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SYSTEMIC STRESS, AND CLIMATE-RELATED FINANCIAL RISK: IMPLICATIONS FOR BALANCE SHEET RESILIENCE

This Financial Sector Assessment Program paper on United Kingdom was prepared by a staff team of the International Monetary Fund. It is based on the information available at the time it was completed on March 18, 2022.

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TECHNICAL NOTE

SYSTEMIC STRESS, AND CLIMATE-RELATED FINANCIAL RISKS: IMPLICATIONS FOR BALANCE SHEET RESILIENCE

Prepared By
Monetary and Capital Markets Department

This Note was prepared by IMF staff in the context of an IMF Financial Sector Assessment Program (FSAP) in the United Kingdom. The FSAP was led by Mr. Udaibir Das. The note contains technical analysis and detailed information underpinning the FSAP's findings and recommendations. Further information on the FSAP can be found at http://www.imf.org/external/np/fsap/fssa.aspx

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AC	Amortised Cost
ACS	Annual Cyclical Scenario
AFS/FVO	Available for Sale/Fair Value Option
AIFMD	Alternative Investment Fund Managers Directive
AML/CFT	Anti-Money Laundering/Combating the Financing of Terrorism
AT1	Additional Tier 1
BAU	Business As Usual
BES	Biennial Exploratory Scenario
BIS	Bank for International Settlements
BMA	Bayesian Model Averaging
BOE	Bank of England
CAR	Capital Adequacy Ratio
CCA	Climate Credit Analytics ©
CCB	Capital Conservation Buffer
CCP	Central Counterparty
CCyB	Counter-Cyclical Capital Buffer
CDR	Carbon Dioxide Removal
CEO	Chief Executive Officer
CET1	Common Equity Tier 1
CIB	Corporate and Investment Banking
CJRS	Coronavirus Job Retention Scheme
CO2	Carbon Dioxide
COREP	Common Reporting Framework
CPI	Consumer Price Index
CRE	Commercial Real Estate
CS01	Risk of Spread Over the Benchmark Rate Moving By 1 Basis Point.
CSD	Central Security Depository
CVA	Credit Value Adjustment
DEFRA	Department for the Environment, Food and Rural Affairs
DNZ	Divergent Net Zero (scenario)
DtD	Distance to Default
DV01	Risk of The Risk-Free/Benchmark Rate Moving 1 Basis Point
EAD	Exposure At Default
ECL	Expected Credit Loss
EDF	Expected Default Frequency
EIOPA	European Insurance and Occupational Pensions Authority
EPC	Energy Performance Certificate
ESMA	European Securities and Markets Authority
ETF	Exchange Traded Fund
EU	European Union
FATF	Financial Action Task Force

FCA	Financial Conduct Authority
FCFE	Free Cash-Flow to Equity
FINREP	Financial Reporting
FMIs	Financial Market Infrastructures
FPC	Financial Policy Committee
FRF	Future Regulatory Framework
FSAP	Financial Sector Assessment Program
FSB	Financial Stability Board
FSCS	Financial Services Compensation Scheme
FSMA	Financial Services and Markets Act 2020
FSR	Financial Stability Report
FSSA	Financial System Stability Assessment
FVA	Fair Value Accounting
FVOCI	Fair Value through Other Comprehensive Income
FVPL	Fair Value through Profit and Loss
FX	Foreign Exchange
GAAP	Generally Accepted Accounting Principles
GBP	British Pound
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GFM	Global Macro Financial Model
GMST	Global Mean Surface Temperature
G-SIB	Global Systemically Important Bank
GTAP-E	Global Trade Analysis Project – Energy/Environment version
GVA	Gross Value Added
HMT	Her Majesty's Treasury
HQLA	High Quality Liquid Assets
IAIS	International Association of Insurance Supervisors
IAM	Integrated Assessment Model
ICP	Insurance Core Principle
IFRS	International Financial Reporting Standards
IM	Initial Maturity
IMF	International Monetary Fund
IOSCO	International Organization of Securities Commissions
IRRBB	Interest Rate Risk in the Banking Book
KA	Key Attributes of Effective Resolution Regimes for Financial Institutions
LCR	Liquidity Coverage Ratio
LGD	Loss Given Default
LME	London Metal Exchange
LTG	Long-Term Guarantee
LTV	Loan to Value
MA	Matching Adjustment
ML/TF	Money Laundering/Terrorism Financing

MMF	Money Market Fund
MoU	Memorandum of Understanding
MPC	Monetary Policy Committee
MTM	Mark-to-Market
MVA	Market Value of Assets
MVE	Market value of Equity
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne (Statistical Classification of Economic Activities in the European Community)
NBFI	Non-Bank Financial Institutions
NDCs	National Determined Contributions
NFC	Non-Financial Corporates
NGFS	Network for Greening the Financial Sector
NPL	Non-Performing Loan
NPLR	Non-Performing Loan Ratio
NPV	Net Present Value
NZ2050	Net Zero by 2050 (scenario)
OB	Open Banking
OPBAS	Office of Professional Body Anti-Money Laundering Supervision
ORSA	Own Risk and Solvency Assessment
O-SII	Other Systemically Important Institutions
OTC	Offshore Trade Center
P&L	Profit and Losses
PBS	Professional Body Supervisor
PD	Probability of Default
PiT	Point-In-Time
PNFC	Private Non-Financial Corporation
PRA	Prudential Regulation Authority
PRC	Prudential Regulation Committee
PVA	Present Value
QRT	Quantitative Reporting Template
RAF	Resolvability Assessment Framework
RAM	Risk Assessment Matrix
RBB	Risks Beyond Banking
RCP	Representative Concentration Pathway
RFRs	Risk Free Rates
RHI	Renewable Heating Incentive
RLF	Resolution Liquidity Framework
RRP	Recovery and Resolution Plan/Planning
RWA	Risk Weighted Assets
SCR	Solvency Capital Requirement
SEC	U.S. Securities and Exchange Commission
SMEs	Small and Medium-Sized Enterprises

SOA	Systemic Oversight Assessment
SRA	Systemic Risk Analysis
SRB	Systemic Risk Buffer
STeM	Stress Test Matrix
SVAR	Structural Vector Auto Regression
TCA	Trade and Cooperation Agreement
TFP	Total Factor Productivity
TMTP	Transitional on Technical Provisions
TPR	The Pensions Regulator
TTC	Through-The-Cycle
U.K.	United Kingdom
VAR	Vector Auto Regression
WEO	World Economic Outlook
y-o-y	Year-on-Year

EXECUTIVE SUMMARY AND RECOMMENDATIONS[1]

The FSAP started in an important macro-financial phase right after the second Covid wave and a third lockdown. The balance sheet resilience of major institutional sectors was at the center of policy considerations. Against this backdrop, the FSAP analyzed the pandemic's potential "scarring" of banks, insurers, corporates, and households balance sheets, focusing on the interplay of macro-financial/structural conditions and financial vulnerabilities.

The core part of the balance sheet resilience and financial stability analysis is stress tests. Potential vulnerabilities are assessed under two adverse scenarios: a protracted recession with a prolonged pandemic and a sharp tightening of global financial conditions, compared to a baseline scenario based on the October 2021 WEO assumptions. The risk analysis on corporates and households focuses on the financial sector's exposures to indebted corporates and less creditworthy households and whether these risks could be systemic. For banks and insurers, the stress tests examine their resilience to solvency and liquidity pressures. Climate-related risk assessment on banks and insurers cover both physical and transition risks, complementing the BOE's climate work.

The analysis revealed that the comprehensive policy response to the pandemic was effective and helped support financial stability. However, there are several potential vulnerabilities that deserve further analysis with enhanced data availability. This is especially important as most pandemic support measures have expired, and the economy is undergoing structural transformations. Specifically:

- *Corporate and household risks could materialize under some adverse scenarios.* While aggregate corporate and household balance sheets remain resilient, vulnerabilities are concentrated in SMEs, particularly in sectors hardest hit by the pandemic, and low-income households. Under adverse scenarios, the estimated corporate liquidity and equity gaps could double, compared with the baseline scenario; and household mortgage risks could increase sizably.

- *Current levels of bank capitalization are high and would help to absorb losses in case risks materialize.* Under adverse scenarios the banking system capital ratios could decline by 2.0 to 5.0 percentage points, driven mainly by loan and market losses. Despite this decline, system capital ratios would remain above estimated aggregate hurdle rates. At the individual level, however, some vulnerabilities are uncovered with two banks falling slightly below their hurdle rates—before conversion of AT1 instruments into CET1 capital—under the most severe scenario. In addition, initial macroeconomic shocks could be amplified through weaker credit growth if macro-financial effects are at play.

[1] This note was prepared by Ruo Chen, Dan Cheng, Pierpaolo Grippa, Jan Moeller, Paola Morales Acevedo, Marika Santoro, and Priscilla Toffano (all IMF) and Timo Broszeit (expert). The FSAP team would like to express its deepest gratitude to the authorities for their close cooperation and support facilitating this comprehensive exercise.

The banking system is overall liquid and resilient to sizable withdrawals of funding and haircuts to liquid assets. Liquidity Coverage Ratios (LCRs) are currently well above the regulatory standard of 100 percent for the 110 domestic banks surveyed. Almost all the banks would maintain high 'total currencies' liquidity ratios under progressively severe scenarios, with rising haircuts on their liquid assets and increasing outflows of retail and wholesale funding; only a few banks would experience LCRs moderately below 100 percent in some scenarios. The analysis of LCRs by single currency—for which there is no formal regulatory threshold—reveals potential FX liquidity shortfalls that, however, would require more granular information to be accurately quantified.

A top-down solvency stress test of 14 larger U.K. insurers showed the sector to be largely resilient with some vulnerabilities stemming from lower interest rates and from equity price declines, particularly for life insurers. The analysis applied two severe scenarios to insurers' balance sheets as of end-2020, covering around 70 percent of the market. Lack of coherent data in a top-down ST typically limits the recognition of hedging instruments, and the instantaneous modeling of shocks does not allow for management actions—companies would normally have different options to de-risk their balance sheet and thereby improve solvency positions.

- In the "scarring" scenario, life insurers are considerably more affected than general insurers. While all life insurers would still sufficiently cover their liabilities with assets, the excess of assets over liabilities declines by more than 15 percent for the median firm. Solvency ratios of two firms would drop below the 100 percent threshold, highlighting the need for recovery plans to be ready and effectively executable. Lower interest rates increase liabilities, but this is partly offset by the Matching Adjustment which rises together with higher credit spreads. Among general insurers, the balance sheet impact is smaller, and solvency ratios remain well above 100 percent.

- In the scenario of tightening financial conditions, the aggregate impact on both sectors is milder, and most life insurers would even see higher solvency ratios. The sharp increase in interest rates compensates for losses on investment assets, as the impact weighs larger on liabilities which decline with higher discount rates. For most general insurers, the impact is minor, although interest rate exposures differ across companies—for the median general insurer, the solvency ratio declines marginally. The analysis, however, does not account for the effect of higher claims inflation on the earnings of general insurers.

Life insurers are largely resilient to variation margin calls in their interest rate swap portfolio, but cash buffers differ markedly at the group level across firms. An analysis of five large life insurers shows that even sizable upward shifts in interest rates, as a single stress to swap positions, would not cause systemic liquidity stress, given existing sufficient buffers of cash and liquid assets—individual firms might however need to liquidate sovereign bond holdings or rely on liquidity from other group entities. However, liquidity risks could increase when margin calls from other derivative types occur simultaneously, or when combined with stressed outflows following policy surrenders or catastrophe events, or from lower premia.

An analysis of climate-related vulnerabilities across a range of financial institutions under two orderly transition scenarios has revealed the presence of non-negligible potential losses; the estimates, however, do not point to imminent threats to the stability if the U.K. financial system. The analysis has focused mainly on transition risks, linked to the financial institutions' exposures to corporate counterparts. It is based on the logic of the 'climate Minsky moment', i.e., a sudden reassessment of asset values, prompted by a drastic change in market expectations, that triggers a crystallization of losses. The change in expectations is simulated through a switch between a 'business as usual' and one of two alternative 'orderly' transition scenarios produced by the Network for Greening the Financial System ('1.5° warming with carbon dioxide removal', and an orderly transition to net zero by 2050 with 2x higher carbon prices). The consequent changes in gross value added by sector are simulated via a computational general equilibrium model, and the impact on the cash flows of a large sample of companies is simulated via a suite of financial models. For banks' corporate loan portfolios, the average loss, in a sample of eight large banks, would be 1.1 or 3.6 percent, depending on the steepness of the carbon price path that companies would have to face under the alternative transition scenarios. Under the same scenarios, banks' market losses (on equity and corporate bond holdings) could represent, on average, 2.5 or 4 percent of their portfolios, while for a sample of 70 defined benefit pension funds losses would represent, on average, 2 or 3.5 percent of their portfolios.

For insurers, the analysis of transition risks revealed that, across all asset classes, the loss in the investment portfolio would correspond to around 2 to 4 percent for most insurers in the sample. The largest price impact is observed in equity holdings, which would on average decline by up to 11 percent. U.K. general insurers are exposed not only to domestic perils, but through their international footprint and specifically the London market to natural disasters worldwide—the largest exposures are towards US hurricanes and European windstorms. A combination of higher severity and frequency of natural disasters (each up by 30 percent) would increase future annual losses of general insurers by up to 50 percent.

The results of the transition risk analysis are conditional on several assumptions, including the adoption of 'orderly' transition scenarios. The outcome would likely be less benign under a scenario characterized by a 'disorderly' transition. Also, the analysis has focused on the impacts at sector and company level, considering the GDP path provided by the NGFS scenarios, but without explicitly modelling other macroeconomic variables. For banks and insurers, it will be interesting to compare these 'top-down' results with the outcome of the BOE's Climate Biennial Exploratory Scenario, which is an exercise more of 'bottom-up' nature.

Table 1. Recommendations

#	Recommendations	Agency	Timing[1]
1	Continue reducing the size of unidentified exposures in experimental statistics on NBFI balance sheets (Who-to-whom data by ONS).	ONS supported by BOE and FCA	MT
2	Consider augmenting banks' data reporting on non-financial corporate exposures, particularly standardizing reported corporate and industry identifications.	BOE	MT
3	Where proportionate to the size of the market and firms within it, collect granular data on consumer credit by type of lender (banks and NBFIs) and type of products (such as credit card and personal loans), with special attention to recording loan performances (arrears or default) and borrower's credit conditions (such as loan-to-income ratio).	BOE, FCA	MT
4	Enhance the usability of micro-data collected for bank stress testing, also through a revision of the validation and plausibility rules and stricter criteria for data resubmissions by banks.	BOE	NT
5	Improve the availability and quality of granular data on credit risk (particularly at a loan level for non-mortgage retail exposures), interest rate risk and market risk.	BOE/FCA	MT
6	To complement the existing bottom-up stress testing framework, complete and consolidate the internal toolkit for stress testing to run independent full-fledged top-down exercises, at a higher frequency when needed, covering all systemically relevant entities.	BOE/PRA	MT
7	Deepen the analysis of risks that fall outside the experience of the last decades (such as stagflation with abrupt tightening of financial conditions and market volatility) to assess the impact on the risk profile of financial firms and their readiness to successfully weather such scenarios.	BOE/PRA and FCA	MT
8	Expand supervisory reporting for insurers to allow for comprehensive top-down analyses of liquidity risks (e.g., data on derivative holdings, definitions of cash).	PRA	NT
9	Analyse liquidity risks of insurance companies with a particular view on cash pooling at group level and netting arrangements for non-centrally cleared derivatives.	PRA	NT
10	Develop tools for top-down analysis of climate-related risks across all relevant authorized financial firms, including gathering data to build a picture of how relevant regulated firms are exposed to, and how they are managing climate related risk.	BOE, FCA, TPR	MT
11	Analyse the network effects in the propagation of climate-related risks across the financial system.	BOE, TPR	MT
12	Evaluate the influence of public climate mitigation and adaptation policies on financial firms' climate-related risks.	BOE	MT
13	Continue efforts to enhance the data quality checking process and ensure high-quality supervisory reporting by insurers.	PRA	C
14	Augment the already strong focus on liquidity risks of insurers and further analyze combined liquidity strains, exacerbated by reduced market liquidity and fungibility of certain assets, and expand supervisory reporting, particularly for annuity writers and insurers with large derivative holdings.	PRA	NT
15	Provide guidance on the risks that should be considered within an insurer's ORSA, which should include indirect climate risks (e.g., through disruptions of global supply chains) and litigation risks covered by liability insurance.	PRA	MT
16	Promote the transition of Flood Re with a view to reward investments in flood resilience measures with premium reductions, and to introduce a build-back-better policy, based on best-practice standards and certifications.	DEFRA	MT

[1] C: Continuous; I: Immediate (within a year); NT: Near term (1-3 years); MT: Medium Term (3-5 years).

INTRODUCTION

1. Financial stability was maintained during the pandemic, thanks to the multipronged policy responses. The output shrank by about ten percentage points in 2020, the biggest contraction since World War II. However, corporate and household insolvency remain low, banks maintain comfortable capital and liquidity buffers, and insurers' balance sheets remain stable. While post-GFC reforms boosted institutions' capital and liquidity positions, this balance sheet resilience, to a large extent, should attribute to the authorities' comprehensive pandemic support measures. Direct and indirect budget support measures helped safeguard households' and corporates' balance sheets. Exceptional prudential measures were adopted to ensure continued lending to households and corporates via banks and securities markets and to prevent amplification of the crisis by mitigating the procyclicality of regulations.

2. With this massive policy support, financial conditions, after an initial sudden tightening, progressively eased throughout the pandemic (Figure 1). Supported by central bank asset purchases and liquidity measures, asset prices recovered, the yield curve flattened, and credit spreads fell from the peaks seen during the March 2020 "dash-for-cash". Bank lending rates remained low, and corporate credit growth was strong—partly on the back of publicly guaranteed loans. Residential real estate prices have risen sharply since mid-2020, while mortgage rates have stayed low except for the high loan-to-value (LTV) segment.

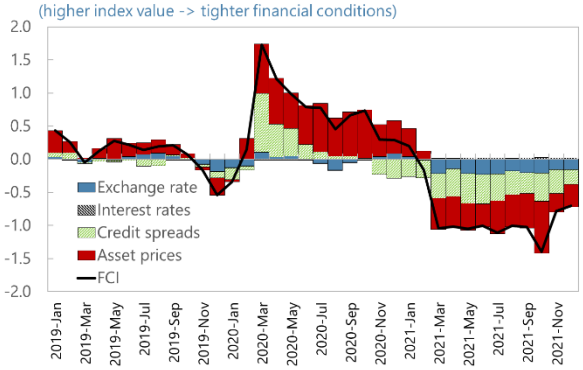
3. The main macro-financial risks are a global resurgence of the COVID-19 pandemic and a tightening of global financial conditions if global inflation risks persist (Annex III. Risk Assessment Matrix). More transmissible, vaccine-resistant, and deadlier virus variants could emerge and dampen global growth, derailing the recovery. Global trade could be further undermined as a protracted pandemic continues to dislocate international supply chains. Supply-demand mismatches combined with a rise in energy and commodity prices could generate inflationary pressures and lead to a tightening of global financial conditions. An inflationary environment with protracted tightening of global financial conditions could further depress investment and increase unemployment. Adverse scenarios were designed to capture these risks.

4. The remainder of this technical note (TN) is structured as follows. The next chapter presents two adverse scenarios for the stress tests. Chapter three analyzes non-financial corporate vulnerabilities, focusing on their liquidity and equity shortfalls. Chapter four moves onto household mortgage vulnerabilities. Chapters five and six analyze banks and insurers' solvency and liquidity, respectively. And the last chapter discusses climate-related risks. Some recommendations are listed in Table 1.

Figure 1. United Kingdom: Macrofinancial Indicators

Financial Conditions Index

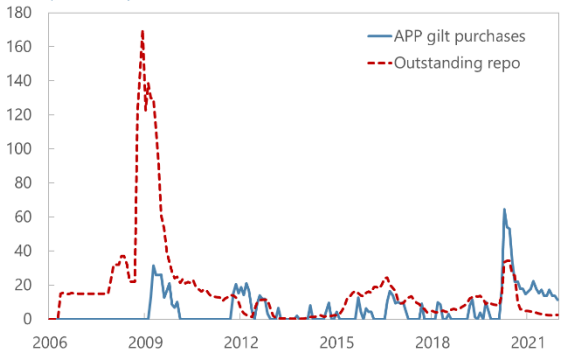
(higher index value -> tighter financial conditions)



Sources: Bank of England, Bloomberg, and IMF staff calculations.

Gilt purchases and repo operations

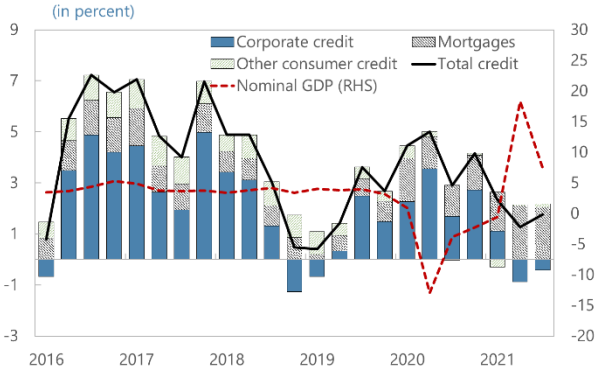
(in billion £)



Sources: Bank of England

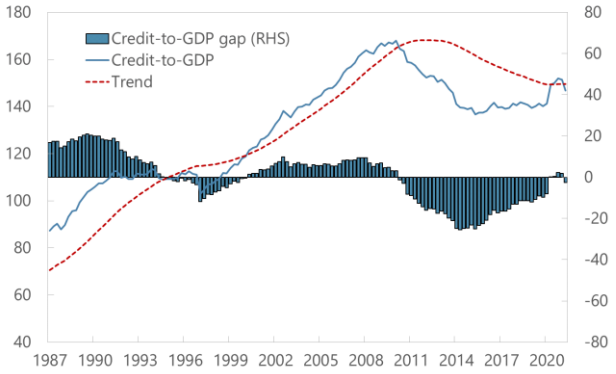
Private sector credit growth

(in percent)



Sources: ONS

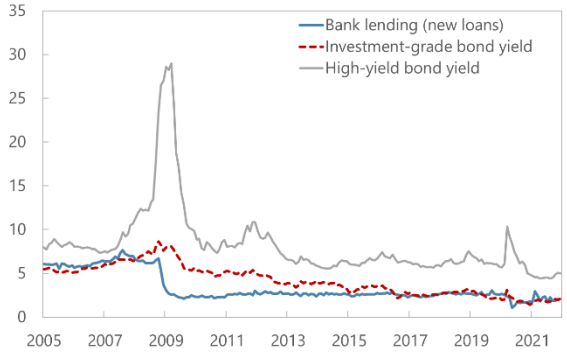
Credit-to-GDP gap



Sources: Bank of England via Haver

Non-financial corporations borrowing cost

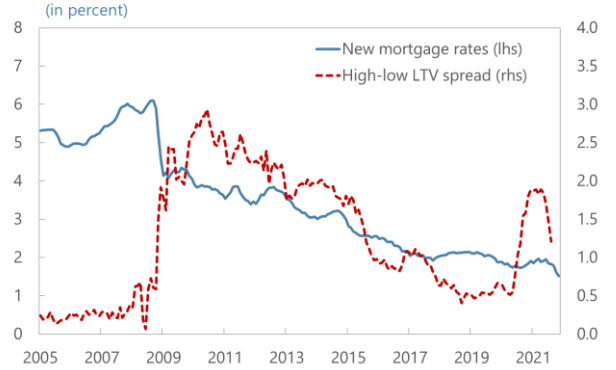
(in percent)



Sources: Bank of England, Bloomberg

Mortage rates

(in percent)



Sources: Bank of England via Haver

ADVERSE SCENARIOS

5. Macroeconomic risks are still considerable, ranging from the effects of a prolonged pandemic, rising global inflation, dislocations in productive capacity, and post-Brexit uncertainties. To assess the resilience of the U.K.'s financial system to such vulnerabilities, we considered a baseline scenario and two separate adverse scenarios upon which we built several stress-tests on corporates, households, banks, and insurers (Figure 2).

- The **baseline scenario** draws from the October 2021 WEO forecast. The economy has been adapting well to Covid-related restrictions, confidence and spending have risen sharply as vaccination has progressed and restrictions have been lifted. Supply disruptions start to emerge, but their impacts are expected to be temporary. Even as the pandemic is progressively contained, the output is expected to remain below the pre-Covid trend, restrained by lower investment and R&D, labor market frictions (and emigration), and higher trade and production costs.

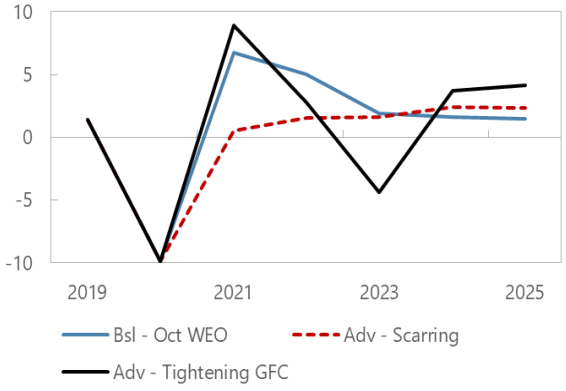
- **The first adverse scenario** (Adv. – Scarring) would entail a **protracted recession with lasting economic scars** from the pandemic. The pandemic recedes in the first half of 2021 as vaccination campaigns pick up, yet later in the year it becomes clear that new variants of the virus will continue to emerge across the world with increasing frequency. The new strains prove to be even more contagious or pathogenic, and resistant to existing vaccines and therapies. With the adaptation of vaccines taking longer than anticipated the pandemic is assumed to be under control not earlier than late 2022 for advanced economies, including the United Kingdom, and by the end of 2023 for the rest of the world. Global trade is depressed as asynchronous resurgences of the pandemic disrupt international supply chains and precipitate an acceleration of de-globalization (e.g., permanent reshoring, vaccine nationalism, long-lasting travel bans). Weaker global economy activity prompts sharp increases of risk premia, which in turn expose financial and fiscal vulnerabilities. Domestically, difficulties in adjusting to the new U.K.-EU agreement prove to be more severe than expected and further lower GDP growth over the short-term. Over the medium and long term, further market fragmentation increases the cost of financial services in the EU and the United Kingdom. The continuing uncertainty about the adjustment path leads to a decrease in business investment and weighs on potential growth. Despite the brief easing of COVID-related restrictions in the middle of the year, the compound effects of the pandemic and the post-Brexit adjustments results in real GDP growth of only 0.5 percent in 2021. Amid the intensifying pandemic real GDP recovers by only 1.6 percent in 2022. The scenario is also characterized by an increase in unemployment and a drop in residential and commercial real estate prices. Scarring in the medium term is manifested by lower potential output growth by 0.3% with respect to the pre-COVID period and higher natural unemployment rate.

- **The second adverse scenario** (Adv. – Tightening GFC) considers a **surge in global inflation and consequent sharp tightening of global financial conditions**. With the pandemic in the global rearview mirror, consumer spending picks up, supported by the drawdown of savings accumulated during the pandemic (for continuously employed workers) and by government support that is receding only gradually (for workers in industries affected by lockdowns). Meanwhile, low investment during the pandemic, business failures, as well as skill mismatches on the labor market reduce global spare capacity. As the global recovery proceeds, energy and commodity prices rise on a sustained basis. The push by many countries to localize key value chains (including but not limited to medical products) reduces the role of globalization as a driver of productivity gains and disinflation. Cautious not to stifle the nascent recovery, major central banks around the world accommodate rising inflationary pressures in the near term, with the Fed showing the greater inflation tolerance among AE central banks in line with its new monetary policy framework. Thus, while policy rates remain near zero, term premia rise sharply as markets revisit inflation expectations, leading to an abrupt increase in the borrowing cost of corporates and sovereigns. This tightening of global financial conditions weighs further on already-low post-pandemic investment while unemployment, despite some initial improvement resulting from the relaxation of containment measures, remains elevated. Central banks finally raise short term rates rapidly by 2022 while uncertainty about the pace of quantitative tightening creates upwards pressure on term premia and long-term rates, exerting financial strains on households with variable rate mortgages. Equity prices, which are flat over the near term due the improvement in economic prospects counterbalancing the rise in long-term rates, decline as policy tightening becomes inevitable. In the United Kingdom, a reduction in risk appetite of foreign investors leads to sterling depreciation and further contributes to goods price inflation. Like the baseline, potential output recovers as pandemic-related supply restriction ease, yet intensifying supply-side snags prevent its full recovery to the pre-COVID path.[2]

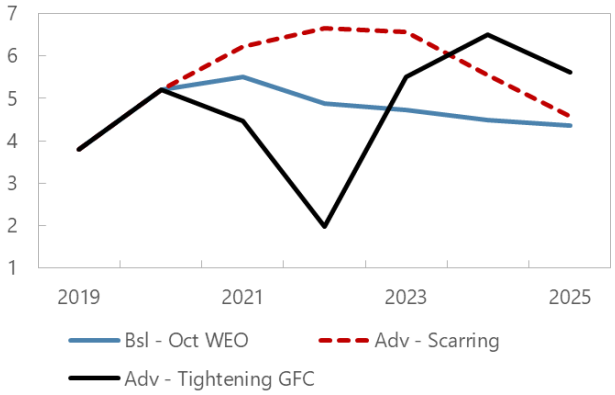
[2] By 2025 (the end of the risk horizon), U.K. real GDP is still 2 percent lower than under the baseline.

