair of motor vehicles) FEWR_I_IGBR (Employment - Wholesale and retail trade; repair of motor vehicles [Intermediate term]) FESERV_I_IGBR (Employment - Services producing industries [Intermediate term])
20. Water supply; sewerage; waste management and remediation [Intermediate term]	FEWW_I_IGBR	Employment - Water supply; sewerage; waste management and remediation [Intermediate term]	Stochastic	Mil. #, SA	FEWW_I_IGBR (Employment - Water supply; sewerage; waste management and remediation [Intermediate term]) FEGOOD_IGBR (Employment - Goods producing industries) FGDPWW$_IGBR (Gross Value Added [GVA] - Water supply; sewerage; waste management and remediation) FGDPGOOD$_IGBR (Gross Value Added [GVA] - Goods producing industries)	FEWW_IGBR (Employment - Water supply; sewerage; waste management and remediation) FEWW_I_IGBR (Employment - Water supply; sewerage; waste management and remediation [Intermediate term]) FEGOOD_I_IGBR (Employment - Goods producing industries [Intermediate term])

Source: Moody's Analytics

About the Authors

Dr. Juan M. Licari is a managing director at the Moody's Analytics London office. He is the global head of the Business Analytics team consisting of risk modelers, economists and statisticians in the U.K., the U.S., China, United Arab Emirates, Czech Republic, and Singapore. Dr. Licari's team provides consulting support to major industry players, builds econometric tools to model credit phenomena, and implements several stress-testing platforms to quantify portfolio risk exposure. His team is an industry leader in developing and implementing credit solutions that explicitly connect credit data to the underlying economic cycle, allowing portfolio managers to plan for alternative macroeconomic scenarios. He currently leads the overall effort to address climate change risk from the perspective of climate risk economic scenarios, economic losses linked to climate events, the impact of climate change on retail portfolios, and the ESG score predictor for small and medium enterprises. Dr. Licari has extensive hands-on experience as a project lead with respect to development, validation, calibration and monitoring of IRB, IFRS 9 and stress-testing credit risk models especially for U.K. banks and financial institutions, for both retail and corporate portfolios. He is actively involved in communicating the team's research and methodologies to the market, including senior management and board members. He often speaks at credit events and economic conferences worldwide. Dr. Licari holds a PhD and an MA in economics from the University of Pennsylvania and graduated summa cum laude from the National University of Cordoba in Argentina.

Dr. Petr Zemcik is a senior director at the Moody's Analytics London office who manages a team of risk modelers and economists in the London and Prague offices. He frequently serves as an engagement lead and a head modeler for projects across several lines of business in the U.K., continental Europe, the Middle East, and Africa to design and validate PD/LGD/EAD credit risk models for IFRS 9, A-IRB, and stress-testing. He supervises quality control, development and validation of macroeconomic country models, credit risk products using proprietary data, satellite market risk models, and other forecasting products. He currently manages the development of climate risk scenarios at Economics and Business Analytics. He previously worked at CERGE-EI, a joint workplace of the Center for Economic Research and Graduate Education of Charles University in Prague and the Economics Institute of the Academy of Sciences of the Czech Republic, and at Southern Illinois University in Carbondale IL. He holds a PhD and an MA in economics from the University of Pittsburgh and an MSc in econometrics and operations research from the University of Economics in Prague.

Chris Lafakis is a director at Moody's Analytics. He is the lead modeler for the Moody's Analytics climate risk initiative and is responsible for climate modeling and scenario creation. He also has expertise in macroeconomics, energy economics, model development and model validation. Based in West Chester PA, he also contributes to Economic View. Mr. Lafakis has been quoted by media outlets, including The Wall Street Journal, CNBC, Bloomberg, and National Public Radio and often speaks at economic conferences and events. Mr. Lafakis received his bachelor's degree in economics from the Georgia Institute of Technology and his master's degree in economics from the University of Alabama.

Janet Lee is a director with the Economics and Business Analytics unit at Moody's Analytics. Currently she is working on the climate risk research effort to quantify the economic impact of acute physical risk and developing models to link transition risk to the macroeconomy. Previously, she led custom projects to develop loss-forecasting and stress-testing models for clients, which included large and medium-size commercial banks, credit unions, auto captives, and financial technology lenders. Janet graduated from the University of Chicago and did her PhD studies in economics at the University of Pennsylvania. She is a CFA charter holder and has previously worked at Prudential Financial and the Federal Reserve Bank of Chicago.

About Moody's Analytics

Moody's Analytics provides financial intelligence and analytical tools supporting our clients' growth, efficiency and risk management objectives. The combination of our unparalleled expertise in risk, expansive information resources, and innovative application of technology helps today's business leaders confidently navigate an evolving marketplace. We are recognized for our industry-leading solutions, comprising research, data, software and professional services, assembled to deliver a seamless customer experience. Thousands of organizations worldwide have made us their trusted partner because of our uncompromising commitment to quality, client service, and integrity.

Concise and timely economic research by Moody's Analytics supports firms and policymakers in strategic planning, product and sales forecasting, credit risk and sensitivity management, and investment research. Our economic research publications provide in-depth analysis of the global economy, including the U.S. and all of its state and metropolitan areas, all European countries and their subnational areas, Asia, and the Americas. We track and forecast economic growth and cover specialized topics such as labor markets, housing, consumer spending and credit, output and income, mortgage activity, demographics, central bank behavior, and prices. We also provide real-time monitoring of macroeconomic indicators and analysis on timely topics such as monetary policy and sovereign risk. Our clients include multinational corporations, governments at all levels, central banks, financial regulators, retailers, mutual funds, financial institutions, utilities, residential and commercial real estate firms, insurance companies, and professional investors.

Moody's Analytics added the economic forecasting firm Economy.com to its portfolio in 2005. This unit is based in West Chester PA, a suburb of Philadelphia, with offices in London, Prague and Sydney. More information is available at www.economy.com.

Moody's Analytics is a subsidiary of Moody's Corporation (NYSE: MCO). Further information is available at www.moodysanalytics.com.

DISCLAIMER: Moody's Analytics, a unit of Moody's Corporation, provides economic analysis, credit risk data and insight, as well as risk management solutions. Research authored by Moody's Analytics does not reflect the opinions of Moody's Investors Service, the credit rating agency. To avoid confusion, please use the full company name "Moody's Analytics", when citing views from Moody's Analytics.

About Moody's Corporation

Moody's Analytics is a subsidiary of Moody's Corporation (NYSE: MCO). MCO reported revenue of $4.8 billion in 2019, employs more than 11,000 people worldwide and maintains a presence in more than 40 countries. Further information about Moody's Analytics is available at www.moodysanalytics.com.