Figure 2. United Kingdom: Systemic Adverse Scenarios. Path Key Variables

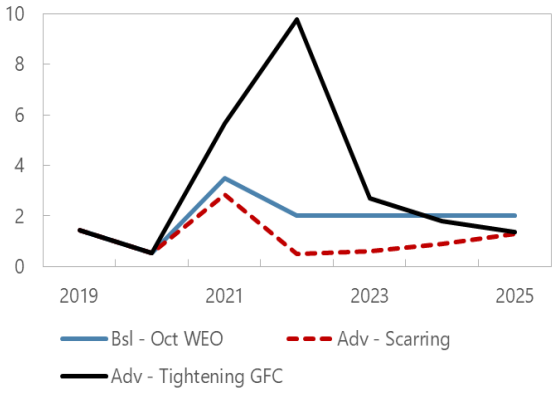
Real GDP Growth
(Percent)



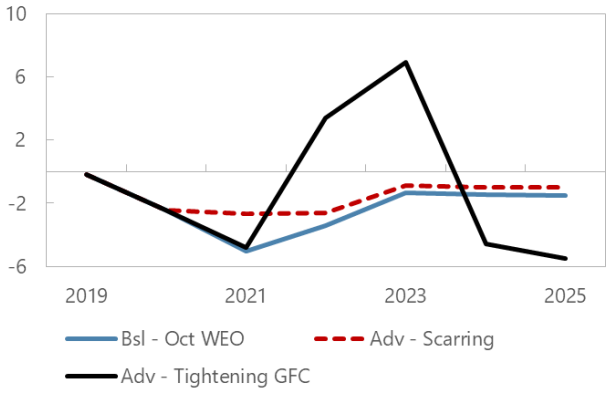
Unemployment Rate
(Percent)



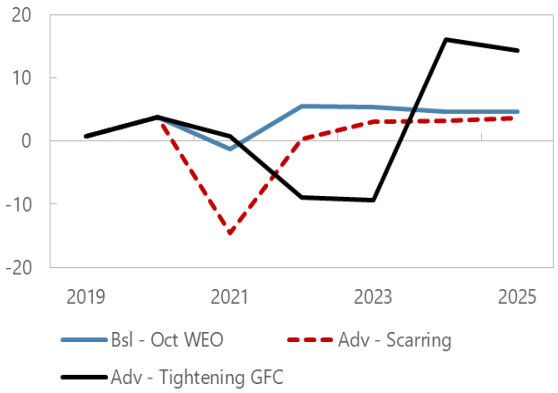
Inflation
(Percent)



Exchange Rate
(YoY Percent Change)



Residential Real Estate
(YoY Percent Change)



Equity Price
(YoY Percent Change)

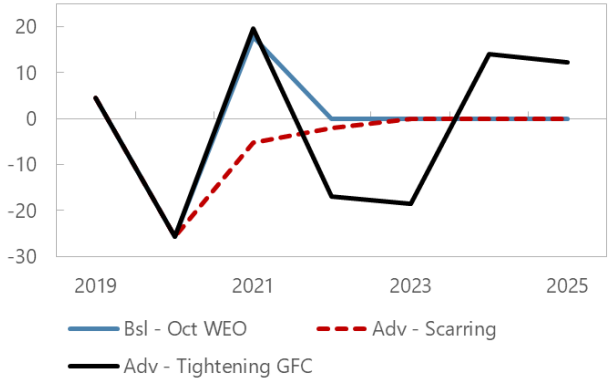
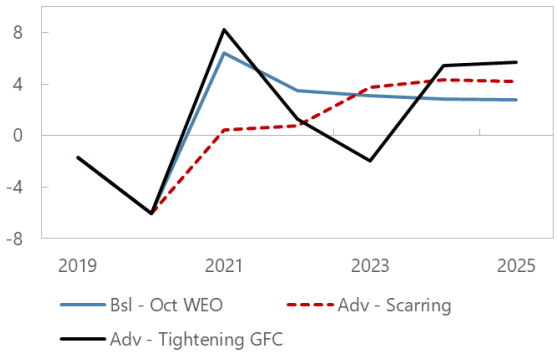
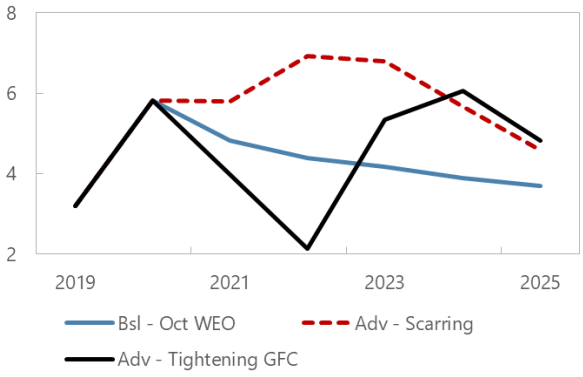


Figure 2. United Kingdom: Other Regions: Systemic Scenarios. Path Key Variables (continued)

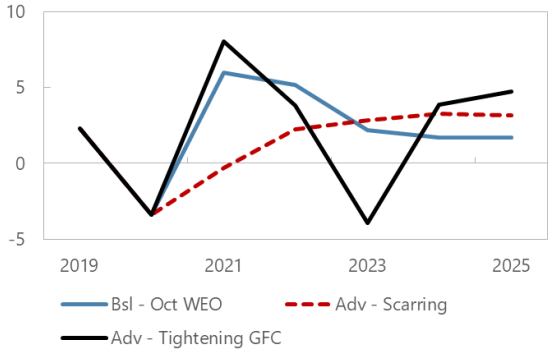
Real GDP Growth- Hong Kong
(Percent)



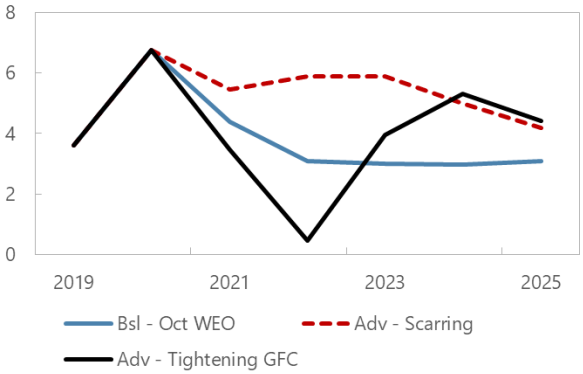
Unemployment Rate- Hong Kong
(Percent)



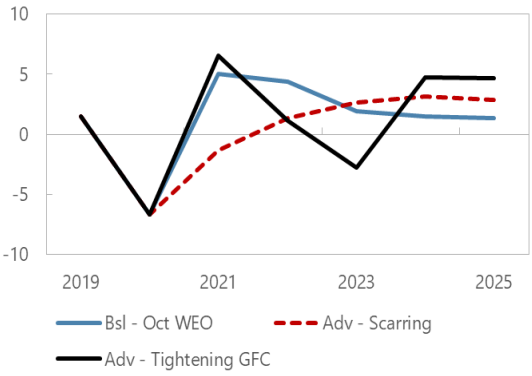
Real GDP Growth- USA
(Percent)



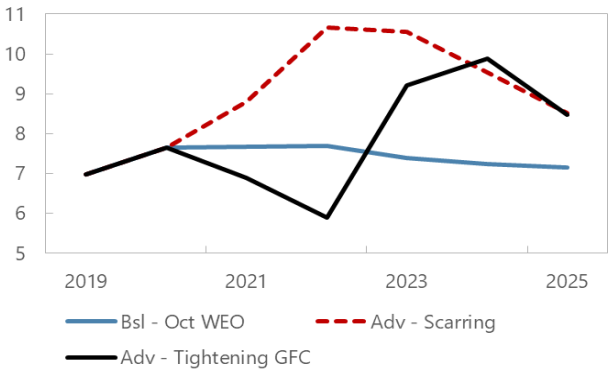
Unemployment Rate- USA
(Percent)



Real GDP Growth- Euro Area
(Percent)



Unemployment Rate- Euro Area
(Percent)



Source: IMF staff estimations.

NONFINANCIAL CORPORATIONS

6. This chapter analyzes post-COVID-19 pandemic vulnerabilities of the non-financial corporate (NFC) sector, focusing on the possible transmission channels for risks to financial stability. Confinement measures to contain the spread of COVID-19 infections forced temporary business closures and led to surges of financing needs in the corporate sector. In 2020, corporate debt increased by seven percentage points of GDP. At the same time, corporates' liquidity position improved by 11 percentage points of GDP, making corporates' aggregate financial balance sheets appear healthy. In addition, some part of the corporate debt increases in 2020 unwound in 2021. However, the aggregate financial accounts do not reveal pockets of vulnerabilities at the firm level. The 2020 U.K. Article IV consultation pointed out that significant numbers of small and medium enterprises (SMEs) may face some forms of balance sheet distress when support schemes sunset. The Bank of England's 2020 December Financial Stability Report estimated that U.K. corporates could have faced a cashflow deficit of around £180 billion (about 8.5 percent of GDP) in 2020-21 even with the government supporting measures. Building on Article IV and BOE analyses, the objective of this chapter is to assess both liquidity and solvency risks of corporates at the firm level and test the systemic resilience of indebted corporates. This chapter undertakes various firm-level panel regressions analysis on a large sample of British firms to i) explore determinants of liquidity and equity gaps, including the role of macro-financial conditions, ii) assess liquidity and solvency risks under various macro-financial stress test scenarios, and iii) characterize risks to financial stability.

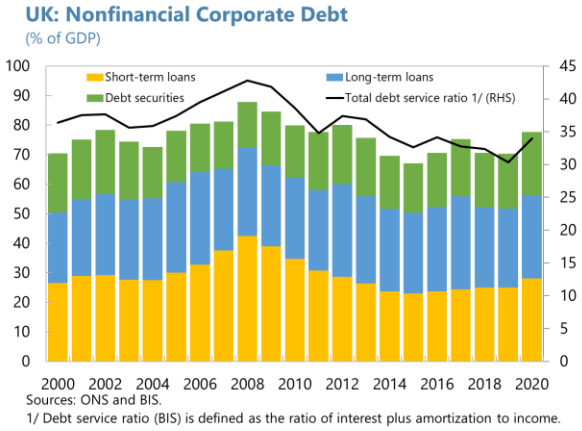
7. The FSAP analysis finds that NFC vulnerabilities are concentrated in sectors hardest hit by the pandemic and could be further intensified under adverse scenarios. The FSAP estimates that SMEs face a liquidity shortfall of about 2 percent of turnover and an equity gap of about 1½ percent of turnover in 2022–23. The liquidity and equity gap would reach 4 percent and 3 percent, respectively, in the accommodation sector. These estimated liquidity and equity gaps are generally smaller than previous studies, mainly due to the improved macroeconomic conditions. Under adverse scenarios, the estimated liquidity and equity gaps could increase to 3-4 percent of turnover. NFC financial stress could transmit to the financial sector and increase the probability of default of banks' corporate loan portfolios. Corporate defaults could lead to some losses to the financial sector, but the sector is well capitalized to absorb them.

A. Development of Nonfinancial Corporate Balance Sheets

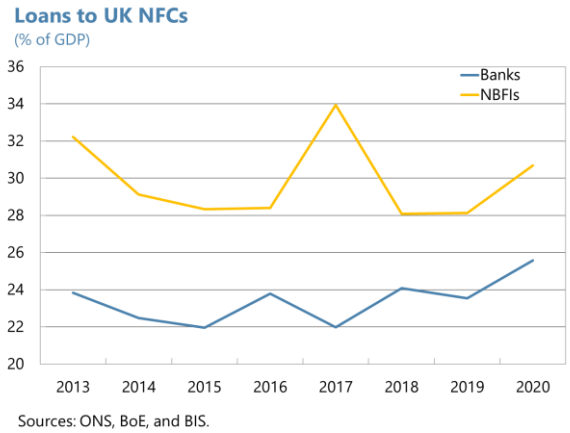
8. The United Kingdom's private nonfinancial corporate debt increased by seven percentage points to 78 percent of GDP in 2020, but still well below the peak of 88 percent in 2008.[3] From 2008 to 2019, NFC debt had declined by about 18 percentage points of GDP. This level of reduction is also the highest among G7 countries; as a result, the United Kingdom's NFC debt level sat at the lower side in this group before the pandemic. Among different debt components, the decline of short-term loans is almost identical to the reduction of the overall debt level, while the fall

[3] Analysis of NFC financial vulnerability takes the end-2020 position as a starting point. Corporate debt further declined during 2021, to about 73 percent of GDP as of end-2021 Q3.

of long-term loans is offset by the increase in debt securities, about three percentage points of GDP. At the end-2019, about one-third of corporate debt was short-term loans, down from almost half in 2008. However, the pandemic-induced social distances and temporary business closures led to rises in corporate borrowing to cover their liquidity shortfalls. The temporary nature of the shock also reflects that close to half of the increase in corporate debt is in short-term loans, followed by market-raised debt securities. The debt service to income ratio dynamic is like the debt level, while the decline in corporate profits in 2020 also contributes to the rise in the debt burden. This corporate debt increases partially unwound in 2021, with large corporate debt ratio now lower than end-2019 level.[4]



9. Both banks and nonbank financial institutions (NBFIs) are significant creditors to NFCs. The FSAP estimates that NBFIs provide slightly more loans to NFCs than banks by combining multiple data sources. NBFIs' and banks' lending cycles to NFCs are generally synchronized to a large extent. Moreover, another FSAP work focusing on NBFIs indicates that NBFIs are important lenders to SMEs, currently representing a small but material share, and tend to focus on clients with shorter credit histories and weak collateral.[5] However, lacking granular data prevents further analysis of NBFIs lending by firm sizes or production sectors (see Recommendation #1). Therefore, the following discussion focuses on banks' lending activities.



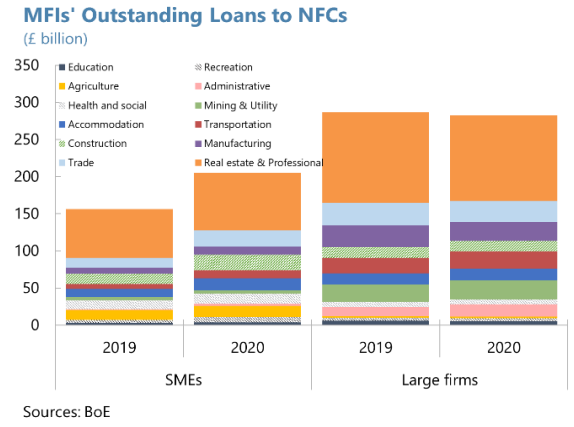
10. Banks' lending to SMEs increased sizably in 2020 while lending to large corporate decreased. Even with similar turnovers, SMEs' bank loans were roughly half of large corporates'

[4] See further details of BOE's analysis at: https://www.bankofengland.co.uk/financial-policy-summary-and-record/2021/october-2021/financial-stability-in-focus#in_focus.

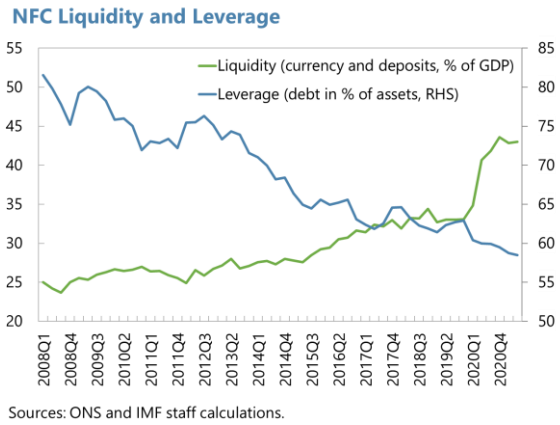
[5] For details see Technical Note "Vulnerabilities in NBFIs, Market-Based Finance, and Systemic Liquidity."

bank loans before the pandemic. However, in 2020, SMEs' borrowing from banks increased by £49 billion, in contrast with a £4 billion decline in large corporates' bank loans. Eased financial conditions allowed large corporates to borrow from the market. Indeed, corporate debt securities increased by £40 billion, and equity liabilities increased by £74 billion in 2020. Among sectors, real estate and professional services take the largest share in outstanding bank loans. However, in 2020, sectors particularly hit hard by the pandemic, such as recreation, accommodation, wholesale and retail trade, and transportation, increased their bank credit by significant shares. As discussed below, the additional bank credit was backed up by government loan guarantees to a large extent.

11. While corporate financial liabilities increased during the pandemic, their financial assets also strengthened. Much of the increased debt was used for boosting liquidity buffers (including currency and deposits) which were increased by 11 percentage points of GDP in 2020. As a result, total NFC's leverage (debt to assets ratio) declined further.

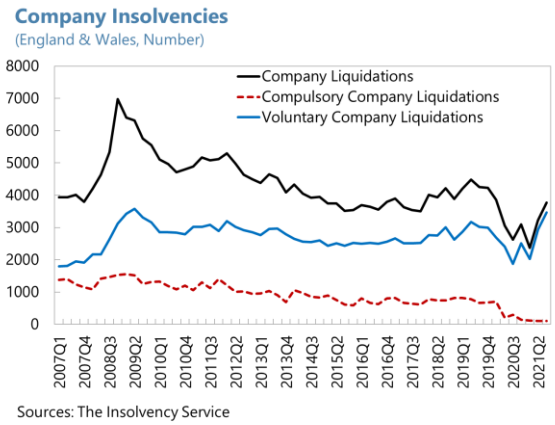


Sources: BoE



Sources: ONS and IMF staff calculations.

12. This resilience of the aggregate corporate balance sheets was supported by unprecedented public support.[6] Several grant schemes have been made available throughout the pandemic for businesses significantly affected by lockdowns. Another targeted support to most-affected corporates is business rates (a tax on business properties) relief. A 100 percent relief was granted to retail, leisure, hospitality, nurseries, and pubs from April 2020 to June 2021, and a 66 percent reduction for the remaining nine months of the 2021-22 fiscal year (July 2021 – March 2022). The Coronavirus Job Retention Scheme (CJRS), also known as the furlough scheme, reduced business labor costs while preserving work relationships. These measures helped reduce business costs and preserved their equities. In addition, government guarantee programs



Sources: The Insolvency Service

[6] The complete list of government support measures during the Covid-19 can be found here.

facilitated financial sector lending to businesses, the Bank Rate cut reduced financing cost, and the Term Funding Scheme provided additional incentives for SME lending. All these measures helped avoid massive business failure during the Covid. Indeed, the total number of company insolvencies remains below the pre-Covid level. Public support to businesses during the COVID-19 pandemic goes beyond the measures listed above to assess near- and medium-term corporate financial risks, and includes, for example, a moratorium on rental evictions and temporary changes to insolvency legislation. For modeling purpose, only measures discussed above are included in the empirical analysis in this chapter. Section B describes how each support measure is incorporated in the empirical analysis for individual firms.

B. Empirical Determinants of Corporates' Financial Vulnerabilities

13. Corporate financial vulnerabilities during and post the COVID-19 pandemic are estimated using firm-level structural models. With limited firm-level data for 2020, the analysis estimates the counterfactual firm profits in 2020 if there were no government support policies. It then incorporates support measures based on policy designs and aggregate disbursements. The key empirical model of the determinants of the firm's profitability, return on assets (ROA), is specified in Equation (1).

$$ROA_{i,s,t} = \alpha \cdot ROA_{i,s,t-1} + \beta \cdot FirmChar_{i,s,t-1} + \gamma \cdot MarcoFinan_{s,t} + dummy_s + \varepsilon_{i,s,t} \qquad (1)$$

where i denotes the individual firm; s denotes the industry sector (based on two-digit SIC2017 classification); and t denotes year t. Firm characteristics include firm's leverage (liability-to-asset ratio), firm's relative size (the ratio of total assets to the sectoral average), fixed assets (the ratio of fixed assets to total assets), sales (the ratio of sales to total assets), and sales growth (growth rate of sales); macro-financial indicator. Macro-financial indicators include sectoral gross value added (GVA) growth rate, inflation, oil price growth rate, short-term interest rate, nominal effective exchange rate, and financial condition index. Combined with the estimated firm's investment and financing plans, the analysis projects the main components of firms' financial balance sheets (see Annex IV for details). Similar analytical approaches have been used in other FSAPs, such as France (2019) and Korea (2020), and October 2020 Global Financial Stability Report.[7] It is worth mentioning that this model internalizes actions taken by firms to maximize their profits given the macroeconomic and financial conditions based on historical patterns. However, given the unprecedented shock induced by the COVID-19, some actions taken by firms to cope with the crisis may not be captured by the model, for example, switching to online ordering and takeout.

[7] Also see Ding, Xiaodan and Thierry Tressel. 2021. "Global Corporate Stress Tests—Impact of the COVID-19 Pandemic and Policy Responses." IMF Working Paper No. 2021/212.

14. Firms' financial vulnerabilities are captured by their liquidity and equity positions. Like 2020 October Regional Economic Outlook, Europe[8], the FSAP defines financial stress as firms encountering a liquidity gap (as illiquidity) or an equity gap (as insolvent). A liquidity gap occurs when firms' current assets are insufficient to cover net operational cash outflows and debt services; and an equity gap occurs when firms' equity becomes negative, i.e., liabilities exceed the value of assets. While the FSAP analysis does not assume that a liquidity gap or equity gap would lead to bankruptcy, the literature suggests that it would increase the probability of future bankruptcy.[9]

15. Policy support measures are applied to individual firms to assess their impact on their liquidity and equity positions. In the ORBIS sample, large firms' financial statements are mainly on a consolidated basis. Therefore, total assets and turnovers of large firms in the ORBIS sample are greater than the official statistics on large U.K. corporates. It is widely reported that most pandemic-generated vulnerabilities are concentrated in SMEs, so the following analysis focuses on calculating liquidity and equity shortfalls of SMEs.[10] Four major policy support measures are applied to individual firms: CJRS, business rates reliefs, grants, and government-guaranteed loans, and estimated as follows:

- Individual firm's receipts on **CJRS** are proportional to its wage bills and then adjusted for i) the annual average shares of furloughed workers in total eligible workers by sector and ii) the total CJRS receipts of SMEs in the sample (Table 2).[11]

Table 2. Costs of Coronavirus Job Retention Scheme

Year	Total cost	To SMEs (% in total Cost)	To SMEs in ORBIS sample
2020	£46 billion	£31 billion (65%)	£4.6 billion
2021	£23 billion	£18 billion (65%)	£2.6 billion

Source: HMRC, ORBIS, and IMF staff calculations.

- The **business rates reliefs** to individual firms are based on the sectoral business rate-to-turnover rate, and then adjusted for the number of months the relief applies and the rates of reliefs.[12] **Grants** are proportional to the business rates reliefs and adjusted to match the total grants disbursed.

[8] Also see Ebeke, Christian, Nemanja Jovanovic, Laura Valderrama, and Jing Zhou. 2021. "Corporate Liquidity and Solvency in Europe During COVID-19: The Role of Policies." IMF Working Paper No. 2021/056.

[9] See Davydenko, Sergei A., and Julian R. Franks. 2008. "Do Bankruptcy Codes Matter? A Study of Defaults in France, Germany, and the U.K." Journal of Finance.

[10] As described in paragraph 8, the increase in SME indebtedness substantially outpaced large businesses during the pandemic. Total debt increase in large firms from Dec 2019 to Mar 2021 is only 2 percent, compared with a 25 percent increase in SMEs. Therefore, the potential NFCs' financial vulnerabilities built up during the Covid are likely concentrated in SMEs, which are the focus of the FSAP analysis.

[11] The total CJRS receipt to SMEs in the ORBIS sample is estimated based on the total CJRS disbursements to SMEs and the share of SMEs in the ORBIS sample in total SMEs according to turnovers. The total CJRS disbursement to SMEs is based on the percentage of furloughed workers in firms less than 250 employees out of total furloughed workers, implicitly assuming the same CJRS cost per work between SMEs and large corporates.

[12] See details on the COVID-specific business rates relief at: https://www.gov.uk/apply-for-business-rate-relief/retail-discount.

- The **government-guaranteed loans** are not directly applied to individual firms. Instead, the sectoral growth rates of MFIs' lending are used. As shown in Table 3, banks' lending to corporates was largely supported by the government guarantee schemes.

Table 3. Guaranteed Loans vs. MFIs Net Lending

Sector	CBILS & BBLS*	MFIs' net lending to SMEs	MFIs' net lending to large corporates
Agriculture	1.7	1.2	-0.3
Mining & Utility	0.8	0.4	1.4
Manufacturing	6.4	2.9	-4.0
Construction	11.7	7.3	-0.5
Trade	12.4	8.6	-1.4
Transportation	3.4	4.2	3.0
Accommodation	6.2	4.9	0.7
Information	3.2	0.0	0.0
Real estate & Professional	11.7	11.6	-7.0
Administrative	6.0	2.0	4.7
Education	1.2	0.8	-0.3
Health and social	2.8	1.5	-0.3
Recreation	1.7	3.4	0.0
Other services	2.8	0.0	0.0
Total	**72.1**	**48.7**	**-4.0**

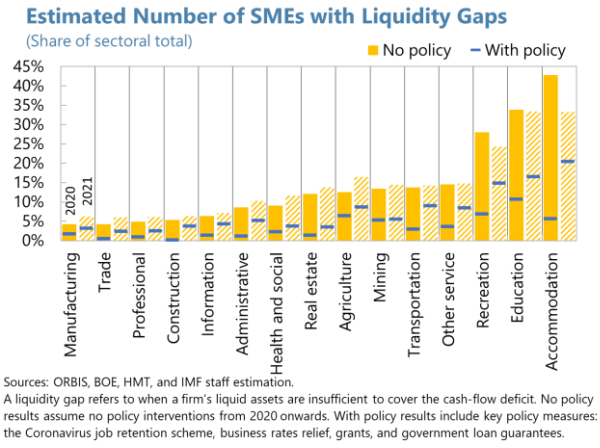
Source: British Business Bank, Banks of England, and IMF staff calculations.

* Sectoral loan disbursements are only available under the Coronavirus Business Interruption Loan Scheme (CBILS) and Bounce Back Loan Scheme (BBLS). Guaranteed loans to financial and insurance activities are not included.

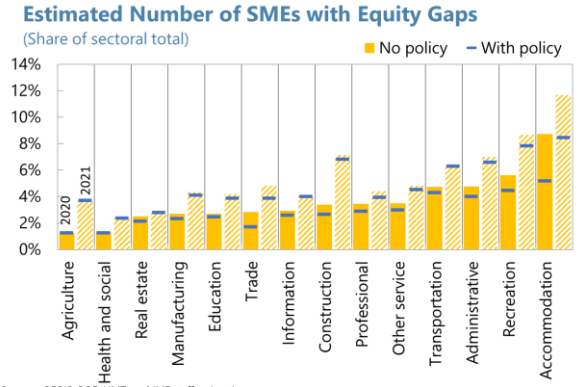
16. Government support measures significantly reduced the financial stress of SMEs, particularly in pandemic hard-hit sectors. The FSAP estimates that, without policy support, 43 percent, and 33 percent of SMEs in the accommodation sector, the most affected, would have faced liquidity shortfalls in 2020 and 2021, respectively. With policy support, the share SMEs estimated to be illiquid significantly reduces to 6 percent and 20 percent in 2020 and 2021, respectively. These substantial reductions in the accommodation sector, and more generally in hard-hit sectors, are attributed to the more targeted support measures such as business rates reliefs and grants. Solvency risks are not as acute as liquidity risks. Still, an estimated 9 percent and 12 percent of SMEs in the accommodation sector would have encountered negative equities in 2020 and 2021, respectively; but this reduces to an estimated 5 percent and 8 percent 2020 and 2021, respectively, once policy measures are considered. The analysis focuses on liquidity and equity gaps induced by the COVID-19 crisis. Therefore, firms with calculated liquidity or equity gaps based on their financial indicators before the pandemic are excluded from the calculations above.[13]

[13] Before the pandemic, about 2 percent of SMEs (0.1 percent of total turnovers) were calculated with liquidity gaps, and 9 percent of SMEs (2 percent of total turnovers) were calculated equity gaps in the ORBIS sample. The relatively

(continued)

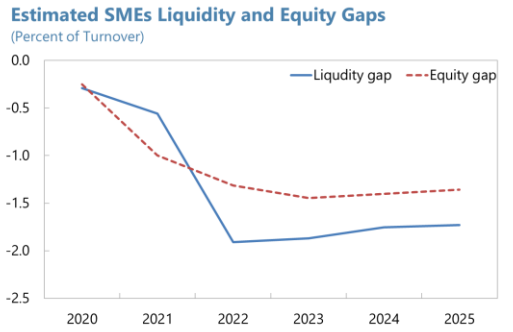


Sources: ORBIS, BOE, HMT, and IMF staff estimation.
A liquidity gap refers to when a firm's liquid assets are insufficient to cover the cash-flow deficit. No policy results assume no policy interventions from 2020 onwards. With policy results include key policy measures: the Coronavirus job retention scheme, business rates relief, grants, and government loan guarantees.



Sources: ORBIS, BOE, HMT, and IMF staff estimation.
An equity gap refers to when a firm has negative equity. No policy results assume no policy interventions from 2020 onwards. With policy results include key policy measures: the Coronavirus job retention scheme, business rates relief, grants, and government loan guarantees.

17. Over the medium term, estimated liquidity and solvency risks increase moderately among stressed firms under the baseline scenario. As output recovers, the estimated number of firms with liquidity or equity shortfalls falls. However, the size of estimated liquidity and equity gaps would continue to increase, potentially as debt overhang reduces firms' capacity to invest and weigh profitability (as demonstrated in the empirical models). The estimated SME liquidity gap would increase from 0.6 percent of turnover in 2021 to 1.9 percent in 2022 and only decline moderately to 1.7 percent in 2025. On the other hand, the estimated equity gap would gradually grow from 1 percent of turnover in 2021 to 1.4 percent in 2025.[14] This medium-term analysis of firms' vulnerabilities assumes that the sectoral compositions of the economy would gradually return to the pre-pandemic levels by 2024. This assumption does not consider possible structural shifts of demand after the pandemic, for example, permanent reduction of transportation services due to remote working. However, some granular changes within two-digit industry classification, such as moving from local to online shopping, are still possible under the baseline assumption.



Sources: ORBIS, BOE, HMT, and IMF staff estimation.
A liquidity gap refers to when a firm's liquid assets are insufficient to cover the cash-flow deficit. An equity gap refers to when a firm has negative equity.

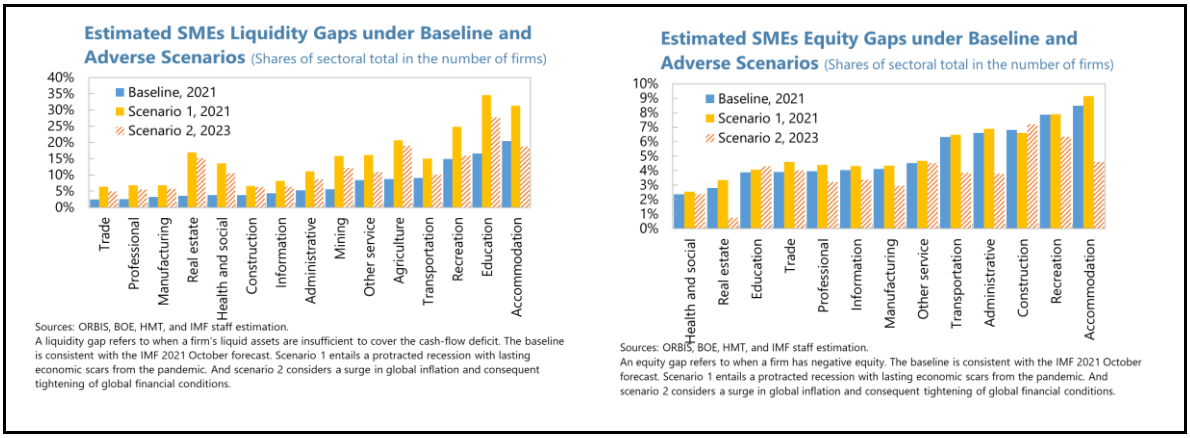
C. Stress Analysis

18. Corporate vulnerabilities would increase under adverse scenarios. To assess how corporate financial risks could reverberate through the financial system, the FSAP conducted stress

large share of SMEs with estimated equity gaps while still solvent indicates underestimated equity using book values. In general, the book value of equity does not capture some dimensions of a firm's economic value; therefore, firms with negative book values of equity could remain solvent. This issue is less imminent for the FSAP analysis as it looks at the changes in equity book values during the pandemic.

[14] If the ORBIS dataset were a representative sample of all SMEs in the UK, the result indicates the similar size of liquidity and equity gaps in percent of GDP, given that the total SME turnover was close to the size of GDP at the beginning of 2020. The estimated gaps are smaller than earlier studies (for example, 2020 Oct European Regional Economic Outlook), reflecting extended public support and the strong economic recovery.

tests under the two adverse scenarios described in Chapter two. Under these scenarios, firms' financial positions would be weakened mainly through lower revenues due to slower GDP growth and rising financing costs. The adverse scenarios capture very different shocks to the economy, and it would be hard to pre-judge what kind of policy measures would be deployed. More importantly, the FSAP analysis aims to identify corporate financial vulnerabilities rather than assess the appropriateness of policy measures. Therefore, no discretionary policy measures are assumed in these scenarios.[15]



- Under the **protracted recession with scarring** scenario, the financial stress of SMEs, especially in hard-hit sectors, would further intensify as the disproportionate impacts from the pandemic continue. For example, the estimated share of the illiquid SMEs in the accommodation sector increases from 20 percent in 2021 under the baseline to more than 30 percent. Total estimated liquidity shortfalls also increase to about 2.7 percent of turnover and stays around this level over the medium term. Firms' estimated equity positions also deteriorate. The estimated equity gap would reach 3.2 of turnover over the medium-term, more than double the level under the baseline.

- Under the **inflationary and tightening of financial conditions** scenario, the impact on NFCs is more concentrated at leveraged firms, where higher interest rates and risk premia outweigh stronger near-term growth. Despite a smaller share of financially stressed firms, the total estimated liquidity shortfall would peak at 3.7 percent of turnover in 2023 when output growth turns negative. With the shock hitting corporates later during the forecast horizon, its estimated impact on corporate equity positions is more muted. The total SME estimated equity gap reaches 0.9 percent of turnover in 2025.

D. Financial Sector Exposures to NFCs' Vulnerabilities

19. The FSAP further explores the financial sector's exposures to corporate vulnerabilities. With detailed information on the bank's corporate exposures (reported by major banks), the FSAP matches some corporations' financial conditions (from ORBIS) with their

[15] Both adverse scenarios deviate from the baseline case starting from 2021. Therefore, existing policy measures in 2021 are not included in stress tests.

outstanding loans with major banks at end-2019. However, due to inconsistent reporting by banks on corporate identifications (see Recommendation #2) and incomplete financial information from ORBIS, a large part of the information is dropped during the matching process. Therefore, the results of this analysis may not be representative of the whole corporate population or banks' corporate exposures. Still, based on historical information, the FSAP estimates the relationship between bank-defined default status of a corporate's loans and the corporate's financial indicators and macro-financial conditions (see Table 4). Built on its empirical analysis, the FSAP projects each corporate loan's probability of default (PD, based on bank's definition of loan default) over the medium term under baseline and two adverse scenarios.

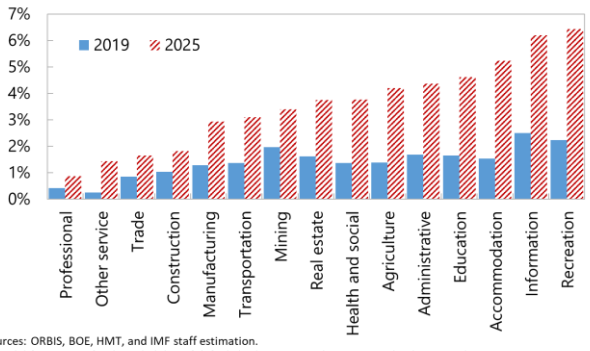
Table 4. Corporate Profit Regression—Default on Bank Loans

	(1)	*(2)*
Return on assets	-3.637***	-3.632***
Liability to assets ratio	0.169	0.171
Liability to equity ratio	-0.0000167	
Relative size (asset to sectoral average)	-0.151**	-0.152**
Fixed assets to asset ratio	1.824***	1.793***
Sales to assets	0.00737	
Sales growth	-0.977***	-0.957***
Sectoral GVA growth	-4.354**	-4.154*
Constant	-4.950***	-4.922***
Observations	12,884	12,908
Pseudo R-squared	0.086	0.086

Source: IMF staff calculations.
Note: *** (**) (*) denotes 1 (5) (10) percent significance level.

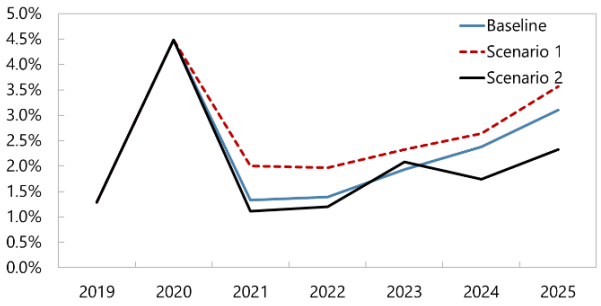
20. The potential NFC's financial stress could lead to some increases in the probability of default of banks' corporate loan portfolios, but the results are subject to large uncertainties due to data limitations. The analysis points to a sharp increase in the average PD given firms' financial conditions in 2020. The actual firm insolvencies were very low, thanks at least in part to comprehensive policy actions. The estimated average PD improves from 2020 to 2021 but gradually increases throughout the projection period. The decrease of PD from 2020 to 2021 is due to improved economic growth, but further increases from 2022 onwards reflect that a fraction of firms would face persistent rises in leverage ratios, which are positively correlated with PD. In addition, recreation and accommodation sectors generally see the most significant increases in estimated PD by the end-2025 compared with pre-pandemic levels, by 3¾ - 4¾ percentage points under the baseline and protracted recession with scarring scenarios and around 2½ percentage points under the inflationary and tightening of financial conditions scenario. As indicated in Chapter five, current capitalization levels at banks are high; hence, the sector is well capitalized to absorb these losses. Unfortunately, due to data limitations, the FSAP cannot conduct a similar analysis on NBFIs to see their exposures to corporate vulnerability (see Recommendation #1).

NFCs' Probability of Default by Sector
(Percent, weighted by draw balances)



Sources: ORBIS, BOE, HMT, and IMF staff estimation.
A model forecasting firm's probability of default (PD) is estimated using major bank-reported corporate exposures in 2019. 2019 refers to model estimated PD in 2019, and 2025 refers to projected PD in 2025 under the baseline scenario. The baseline scenario is consistent with the IMF 2021 October forecast.

NFCs' Probability of Default under Different Scenarios
(Percent, weighted by draw balances)

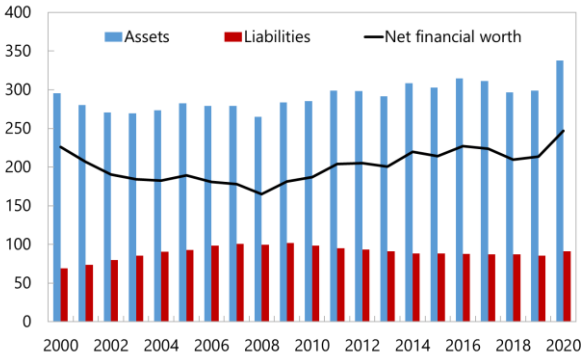


Sources: ORBIS, BOE, HMT, and IMF staff estimation.
A model forecasting firm's probability of default (PD) is estimated using major bank-reported corporate exposures in 2019. The baseline scenario is consistent with the IMF 2021 October forecast. Scenario 1 entails a protracted recession with lasting economic scars from the pandemic. And scenario 2 considers a surge in global inflation and consequent tightening of global financial conditions. The year in the legend refers to the projected PD in that year.

HOUSEHOLDS

21. Since the global financial crisis (GFC), households' net financial assets have improved steadily at a macroeconomic level, even during the COVID19 pandemic. Households' financial assets increased from 285 percent of GDP at end-2010 to 307 percent of GDP at end-2019, and further to 349 percent of GDP at end-2020.[16] On the other hand, households' financial liabilities declined from 97 percent of GDP to 86 percent from 2010 to 2019 but increased to 93 percent of GDP in 2020. Households' net financial wealth stood at 256 percent of GDP at the end of 2020. It is worth noting that the large contraction in GDP in 2020 also contributes to the increases in household financial assets and liabilities relative to GDP. However, with the pandemic, there is considerable heterogeneity across households. Therefore, this FSAP chapter aims at examining if vulnerabilities that are macro-relevant can arise and from what component of the sub-population of households at risk (HaR). The FSAP undertakes various household level regression analyses to i) demonstrate the determinants of on the evolution of households' earnings, savings, and financial balance sheets, ii) estimate the post-pandemic households' financial positions and identify HaR, and iii) explore transmission channels of household financial stresses to financial stability risk.

Household Financial Assets and Liabilities
(Percent of GDP)



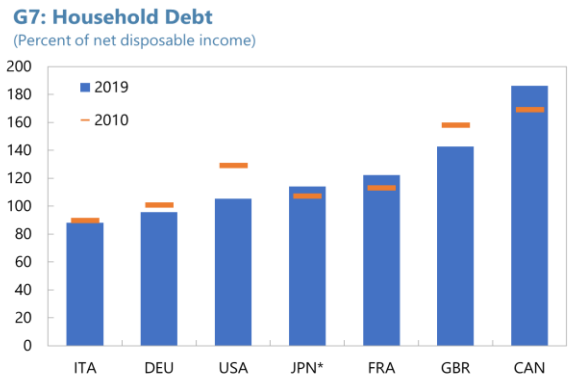
Sources: ONS

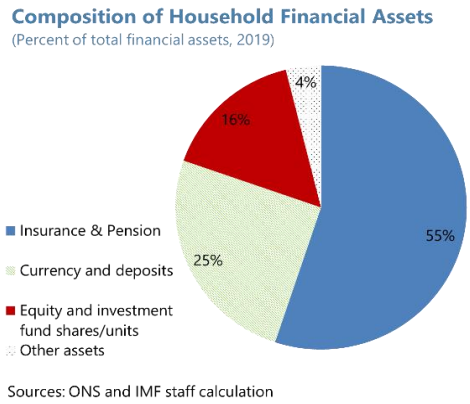
[16] The analysis aims at the potential transmissions of household financial vulnerabilities to the financial sector through household financial liabilities. Therefore, the discussion focuses on households' financial assets and liabilities. While households' real assets (mainly real estate properties) are not directly discussed, their values are considered when estimating mortgage losses.

22. The FSAP finds that households' financial vulnerabilities are concentrated in low-income households, and an abrupt tightening of financial conditions would further exacerbate household financial stress. In general, households weathered the COVID-19 shock relatively well, thanks to comprehensive policy actions. In the baseline scenario, mortgage arrears would increase moderately in 2021 and 2022, comparable with historical averages. However, the bottom income quintile has the highest average probability of default. Under the inflationary and tightening of financial conditions scenario, households' financial conditions would deteriorate more significantly, and the average probability of mortgage arrears would exceed the peak level during the GFC. Given the banks' exposure to mortgage loans and their level of capitalization as indicated in Chapter five, financial losses from mortgage default could be absorbed.

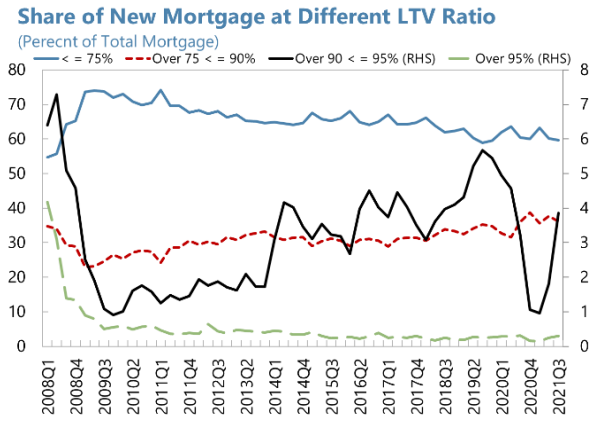
A. Development of Household Balance Sheets

23. Before the pandemic, household indebtedness had reduced but remained high among G7 countries. At 143 percent of disposable income at end-2019, U.K. household debt was the second highest among G7 countries after Canada. However, as household income grew faster than debt, household debt burden (debt to disposable income ratio) declined by about 15 percentage points from 2009 to 2019. This reduction mainly came from mortgages, whereas consumer credit has increased slightly. Still, mortgages are the primary source of household financial vulnerabilities, accounting for more than 70 percent of household debt. On the asset side, despite the high level of financial assets, many of their assets are illiquid—such as pension and insurance entitlements—and sensitive to valuation changes.



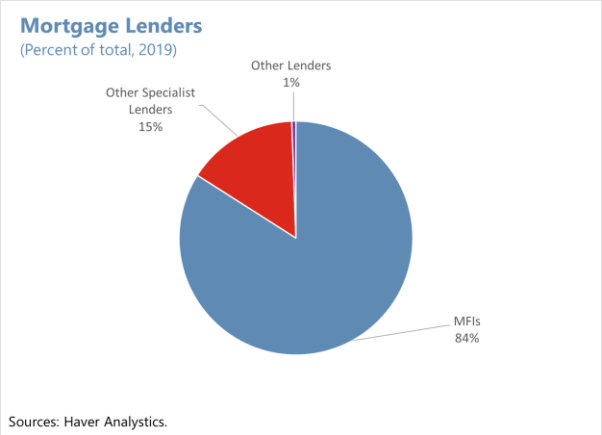


24. The higher-risk segments of household mortgages have declined since the GFC, supported by the authorities' mortgage market recommendations introduced in 2014. Immediately after the GFC, the share of mortgages issued at loan-to-value (LTV) ratios higher than 75 percent dropped significantly. Since then, mortgages at LTV ratios above 75 but below 90 percent gradually recovered, while mortgages at LTV ratios above 95 percent stayed low. Two mortgage market recommendations helped contain mortgage risks. The two recommendations are i) limiting mortgages with loan-to-income (LTI) ratios of 4.5 percent or higher to 15 percent of new mortgage lending, and ii) an affordability test that ensures households can still afford their mortgages even if, at any point over the first five years of the loan, the mortgage rate was to be 3 percentage points higher than the reversion rate at origination.[17]



Sources: Bank of England and Financial Conduct Authority.

25. Banks are the primary lenders to households, but NBFIs are exposed to the riskier part of the household debt. Given the size of mortgages in total household debt and more than 80 percent mortgage lent by banks, banks are the primary credit providers to households. NBFIs, on the other hand, take an important share in unsecured consumer credit. FSAP analysis shows that consumer credit is generally procyclical and more used by low-income households to finance their consumption.[18] However, a lack of detailed information on the historical performance of consumer credit and lending standards prevents further analysis on how household financial vulnerabilities could arise from consumer credit and the possible transmission channels to the financial sector (see Recommendation #3).



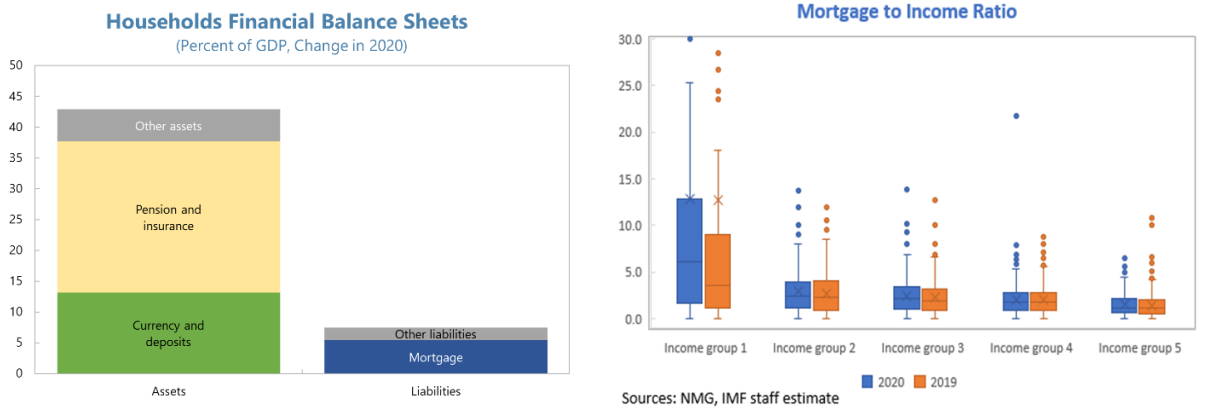
Sources: Haver Analytics.

26. Household net financial wealth further increased in 2020, while household debt also increased. Household financial assets increased significantly in 2020, by more than 40 percentage points of GDP. This significant increase was driven by extraordinarily high levels of household savings forced by the pandemic and significant positive valuation effects on insurance and pension

[17] The reversion rate is the interest rate that a mortgage 'reverts' to after the fixed-rate mortgage period comes to an end. If the mortgage contract does not specify a reversion rate, the rate used in the FPC's affordability test is 3 percentage points higher than the product rate at origination.

[18] Based on the NMG household survey, the consumer credit-to-income ratio of the lowest income quintile is about three times the ratio of the whole sample. Moreover, the empirical analysis shows that consumer credit positively correlates with individual household consumption and GDP growth.

assets, mainly from further decreases in interest rates. Total outstanding mortgage debt also increased by about five percentage points of GDP, again in part due to the large contraction in GDP in 2020. Debt burden remained stable on average but increased moderately among low-income households. In the 2020H2 NMG household survey, the lowest income quintile reported an average mortgage-to-income ratio that was 2.5 times income greater than the average ratio reported by the lowest income quintile households in the 2019H2 survey. In contrast, this ratio barely changed for the whole sample.



27. The overall resilience of household balance sheets during the pandemic was supported by government support measures. The CJRS covered up to 80 percent of the wages of workers not working due to the pandemic, while keeping their jobs. The Universal Credit (UC), a mean-tested social benefit for people in work but on low incomes as well as unemployed or disabled, was increased by £20 per week. The conditions to access the UC were also relaxed. In addition, the government also provided temporary liquidity support to households and coordinated with the FCA to create guidance for firms to also do so, such as through the mortgage payment deferral scheme. All these measures protected household financial positions during the pandemic. As these measures ended, household post-pandemic financial positions once again rely primarily on their employment status and debt levels. The FSAP used empirical models to underpin the dynamics of households' earnings, savings, and financial positions.

B. Empirical Determinants of Household Debt-at-Risk

28. Post-pandemic households' financial conditions are largely determined by households' employment status, debt levels, and macro-financial conditions. Using the NMG survey data, the FSAP estimates household employment status and consumption as follows:

$$Prob(E_{i,t} = 1) = c + \alpha \cdot E_{i,t-1} + \beta \cdot HM_{char_{i,t-1}} + \gamma \cdot macro_{financial_t} + \varepsilon_{i,t} \quad (2)$$

$$Cons_{i,t} = c + \alpha \cdot Cons_{i,t-1} + \beta \cdot HH_{char_{i,t-1}} + \gamma \cdot macro_{financial_t} + \varepsilon_{i,t} \quad (3)$$

where $E_{i,t}$ represents the joint employment status of all adult members[19] and $C_{i,t}$ denotes household consumption. Household characteristics include gross income, net income (after paying taxes, social security contributions, debt service payments, rent, and utility bills), outstanding mortgages and consumer credit, age of the household member who finished the survey, number of adults, and number of children. Macro-financial indicators include unemployment rate and inflation. The regression results are presented in Table 5. Household employment status was further adjusted based on the household weight in the survey and the actual or projected unemployment rate under the baseline or adverse scenarios.[20] Then, the analysis estimates the key components determining the dynamics of household financial conditions: income, consumption, outstanding mortgage, and saving stock through the following three steps.

Table 5. Household Regressions

	Pr (Employment = 1)	Consumption	Pr (Mortgage arrear =1)
Pr (Employment = 1)			-0.35***
Lag Pr (Employment = 1)	0.64***		
Lag gross income	6.2e-6***		
Net income		0.07***	
Mortgage		-0.003***	
Mortgage payment to gross income ratio (DSTI)			0.001*
Mortgage to house value (LTV)			0.007*
Mortgage interest rate			7.99***
Consumer credit		0.008	
Saving (stock)			-6.03e-6***
Age	-0.04***	13.5***	-0.01***
Number of adults	-0.75***		
Number of children		39.01	
Unemployment	-0.93***		
Inflation	-0.46***		0.10***
Constant	9.69***	-847.46***	-0.55***
Observations	6,776	1,726	11,765
R-squared	0.53	0.72	0.05

Source: IMF staff calculations.
Note: *** (**) (*) denotes 1 (5) (10) percent significance level.

[19] The employment status (i.e., the probability of employment) is calculated as the number of employed people divided by the number of adults in a household. Based on the NMG household survey, employment includes those whose working status is full-time, part-time, furloughed, or self-employed.

[20] The calculated employment ratios (total employment over adult population) in the household survey are similar but not the same as the labor force survey. Therefore, the projected employment probability for each household is rescaled to ensure the projected employment ratios in the survey are proportional to the macro forecast in the FSAP scenarios, matching the average ratio from 2014 to 2019.

- **Employment and income.** *Household gross income* grows at the average rate of wage growth but is subject to the change in *probability of employment*, as shown in Equation 4.[21] *Household net income* is estimated as a share of gross income based on the historical pattern of the relationship between the net and gross income.

$$GrossIncome_{i,t} = \begin{cases} GrossIncome_{i,t-1} \cdot (1 + g_t^w) \cdot \dfrac{prob(E_{i,t} = 1)}{prob(E_{i,t-1} = 1)}, & if\ prob(E_{i,t} = 1) \neq 0 \\ UnempInsur_{i,t-1} \cdot (1 + Inflation_t), & if\ prob(E_{i,t} = 1) = 0 \end{cases} \quad (4)$$

- **Consumption and saving**. The increase of household *saving stock* equals household net income after *consumption*. The FSAP analysis does not assume new mortgages or changes in consumer credit.

- **Mortgage and house value.** The outstanding *mortgage stock* is reduced by the principal amount in each mortgage payment. The principal payment is the total mortgage payment after reducing interest payment, calculated based on the mortgage interest rate. The mortgage interest rate will be adjusted based on the changes in policy rate when the current mortgage interest rate expires. Given that the forecast period ends in 2025, the FSAP analysis assumes only one remortgage for each existing mortgage loan.[22] For each mortgage, the underlying house value will grow in line with national average house prices, which are projected under each FSAP scenarios.

29. The FSAP's analysis of household financial risks focuses on household stress in paying mortgages. The FSAP defines a mortgage arrear if households report having more than two months behind mortgage payments, excluding payment holidays, according to the NMG survey. The reported share of households behind mortgage payments, at an average of 14 percent between 2012 and 2019, is significantly higher than the share of loans in arrears, at about 1.6 percent, in the mortgage lending statistics from FCA. The underlying reasons are unclear; therefore, the estimated mortgage arrears are adjusted for this difference. The FSAP estimates the probability of mortgage arrears as follows:

$$Prob(Arrear_{i,t} = 1) = c + \alpha \cdot HM_{char_{i,t}} + \beta \cdot macro_{financial_t} + \varepsilon_{i,t} \quad (5)$$

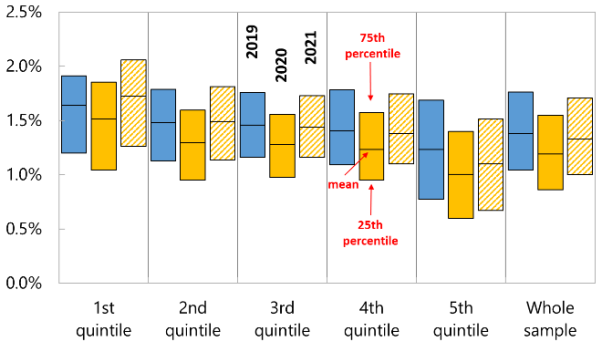
[21] The unemployment insurance per household is calculated based on £73.10 per week per adult for 26 weeks and multiplied by the number of adults. If the probability of employment is zero in the previous period, the gross income is projected to grow in line with inflation. Since the model projected employment probability generally moves gradually, this approximation is still valid even household changes from "unemployed" (employment probability equals zero) to "employed" (employment probability is positive but generally very small).

[22] The duration of the U.K.'s fixed-rate mortgage period generally lasts between 2 to 5 years. In the NMG survey, about a quarter of mortgage loans' fixed interest rates will expire each year between 2021 and 2023, and the remaining loans' interest rates will expire in 2024 or after.

Household characteristics include mortgage payment to income ratio (DSTI), mortgage stock to property value ratio (LTV), mortgage interest rate, household saving stock, employment status, and age of the household member who finished the survey. For macro-financial conditions, only inflation is statistically relevant.

30. Government support measures not only reduced household financial stress during the pandemic but also mitigated risks post-pandemic. In the NMG survey, the reported share of mortgages in arrears (see above) is one percentage point (unadjusted) lower than in 2019, despite the significant GDP contraction and widespread temporary business closures. More importantly, the average mortgage arrears are projected to increase moderately in 2021 and 2022 while remaining comparable with historical averages. From 2023 onwards, the average mortgage arrears would decline and stay low over the medium term. This analysis focuses on existing mortgage debt stock at the end-2020 and does not make assumptions about new mortgage loans. Therefore, it is expected that the average mortgage arrears would gradually decline to even below the historical averages as mortgage payments reduce outstanding stocks while household incomes continue to grow.

Estimated Probability of Mortgage Arrears
(Percent, by gross income quintile)



Sources: MNG, BOE, ONS, and IMF staff estimates.
A dummy of mortgage arrear equals one if the household reports more than two months behind with mortgage payments (excluding payment holidays); otherwise, it equals zero.

31. Despite low overall risks, financial vulnerabilities are concentrated among low-income households. The bottom quintile income group has the least reduction of mortgage arrears in 2020 and the highest projected average probability of arrears over the projection period. The NMG survey also indicates that the increased savings in 2020 are concentrated in the top two income quintiles, whereas the bottom income quintile dissaved.[23] The relatively higher probability of mortgage arrears among low-income households is projected to continue in 2021 and 2022, about one percentage point higher than the top quintile.

C. Stress Analysis

32. The risk of household mortgage arrears would increase sizably under severe financial tightening scenarios. Household financial positions, estimated by the empirical models, would be affected by their employment status (related to output growth) and debt burden (associated with interest rates).

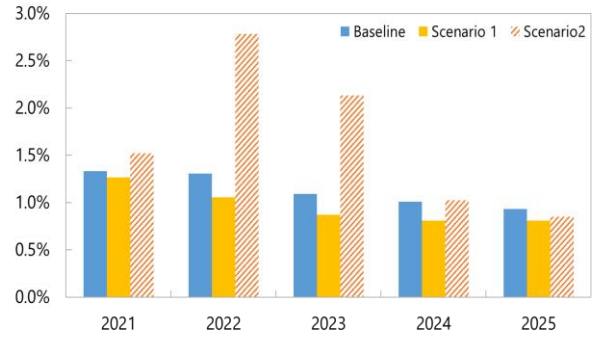
- Under the **protracted recession with scarring** scenario, households—particularly the lower-income quintiles—would face higher unemployment risk as the probability of employment would decrease more for low-income households as the overall unemployment rate increases.

[23] See Bank of England "Household debt and Covid," Quarterly Bulletin 2021 Q2.

The income shortfalls would then impair their debt serving capacity. However, under the protracted recession, interest rates would decrease further, alleviating some debt burdens. The FSAP finds that the average mortgage arrear probability would be like the baseline scenario in this scenario.

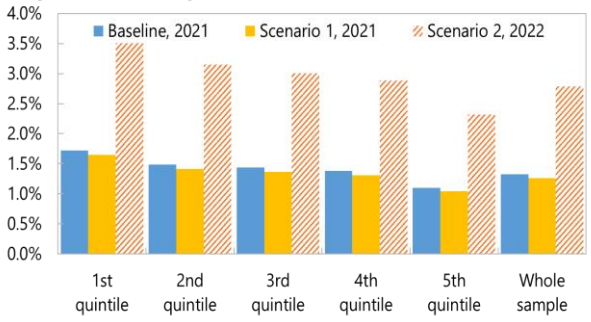
- Under the **inflationary and tightening of financial conditions** scenario, the risk of household mortgage arrears would increase more significantly. The increase in output growth and further decline of the unemployment rate would improve household income in the near term. However, the abrupt tightening of financial conditions, reflecting the rapid increase in interest rate, would significantly deteriorate household financial conditions, as about a quarter of residential mortgages would be repriced each year during the forecast horizon in the sample. The average probability of mortgage arrears would peak to 2.8 percent in 2022, more than double the level in the baseline scenario and higher than the peak level during the GFC.

Estimated Probability of Mortgage Arrears under Different Scenarios



Sources: MNG, BOE, ONS, and IMF staff estimates.
A dummy of mortgage arrear equals one if the household reports more than two months behind with mortgage payments (excluding payment holidays); otherwise, it equals zero. The baseline is consistent with the IMF 2021 October forecast. Scenario 1 entails a protracted recession with lasting economic scars from the pandemic. And scenario 2 considers a surge in global inflation and consequent tightening of global financial conditions.

Estimated Probability of Mortgage Arrears by Income Groups and under Different Scenarios

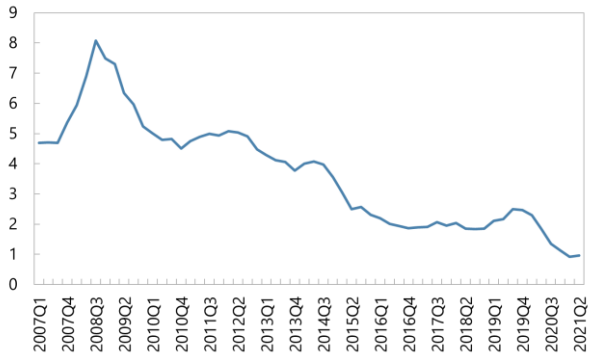


Sources: MNG, BOE, ONS, and IMF staff estimates.
A dummy of mortgage arrear equals one if the household reports more than two months behind with mortgage payments (excluding payment holidays); otherwise, it equals zero. The baseline is consistent with the IMF 2021 October forecast. Scenario 1 entails a protracted recession with lasting economic scars from the pandemic. And scenario 2 considers a surge in global inflation and consequent tightening of global financial conditions. The year in the legend refers to the projected probability of mortgage arrear in that year.

D. Financial Sector Exposures to Households' Vulnerabilities

33. Not all mortgage arrears will end up with repossession or default. In fact, the number of mortgages in repossession is, on average, 3 percent of the number of mortgages in arrears between 2012 and 2019. Some mortgages will enter default but will not be repossessed. The share of repossessions peaked at 7 percent in 2008. To estimate the potential loss given mortgage repossession (LGR), the FSAP maps the projected probability of mortgage arrear into a repossession status through the following steps. First, a threshold for arrear probability is calculated to ensure that the share of projected arrear probability

Mortgage in Possession
(Pecent in total mortgage arrears)



Sources: FCA Mortgage lending statistics

above this threshold from 2012 to 2019 matches the actual percentage of mortgage arrears, i.e., 1.6 percent. Second, the dummy for mortgage arrears is one if the projected arrear probability is above the threshold from 2021 to 2025. Third, the top 7 percent of mortgage arrears (ranked by arrear probability) are cast into default/repossession to estimate the maximum potential impact (as experienced in 2008). Finally, once a mortgage is cast into repossession, the mortgage loss is estimated as the difference between the remaining outstanding mortgage and the repossessed house value (assumed 25 percent below the market value). Then, the LGR is calculated as the total mortgage losses on repossessed loans as a share of the total repossessed loans.

34. Household mortgage arrears could lead to some losses to the financial sector, but the sector is well capitalized to absorb them. The FSAP estimates that LGR would reach about 17 percent of repossessed mortgage portfolio, which represents about 0.3 percent of total outstanding mortgages, when the average probability of mortgage arrears reaches about 1.3 percent under the baseline scenario. The LGR would amount to 21 percent under the inflationary and tightening of financial conditions scenario where the average probability of mortgage arrears would peak to 2.8 percent and 0.9 percent of outstanding mortgages would be repossessed. The FSAP assumes a 25 percent loss during the mortgage repossession procedure relative to the market value in this analysis, including factors such as lower selling prices and administrative costs. However, this repossession cost could be over-estimated under the baseline scenario with no national-wide house price corrections. And in the adverse scenarios, losses could be mitigated if lenders delay selling repossessed properties until house prices have partially recovered. Further breakdown of financial losses to different parts of the financial sector is impossible, as the information on mortgage providers is not available in the NMG survey. Given the large share of banks in mortgage lending and banks' high capitalization levels, these losses would be mostly absorbable.

BANK SOLVENCY STRESS TEST

35. Major U.K. banks have weathered the "twin challenges" well so far (Figure 3) The banking system is well capitalized (aggregate CET1 ratio reached 15.6 percent at the end of 2020) and NPL ratios are low, at 1.8 percent. Liquidity position appears secure. Return on assets has been hovering about 0.4 percent in recent years, with a declining contribution of the more stable component of net interest income, compensated by increasing trading income. Banking analysts are projecting a positive outlook for the U.K banks. The non-systemic sector[24] is also well capitalized, with an aggregate CET1 ratio of around 17 percent and an aggregate liquidity coverage ratio of over 200 percent.

[24] The non-systemic sector, which represents less than 10 percent in terms of assets, is comprised mainly of institutions with relatively risk averse and narrow business models. Most institutions are mortgage or niche lending focused and are retail funded. Although there have been also some situations of rapid growth with excessive risk taking, reliance on regular capital injections, significant and rapid changes in strategy and business model, and immature controls, the sector has been overall able to absorb the impact of the pandemic and BoE has mechanisms for ensuring that stresses in the non-systemic sector would not become systemic.

36. The potential systemic impact of risks to banks was assessed with a top-down solvency stress-test of the eight major U.K. banks and building societies (STeM for details).[25] The solvency stress test assesses whether banks have adequate capital buffers to withstand a set of macro-financial shocks envisioned under the three five-year horizon scenarios. The exercise assessed the impact on banks' buffers via several channels, including **credit risk** (of loan exposures and securities held at amortized cost), **market risk** (revaluation of debt securities held at fair value and valuation changes in open foreign positions), and **interest rate risk**.[26] Results are reported on a fully loaded basis, i.e., IFRS9 transitional arrangements are not accounted for. Figure 4 illustrates selected elements of the solvency tool.

37. The solvency analysis is conducted based on a quasi-static balance sheet assumption. The allocation of assets and the composition of funding sources remain constant as of the cut-off date. Gross exposures in bank balance sheet, such as loans and holdings of debt securities, are assumed to growth in line with nominal GDP growth. Banks can build capital buffers only through retained earnings. Dividends are linked to banks' net profits and solvency. Under positive profits and capital ratios above hurdle rates, the dividend payout is set at 30 percent. Otherwise, no dividend payout is assumed. It is also assumed that banks do not issue new shares or make repurchases during the stress test horizon. Finally, in contrast to the ACS, the IMF exercise does not take account of any corrective action banks might be expected to take under stress.

38. Minimum capital requirements are based on actual supervisory requirements during the stress test horizon. Individual bank's hurdle rates are comprised of Pillar 1 CET1 (4.5 percent), bank-specific uplifts to the CET1 minimum as set by the Prudential Regulation Authority (Pillar 2A); and any applicable global or domestic systemically important institution buffers (G-SIB, O-SII, and SRB). Importantly, hurdle rates are not adjusted to reflect the impact of earlier loss recognition under IFRS9.[27]

[25] The exercise follows the standard FSAP approach and carefully accounts for the cross-border dimension that characterize the U.K. financial system. It is based on the relationships between cross-border macroeconomic and financial variables on one hand, and bank-level variables (PDs, LGDs, and P&L components, in particular) on the other. These are captured via satellite models, but also via a link to the results of the corporate stress tests. The framework, unlike the Bank of England ACS, does not account for management actions banks might be expected to take under stress. The exercise spans a five-year time horizon, has been run under the October WEO baseline and two distinct adverse scenarios—simulated with the IMF's Global Macrofinancial Model.

[26] Buffers have been estimated according to the Basel III framework and U.K.-specific rules. Credit risk includes lending risk from exposures to sovereign and public entities, combined with evaluating sovereign risk from shocks to interest rates and credit spreads in bank trading book and AFS/FVO linked to macro scenario.

[27] Since 2018, the BoE has introduced in its ACS exercises an adjustment to hurdle rates to neutralize the interaction of IFRS9 with the simulation of banks' capital under stress: in line with internationally agreed transitional arrangements for the IFRS 9 accounting standard, banks are allowed to 'add back' a proportion of capital losses that are associated with earlier recognition of impairments under IFRS 9, relative to the previous accounting standard; moreover, the BoE adjusts the banks' hurdle rates to take into account the impact of the IFRS 9 accounting standard, which is to reduce CET1 at the capital low point by bringing forward the point in a stress at which banks provision for losses; these adjustments reflect the FPC's commitment to prevent the interaction of the IFRS 9 accounting standard with the stress-testing framework from resulting in an unwarranted de facto increase in capital requirements (see https://www.bankofengland.co.uk/-/media/boe/files/financial-stability-report/2019/december-2019.pdf?la=en&hash=99431A541357AC6D601A99B950455E2344C12901#page=12). To ensure conservatism of the

(continued)

A. Credit Risk Modelling Approach

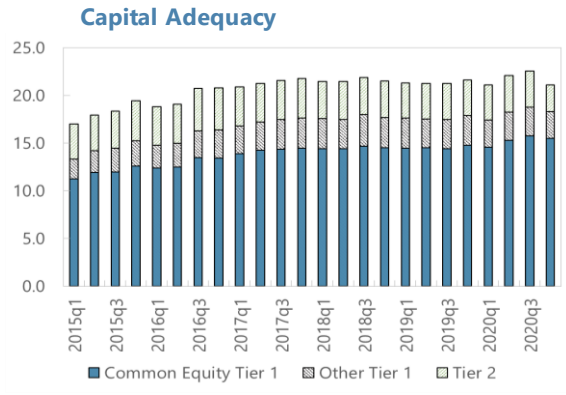
39. Credit risk is one of the most important risk factors for the U.K. banking system, as the loan portfolio accounts for about 56 percent of total assets. Mortgage loans account for about 54.9 percent of the total exposures at default (EAD) of loan portfolios. Corporate loans correspond to 32.5 percent of credit exposures and retail to 12.6 percent. By geography, about 67.5 percent of total exposures are domestic and the remaining are split across several countries with a large fraction concentrated in the Euro Area, United States and Hong Kong. However, individual banks appear to be quite diverse in terms of their geographical footprint. The relative importance of credit risk is also evidenced by the proportion of total RWAs that are attributed to credit risk versus residual risk types, which is almost 76 percent.

40. Satellite models for credit risk are based on cross-country panel regressions of probabilities of default (PDs). PDs are taken from banks' IFRS 9 submissions. These correspond to probabilities of default over a one-year period and are reported based on exposure weighted averages. The logistic transformation of PDs is taken as a dependent variable and a broad set of explanatory macroeconomic variables is considered, including, GDP growth, unemployment rate, house price growth, exchange rate change, interest rates and inflation. Different lag structures are considered, and country/region fixed effects are included. The final specifications were chosen based on goodness of fit, and the statistical and economical significance of individual variables. The estimation period comprises 2014:Q1–2020:Q1, which purposively excludes the pandemic period, as covid related policy measures may have attenuated the relationship between credit risk and macroeconomic variables. The countries included vary depending on the type of loan, consistent with the cross-border exposures of mortgage, retail, and corporate loans. Even though the estimation period does not cover an entire financial cycle, our estimates are able to capture sensitivities of PDs to macroeconomic variables by using the cross-country variation.

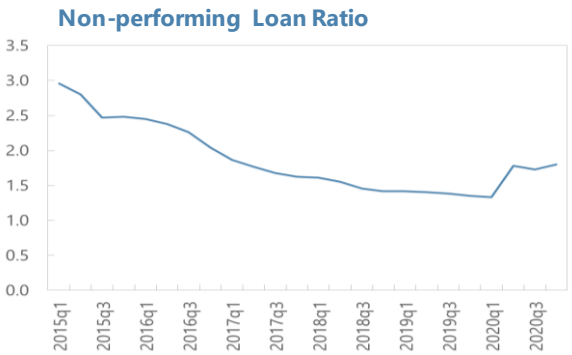
capital depletion estimates and for better cross-country comparability, no adjustment to the hurdle rates is made for IFRS9 in the FSAP solvency stress test exercise.

Figure 3. United Kingdom: Banking System Performance

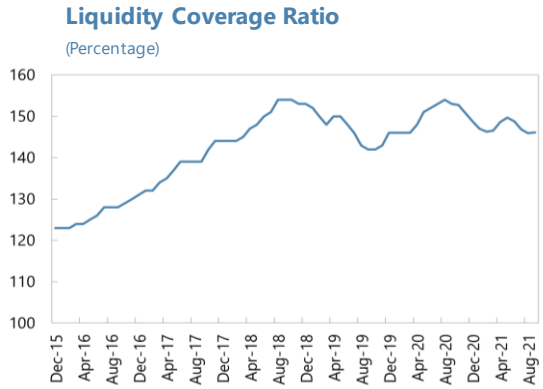
Capitalization has improved since the 2016 FSAP, with CET1 increasing from 12.4 percent to 15.6 percent….



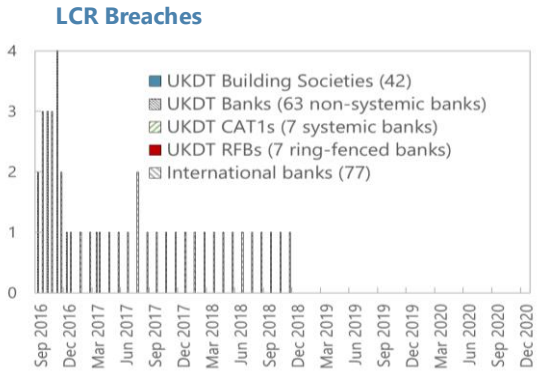
…asset quality has improved. NPLR drop from 2.5 percent to 1.8 percent in December 2020.



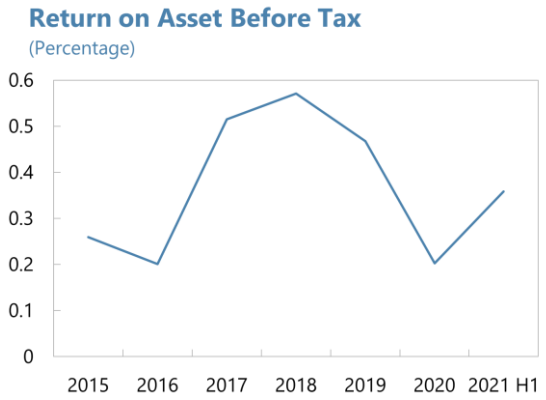
The banking system has continued to hold significant liquidity buffers…



…. with no LCR breaches during the period 2019-2020.

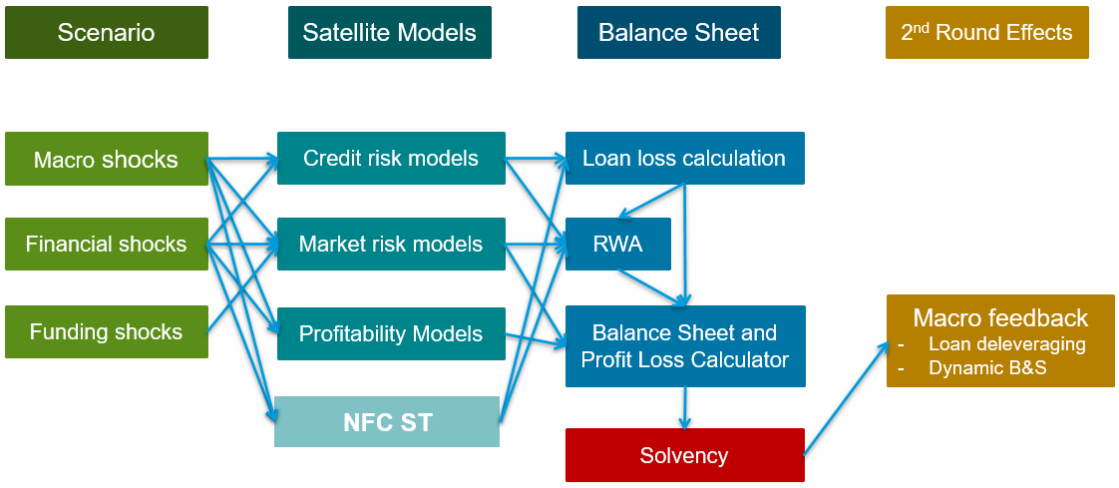


The ROA before taxes increased from 0.20 percent in 2016 to 0.57 on 2018, but drop back to 0.20 in 2020…



Price-to-book ratio dropped from 0.7 in 2016 to 0.5 in 2020…

Figure 4. United Kingdom: Macroprudential Solvency Stress Tests: A Block Diagram



Source: Adapted from Henry and Kok (eds.), ECB Occasional Paper 152 (*https://www.ecb.europa.eu/pub/pdf/scpops/ecbocp152.pdf*)

41. Credit risk satellite models are estimated separately for mortgage, retail, and corporate loans. The final models are reported in Table 6. Unemployment turns out to be a key driver for PDs across all loan types. Changes in house prices are an important determinant for mortgage PDs, while changes in exchange rates are important for retail PDs and corporate PDs. Real GDP growth is also a key driver for corporate PDs. The credit risk models are used to derive PD projections conditional on the three cross-country scenarios.

42. Projected PD paths increase during the first years of the stress test horizon under adverse scenario1 and towards the end under adverse scenario 2 (Figure 5). Domestic mortgage PDs increase by 4pp at the start of 2022 under the first adverse scenario. Under the second adverse scenario they initially fall and then peak at 7.7 percent by the end of 2023. This is consistent with the scenario paths for house prices and unemployment. Similarly, foreign mortgage PDs peak at 8.1 in 2022 under the adverse scenario 1 and reach 9.9 percent in 2023 under scenario 2. On the other hand, domestic retail PDs, with relatively higher PDs at the cutoff date, reach 24 and 22 percent at the peak under the adverse scenario 1 and 2 respectively. Foreign retail PDs, with lower starting points, increased to 8.2 and 6.7 percent respectively. Finally, domestic corporate PDs increase to 4.3 and 3.5 percent under adverse scenario 1 and 2, while foreign corporate PDs increase to 4.2 and 3.9 percent, respectively.

Table 6. Credit Risk Models

		logit(PD_gq)	
VARIABLES	**MORTGAGE**	**RETAIL**	**CORPORATE**
logit(PD_gq)(t-1)	0.280***		0.665***
	(0.0419)		(0.0468)
Residential REL (t-1)	-0.0373***		
	(0.00810)		
Real GDP Growth			-0.0275*
			(0.0147)
Exchange Rate YoY % Change		0.0458***	0.00444*
		(0.0121)	(0.00226)
Delta Unemployment Rate	0.0995*	0.523***	
	(0.0546)	(0.116)	
Unemployment Rate			0.142***
			(0.0337)
Constant	-3.802***	-8.137***	-2.115***
	(0.334)	(0.602)	(0.350)
Observations	252	352	189
Country FE	Yes	Yes	Yes
R-squared	0.950	0.849	0.921

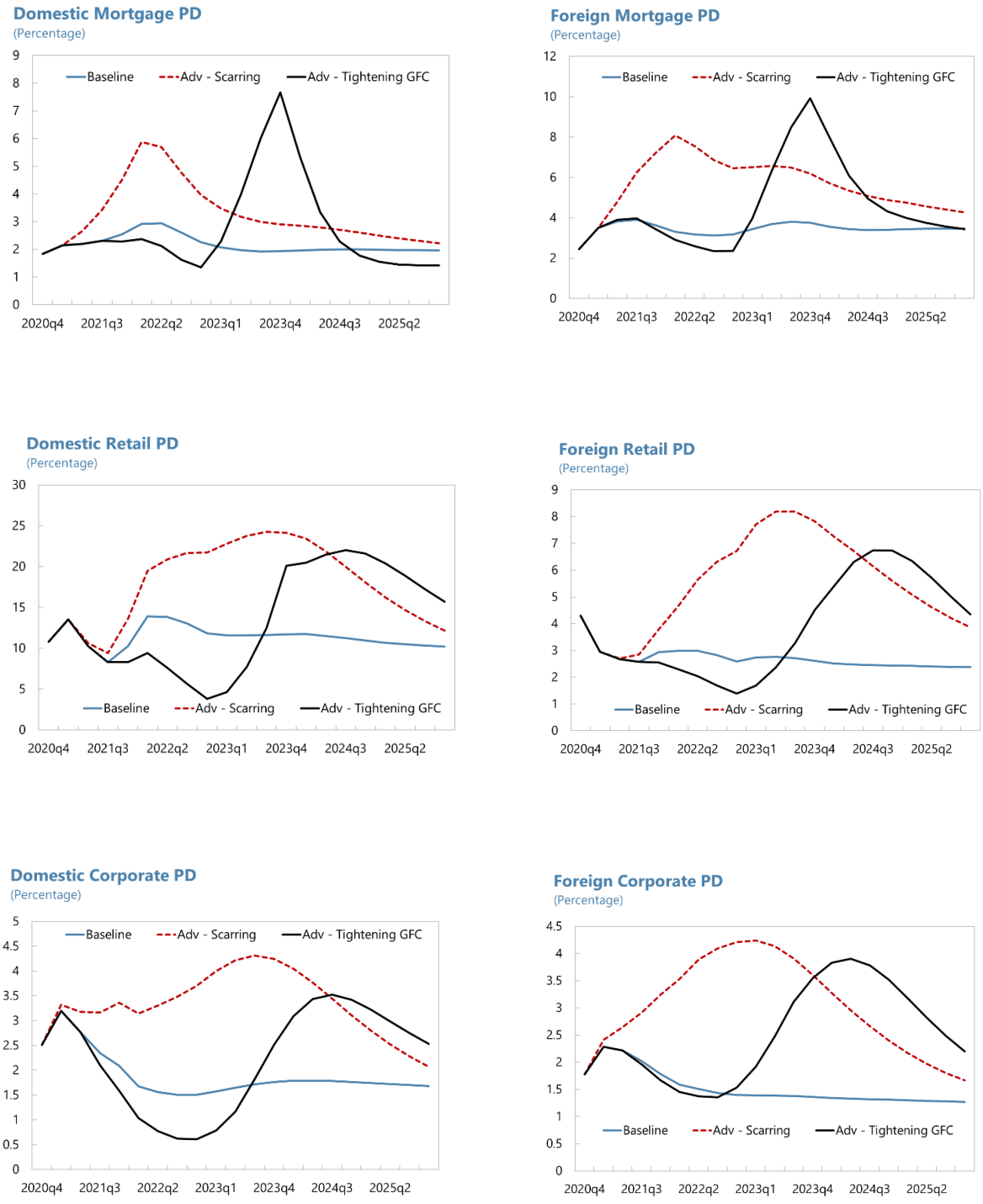
Source: IMF staff calculations.
Note 1: *** (**) (*) denotes 1 (5) (10) percent significance level.
Note 2: PD_gq denotes the PDs per country/country group and quarter.
Note 3: The mortgage model includes the United Kingdom, Euro Area, USA, Canada, Ireland, Hong Kong SAR, Australia, Singapore, China, Korea, a group of other advance economies and a group of emerging economies. The retail model includes the United Kingdom, USA, France, Hong Kong SAR, Singapore, Germany, Canada, Malaysia, Ireland, China, Mexico, India, Korea, other euro area countries, other emerging economies, and other advanced economies. The Corporate model includes the United Kingdom, USA, Euro Area, Canada, Singapore, Hong Kong SAR, China, other emerging economies, and other advanced economies.

43. Aggregate PD paths are mapped to bank PDs based on starting points. The mapping is done at the bank-asset class level, for domestic portfolios, and at the bank-country level for foreign corporate exposures. In total 25 segments are considered. The starting PDs vary largely across segments, with retail SME, retail non-mortgage non-SME and SME, among the ones with the largest starting PDs. The mapping is done by using the standard score (z-score in a standard normal distribution) of aggregate PDs and of individual banks' starting PDs by segment [28]. This approach guarantees that the projected PDs of individual banks remain within the [0, 1] range.

44. Given the unusual uncertainty in the estimations, several robustness checks where performed, including: i) use of the full sample period (2014: Q1-2020: Q4), while incorporating a dummy for the pandemic quarters, ii) estimate the cross-country panel regressions using sub samples of countries with similar characteristics, iii) use of longer time series using various PD proxies, e.g., Moody's EDFs, aggregate U.K. NPLs, write off rates. While the dynamics of the generated PDs vary with different approaches and PD proxies, the range of change in PDs remain broadly consistent across approaches.

[28] For instance, the domestic mortgage PD paths for each bank are given by the formula $PD_{i,t} = \Phi\left(\Phi^{-1}(PD_{i0}) + \left(\Phi^{-1}(PD_{UK\ Mortgage,t}) - \Phi^{-1}(PD_{UK\ Mortgage,0})\right)\right)$, where $\Phi(.)$ is the cumulated distribution function (CDF) of a the Normal Distribution and $\Phi^{-1}(.)$ is the inverse CDF.

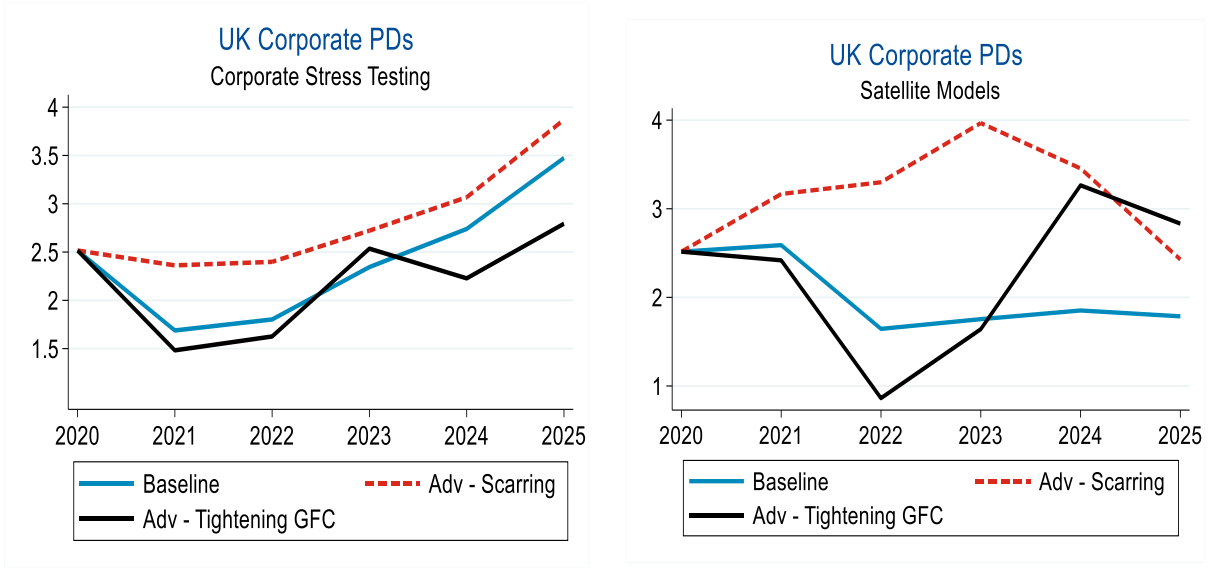
Figure 5. United Kingdom: Projected PDs under Scenarios



Sources: BoE, IMF staff calculations.

45. A link to the corporate stress test was also incorporated as a robustness exercise[29]. Given its granularity, the corporate stress test is better able to capture the impact across different sectors, considering COVID-19 related measures. For this exercise, the aggregate corporate paths of domestic exposures are replaced by sectoral level PDs for each of the three scenarios. The mapping of PD paths coming from the corporate stress test (which are based on arrears) to the banking level PDs is done using one more time the standard z-score. Sectoral paths are then mapped at the sector-bank level based on starting PDs. Figure 6 compares the resulting aggregated PD paths of the corporate stress test with those of the satellite models. The PDs projected by the corporate stress test initially drop under the three adverse scenarios but increase after 2022, reaching the highest points at the end of the five-year horizon. This contrast with the PDs projected by the satellite model, which decrease under the baseline and reach the highest point in different years under the adverse scenarios. The differential impact of these set of paths on banks' solvency is presented in sub-section D of this chapter.

Figure 6. United Kingdom: Corporate Stress Test vs. Satellite Models



Source: BoE, ORBIS, HMT and IMF staff estimation.

[29] Notice that this exercise only affects the domestic component of the corporate portfolio, which corresponds to less than 14 percent of the total loan portfolio.

46. Paths for PiT LGDs are produced for each loan segment. For mortgage loans, PiT LGDs are derived by a simple model that links the starting point LGD (LGD_0) to the country-level house price path of a given scenario ($House\ Price_t$) and the fraction of mortgage loans with high LTV per bank[30] at the cutoff date. The model is given by the following expression:

$$LGD_{bt} = (1 - \%highLTV_b) * LGD_0 + \%highLTV_b * [1 - (1 - LGD_0) * \min(House\ Price_t / House\ Price_0, 1)]$$

The fraction of mortgage loans with high LTV accounts for overcollateralization, i.e., the LGD of mortgages that are overcollateralized does not increase with drops in house prices. For non-mortgage exposures, we take the maximum LGD observed during the available sample period 2014-2020 (see Figure 7).

47. The FSAP stress testing framework accounts for IFRS9 loan loss provisions principles. The expected credit loss is calculated based on a 12-month horizon for stage 1 assets and on a lifetime horizon for stage 2 and stage 3 assets. Loan loss provisions are projected using banks stressed stage transition probability matrices for each asset segment[31]. The evolution of transition matrices over the scenario horizon is linked to the projected PiT PD for each scenario based on the beta-linking approach[32]. Perfect scenario foresight is assumed to simplify provisioning projections. A similar approach has been applied in other FSAPs (Canada, France, Latvia, Singapore, and South Africa).

48. RWAs for credit exposures are treated differently for exposures under the standardized approach (STA) and the internal ratings-based approach (IRB). Projections of RWAs for STA exposures account for balance sheet growth, structural FX growth and triggered credit lines. For exposures under the IRB, the framework uses the Basel formula to translate credit parameters (e.g., TTC PDs, TTC LGDs, correlation, maturity, and scaling factors) into stressed RWAs. The TTC PDs for non-defaulted exposures is updated based on PiT PDs and a smoothing parameter that reflects their sensitivity to PiT PDs. RWAs for market risk, operational risk and other RWAs are assumed to growth in line with nominal GDP growth.

[30] $\%highLTV_b$ is calculated as the fraction of loans with LTV higher than 70%, based on U.K.-mortgages. It is applied to non-U.K. mortgages based on the assumption that that a bank's mortgage granting policy is similar across different country portfolios.

[31] When transition matrices are not available at the bank-asset class level for the starting point, transition matrices at the asset class level are used instead (same across banks). In addition, transition matrices at the starting point are re-escalated to match starting PiT PDs.

[32] See Gross, M., Laliotis, D., Leika, M., and P. Lukyantsau, 2020, "Expected Credit Loss Modeling from a Top-Down Stress Testing Perspective", IMF Working Paper No. 2020/111.

Figure 7. United Kingdom: Projected LGDs Under Scenarios

Source: BoE, IMF staff calculations.

B. Market Risk Modelling Approach

49. The market risk module captures the valuations changes of debt securities due to changes in risk-free interest rates and credit spreads. For FVPL and FVOCI debt securities market losses/gains are estimating following a mark-to-market approach. A modified duration approach is employed to reevaluate exposures as a function of their residual duration, the relevant bond yield[33] and the stressed spreads. Spreads are only stressed for adverse scenario 1. Stressed spreads are consistent with the macroeconomic scenario and are equal to those applied for the insurance stress test[34]. Importantly, bank specific interest rate hedge ratios for FVOCI portfolios are accounted for, based on information for 2021 projections provided by the BoE. For amortized cost (AC) securities, the framework uses a credit risk approach. Provisions are made to cover expected loss as asset quality deteriorates. FVOCI of corporate securities are also subject to the credit risk approach.

50. Domestic and foreign equity holdings (FVPL and FVOCI) are revaluated based on the equity paths under different scenarios. Country specific equity paths for 17 jurisdictions[35] and for the world are used to determine equity gains/losses over the stress test horizon. The market risk module also captures valuation changes in open positions in foreign currencies and commodities.

51. The impact on regulatory capital varies depending on the accounting class. Losses from FVPL portfolios are considered realized losses, affect net profits and are subject to taxation and dividend payout, while unrealized losses from FVOCI portfolios affect capital through other comprehensive income.

C. Modelling of P&L Components

52. The interest income and expense module capture interest rate risk in the banking book (IRRBB). Econometric models are estimated for the aggregate historical interest income and interest expense ratios. The key driver for both ratios is the bank rate (see columns I-II, Table 7). Projected paths conditional on scenarios suggests increases on implied net interest margin ratio[36] under the three scenarios, with a more pronounced increase for the second adverse scenario (see Figure 8). The impact of IRRBB on net interest income is estimated by measuring the gaps between assets and liabilities that reprice in each maturity bucket, up to the five-year scenario horizon. Banks' maturity profile is assumed to remain the same over the stress testing period.

[33] The relevant yield for a portfolio, with a specific duration, is proxied via linear interpolation between the short - and long-term bond yields of a given scenario.

[34] Shocks to credit spreads are split equally over the first three years of the stress test horizon.

[35] Including the United Kingdom, US, Singapore, China, Ireland, France, Netherlands, Hong Kong, Germany, Spain, Italy, Belgium, Canada, Finland, Australia, Greece, and Portugal.

[36] Net interest margin ratio = interest income ratio – interest expense ratio.

Table 7. P&L Models

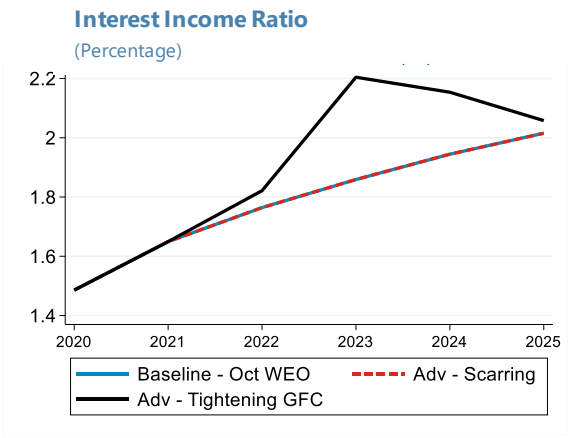
	logit(PD_gq)		
VARIABLES	**MORTGAGE**	**RETAIL**	**CORPORATE**
logit(PD_gq)(t-1)	0.280***		0.665***
	(0.0419)		(0.0468)
Residential REL (t-1)	-0.0373***		
	(0.00810)		
Real GDP Growth			-0.0275*
			(0.0147)
Exchange Rate YoY % Change		0.0458***	0.00444*
		(0.0121)	(0.00226)
Delta Unemployment Rate	0.0995*	0.523***	
	(0.0546)	(0.116)	
Unemployment Rate			0.142***
			(0.0337)
Constant	-3.802***	-8.137***	-2.115***
	(0.334)	(0.602)	(0.350)
Observations	252	352	189
Country FE	Yes	Yes	Yes
R-squared	0.950	0.849	0.921

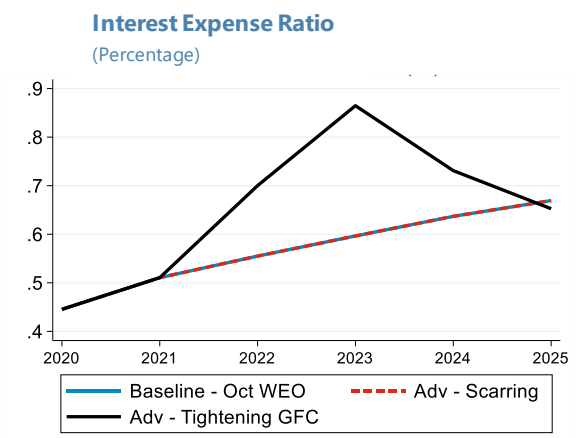
Source: IMF staff calculations.
Note 1: *** (**) (*) denotes 1 (5) (10) percent significance level.
Note 2: The P&L ratios are defined as follows: IIR = Interest Income/Earning Assets, IER = Interest Expense/Earning Assets, FCIR = Fee and Commissions Income/Earning Assets, FCIR = Other Non-Interest Income/Earning Assets, NIER = Non-Interest Expense/Total Assets.

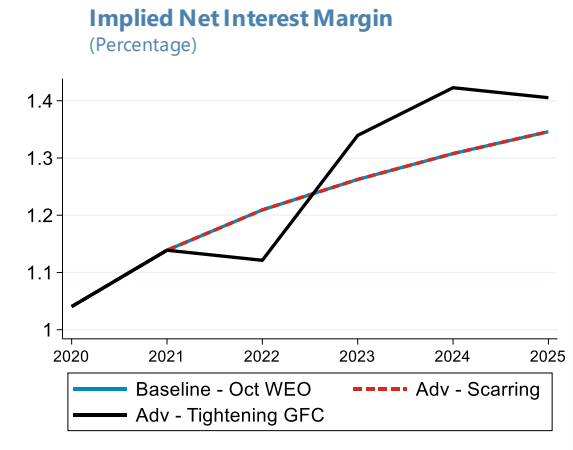
53. Satellite models for fee and commissions income ratio, other non-interest income ratio and non-interest expense ratio are also developed. The key driver across the three ratios is real GDP growth (see columns III-V, Table 7). Projected paths suggest a decrease in non-interest income in the first year of the scenario, followed by an increase in the subsequent years under the baseline and adverse scenario 1. Under the second adverse scenario, non-interest income is initially higher compared to the first adverse scenario, but drops towards the end of the horizon, consistent with the GDP path. Similar paths are projected for non-interest expense ratio (see Figure 8). Aggregated paths of P&L ratios are mapped at the bank level based on the starting points, using the standard z-score, as for the credit risk variables.

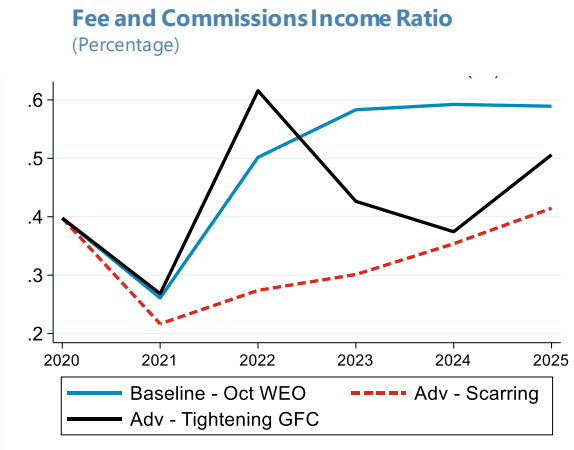
54. The models for interest expense ratio and fee and commissions ratio are used to implement a "Fintech Overlay" analysis. The models of these two P&L components include as an explanatory variable a proxy for competition. The change in the share of bank's credit to total credit to the private non-financial sector is used as measure of competition. This variable is assumed to remain constant over the scenario horizon under the three scenarios in the main exercise. Its path is only modified as part of the fintech overlay.

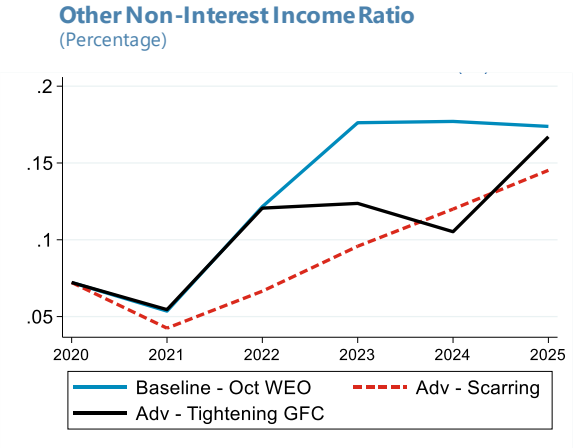
Figure 8. United Kingdom: Projected P&L Components under Scenarios

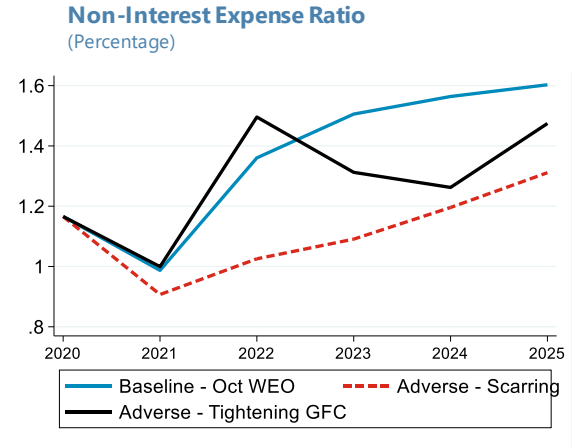












Source: BoE, IMF staff estimations.

D. Solvency Stress Tests Results

55. The results suggest the system would remain resilient under the baseline and both adverse scenarios (Figures 9-11). Banks' aggregate CET1 ratio would decline from the 2020 starting point (15.6 percent) by 2.0 pp and 5.0 pp—before conversion of AT1 instruments into CET1 capital—at the low points (2022) of the adverse scenarios 1 and 2, respectively. In both scenarios, the aggregate CET1 ratio would remain above estimated aggregate hurdle rates[37] in all years of the scenario horizon. Some AT1 instruments would convert into CET1 under adverse scenario 2, thus increasing the low-point aggregate CET1 ratio by 30bp.

56. The banks would experience higher credit losses under both adverse scenarios. Under the first adverse scenario they would also experience lower interest income on accrual loans compared to the baseline; all banks, however, would remain above their hurdle rates over the whole risk horizon. Under adverse Scenario 2, the decline in capital ratios would reflect mainly the combination of higher credit losses with market valuation losses caused by an abrupt increase in interest rates and a decrease in equity prices. Following the decline in 2022, capital ratios would follow an upward trend, driven by an increase in net interest income and market valuation gains due to a recovery in equity prices. Two banks would fall below their hurdle rates in 2022 or 2023, with CET 1 shortfalls amounting to 0.08 (0.035) percent of GDP in 2022 (2023), respectively.[38] Factoring in the conversion of AT1 instruments into CET1 capital, the trigger for conversion would be activated for one of the two banks, and it would bring its CET1 ratio back above the hurdle rate. CET1 shortfalls would drop to zero in 2022 and would remain at 0.035 percent of GDP in 2023.

57. Results are very similar when linking the PD paths projected by the corporate stress testing with the bank solvency stress test (see Figure 11). Under the baseline scenario the aggregate CET1 ratio is lower by 41 bps at the end of the five-year horizon. Under the first adverse scenario the CET1 ratio is higher by 26 bps at the low point and under the second adverse scenario the difference is almost negligible. At the individual level, the banks more affected by this exercise are the ones with a larger participation of domestic corporate loans on their portfolio. Given large model uncertainty, the similarity of results across different approaches provides certain degree of confidence in the robustness of our results. Nonetheless, the stress tests exercise is structured to give conservative estimates and is not meant to provide forecasts, not even under the baseline scenario

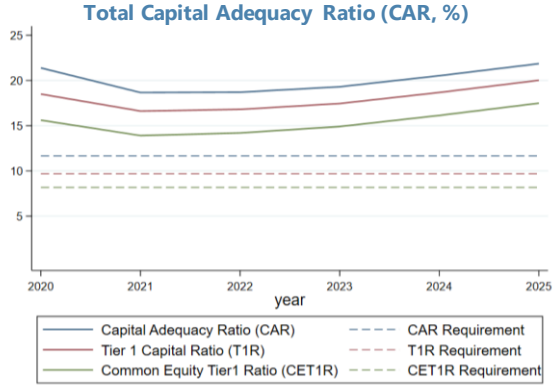
[37] The aggregate hurdle rate is calculated as a weighted average of individual banks' hurdle rates.

[38] As mentioned, the nature of the exercise is static, meaning that it does not consider any management action by the banks that could potentially prevent the CET1 ratio from following below the hurdle rate.

Figure 9. United Kingdom: Bank Solvency Stress Test Results

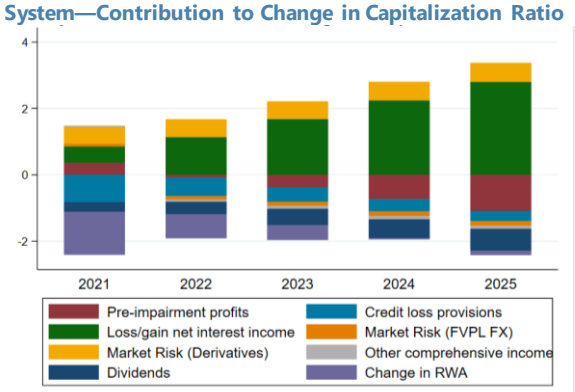
Under the baseline, October WEO, the CET1 ratio will increase by 1.9 percentage points by the end of the scenario horizon ….

Total Capital Adequacy Ratio (CAR, %)



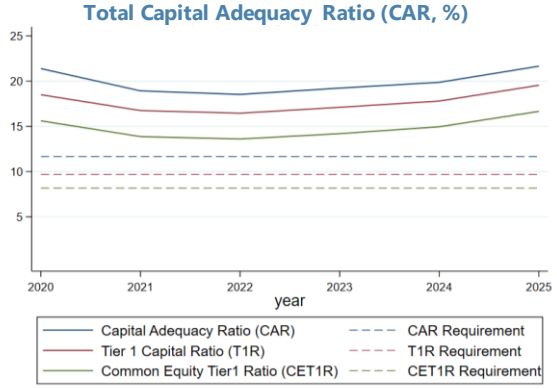
…. reflecting an increase in net interest income

System—Contribution to Change in Capitalization Ratio



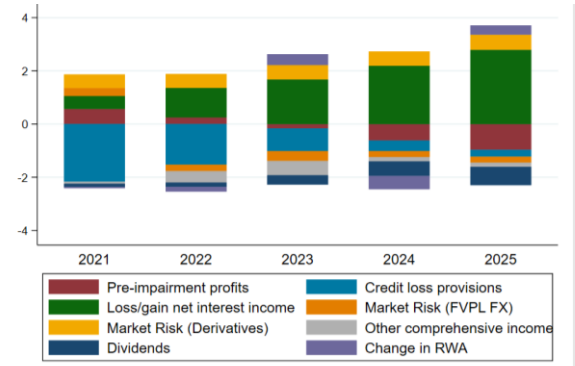
Under the Adverse Scenario 1, the CET1 ratio reduces to 13.6 percent in 2022….

Total Capital Adequacy Ratio (CAR, %)



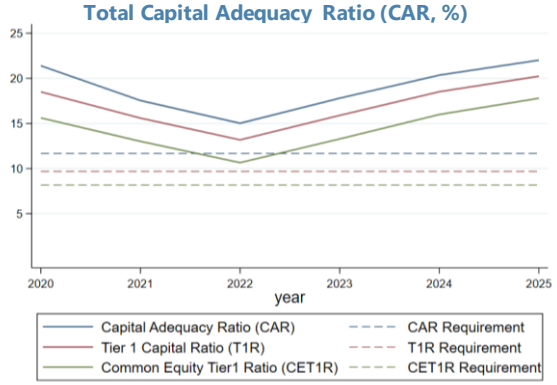
…. due to higher loan losses and lower net interest income compared to baseline

System—Contribution to Change in Capitalization Ratio



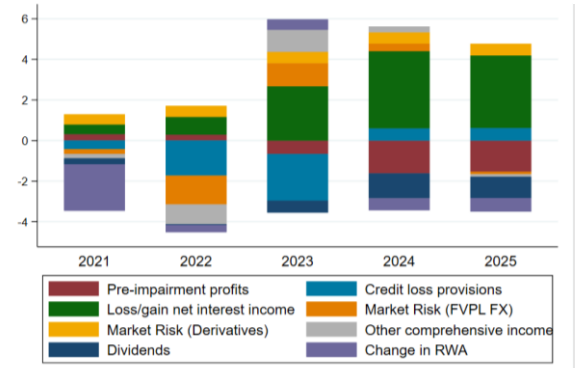
Under the Adverse Scenario 2, the CET1 ratio reduces to 10.7 percent in 2022….

Total Capital Adequacy Ratio (CAR, %)



…. driven by market and credit losses

System—Contribution to Change in Capitalization Ratio

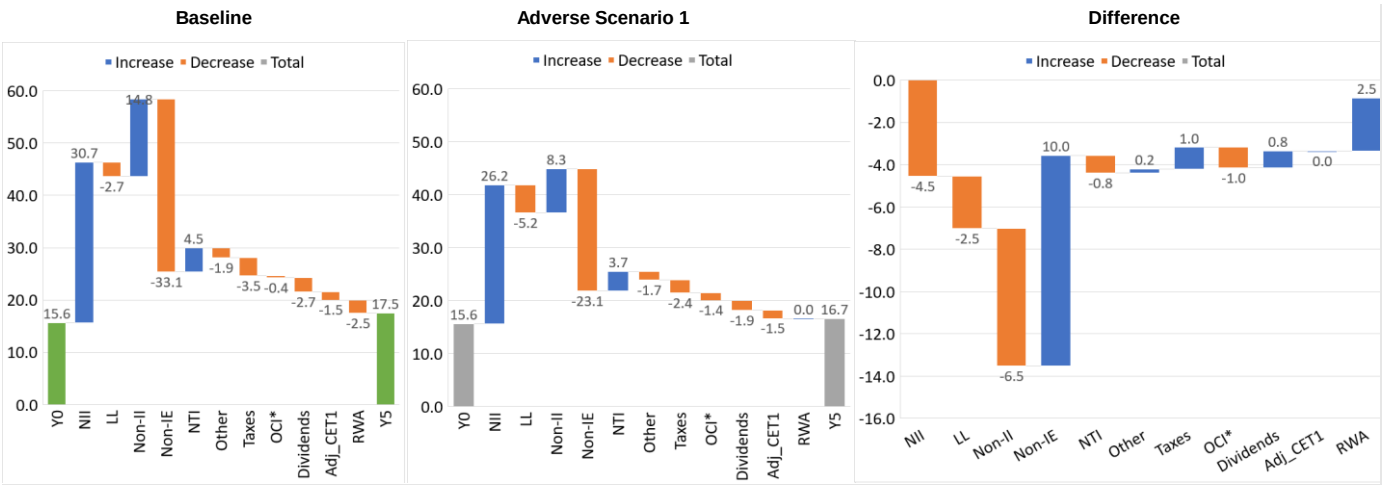


Source: BOE, FINREP, COREP, and IMF staff calculations.

Figure 10. United Kingdom: Bank Solvency Stress Test Results

Cumulative Decomposition 2020–2025

Under the Adverse Scenario 1, over the five-year horizon, banks face lower net interest income, higher loss loan provisions, higher non-interest income and lower RWAs compared to the Baseline Scenario.



In the first two years of Adverse Scenario 2, banks experience higher loss loan provisions and lower OCI and trading income compared to the Baseline Scenario. This is more than compensated, in the following years, by higher net interest income and market gains.

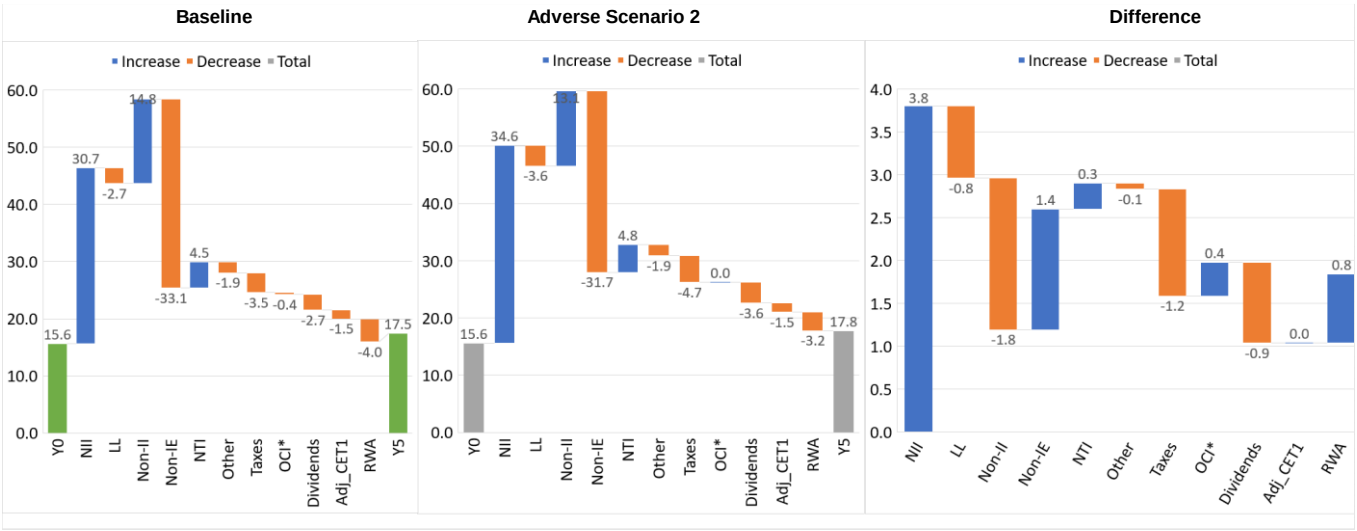
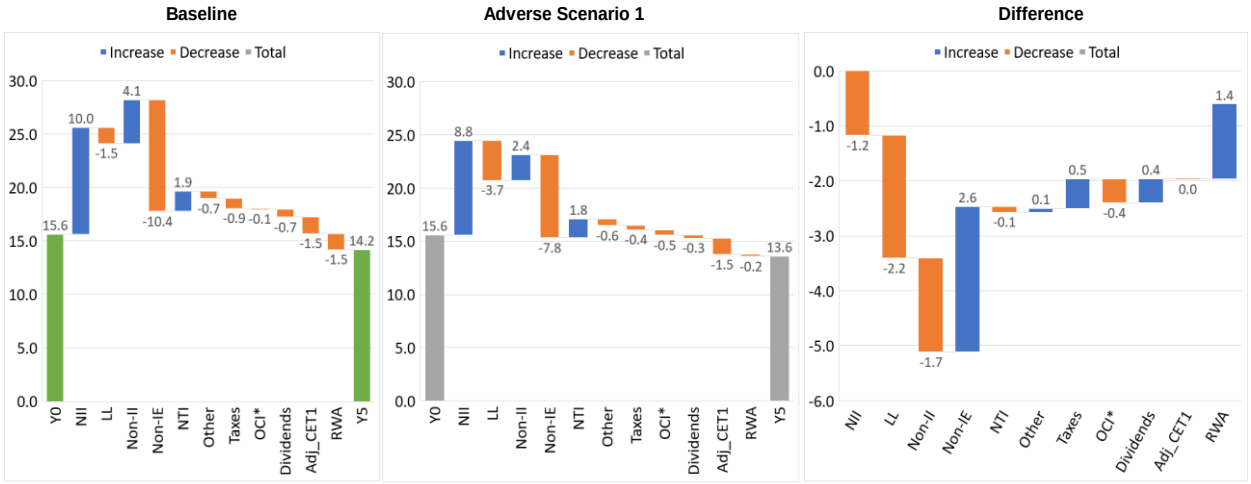


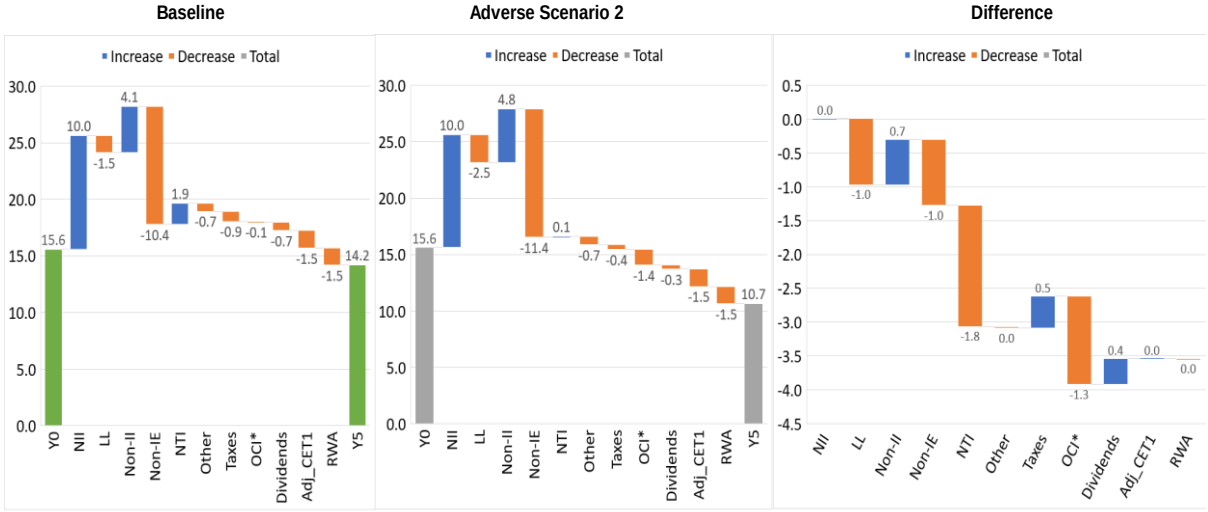
Figure 10. United Kingdom: Bank Solvency Stress Test Results (concluded)

Cumulative Decomposition Up to the Low Point

Under the Adverse Scenario 1, up to the low point, banks face lower net interest income, higher loss loan provisions, higher net non-interest income and lower RWAs compared to the Baseline Scenario.

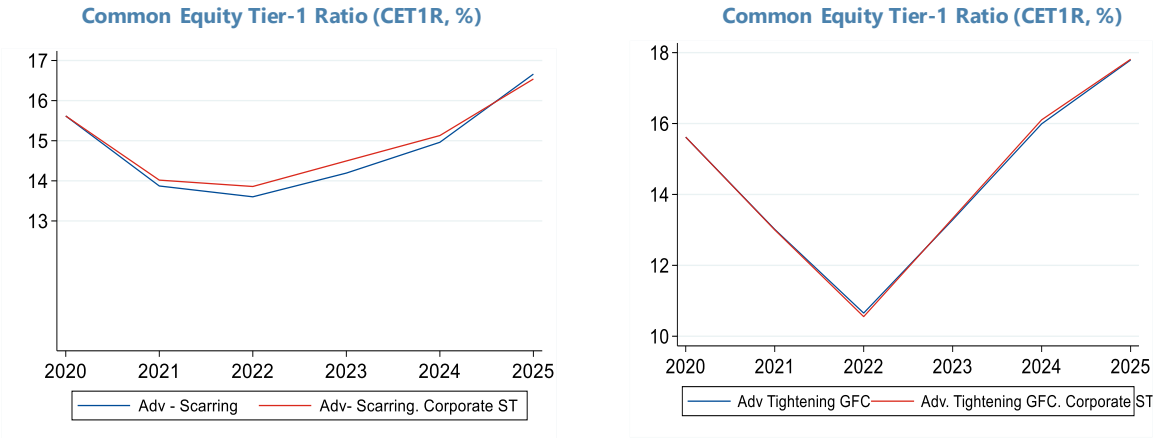


Under the Adverse Scenario 2, up to the low point, banks experience higher loss loan provisions, lower trading income and lower OCI compared to the Baseline Scenario.



Source: BOE, FINREP, COREP, and IMF staff calculations.

Figure 11. United Kingdom: Bank Solvency Stress Test Results. Link to Corporate Stress Test



Source: IMF staff calculations.

58. The potentially stronger impact of Scenario 2 on banks' capital ratios may be a useful starting point for further exploration of potential risks soon. Scenario 2 corresponds to a (relatively short-lived) burst of stagflation with abrupt tightening of financial conditions and market volatility. This is a scenario that falls outside the common experience of advanced economies in the last decades and was purposely chosen for the insights it might offer as to the preparedness of financial regulators and supervised entities worldwide. While the BOE had run a stress test exercise under a scenario with some similar features in 2019, the accumulation of inflationary pressures and demand-supply imbalances currently looming at the horizon deserves a wider exploration of these risks. Appreciating the readiness of financial firms to successfully weather such scenarios is also paramount.

59. After having implemented and consolidated its approach to bottom-up stress testing, the BOE could invest on strengthening its top-down stress testing capacity. The BOE has been running its program of annual cyclical scenarios (ACS) and biennial exploratory scenarios (BES) since 2016. The framework is well-consolidated, and it has produced interesting results through the years. The exercises are run in bottom-up modality, with the BOE employing some internal tools to validate the banks' own results. The BOE ran a top-down stress test in 2020 and took a partial top-down approach (for non-credit areas) for the 2021 interim results. Its internal toolkit is wide, but it does not cover the whole spectrum of portfolios and P&L components that would be needed to run a full-fledged top-down stress test. Key areas that need further development and that could benefit from improved availability and quality of granular data include credit risk, interest rate risk and market risk (see Box 1). For credit risk, certain segments, particularly, retail non-mortgage for both domestic and foreign exposures, would benefit from more granular data to build more reliable models. For interest rate risk, more granularity in terms of maturity buckets by type of asset and liability could allow to better assess risks coming from sudden interest rates shocks. For market risk, improved quality of key parameters (e.g., duration of securities) and detail information on hedges would improve the accuracy of market risk estimations. The BOE could invest on completing and consolidating its in-home analytics, by ensuring that all relevant portfolios are covered, and all the

most important P&L components are modelled. This would allow it to independently run stress tests at a higher frequency, when needed, and progressively cover all systemically relevant entities in the financial system and their mutual interactions.

E. Fintech Overlay

60. Fintech developments in the U.K. financial system can drive substantial efficiency gains but can also pose potential financial stability risks.[39] The Open Banking (OB) initiative particularly, could unfold its impact through rising competition (although it is important to note this has not caused financial stability risks to date)[40]. For example, depositors could be inclined to switch their deposits across banks and from banks to OB service provides searching for higher deposits rates. This, in turn could impact the stability of banking deposits and generate pressure to banks' interest expense. Similarly, customers could be inclined to switch to entities with lowers fees and commissions, eventually hampering banks' non-interest income. These risks, however, have been mitigated by the gradual uptake of OB. The sudden entry of large platform-based technology companies (active in OB) into the provisions of financial services, on the contrary, could pose a risk should it happen.

61. The fintech overlay examines the potential effects of intensifying competition in the financial system. The methodology is anchored in the econometric models for interest expense ratio and fees and commissions income ratio, which include a proxy for competition as an explanatory variable. The change in the share of bank's credit to total credit to the private non-financial sector is used as measure of competition. The empirical relationship suggests that when credit markets are more concentrated in the banking sector, banks have lower interest expenses and higher fee and commissions income, consistent with an increase on market power. The exercise assumes that market share of bank's credit decreases by 3.5 percent[41] in 2021, 2022 and 2023, resulting in a cumulated drop of 10 percent. This drop is considered very large by historical standards and is an extreme scenario but is used to illustrate the potential impact of large-scale market structure changes that could result from bigtech entry into financial services. The lost in market share is assumed to be driven by a larger growth on non-bank credit (rather than a decrease in bank credit). The exercise also assumes no business model changes and no impact on interest income ratio from increased competition

62. The results suggest that banks could experience an erosion in net income margins and fee and commissions income that would lead to a reduction on capital ratios over a short-term horizon. The system-wide capital depletion would rise to 2.5 percent, from 2 percent at the low point, when adding the Fintech Overlay under the adverse scenario 1. By the end of the five-year horizon the CET1 ratio would be 1.6 lower under the Fintech Overlay. Figure 12 shows the impact on

[39] See chapter on Open Banking Risks and Opportunities in the Financial Stability and Managing Institutional, Technology, and Market Transitions Technical Note.

[40] By enabling access to data across incumbents and new competitors, OB can facilitate entry, competition, and innovation through new and better products and services

[41] A two standard deviation shock is equal to 3.5 percent.

the interest expense ratio and the fee and commissions income ratio, which are the main underlying channels through which stronger competition would affect capital ratios. This is however a partial equilibrium analysis, and from a broader perspective of technological adaptation, banks could themselves benefit from new opportunities from OB offsetting pressure on their net income.

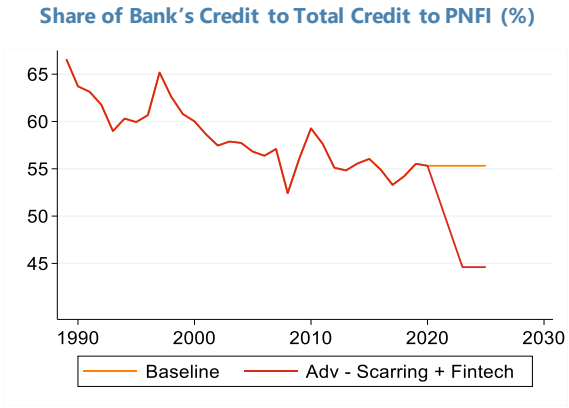
F. Macro-Financial Feedback Effects

63. The solvency bank stress test was complemented by an assessment of macro-financial feedback effects. Banks with declining capital ratios might find themselves compelled-or anyway prefer-to cut their lending activities. The reduced flow of credit to the real economy could lead to further deterioration in the financial health of corporate and households, reinforcing the initial stress. To evaluate this potential amplification channel the FSAP team devised an iterative algorithm that links the stress testing framework to a macro structure represented by a VAR, like Catalan and Hoffmaister (2021) (see Figure 13).

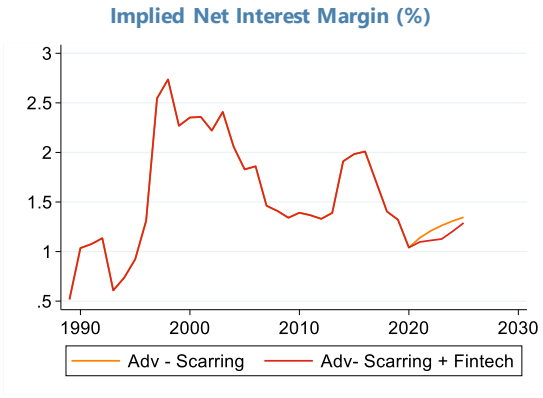
64. The SVAR includes a block of foreign macroeconomic variables, a block of domestic macroeconomic variables and two banking sector variables. The block of foreign macroeconomic variables includes US real GDP, oil price and US policy rate. The block of domestic macroeconomic variables comprises U.K. real GDP, unemployment rate, CPI, real exchange rate and bank rate; and the banking sector variables include interest income ratio and the credit growth. Block exogeneity is assumed for foreign variables such that these are not affected by domestic variables (neither on impact nor with lags). Banking sector variables enter the VAR as exogenous regressors. The SVAR is estimated over 2000Q1 to 2019Q4 in quarterly growth rates (except for interest rates and the interest income ratio). A specification with two lags was selected.

Figure 12. United Kingdom: Fintech Overlay

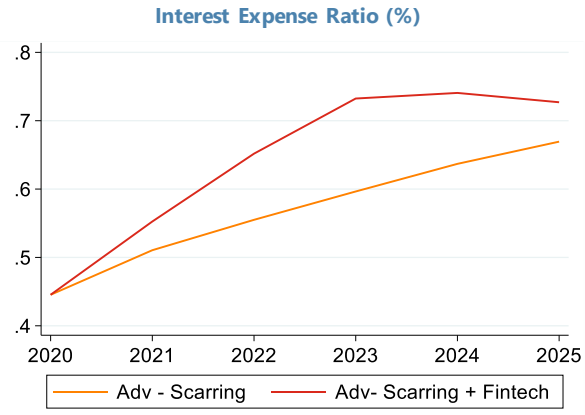
Under the Fintech Overlay, market share is assumed to drop from 55.3 percent to 44.6 percent over the horizon….



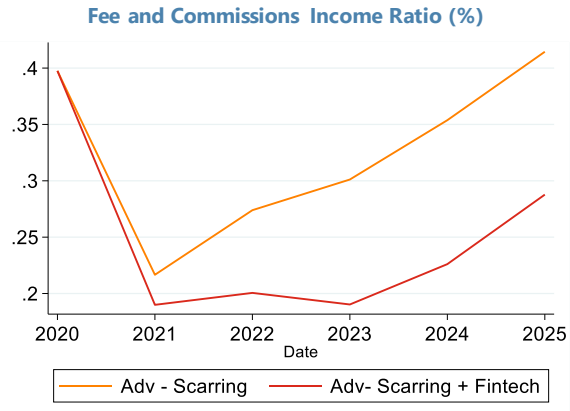
…as a result, the implied net interest margin drops by 14bps in 2023…



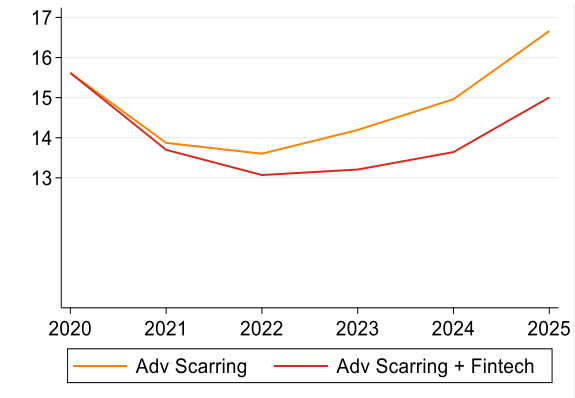
…driven by an increase on the interest expense ratio of 14bps in 2023.



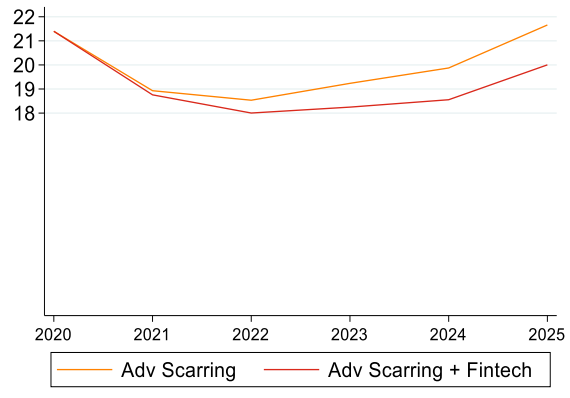
In addition, fees and commissions income ratio decreases by 13bps by the end of the scenario.



CET1 ratio decreases to 13.0 percent at the low point…

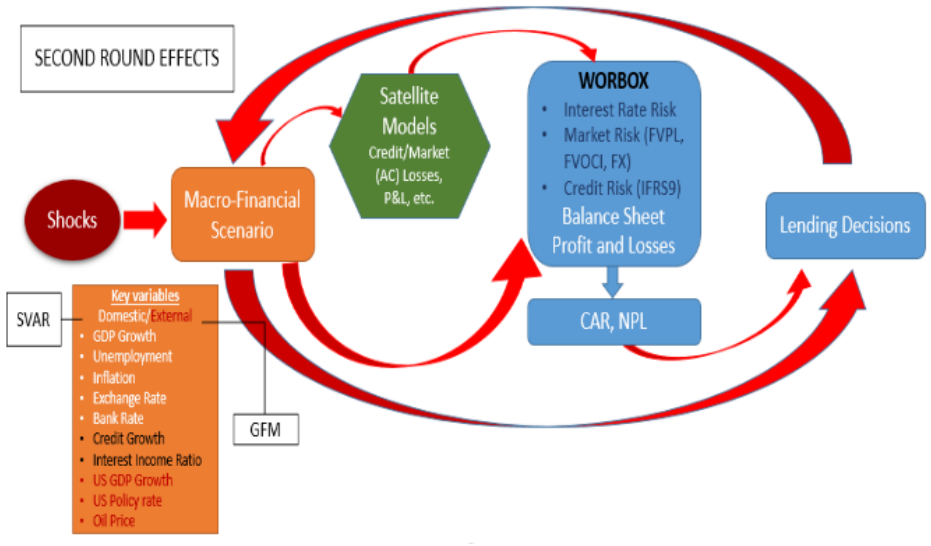


….and the CAR to 18 percent, down from 18.5 without the Fintech Overlay



Source: IMF staff estimations.

Figure 13. United Kingdom: Macro-Financial Feedback Effects Diagram



Source: IMF staff.

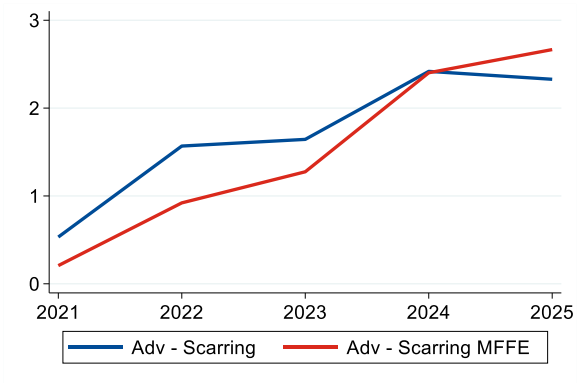
65. The banking sector is represented in the SVAR through the two sector-level variable—the interest income to asset ratio of U.K. banks and lending growth—which allows feeding back bank-level stress testing results to macroeconomic outcomes. The amended path for macro variables, such as real GDP or the unemployment rate, is then used for another round of bank-level stress tests and the procedure is continued until convergence. The FSAP team used the GFM for initial projections for the interest income ratio and credit growth. The difference between the initial paths and the final paths (after iterations) determines the magnitude of the inferred feedback effects. Several caveats to the approach apply, most notably the use of a model with built-in macrofinancial linkages, such as the GFM, to construct projections in the "assumed" absence of macrofinancial feedbacks. This approach was used for comparability proposes with the main results, presented in section D.

66. A credit growth model is developed to create the bridge between the stress testing framework and the SVAR. The credit growth model is estimated over the period 1994Q2 – 2019Q4 and includes the change in capital ratios (CAR), the change in non-performing loans ratio (NPLR) and an autoregressive term. The model is estimated for the system and is used to project credit growth conditional on the aggregated outcome for CAR and NPLR generated by the stress testing framework. The resulting credit path is fed to macro-financial S-VAR as part of the second-round effects.

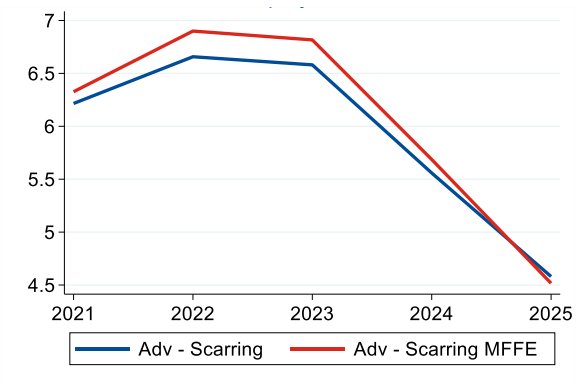
67. The analysis reveals that initial macroeconomic shocks could be amplified through weaker credit growth if macro-financial feedback effects are at play (Figure 14). The exercise, which is performed over the first adverse scenario, shows that real GDP growth would be reduced by additional 0.65 percentage points in 2022 and 0.37 percentage points in 2023. The unemployment rate, on the other hand, would be higher by 0.24 percentage points in 2022 and 2023. This in turn would increase the probability of default of domestic portfolios by 33 and 43 basis points in 2022 and 2023, respectively. As a result, capital ratios would reduce by 57 basis points on average across the scenario horizon.

Figure 14. United Kingdom: Macro-Financial Feedback Effects

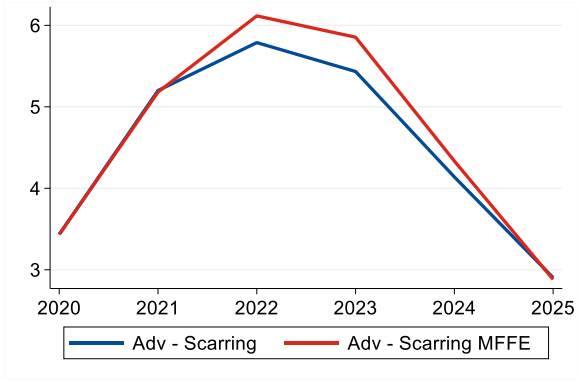
GDP would be reduced by additional 0.65 p.p. in 2022 and 0,37pp in 2023....



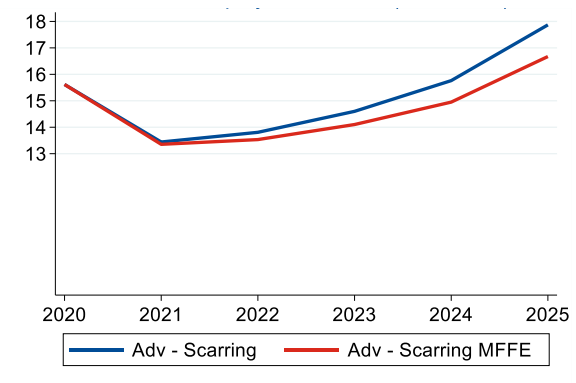
... while the unemployment would be higher by 0.24 p.p. in 2022 and 2023.



This in turn would increase the PD of domestic portfolios by 33 and 43bps in 2022 and 2023, respectively...



...as a result, capital ratios would reduce by 57bps on average across the scenario horizon.



Source: BOE, FINREP, COREP, and IMF staff calculations.

BANK LIQUIDITY STRESS TEST

68. The results of LCR-based stress tests show that the U.K. banking system is overall liquid and resilient to sizable withdrawals of funding and haircuts to liquid assets. Liquidity Coverage Ratios (LCRs)—which measure the ability of banks to meet net liquidity outflows over a 30-day horizon by using a stock of unencumbered high-quality liquid assets (HQLAs)—are currently well above the regulatory standard of 100 percent for the 110 domestic banks surveyed. The FSAP team conducted an LCR-based stress test, based on the combination of three "haircut" scenarios with four "outflows" scenarios, with increasing haircuts applied to HQLAs and run-off rates applied to either retail or wholesale outflows or both (Annex I). Simulation results show that U.K. banks generally maintained high 'total currencies' liquidity ratios under all scenarios. For seven banks the stressed LCR would fall below 100 percent in some of the severe scenarios, albeit only moderately.[42] This would generate a gap of GBP 46 billion between net outflows and HQLAs over the 30-day horizon in the most extreme combined scenario.

69. The analysis of LCRs by single currency—for which there is no formal regulatory threshold—reveals potential FX liquidity shortfalls that would require more granular information to be accurately quantified. The calculation of net outflows with a cap on inflows, as required by the regulation, could excessively penalize certain typical FX transactions done by some banks, that are matched by design (back-to-back transactions, mostly collateralized), but appear as unbalanced in the LCR as a consequence of the cap. Removing the cap—for the mere objective of gauging the size of this issue—reveals that in the base case, with regulatory weights, the aggregate FX liquidity gap between net outflows and HQLAs would shrink to about GBP 5 billion; while in the most extreme (and least probable) combined scenario the gap would be about GBP 20 billion. The addition of further details to the PRA own reporting scheme on liquidity over the 30-day horizon (PRA 110) would help to more accurately identify the items for which the imposition of a cap on inflows could be excessive and, as a result, provide a better sense of the potential liquidity gaps in foreign currency.

INSURANCE STRESS TEST

A. Scope and Sample of the Solvency Stress Test

70. A top-down (TD) solvency stress test was performed for the U.K. insurance sector, which included 14 large insurers, on a consolidated basis.[43] With eight life insurers and six general insurers, the stress test reached a representative market coverage of around 70 percent in both sub-sectors, based on gross written premiums. The groups' aggregated balance sheet assets amount to GBP 1,879bn, of which 1,738bn can be attributed to groups which undertake predominantly life business.

[42] In the LCR framework usage of liquidity buffers under a severe scenario is to be considered 'entirely appropriate'.

[43] For a summary of the stress testing approach, refer to the Insurance Stress Testing Matrix (STeM) in Annex V.

71. Investment holdings of participating groups differ depending on the main business, and life insurers take more market risks than general insurers. Assets backing unit-linked and index-linked insurance account for 39 percent of total assets of life insurers. With another 16 percent, equity and participations are the second-largest asset class, ahead of corporate and sovereign bonds (14 and 10 percent, respectively). General insurers hold 50 percent of their assets in sovereign and corporate bonds with only minor exposures to equity and real estate. Sovereign bond exposures of life insurers are dominated by domestic exposures (57 percent), while general insurers also hold sizable exposures in US and Canadian government bonds (46 and 20 percent)—these serve as natural currency hedge for liabilities outside the United Kingdom. In both sub-sectors, corporate bond investments are of a good credit quality with 60 percent being rated A or better, and less than 3 percent being speculative grade (Figure 15).

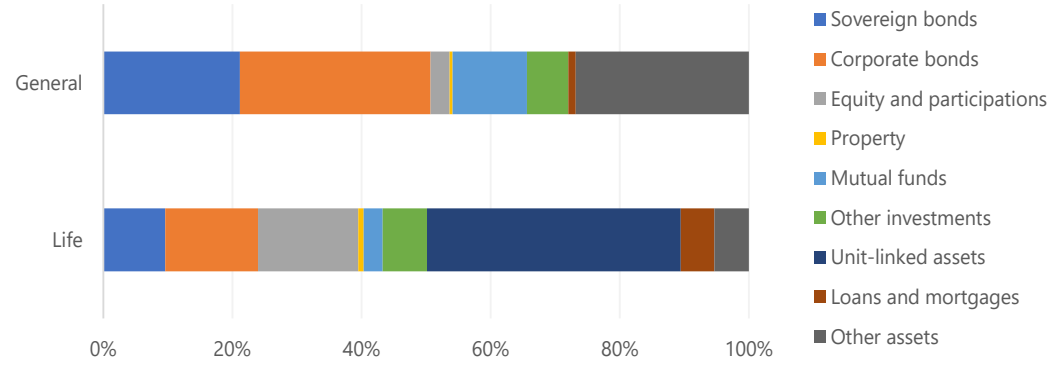
72. All 14 participants record solvency ratios before stress well above the regulatory threshold of 100 percent, taking account of long-term guaranteed measures and transitionals in the life insurance sector. Seven of the participating groups calculate their solvency capital requirement (SCR) with a full internal model, and the remaining seven apply a partial internal model. Almost 70 percent of eligible own funds are unrestricted Tier 1 capital, while only 2 percent is comprised of Tier 3 (Figure 16a). The Long-Term Guarantee (LTG) measures and transitionals have a sizable effect in the U.K. life insurance sector, mainly through the Matching Adjustment (MA) and the Transitional Measure on Technical Provisions (TMTP). While technical provisions would be only 4 percent higher without these measures, a considerably larger effect can be observed in the capital position: eligible own funds increase by 109 percent and the SCR is lowered by 43 percent. Accordingly, without these measures the median SCR ratio of the life insurers in the sample would be 90 percentage points lower (62 instead of 152 percent)[44] (Figures 16b-d).

[44] In the remainder of the analysis, any references to the pre-stress SCR ratio will always include LTG measures and transitionals, being the only relevant solvency measure for supervisory purposes under Solvency II.

Figure 15. United Kingdom: Insurers' Balance Sheets and Fixed-Income Portfolios

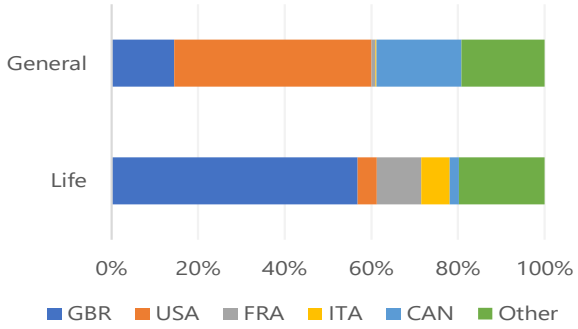
The asset allocation of life and general insurers differs: While the former holds significant amounts in equity and participations, the latter invest predominantly in sovereign and corporate bonds.

Asset Allocation
(In percent)



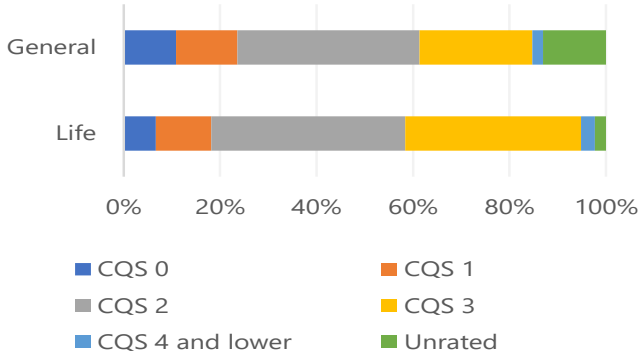
Sovereign bond holdings of life insurers are characterized by a strong home bias (57 percent), while general insurers have more diverse holdings reflecting their liability mix.

Sovereign Bonds: Geographic Distribution (in percent)



Corporate bond investments are of high quality with around 60 percent being CQS 2 (~A rating) or better.

Fixed-Income: Rating Distribution (in percent)

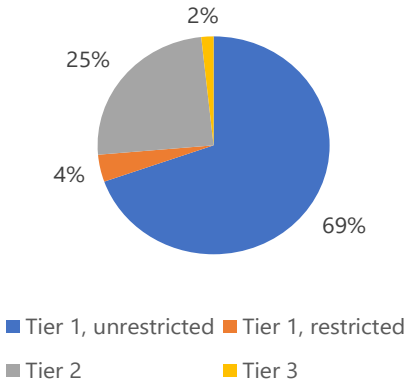


Sources: IMF staff calculations based on PRA data.
Notes: Stress test participants only. The breakdown of sovereign and corporate bonds excludes unit-linked and index-linked insurance.

Figure 16. United Kingdom: Own Funds and Solvency Capital Requirement

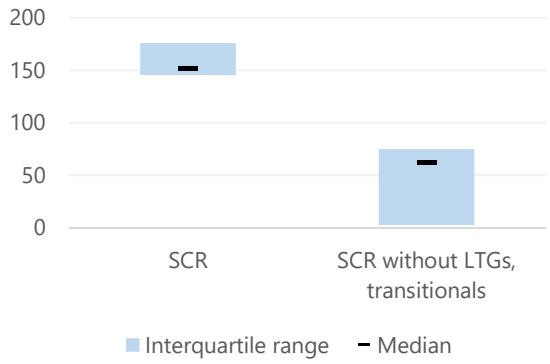
69 percent of eligible own funds are unrestricted Tier 1 capital, while only 2 percent is comprised of Tier 3.

Composition of Eligible Own Funds (in percent)



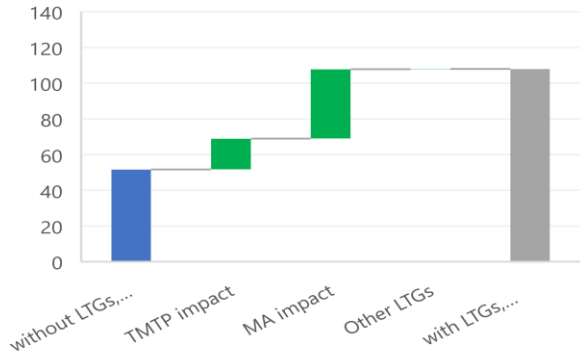
Without LTG measures and transitionals, the median life insurer would have an SCR ratio of only 62 percent.

SCR Ratios with/without LTG Measures and Transitionals-Life (in percent)



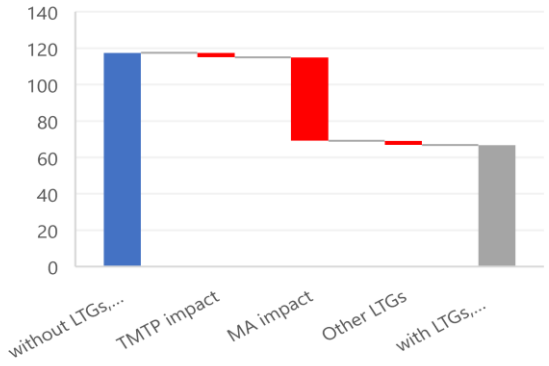
In particular, the MA increases the eligible own funds: by around 75 percent and together with other measures by 109 percent.

Impact of LTGs and Transitionals: Eligible Own Funds (in GBP bn)



At the same time, the MA reduces the SCR by 39 percent.

Impact of LTGs and Transitionals: SCR (in GBP bn)



Sources: IMF staff calculations based on PRA data.
Notes: Stress test participants only.

B. Scenarios for the Solvency Stress Test

73. The macrofinancial scenarios specified by the IMF for the banking sector stress test were in some instances slightly adjusted and amended for the purpose of the insurance stress test. Scenario 1 centers around a further deterioration of the COVID-19 pandemic, and scenario 2 assumes tighter financial conditions together with an inflationary shock. Both scenarios are highly relevant for the insurance sector, but some adjustments were made to make the scenario directly applicable to an insurer's balance sheet. While the scenario includes a projection of macro and market variables for the next five years, for the insurance stress test all shocks were assumed to occur at the beginning of the first year (instantaneous shock). Market shocks, like e.g., on equity and

property prices, have therefore been front-loaded so that the maximum drawdown during the projection horizon of the macrofinancial scenario is already realized immediately after the reference date (31 December 2020).

74. To cover the most relevant risk factors for an insurer's balance sheet, the market risk stresses have been defined more granularly. The scenario includes shocks to the risk-free interest rate, equity, and property prices, as well as credit spreads of corporate and sovereign bonds (Table 8). Given the increase of credit spreads in the scenario, also the MA and the volatility adjustment increases, following the Solvency II calculation method. For insurers using these measures, the result is a higher risk-free rate which offsets to a large degree the negative impact of the credit spread shock.

75. Across risk-free rates and government bond spreads, the severity of the two scenarios is more severe compared to previous stress tests run by the PRA and the European Insurance and Occupational Pensions Authority (EIOPA). As an example, the EIOPA 2018 ST, in its "yield curve down" scenario, assumed 10-year GBP swap rates to decline by 72 bps and equity prices to drop by 16 percent (EU average); spreads of 10-year U.K. government bonds were to increase by 24 bps and those of A-rated EU financials by 40 bps. EIOPA's "yield curve up" scenario prescribed a 112-bps increase in the 10-year GBP swap rate, a 39 and 20 percent shock to EU equity and property prices, respectively, an increase in 10-year U.K. government bond spreads of 37 bps, and an increase in the spread of A-rated EU financials of 138 bps. The 2019 PRA stress test included a 100-bps decline in the risk-free rate, an increase in the spread of A-rated corporate bonds of 200 bps, but no increase in sovereign bond spreads; equity and commercial property prices were assumed to decline by 30 and 40 percent, respectively.

76. An additional single-factor shock, assuming the default of the largest banking counterparty, complemented the stress test. The largest banking counterparty was determined based on investment asset data in reporting template S.06.02, at the level of the issuer group. It was assumed that equity exposures need to be fully written off (i.e., a 100 percent haircut). Furthermore, a loss given default (LGD) of 50 and 15 percent was applied to unsecured and secured bonds, respectively, and an LGD of 30 percent to other on-balance sheet exposures. The result of this sensitivity analysis was not added to the results of the scenario.

Table 8. Insurance Stress Test Specification

	Scenario 1	Scenario 2
Equity		
United Kingdom	-19.5%	-15.8%
United States, Euro area	-25.0%	-15.0%
Other advanced economies	-15.0%	-15.0%
Emerging economies	-25.0%	-30.0%
Corporate bond spreads		
Non-financials, credit quality step 0	0.70%	0.40%
Non-financials, credit quality step 1	0.85%	0.50%
Non-financials, credit quality step 2	1.00%	0.70%
Non-financials, credit quality step 3	1.30%	1.10%
Non-financials, credit quality step 4	1.90%	1.90%
Non-financials, credit quality step 5	2.90%	3.20%
Non-financials, credit quality step 6	2.90%	3.20%
Non-financials, unrated	2.00%	2.00%
Financials, CQS 0	0.85%	0.70%
Financials, CQS 1	1.00%	0.90%
Financials, CQS 2	1.20%	1.20%
Financials, CQS 3	1.50%	1.70%
Financials, CQS 4	2.10%	2.40%
Financials, CQS 5	3.20%	3.60%
Financials, CQS 6	3.20%	3.60%
Financials, unrated	2.40%	2.40%

	Scenario 1	Scenario 2
Sovereign bond spreads		
United Kingdom	0.80%	0.50%
Other low-yield advanced economies	0.70%	0.30%
High-yield advanced economies	1.40%	1.20%
Emerging and developing economies	1.60%	1.80%
Supranationals	0.00%	0.00%
Property		
Residential, domestic	-14.6%	-8.4%
Commercial, domestic	-29.7%	-20.1%
Residential, other countries	-10.0%	-6.0%
Commercial, other countries	-18.0%	-8.2%
Investment funds		
Alternative funds	-8.0%	-5.0%
Private equity funds	-10.0%	-12.0%
Infrastructure funds	-5.0%	-3.0%
Structured notes and collateralised securities		
Structured notes	-5.0%	-6.0%
Collateralised securities	-5.0%	-3.0%

Sources: IMF staff.
Notes: Investment funds not explicitly mentioned, like bond funds and equity funds were stressed with the respective shock for the underlying asset class—for bond funds, it was assumed that maturities and ratings resembled those of directly held bonds. More details on the shock to the risk-free interest rates can be found in Appendix VI.

C. Capital Standard and Modeling Assumptions

77. Solvency II[45] was implemented in the European Union in 2016 and on-shored into U.K. law at the time of the Brexit—it forms the basis for the insurance stress test. As a general principle of Solvency II, assets and liabilities are valued mark-to-market. However, Solvency II also allows for some notable deviations from the market-consistent framework in the valuation of insurance liabilities, especially about the discount rate which can incorporate Long-Term Guarantee (LTG) measures and transitional measures. In the United Kingdom, the matching adjustment (MA) has a substantial effect on the valuation of liabilities and ultimately the capital position, and the transitional measure on technical provisions is used by several life insurers in the sample, as shown above.

78. The main output of the stress test calculations is the effect on own funds, eligible for the coverage of the solvency capital requirement (SCR). As the stresses also affect the capital requirement, the SCR was partially recalculated after stress.

79. Data for the TD solvency stress test was gathered from the Solvency II quantitative reporting templates (QRTs). Solvency II has introduced very granular supervisory reporting especially on the asset side. Reported data must meet several automated validation checks, and the PRA has undertaken initiatives since the introduction of Solvency II to improve the quality and consistency of data. Still, remaining inconsistencies and data gaps posed limitations to the TD stress test, notably about derivative data or, more generally, the availability of data at the consolidated level. For the stress test, the following QRTs were used:

[45] Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance

- Balance sheet (S.02.01),
- Asset-by-asset investment holdings (S.06.02),
- Derivative positions (S.08.01),
- Cash-flow projections (S.13.01, S.18.01)[46],
- Impact of long-term guaranteed measures and transitionals (S.22.01, SR.22.03[47]),
- Own funds (S.23.01),
- Calculation of the solvency capital requirement (S.25.02, S.25.03).

Besides QRTs, the stress test also made use of national specific reporting templates which were introduced by the PRA, notably template SF.01.01 which collects the standard formula calculation of the SCR by internal model users.

80. For the TD stress test, the shocks specified in the scenario were applied to the investment assets and insurance liabilities. Haircuts in line with the adverse scenario were applied to the market value of directly held assets. A look-through was not applied, so investment fund holdings were stressed with the corresponding shocks for the underlying asset classes. Fixed-income assets were re-valued with the stressed term structure (per currency). Similarly, technical provisions (except for unit-linked business) after stress were approximated with the stressed term structure including the matching or the volatility adjustment.[48] For unit-linked business, the decline in liabilities mirrored the market value loss of underlying assets.

81. The re-calculation of the SCR after stress was limited to selected risk modules. In the market risk module, the capital charges for equity risk, spread risk and property risk were proportionately adjusted in line with the change in exposures due to the stress. Furthermore, the equity risk capital charge was corrected for the symmetric equity adjustment which changes from -0.5 to -10.0 percentage points after the fall in equity prices in scenario 1 and to -9.2 percentage points in scenario 2. The capital charge for life underwriting risk was assumed to change proportionately with the technical provisions after the application of the stressed discount curve. All other components of the basic SCR, including the capital charge for counterparty default risk, non-life underwriting risk and operational risk were assumed unchanged. For internal model users, the SCR calculations including the aggregation and resulting diversification effects were made in a simplified approach building on the standard formula. In a last step, the loss-absorbing capacity of deferred taxes was re-calculated based on the modeled valuation losses in the excess of assets over liabilities.

[46] As the templates are not reported on a group level, the solo templates of the largest domestic subsidiaries were used as a proxy.

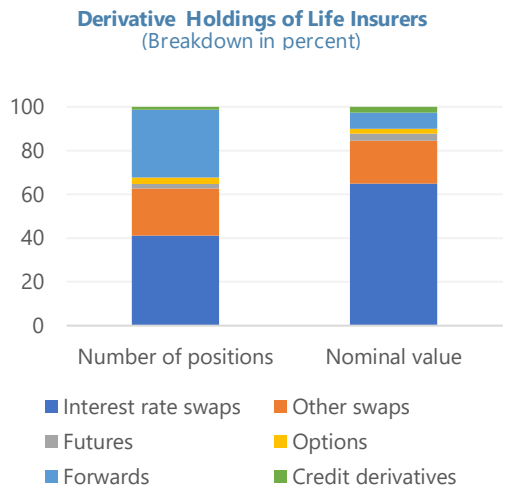
[47] As the template is not reported on a group level, the solo templates of the largest domestic life subsidiaries were used as a proxy.

[48] Due to data limitations, not all product features could be fully incorporated in the approximation.

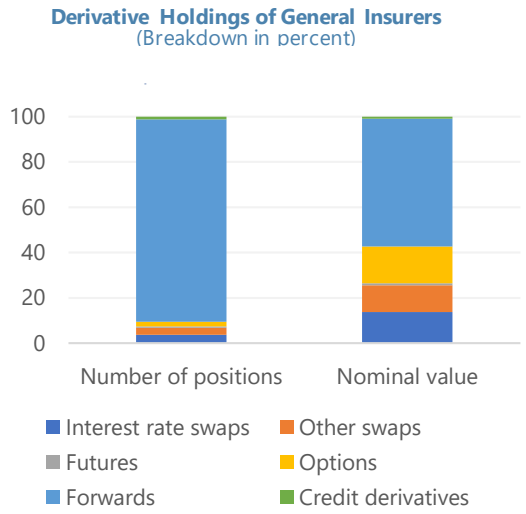
82. Insurance companies have a broad range of risk-mitigating mechanisms in place which cannot be fully captured in a TD stress test. U.K. insurers hedge large parts of their interest rate and market risks with derivatives (Figure 17). For life insurers, the market value of asset-side derivatives amounts to 5.8 percent of assets while liability-side derivatives constitute 5.6 percent of total liabilities. Interest rate swaps account for 40 percent of the number of positions and 62 percent of the notional value. For most life insurers in the sample, the interest rate swaps could be re-valued after stress—for the remaining ones, the derivative reporting in S.08.01 was insufficiently detailed. General insurers use derivatives to a much smaller extent, with market values of 0.6 percent and 0.5 percent of assets and liabilities, respectively. These positions are predominantly used for the hedging of currency risks; however, no currency shock was applied.

Figure 17. United Kingdom: Insurers' Derivative Holdings

Interest rate swaps account for 41 percent of all derivative positions and 65 percent of the notional value.



For general insurers, forwards are the predominant derivative type, used mainly for currency hedging.



Sources: IMF staff calculations based on PRA data.

83. The transitional measure on technical provisions (TMTP) is not re-calculated after stress. Until 2031, insurers may apply the TMTP, a deduction to insurance obligations concluded before the start of Solvency II, based on the difference between technical provisions under Solvency I and technical provisions under Solvency II. Over a period of 16 years the transitional deduction is reduced to zero. The impact of this transitional is sizable for some of the U.K. life insurers, as shown above. After an adverse scenario comparable to scenario 1 used in this FSAP, the re-calculation of the TMTP by life insurers could result in either higher or lower SCR ratios.[49] However, the actual impact of the re-calculation could not be replicated in this TD stress test.

[49] The direction of the impact is not the same for all life insurers and depends on interest rate sensitivities and the share of the portfolio to which the TMTP can be applied. In an additive combination of TMTP re-calculations following a -100-bps interest rate shock, a +50-bps sovereign spread increase and an increase in corporate bond

(continued)

84. Dynamic management actions were not modeled in the stress test. In times of financial stress, insurers have several options to restore their capital adequacy and/or their profitability, including changes in underwriting standards, in the reinsurance programmed or by withholding profits. An even more effective way to improve the solvency position relatively quickly is a de-risking of the balance sheet, e.g., by selling equity or high-yield corporate bonds and buying sovereign bonds instead—this change in the asset allocation can substantially reduce required capital. As the stress test assumed a static balance sheet, these types of management actions were not modeled.

D. Results of the Solvency Stress Test

Scenario 1

85. In the "scarring" scenario, which assumes a further deterioration of the COVID-19 pandemic, life insurers are considerably more affected than general insurers (Figures 18a-b). While all life insurers would still sufficiently cover their liabilities with assets, the excess of assets over liabilities declines by 17 percent for the median firm, but with a considerable dispersion across the sample. The downward interest rate shift of the scenario increases liabilities, but this is partly compensated by higher values of fixed-income assets. The ratio of assets over liabilities declines, for the median life company, from 106.4 to 103.6 percent. For unit-linked business, the decline in assets, which corresponds to a roughly equal decline in liabilities amounts to around 13 percent for most life insurers. General insurers can weather the scenario comparably better—while the decline in the excess of assets to liabilities is the same as for the median life firm, all general insurers start from a much higher asset to liability ratio. Hence, the ratio after stress still amounts to 126.1 percent for the median general insurer (down from 129.0 percent).

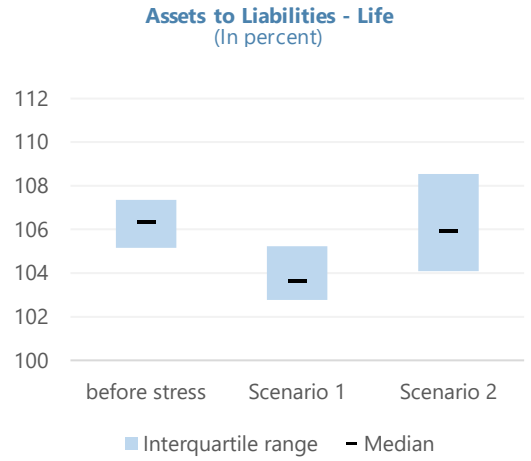
86. The increase in corporate bond spreads contributes most to the reduction in available capital, but this is offset through the MA and the resulting interest rate shock in the life insurance sector (Figures 18c-d). While fixed-income investments increase in value with lower interest rates, the main impact subsumed under the interest rate shock stems from the discount rate to which the MA is added—hence the spread shock is to a very large degree offset. Without this offsetting effect, therefore the most relevant shock for life insurers relates to the decline in equity prices, while for general insurers with their lower exposures to stock markets the most relevant shocks are those to corporate bonds spreads.

87. Solvency ratios of two life insurers would drop below the 100 percent threshold, highlighting the need for recovery plans to be ready and effectively executable (Figure 19). The SCR ratio of the median life insurers drops from 158 to 116 percent, and the aggregated capital shortfall of the two firms with a post-stress SCR ratio below 100 percent amounts to GBP 9bn. Among general insurers, the balance sheet impact is significantly smaller, and solvency ratios of all firms in the sample remain well above 100 percent—for the median firm, the SCR ratio falls just slightly from 149 to 140 percent.

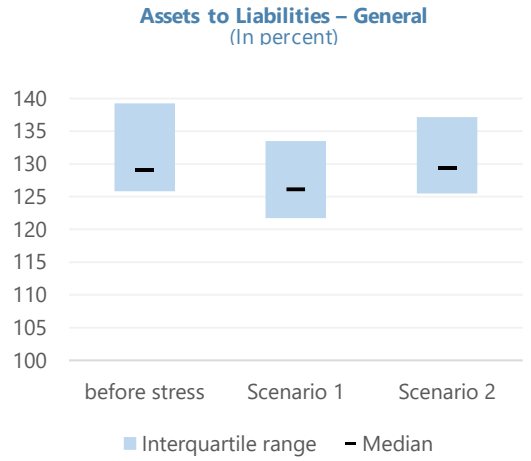
spreads, the SCR ratio can increase by up to around 10 percentage points, but not all life insurers benefit from this effect—for around half of the firms the SCR ratio even decreases.

Figure 18. United Kingdom: Insurance Stress Test—Impact on Assets and Liabilities

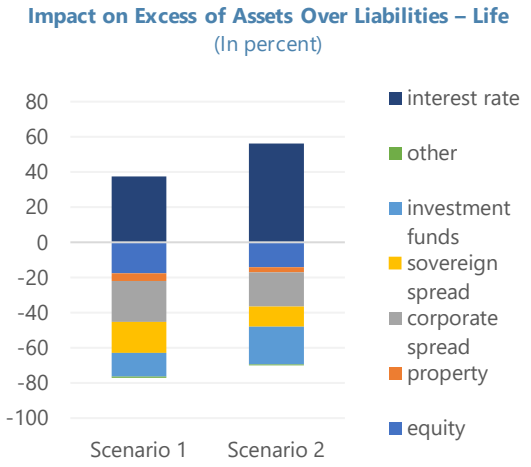
Scenario 1 results in a substantial decline in the asset-liability-ratio of life insurers, while in scenario 2 the impact is more disperse.



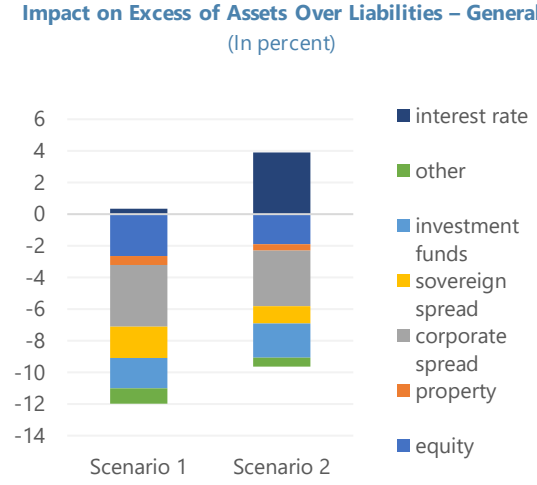
Balance sheets of general insurers are less affected in both scenarios than those of life insurers.



In Scenario 1, the increase in spreads contributes most to the decline in assets of life insurers, but this is largely offset through the increase in the MA.



The offsetting effect from interest rates is more limited among general insurers (which do not apply the MA), especially in Scenario 1.



Sources: IMF staff calculations based on PRA data.
Notes: "Other" includes structured notes and collateralized securities.

Scenario 2

88. In Scenario 2 with tightening financial conditions, the aggregate impact on both sectors is milder, and most life insurers would even see higher solvency ratios. The sharp increase in interest rates in the scenario generally compensates for losses on investment assets, as the impact weighs larger on liabilities which decline with higher discount rates. For most general insurers, the impact is minor, although interest rate exposures differ across companies. The ratio of assets to liabilities declines marginally for the median life insurer (from 106.4 to 105.9 percent), but the range of post-stress numbers is quite dispersed—for half of the sample the ratio either increases

or decreases. Among general insurers, the median firm records slightly higher ratio of assets to liabilities (from 129.0 to 129.4 percent) (Figures 18a-b).

89. When looking at the overall market risk impact of scenario 2, most is contributed by the interest rate shock which lowers the liabilities of life insurers—this effect clearly outweighs the market value losses in the fixed-income portfolios (Figures 18c-d). Even for general insurers, the interest rate effect is dominant (together with the impact from higher corporate bond spreads), although much smaller than for life insurers given the shorter durations of non-life liabilities. It should be noted, however, that the analysis focuses only on market risks and does not consider the effect of higher claims inflation on the earnings of general insurers, which would be likely according to the narrative of the scenario. Practical difficulties exist, though, in deriving claims inflation from observed consumer price increases, as the disruptions to global supply chains have shown over the course of 2021.

90. In Scenario 2, the SCR ratios of most life firms increase significantly, and drop only marginally in the general insurance sample (Figure 19). The median life firm would see an SCR ratio after stress of 187 percent (up from 158 percent), and only two life insurers would face a falling SCR ratio. A lower capital requirement, mainly for spread risks, contributes substantially to the increase in the SCR ratio. For the median general insurer, the SCR ratio declines marginally from 149 to 146 percent.

Sensitivity Analysis

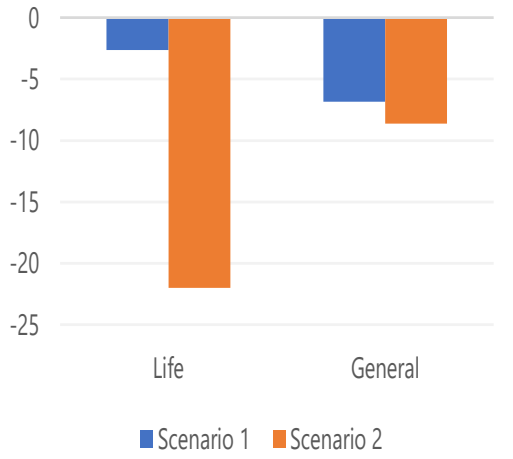
91. The individual default of the largest banking counterparty is unlikely to cause major distress for any of the insurers in the ST sample (Figure 20). Utilizing the investment asset data from QRT S.06.02, a sensitivity analysis was performed to assess the impact of the default of the largest banking counterparty. The largest counterparty typically differs across insurers which implies an individual stress per company instead of a systemic adverse scenario. The analysis assumes a full write-off of equity exposures towards the banking group, a 50 percent, and a 15 percent loss-given default on unsecured and secured bonds, respectively, as well as a 30 percent haircut on all other types of investment exposures. As a result of this stress, the excess of assets over liabilities declines, on average, by 3 percent for life insurers and by less than 2 percent for general insurers. The SCR ratio accordingly declines only marginally by only 4 and 2 percentage points in the life and the general insurance sample, respectively.[50]

[50] For this sensitivity analysis, the SCR was not re-calculated after stress.

Figure 19. United Kingdom: Insurance Stress Test—Impact on Solvency Ratios

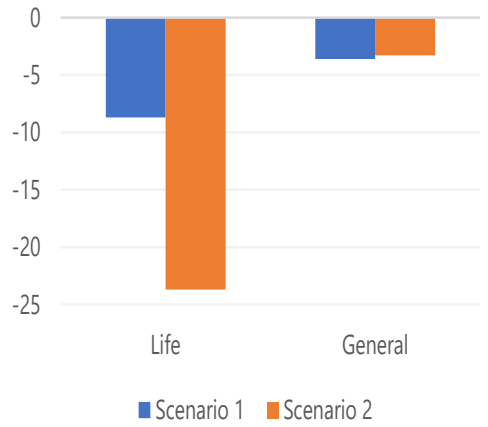
In both scenarios, required capital for market risks declines, as the value of investment assets declines.

Change in the Capital Requirement for Market Risk
(In percent)



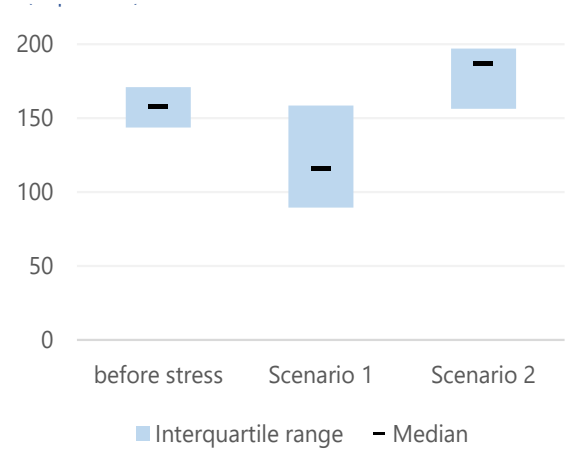
The overall SCR also declines, albeit much more for life insurers—in Scenario 2 by 24 percent.

Change in the SCR
(In percent)



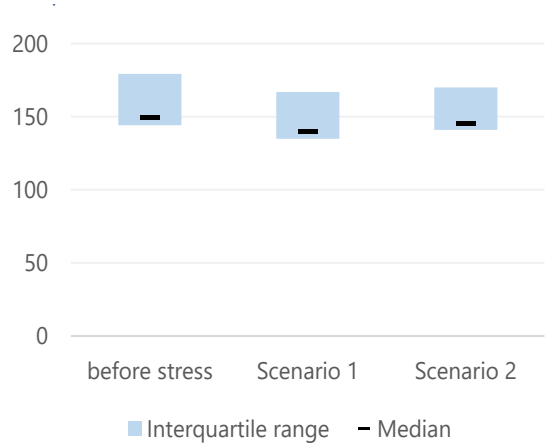
SCR ratios in the life sector drop significantly in scenario 1, but increase across the sample in scenario 2…

SCR Ratios– Life
(In percent)



…while in the general insurance sector, both scenarios have a similar, mild impact.

SCR Ratios – General
(In percent)

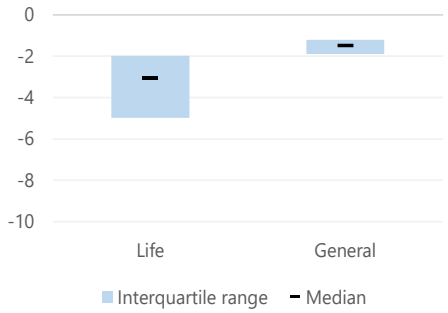


Sources: IMF staff calculations based on PRA data.

Figure 20. United Kingdom: Insurance Sensitivity Analysis

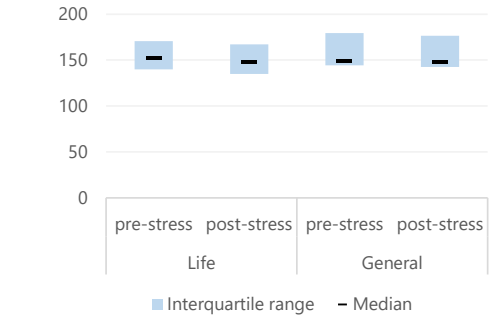
Life insurers' excess of assets over liabilities drop by 3 percent on average with a much larger variation than in the general insurance sector.

Sensitivity Analysis: Change in Excess of Assets Over Liabilities (in percent)



SCR ratios are largely unaffected by the default of the largest banking counterparty, dropping only by 4 and 2 percentage points for the median life and general firm.

Sensitivity Analysis: SCR Ratios
(In percent)



Sources: IMF staff calculations based on PRA data.

E. Liquidity Risks

92. The liquidity analysis for the U.K. insurance sector focused on the need to meet variation margin calls for a single stress on interest rate swaps after a sudden rise of interest rates. As outlined above, derivatives and in particular interest rate swaps are an important risk-mitigating tool for life insurers. They are typically fix-receivers making them vulnerable to increases in interest rates which would trigger variation margin calls. Data availability[51] resulted in a smaller sample than for the solvency ST—five life insurance groups with a market coverage of around 50 percent were included. The reference date for the analysis is end-2020.

93. The scenarios for the analysis assume very severe interest rate increases of up to 100 basis points within a five-day period. For the liquidity analysis, three interest rate shocks were modeled, over two different time horizons: A 25 basis point (bp) increase (parallel shift of the interest rate term structure, for all relevant currencies) is assumed to occur overnight, hence to meet cash margin calls, only the most liquid assets could be drawn upon—the FSAP analysis uses the narrowest definition by including only cash deposits.[52] The other two scenarios, interest rate increases of 50 and 100 bps, would unfold over a period of five days. In that case, it is assumed that insurers could liquidate some of their most liquid high-quality assets, so that the pool of liquid assets enlarges, and the margin calls could be met with cash deposits plus unencumbered sovereign bonds of credit quality steps 0 and 1, revalued after the interest rate increase and with an additional haircut.

94. Encumbrance levels of high-quality assets are moderate among insurers in the sample. Only around 10 percent of sovereign bonds in the two highest credit quality steps are encumbered,

[51] The analysis uses derivative positions as reported in QRT S.08.01. An alternative source would be the data reporting introduced with the European Markets and Infrastructure Regulation (EMIR), however this reporting is also still suffering from data quality issues, as noted e.g. in ESMA's EMIR and SFTR data quality report 2020.

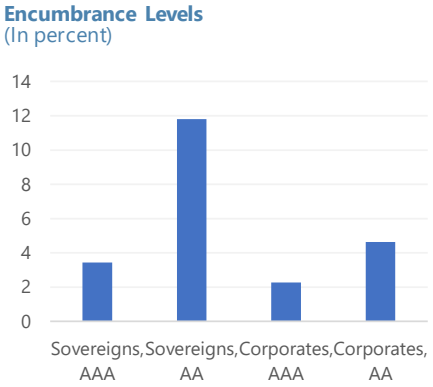
[52] Central counterparties would often also allow high-quality securities to meet margin calls.

and for corporate bonds the share is below 4 percent (Figure 21a). Encumbered assets comprise mostly U.K. government bonds.

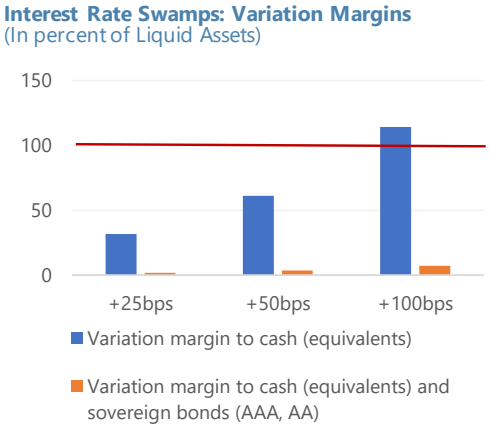
95. The analysis shows no systemic liquidity stress for the overall sample of life insurers, but notable differences across individual firms (Figure 21b). Most insurers are capable of meeting margin calls on interest rate swaps with their cash equivalents only, even in the case of a 50-bps interest rate increase. However, assuming a 100-bps shock, more insurers would have to liquidate on aggregate 7 percent of their highest-quality sovereign bonds (unless the counterparty also accepts securities as admissible assets). As the analysis used consolidated data, it remains unclear how liquidity is allocated within each insurance groups, i.e., whether it is available at those entities which face short-term liquidity needs.

Figure 21. United Kingdom: Insurance Liquidity Stress Test Results

Encumbrance levels are highest among domestic government bonds, but only 10 percent of all high-quality government bonds are encumbered.



A cash margin calls on interest rate swaps following a 25-bps interest rate increase could be met by drawing on 32 percent of cash equivalents—these would be, on aggregate, depleted if interest rates increase by more 100 bps.



Source: IMF staff calculations based on PRA data.

96. The PRA's experience from March 2020 indicated that insurers used the full range of mitigating measures to preserve liquidity when faced with simultaneous margin call stresses. As an example, they stopped investing cash inflows from premiums and withheld dividend payments, but widely tried to avoid asset sales—this could be interpreted in a way that the regulatory incentives for buy-and-hold investments, particularly related to the MA, have worked in practice. To further analyze combined liquidity strains, exacerbated by reduced market liquidity and fungibility of certain assets, more granular liquidity data and a monitoring framework is needed, particularly for annuity writers and insurers with large derivative holdings. The PRA plans to require specific liquidity data from certain insurers, which would provide an opportunity to close these data gaps. Box 1 includes further examples of how the supervisory reporting for insurers could be expanded to further facilitate a comprehensive analysis of risks and vulnerabilities in the insurance sector.

F. Recommendations

97. The PRA should continue its efforts to enhance the data quality checking process and ensure high-quality supervisory reporting by insurers. As a basis for the PRA's risk analysis work, supervisory reporting should be thoroughly scrutinized, and companies should be guided to report data more completely and consistently, particular regarding investment assets (S.06.02, in combination with S.02.01) and derivatives (S.08.01). Box 1 includes further examples of how the supervisory reporting for insurers could be expanded to further facilitate a comprehensive analysis of risks and vulnerabilities in the insurance sector.

98. The PRA should augment its already strong focus on liquidity risks and further analyze combined liquidity strains, exacerbated by reduced market liquidity and fungibility of certain assets, and expand supervisory reporting, particularly for annuity writers and insurers with large derivative holdings. In this context, it is necessary to understand cash management arrangements and intra-group flows of liquidity. The PRA has announced plans to require specific liquidity data from certain insurers, which would provide an opportunity to close these data gaps.

Box 1. The Importance of Data in Support of Financial Stability Monitoring and Analysis

Data are fundamental for monitoring financial stability and analyzing risks and vulnerabilities across the financial system, both from a domestic and a global financial stability perspective. In the case of the U.K., this is a challenging and delicate task, given the heterogeneity and complexity of the domestic financial system, its deep links with other financial systems abroad, and London's central role in the global financial network.

Banks

The Prudential Regulatory Authority (PRA) has the power to require banks to provide information or documents and to make general rules that apply to authorized firms, including rules about the provision of information. The regulatory reporting framework includes reports inherited from the Financial Services Authority (FSA) and those adopted in the recent past as part of the EU (esp. COREP and FINREP). Additional data requirements have been introduced more recently to address specific information needs (e.g., liquidity, Annual Cyclical Scenario (ACS) exercise). The PRA regularly runs validation and plausibility checks on the regulatory returns it receives from banks. However, for data collections of more recent origin or falling outside of the regulatory reporting perimeter, the validation and plausibility checks in place do not necessarily ensure the quality and – ultimately - full usability of the data. This is the case for certain datasets reported by the banks participating in the ACS as part of the Stress Test Data Framework (STDF): while potentially very useful for several purposes (like solvency stress testing, climate risk analysis, etc.), they sometimes present limitations that constrain their use for broader purposes, as experienced directly by the FSAP team. A revision of the validation and plausibility rules (e.g., regarding the admissible values for identifiers), together with stricter enforcement of those rules would help enhance the quality of these data collections.

Insurers

The implementation of Solvency II in 2016 brought a substantial improvement in the supervisory reporting of (re)insurance undertakings, including detailed asset-by-asset reporting on a quarterly basis. In addition, the PRA has introduced a set of national-specific reporting templates which allow a comprehensive monitoring of internal model drift. However, some gaps remain, most notably in the areas of liquidity risk and cross-border business. Liquidity analyses suffer from inadequate reported data and a lack of consistency, such as the amount of cash and cash equivalents is reported differently by firms depending upon their interpretation of cash equivalent. Derivative data, which is also available from trade repository data under EMIR, needs to be further enhanced and quality-checked to allow for a more robust monitoring of margin call risks. Data on cross-border business and intermediation channels is limited, complicating e.g., an assessment of the systemic relevance of Lloyds in foreign markets. For insurance intermediaries, including some of the larger brokers in the Lloyds and London market, liquidity reserves have been collected only ad-hoc during the pandemic.

Source: IMF staff.

CLIMATE-RELATED VULNERABILITIES

Climate-related balance sheet risks for financial institutions have been assessed through a separate scenario-based analysis for transition risk and sensitivity analyses for physical risks.

A. Transition Risk

99. For the assessment of the U.K. financial system's exposure to transition risk a 'climate Minsky moment' approach was adopted. The team assessed the exposure of financial institutions to the potential materialization within a five-year horizon of credit and market losses in a 'climate Minsky moment' situation (Figure 22). The main source of shock is assumed to be a policy change, in the form of a switch in the economic agents' expectation from a low and relatively flat to a high and steep path for carbon prices, in the United Kingdom and at global level.[53]

100. The evolution of the relevant risk factors was simulated over the long term (up to 2050), but the estimation of the impacts was based on a revision of asset valuations and risk repricing, assumed to occur in the shorter term (within a five-year horizon).[54] The difference in valuations at the climate Minsky point under the two scenarios represents the potential asset price correction affecting all marketable assets and—via an approach à-la-Merton—the probabilities of default and credit ratings of companies (Figure 23).

Corporate Exposures

101. The exercise covered the exposure of U.K. financial institutions to their corporate counterparts in the domestic and most relevant foreign markets. The exercise covered: the same eight banks of the solvency stress test; eight large life insurers and seven large general insurers; a representative sample of investment and pensions funds (Table 9).

102. The exercise was based on the scenarios published by the Network for Greening the Financial Sector (NGFS; Box 2). In particular, for the main exercise, the following NGFS 'Phase I' scenarios were adopted, in the REMIND-MAgPIE version: 'National Determined Contributions', as a representation of the 'status quo', assumedly incorporated by market agents in the pricing of all assets (this scenario is labelled as 'BASE'); and the '1.5°C with Carbon Dioxide Removal' (1.5°C+CDR) scenario, representing a new status, with the expectation, by market agents, of more ambitious decarbonization policies and a steeper carbon price path (this scenario is labelled as 'ADV' – for 'adverse'). The '1.5°C+CDR' scenario is one of the scenarios labeled by the NGFS as 'orderly' (see

[53] While policies supporting a transition to a low-carbon economy can take different forms (e.g., subsidies to renewable energy production, caps on fossil-fuel-based power generation, etc.), the assumed shock is represented by a (sharp) increase in carbon prices. This is a convenient, powerful, and relatively tractable assumption that allows to characterize and model a decarbonization scenario effectively and parsimoniously. It is also extensively used in the scenario design for transition risk by central banks. Finally, it is justified by recognizing that, even in the absence of 'explicit' carbon prices, alternative decarbonization policies would produce effects corresponding to the adoption of an 'implicit' carbon price.

[54] For all purposes, the climate Minsky moment was assumed to occur in the year 2024.

charts at the bottom of Box 2): they represent a state of the world in which "immediate action is taken to reduce emissions consistent with the Paris Agreement" (NGFS, 2020).[55]

103. The NGFS scenarios were expanded via simulations of a global computational general equilibrium model (GTAP-E) to capture sectoral effects (Box 3). The model was used to simulate sectoral Gross Value Added (GVA) under the 'base' and 'adverse' scenarios.

104. The heterogeneity of impacts within sectors was captured at company level via the Climate Credit Analytics (CCA) model suite (Box 4).[56] While the results are mainly driven by the evolution of GVA by sector and country in the GTAP-E model, an insight into the dispersion of results was gained via the CCA model: the evolution of free cash flows to equity (FCFE) was simulated for each company in the database between the climate Minsky point (assumed to be 2024) and the end of the valuation horizon, i.e., 2050.[57] The exercise was based on end-2019 financials (of about 1.2 million companies worldwide) for the run based on NGFS Phase I scenarios and on end-2020 financials (of a stratified sample of more than 160,000 companies) for the run based on NGFS Phase II scenarios.[58,59] Consistency between the GTAP-E and CCA simulation results was ensured by an integration procedure (Annex VII).

[55] In contrast, the 'disorderly' scenarios show "a much more challenging pathway to meeting the Paris Agreement targets" (NGFS 2020). In those scenarios, "climate policy follows NDCs until 2030. Acknowledging that these efforts will not be enough to meet commitments, the emissions price is revised substantially upward after 2030. The scenario further assumes that there will be only limited CDR technologies available. The period of delay means that net zero CO2 emissions must be reached more quickly, by around 2050. Correspondingly the increase in emissions prices is much more rapid" (ibid.).

[56] The FSAP team would like to express its gratitude to Ilya Khaykin, Jared Beekman, Matt Doyle, and Rudolf Vakker (all Oliver Wyman) for the external support and access to the CCA database they provided.

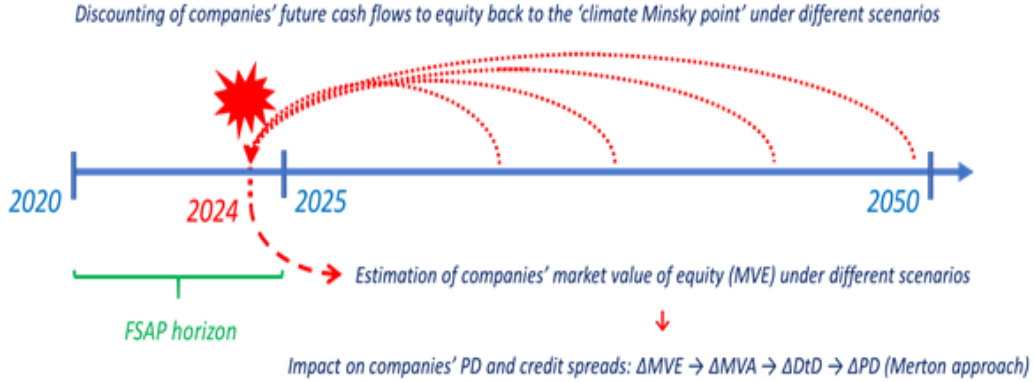
[57] See Annex II for an explanation of how the results from GTAP-E and CCA are integrated and then translated into impact on financial institutions' credit and market losses.

[58] It is assumed that end-2019 and end-2020 financials are representative of the financials to be expected at the climate Minsky point (2024), with the only correction of an adjustment to leverage for companies in the end-2019 financials, to incorporate the impact of increased indebtedness during 2020, because of the COVID crisis.

[59] The sampling for end-2020 financials was done in such a way as to include all companies modelled in CCA with a dedicated module (Oil&Gas, Metals&Mining, Power Generation, Airlines, Automobiles); for the remaining sectors (modelled as 'Generic' in CCA), stratified sampling was used, with strata based on a) private/public status, b) sector; c) geography.

Figure 22. United Kingdom: The Logic of the Climate Minsky Moment

"A wholesale reassessment of prospects, as climate-related risks are re-evaluated, [that] could destabilize markets, spark a pro-cyclical crystallization of losses and lead to a persistent tightening of financial conditions"

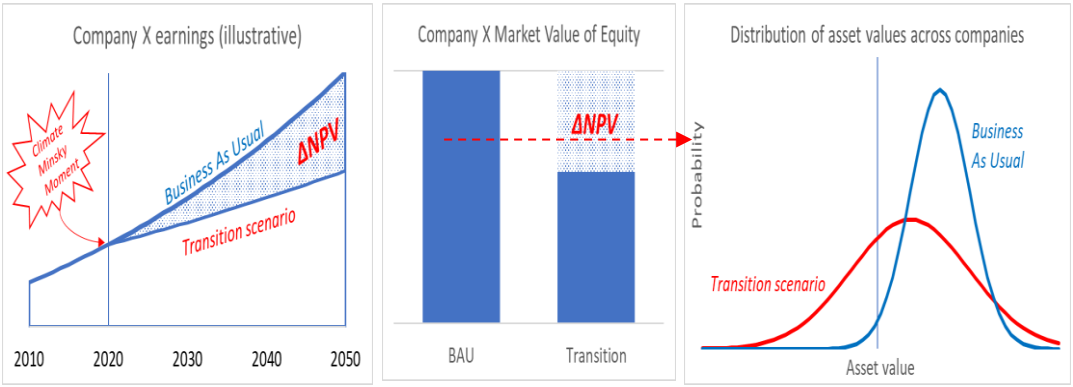


ΔMVE: change in market value of equity
ΔMVA: change in (unobserved) market value of assets
ΔDtD: change in Distance to Default
ΔPD: change in probability of default

Source: Carney (2016) Resolving the climate paradox, and IMF staff.

Figure 23. United Kingdom: Impact on Asset Valuations at the Climate Minsky Point

The difference in valuations at the climate Minsky point under the two scenarios represents the potential asset price correction affecting all marketable assets



Source: IMF staff.

Table 9. Methodological Approaches for Climate Risk Analysis

	Scenario-based Analysis		Sensitivity Analysis
	NGFS 'Phase I' + GTAP-E + CCA [a]	NGFS 'Phase II' + GTAP-E + CCA [a]	
Banks (8 largest banks)			
• Corporate loan portfolio	T	T	
• U.K. mortgage loan portfolio			T [b]
• Securities portfolio	T (stocks, corporate bonds)	T (stocks, corporate bonds)	P [c] (sovereign bonds)
Life Insurers (8 large insurers)			
• Securities portfolio	T (stocks, corporate bonds, funds)	T (stocks, corporate bonds, funds)	
General Insurers (5 large insurers + Lloyd's)			
• Securities portfolio	T (stocks, corporate bonds, funds)	T (stocks, corporate bonds, funds)	
• Technical reserves			P [d]
U.K.-domiciled funds (~2000 funds)			
• Securities' holdings	T (stocks, corporate bonds)		
Pensions funds (~70 DB schemes)			
• Securities' holdings	T (stocks, corporate bonds)	T (stocks, corporate bonds)	

T = Analysis of transition risk
P = Analysis of physical (chronic/acute) risk
NGFS = Network for Greening the Financial Sector
NGFS 'Phase I': 'National Determined Contributions' and '1.5°C with Carbon Dioxide Removal' scenarios, published in June 2020
NGFS 'Phase II': 'National Determined Contributions' (NDC) and 'Net Zero 2050' (NZ2050) scenarios, published in June 2021
GTAP-E = Global Trade Analysis Project model (Energy/Environmental version), used by IMF staff to simulate sectoral Gross Value Added under different NGFS scenarios up to 2050
CCA = Climate Credit Analytics, a climate scenario analysis and credit analytics model suite developed by S&P Global Market Intelligence and Oliver Wyman, used to simulate companies' financials up to 2050 under different NGFS scenarios
[a] = impact on companies' financials simulated in CCA under the NGFS scenarios up to 2050, conditional on GTAP-E's simulated GVA paths; impact on probabilities of default, ratings, and credit spreads based on S&P Global Market Intelligence PD Model Fundamentals and IMF staff calculations
[b] = impact on U.K. mortgage loss-given default (LGD) by U.K. region based on carbon price paths under NGFS Phase II scenarios (NDCs, NZ2050, and Divergent Net Zero) and buildings' Energy Performance Certificates (EPCs)
[c] = impact on sovereign bonds based on expected sovereign rating migration under RCP8.5 scenario (from Klusak et al., 2021) and IMF staff calculations
[d] = impact on loss distribution based on assumed increase in frequency and severity of U.K. floods, US hurricanes and European windstorms
Source: IMF Staff.

Box 2. NGFS Scenarios

The Network for Greening the Financial System (NGFS) was launched in December 2017 by a group of 8 Central Banks and Supervisors, including the Bank of England (see https://www.banque-france.fr/sites/default/files/medias/documents/joint_statement_-_greening_the_financial_system_-_final.pdf). It has since expanded, and its membership counts 102 members and 16 observers (as of end-November 2021). Its objective is to contribute to the analysis and management of climate and environment-related risks in the financial sector, and to mobilize mainstream finance to support the transition toward a sustainable economy. It is structured into five workstreams, including the workstream on macrofinancial, tasked, inter alia, with developing climate scenarios for central banks and supervisors.

To that aim the workstream on macrofinancial established a collaboration with an academic consortium encompassing several institutions and three different integrates assessment models (IAMs): REMIND-MAGPIE, GCAM, MESSAGEix-GLOBIOM.

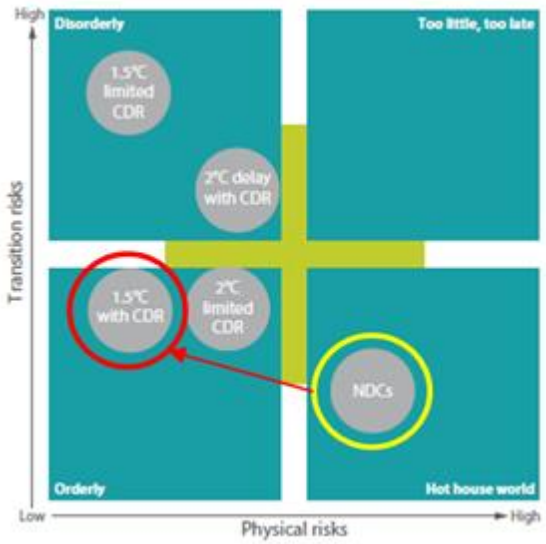
The first phase of this collaboration (labelled 'Phase I') has produced a set of scenarios published in June 2021 (see https://www.ngfs.net/sites/default/files/medias/documents/820184_ngfs_scenarios_final_version_v6.pdf). These are based on a socioeconomic pathway (SSP) with specific assumptions on GDP, population, and urbanization up to 2100 (in particular, the choice fell on SSP2, considered a 'middle or the road' pathway with global population growth decelerating and GDP continuing to grow in line with historical trends). Five scenarios span a range of combinations in terms of physical and transition risks. The IAMs produce a wide range of variables, also covering climate, land use, and the energy system; their coverage of macro variables, however, is limited (basically restricted to GDP and little more). Also, the simulations are run at the level of large geographic areas and, in the case of REMIND-MagPIE, only the main countries are simulated separately.

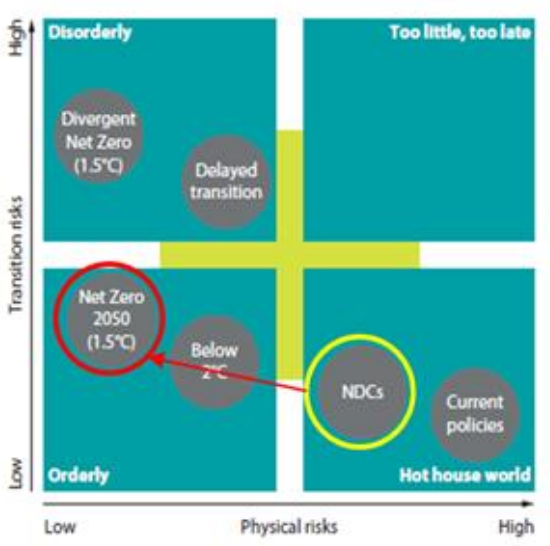
The continuation of the collaboration between NGFS and the academic consortium after the publication of the first suite of scenarios (labelled 'Phase II') led to the production and publication of a second set of scenarios, in June 2021 (see https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs_climate_scenarios_phase2_june2021.pdf). These improved substantially with respect to the Phase I scenarios, along three dimensions: the 'downscaling' of the IAMs' output at a more granular geographic level; the integration of a widely used macroeconometric model (NiGEM by the British National Institute of Economic and Social Research) with the suite of IAMs to simulate a large set of macroeconomic and financial variables at a detailed geographic level (on around 60 countries and regions); the update of the scenarios by incorporating new country commitments to reach net-zero emissions.

Box 2. NGFS Scenarios (concluded)

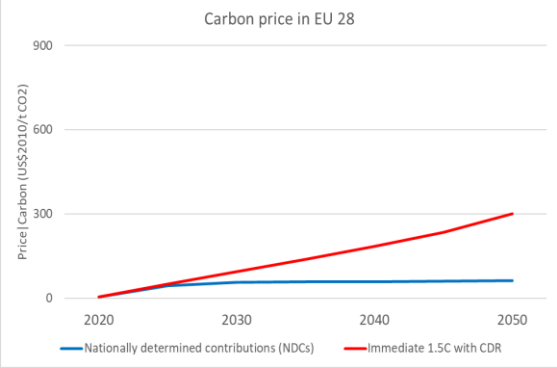
'Phase I' (left) and 'Phase II' (right) suites of NGFS scenarios

Scenarios used in the exercise are circled yellow and red for 'base' and 'adverse' scenarios, respectively

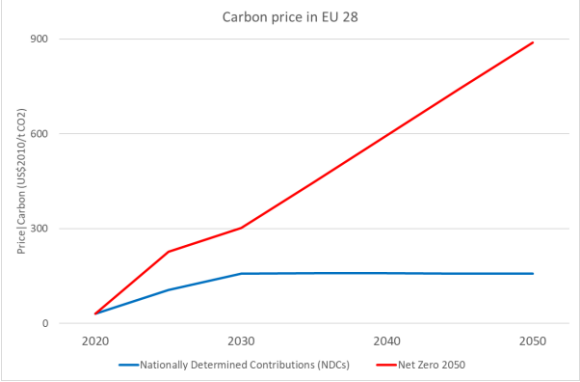




Carbon price paths under the selected 'Phase I' scenarios



Carbon price paths under the selected 'Phase II' scenarios



Source: NGFS, IMF staff.

Box 3. The GTAP-E Model and Its Role in the Transition Risk Analysis

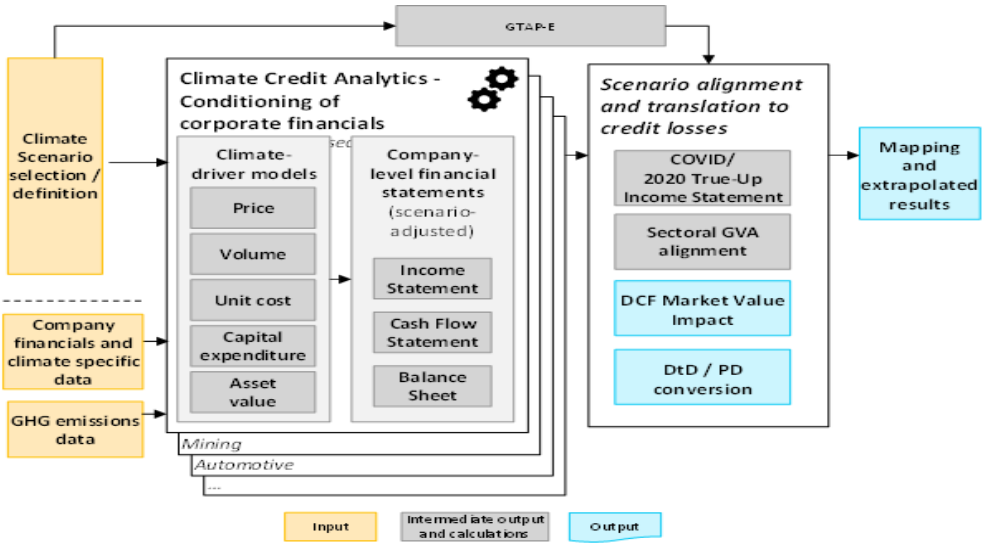
GTAP is a multiregional, multisector, computable general equilibrium model, with perfect competition and constant returns to scale. GTAP-E is an Energy-Environmental version of the GTAP Model (Burniaux and Truong, 2002) that incorporates energy substitution into the standard GTAP model. Energy inputs determine the value added, separately from other inputs. Households, government, and commodity sectors consume energy and other goods.

GTAP-E is used to translate the scenarios into impacts on nominal gross value added and relative prices for relevant sectors. NGFS scenarios provide key macro and policy variables but limited sectoral breakdown. Carbon prices and GDP from each NGFS scenario are used to guide policy and other types of transition shocks in GTAP-E: change in carbon prices affect direct prices of inputs and total price of the consumption bundle; sectors are affected differently depending on their energy consumption; under NGFS 'Phase I' scenarios, a common TFP shock is applied to all sectors, to ensure alignment between the real GDP path provided in the NGFS scenario and aggregate real Gross Value Added (GVA) in GTAP-E. That shock is assumed to capture, in a reduced form, the technological changes that each sector will undergo in response to climate policies as well as any residual aspect that is incorporated in NGFS models and is not present in GTAP. This leads to a change in the sectoral composition of output and of each sector's value added.

The same approach was used under NGFS 'Phase II' scenarios, with an important difference in the assumptions about TFP shocks. The 'Net Zero 2050' (NZ2050) achieves the same target as the 1.5°C+CDR 'Phase I' scenario (i.e. no more than 1.5°C above the pre-industrial level by 2100), but with higher carbon prices (more than twice as high at global level, on average, over the horizon up to 2050) and "medium availability of carbon sequestration [..], lower than in the first set of NGFS scenarios" (NGFS, Climate Scenarios Database – Technical Documentation V2.1, June 2021). For this reason, GDP paths are weaker in the NZ2050 scenario, when compared with the 1.5°C+CDR 'Phase I' scenario. Given the lower availability of CDR technologies, with respect to the 'Phase I' scenario, the assumption of a single, common TFP shock to all sectors (to ensure NGFS-GTAP alignment) appears as no longer plausible: carbon-intense sectors are more likely to face a less favorable technological transformation than less carbon-intense ones. The alignment between NGFS' GDP and GTAP-E's aggregate GVA has hence been pursued by having sectors face different TFP shocks. Those shocks have been distributed across sectors by using some judgement, that is dependent on their carbon intensity and the availability of non-CDR technologies that could help decarbonize (e.g., the electric vehicle technology for automakers). This leads to a wider dispersion of outcomes across sectors than under the 1.5°C+CDR 'Phase I' scenario. Given the use of judgement in the distribution of shocks, we also conducted a sensitivity analysis.

Source: IMF staff.

Box 4. The Climate Credit Analytics Model Suite



Climate Credit Analytics (CCA) is a climate scenario analysis and credit analytics model suite developed jointly by S&P Global Market Intelligence and Oliver Wyman. CCA conditions financials of corporates on climate scenarios to evaluate corporate performance. These conditioned financial statements are then further analyzed to assess the risk to the banking sector lenders. CCA applies a common framework across six sectors: Oil & Gas, Power generation, Metals & Mining, Auto manufacturing, Commercial Airlines, and generic approach for the remaining non-financial corporate sectors. The specific methodologies vary significantly between sectors, reflecting the different business activities, adaptation pathways, dynamics, and financial reporting particular to each sector. In some industries, such as Oil & Gas, there is no long-term alternative in a transition other than to divest and move into new business lines. In others, such as Automotive Manufacturing and Power Generation, demand for their output is expected to be resilient in the climate transition, though their product(s) and the method of production must change significantly. These dynamics are captured in detail in the individual sectoral modules of CCA.

(DCF = Discounted Cash Flow; DtD = Distance to Default)

Source: Oliver Wyman.

105. The results of the transition risk analysis under the 'Phase I' NGFS scenarios show that, under an orderly scenario, U.K. banks would be affected significantly, but financial stability is unlikely to be jeopardized. Losses on the banks' corporate loan portfolios would be slightly higher, on average, than 1 percent, corresponding to GBP bln 24.[60] Banks would also suffer market losses of 3.5 percent, on average, on their equity holdings, and 1.6 percent on their corporate bond portfolios, bringing banks' economic losses on all their corporate exposures (across their accrual-accounting and fair-valued portfolios) to a total of GBP 31 bln.

106. Losses on equity and corporate bond holdings under the same 'Phase I' NGFS scenarios would also be modest for a large sample of U.K.-domiciled investment funds and a smaller sample of defined-benefit pension schemes. For investments funds the losses would

[60] For comparison, under the BoE 2021 solvency stress exercise, the same banks incur credit impairments (on all their loan portfolios, not only corporate) of more than GBP 70 billion over 2021 and 2022 (https://www.bankofengland.co.uk/stress-testing/2021/bank-of-england-stress-testing-results).

average about 0.32 percent of the overall portfolio. The results, however, are quite dispersed: even after excluding outliers (below the 1st and above the 99th percentiles) across the more than 2,000 funds and sub-funds considered, the range of results would span from a gain of 0.5 percent of the portfolio to a loss of around 2 percent. For pension schemes see Box 5.

107. The analysis of transition risks in the insurance sector followed closely the approach used for the banks and investment funds, covering all insurers of the solvency ST sample as of end-2020. For most stocks and bonds held by insurers, either an issuer-specific shock or a sector-specific shock was derived from the climate change model. The shock was specified as an equity price change or, for bonds, as a spread increase and a default rate. A universal shock was applied for all investment holdings for which no economic sector was reported (around 5 percent of all positions). Only the impact on the asset valuation was estimated, not the impact on solvency ratios.

108. The sectoral allocation of U.K. insurers is well diversified, but the Solvency II reporting does not allow for a comprehensive analysis of transition risks purely based on the reported sector. QRT S.06.02 requests insurers to report the economic sector following the classification of the Statistical Classification of Economic Activities in the European Community (NACE)–a reporting at the one-letter level (e.g., "C – Manufacturing") is sufficient, except for exposures to the financial sector (letter "K") where a more granular classification must be used. Such a broad classification naturally dilutes the informational value of the sensitivity of a certain sector to climate change and an assumed carbon price path (Table 10).

Table 10. Insurance Sectoral Investment Exposures

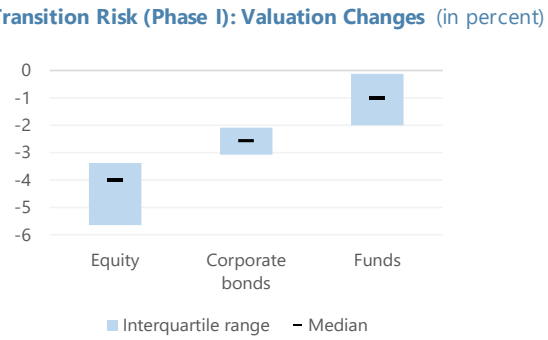
Sector (NACE classification)	Exposure (GBP bn.)	*as percent of corporate exposures*	*as percent of total assets*
C - Manufacturing	158,517	20.4%	8.4%
K64.1.9 - Other monetary intermediation	126,483	16.3%	6.7%
L - Real estate activities	63,433	8.2%	3.4%
J - Information and communication	62,738	8.1%	3.3%
D - Electricity, gas, steam and air conditioning supply	48,546	6.2%	2.6%
H - Transporting and storage	40,988	5.3%	2.2%
G - Wholesale and retail trade; repair of motor vehicles and motorcycles	28,888	3.7%	1.5%
K65.1.2 - Non-life insurance	26,202	3.4%	1.4%
K65.1.1 - Life insurance	24,813	3.2%	1.3%
K64.9.9 - Other financial service activities, except insurance and pension funding n.e.c.	22,892	2.9%	1.2%
K64.2.0 - Activities of holding companies	21,445	2.8%	1.1%
E - Water supply; sewerage; waste management and remediation activities	17,336	2.2%	0.9%
K66.1.9 - Other activities auxiliary to financial services, except insurance and pension fundin	16,530	2.1%	0.9%
L68.2.0 - Renting and operating of own or leased real estate	16,303	2.1%	0.9%
B - Mining and quarrying	14,291	1.8%	0.8%
Q - Human health and social work activities	13,478	1.7%	0.7%
K66.1.2 - Security and commodity contracts brokerage	9,839	1.3%	0.5%
F - Construction	8,244	1.1%	0.4%
M - Professional, scientific and technical activities	8,140	1.0%	0.4%
K64.9.2 - Other credit granting	6,524	0.8%	0.3%
Other sectors (except public sector and mutual funds)	41,602	5.4%	2.2%

Sources: IMF staff based on PRA data.
Notes: Stress test participants only.

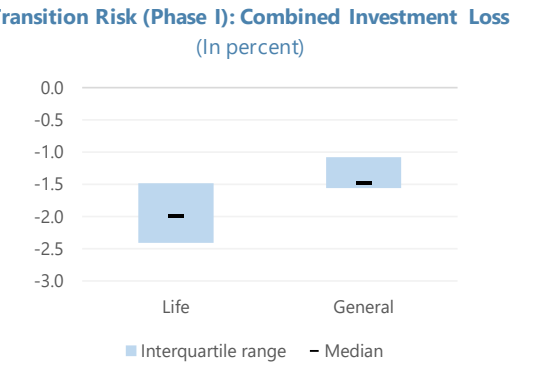
109. The simulation under 'Phase I' scenarios produces a valuation loss of close to GBP 40bn for the insurers in the sample (Figure 24, top charts). The valuation impact is highest for equity holdings which would decline by 4 percent on average. The value of corporate bonds would decline by 2.5 percent, and the value of investment funds—as a combination of stock, sovereign bond, and corporate bond valuations—by 1 percent.[61] Given the much larger asset size of the life insurance sector, around 38bn of the total impact is seen among the life insurers of the sample. In relative terms, the losses for most insurers range between 1 and 3 percent of total investments, and 2 percent for the median life firm. Some of these valuation losses would ultimately be borne by policyholders, especially in unit-linked life contracts. Furthermore, some losses would be offset by changes in the calculation of liabilities, e.g., in matching adjustment portfolios.

Figure 24. United Kingdom: Climate Transition Risks in Insurance

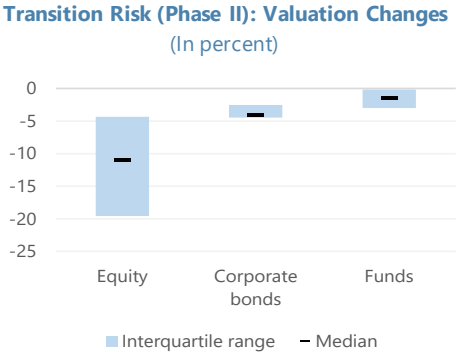
The valuation of stocks, corporate bonds and investment funds declines on average by 4, 2.5 and 1 percent, respectively…



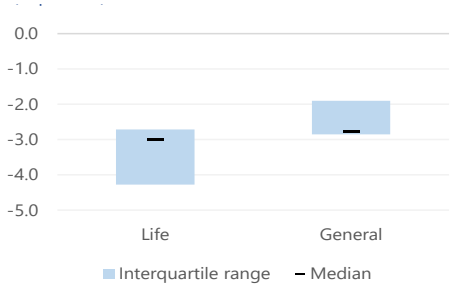
… resulting in a combined valuation loss of 2 percent for life insurers and 1.5 percent for general insurers.



In the Phase 2 scenario, stocks decline considerably more in value than in Phase 1—on average by 11 percent.



Investment assets of life insurers decline by 3 percent on average, slightly more than those of general insurers.



Source: IMF staff calculations based on PRA data.
Notes: The dispersion of valuation changes shows the dispersion across the sample of insurers, not for the universe of firms which were re-valued in the climate risk valuation model.

[61] Note that investment funds would also include money-market funds and alternative funds to which no transition shock was applied.

110. These results need to be interpreted carefully. They represent the outcome of a single simulation, covering a subset of the relevant portfolios, based on an 'orderly' scenario, that is not the most severe one can assume from the perspective of transition risk.

111. The results change significantly under an alternative orderly scenario with even higher ambitions to decarbonize and more dispersion across industries. The exercise has been repeated under a scenario from the most recent suite of 'Phase II' scenarios published by the NGFS, in June 2021: the so called 'Net Zero 2050' (NZ2050), which is considered by the NGFS an 'orderly' transition scenario. It envisages a steeper carbon price path until 2050 than the Phase I 1.5°C+CDR scenario, with carbon prices more than twice as large (see bottom charts of Box 2). Also, it assumes a lower availability of carbon dioxide removal technologies and, consequently, a strong differentiation of productivity growth between carbon-intensive and low-carbon industries.

112. Under such a scenario the impact on financial institutions could be significantly larger. The switch between the 'National Determined Combination' scenario (representing, again, the status quo) and NZ2050 could cause significantly larger losses for financial institutions: losses on banks' corporate loan portfolios, for example, could more than triple (from 1.1 to 3.6 percent) with respect to the exercise with Phase I 1.5°C+CDR as the adverse scenario; this would correspond to an amount of credit losses increasing from GBP 24 billion to almost 79 billion. Banks' market losses (on their equity and corporate bond holdings) would increase from 2.5 (GBP 7 billion) to more than 4 percent (GBP 11.5 billion). In total, banks' losses across all their corporate exposures would then increase from GBP 31 billion to more than 90 billion.

113. Insurance companies would also experience a much larger dispersion of shocks across the investment universe, particularly for stocks—valuation losses would total GBP 66bn (Figure 24, bottom charts). Like Phase I, the price impact on stocks is the largest, but even within individual sectors, the valuation changes can vary to a large extent. Equity holdings in this scenario would decline on average by 11 percent. Corporate bonds and investment funds would decline by 4 and 1.5 percent, respectively. Across all asset classes, the loss corresponds to around 2 to 4 percent for most insurers in the sample—again the impact in the life sector would be larger than in the general sector.

114. Given the significant non-linearity of the impacts with respect to the carbon price paths, even larger losses could be expected under a 'disorderly' transition scenario (like, for example, the NGFS' 'Divergent Net Zero').

115. This second batch of results confirms the extreme sensitivity of the estimation of transition risks to the underlying assumptions and methodological choices. There are several factors that could further influence the results. One is the effect on LGDs at the climate Minsky point: they are kept constant in the exercise but could instead be modelled within the Merton framework adopted for the derivations of changes in ratings and credit spreads. Another one is the reaction of the volatility of market value of assets (linked to that of the market value of equity) to the climate Minsky shock: it is plausible to assume that volatility could change (most probably increase), with uncertain effects, though, i.e. likely positive on the market value of equity (which,

seen as a put option, would benefit from the higher volatility of the underlying), but negative on firms' credit standing (via a reduction in the distance to default, that could lead to an increase in default rates and credit spreads). Also, the increase in credit spreads, in the current exercise, is determined entirely by companies' migrations across rating classes, with unchanged spreads by rating class, while it is plausible that these too would change (likely increase) at the climate Minsky point. It is also worth highlighting that the whole exercise is aimed at capturing first-order losses, without considering second-round effects and feedback loops.

116. Another factor that could influence the results, the reaction of risk premia to a climate Minsky moment shock, has been explored via a sensitivity test. In the exercise, risk premia are an important input in the discounting process. If they were to increase at the climate Minsky point —e.g., because of a jump in market agents' risk aversion—companies' cash flows would be discounted at a higher rate, thus determining lower net present values, i.e., more negative, or less positive changes in the market value of companies' equity. While a precise modelling of this effect falls outside the current analytical framework, a sensitivity test has been run by increasing all risk premia by ½ in the second simulation, with NZ2050 as adverse scenario.[62] As expected, the overall results worsen significantly: e.g., banks' credit losses on their corporate loan portfolios would rise, on aggregate, to 5.8 percent (from 3.6 percent under current risk premia), corresponding to an amount of GBP 126 billion (as opposed to 79 billion under current risk premia). This experiment illustrates the large uncertainty bounds around projected climate risk related losses.

117. Finally, the exercise has focused on the modelling of differentiated impacts across and within sectors, while remaining agnostic with respect to the macroeconomic environment. A switch in market expectations between scenarios that are vastly different, in terms of their implication for the evolution of the economy, is likely to generate widespread effects on most macroeconomic variables, also via the policymakers' responses. Monetary policy, for example, would have to balance, on one hand, the inflationary pressures from the expected increase in energy prices and potential bottlenecks caused by a fast transition to a low-carbon economy; and, on the other hand, the recessionary forces that could be triggered by a shrinking purchasing power (for households, for example) and frictions in the necessary reallocation of resources. Fiscal policy decisions could also have very significant effects, depending especially on the choices about the use of revenues from carbon taxes, e.g., if used to support public investments or to reduce public debt.[63] The current exercise has not attempted to model these effects.

[62] Historically, increases in equity risk premia of that size, or larger, have been recorded in the US equity market: e.g., Damodaran (2019) estimates that implied equity risk premia for the S&P 500 index (backed out from the application of a Dividend Discount Model) have jumped by more than ½ year-over-year twice over the past sixty years, in 1973 and 2008 (see https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/histimpl.html).

[63] These decisions could have drastically different impacts, for example, on the GDP path (see https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs_climate_scenarios_phase2_june2021.pdf, slide 39).

Residential Mortgage Loans

118. A complementary exercise was run to capture transition risk in U.K. residential mortgage portfolios under different NGFS scenarios. The exercise follows the same 'climate Minsky logic' adopted in the analysis of transition risk for corporates. The value of residential properties is affected by an increase in carbon prices via the impact of higher cost for heating and electricity (or to implement efficiency-improving measures); this, in turn, can have an impact on the Loss Given Default (LGD) of mortgage loans.[64] The analysis uses the information available in the Energy Performance Certificate (EPC) database for England and Wales (see Box 6).[65]

119. A 'switch' from a 'business-as-usual' (BAU) scenario to one with ambitious climate mitigation policies would have consequences for the owners' decisions on energy efficiency improvements and, ultimately, for the property value. It is assumed that the impact of future bills' extra cost and/or the cost of improvement measures under a BAU scenario are already priced in into property values. Under a different, 'climate ambitious' scenario, with higher bills in the future and/or more urgency to implement energy efficiency measures, the valuation of properties would change; in particular, a) if energy efficiency improvements are not implemented, property values are impacted by the cumulated, discounted extra costs from higher heating and electricity bills caused by the increasing carbon price (applied to the building's current CO2 emissions); b) if energy efficiency improvements are, instead, implemented, property values are impacted by the sum of two components: i) improvement costs (net of government subsidies), and ii) the cumulated, discounted impact on heating and electricity bills of the energy efficiency measures implemented (which reduce costs) and of the extra cost from higher carbon prices (applied to the residual CO2 emissions after the implementation of the energy efficiency measures).[66]

120. The exercise was based on 'Phase II' NGFS scenarios produced by the REMIND-MAgPIE model. The BAU scenario is represented by the carbon price paths in Europe under Phase II NGFS 'National Determined Contributions' (NDCs). For the 'climate ambitious' scenario two alternatives were used: 'Net Zero 2050' (NZ2050) and 'Divergent Net Zero' (DNZ) (see figure 25).

121. Increases in carbon prices would ultimately affect the LGD of mortgage loans via the impact on property values. The impact on valuation is divided by the estimated value of each property, to obtain an estimated percentage valuation impact (%VI) at single property level.[67] This is

[64] This is also one of the two options proposed by the BoE to the participants of the CBES to capture energy efficiency risk in their mortgage portfolios (i.e., via "an impact on property value (akin to assuming that prospective buyers incur the cost)"). The other one (via "an impact on debt serviceability (akin to assuming that the borrower pays the expenses)") is less relevant from the single-point-in-time angle of the climate Minsky moment, where what matters most is the (abrupt) change is asset valuations. See BOE, Guidance for participants of the 2021 Biennial Exploratory Scenario: Financial risks from climate change, June 2021, Annex 4.

[65] A similar database is available for Scotland.

[66] Carbon prices might not be entirely passed through to property dwellers: e.g., over the horizon the utilities that charge the bills might switch to lower-carbon energy sources; or the government might dampen the impact of higher carbon prices on electricity and heating bills via subsidies or rebates. This is captured in the exercise by comparing the results with full (100%) carbon price pass-through with those under the assumption of a reduced pass-through, i.e., with only a fraction (say 50%) of the costs borne by the property dwellers. For discounting, the discount rate was set at 2.5 percent, i.e., approximately the current average interest rate on mortgage loans.

[67] Current property values are estimated by multiplying the information on each building's total floor area (available in the EPC database) by the current price per square meter at local authority level.

then crossed with information on banks' owner-occupied and buy-to-let mortgage loans, broken down by U.K. region and Loan-to-Value (LtV) band.[68] The way a reduction in the property value can affect LGDs depends on the degree of collateralization: for loans that are overcollateralized (i.e. LtV ≤ 100%) and remain so also after a negative impact on valuation, there will be a 'migration' towards a higher LtV band (caused by the reduction in the denominator of the LtV ratio), which generally entails a higher LGD; for loans that were already undercollateralized (LtV > 100%) or become so after the valuation impact (100%-%VI < LtV ≤ 100%), the expected recovery rate (i.e. 100% - LGD) is affected in proportion of the drop in value.[69]

122. The sensitivity analysis explored the combination of different alternatives along three dimensions: adverse scenario (NZ2050 or DNZ); carbon price pass-through rate (100% or 50%); cost of the energy efficiency improvement measures (the median of the range indicated by the assessors in the energy performance certificate or the maximum of that range).[70] This produces eight different combinations that range from a 'best case' (NZ2050 + 50% pass-through rate + median cost of energy efficiency measures) to a 'worst case' (DNZ + 100% pass-through rate + max cost of energy efficiency measures).[71]

123. The results of the analysis show the importance of the assumptions on pass-through rates. Figure 26 shows the average impacts on property valuations across different geographic areas ('local authorities') in the 10 regions considered (9 for England plus Wales) under the most extreme combination of assumptions and under a similar combination but with the carbon pass-through reduced to 50 percent: in the former case the weighted average impact on valuation is almost 5 percent and ranges by region from around 2 to around 11 percent, but in some local areas it can reach as high as almost 20 percent. Both the average impacts and the dispersion of results shrink considerably under the second combination. It is evident how the pass-through rate plays a crucial role in the analysis, with the valuation impacts dropping approximately in the same proportion.[72]

[68] This information is available for six of the eight banks included in the overall climate risk analysis.

[69] See equation 1 in Box 3 of Gross et al., Expected Credit Loss Modeling from a Top-Down Stress Testing Perspective, IMF Working Paper, July 2020.

[70] The choice of the maximum in the range of indicative costs could be justified by the consideration that the assessors' indications could be affected by systematic underestimation of the cost of appliances and material, lack of fully accounting for labour costs, etc.

[71] The higher severity of the DNZ with respect to the NZ2050 is explained by the steeper carbon price path in the first part of the horizon.

[72] This is a result of the strong prevalence of the extra costs from higher carbon prices (affected by the pass-through rates) over the costs to implement energy efficiency measures. The latter have a lesser relative weight on the overall economics of buildings' energy efficiency also because of the government subsidies, that often cover most of the implementation costs.

Box 5. Transition Risk in the Pension Fund Sector

The analysis of transition risk was extended also to a small sample of corporate occupational defined benefit pension schemes (~70 out of more than 5000 schemes, representing 1/3 of the segment in terms of total assets).

With the collaboration of The Pensions Regulator (TPR), a survey was submitted to these schemes to collect data on their equity and bond holdings: unlike for the securities holdings of other financial institutions in the scope of the exercise, pension schemes did not provide granular information at security level, but aggregated by asset class, industry/sector (NACE classification) and, for bonds, type of bond (floating/fixed rate, etc.) and modified duration.

Because of the less granular nature of the data, average sector-level changes in the relevant variables (market value of equity, default rates, credit spreads) were applied to the corresponding sector-level holdings of securities by the pension schemes. In particular, the NACE level 1 classification was used – except for the Mining and quarrying sector, split between Fossil fuels and other mining.

The results are similar, in magnitude, to those found for the security holdings of other types of financial institutions: under the 'Phase I' NGFS scenarios (1.5°C+CDR vs NDCs), the weighted average portfolio loss in the sample of pension schemes at the climate Minsky point would be approximately 2 percent, with individual scheme results ranging from –7 to 0 percent.

Under the 'Phase II' scenarios (NZ2050 vs NDCs), however, the weighted average portfolio loss would rise to approximately 3.5 percent, with a range of results between –12.5 and 0 percent.

Source: TPR data, IMF staff calculations.

Box 6. Buildings' Energy Efficiency in the United Kingdom

Energy Performance Certificates (EPCs) were first introduced in England and Wales in 2007 as a requirement for the sale of residential properties. The certificates are issued by qualified and accredited energy assessors upon examination of a property's characteristics in terms of energy efficiency and environmental impact. The certificates, stored in the EPC database, contain information that is relevant from a transition risk analysis perspective. In particular: CO2 emissions, current and potential (the latter being those attainable by implementing the recommended energy efficiency measures); heating/hot water cost, current and potential; total floor area of the building (in square meters). The EPC database for England and Wales (available at https://epc.opendatacommunities.org/) counts 21.4 million certificates.

The database also provides a dataset with the recommendations associated with each certificate (there are 88.8 million recommendations in the database, so approximately 4 per certificate). The recommendations concern the energy efficiency measures that could be implemented and their indicative cost in GBP (provided as a min-max range). This information is relevant also for the estimation of potential government subsidies (like the domestic Renewable Heat Incentive, or RHI).

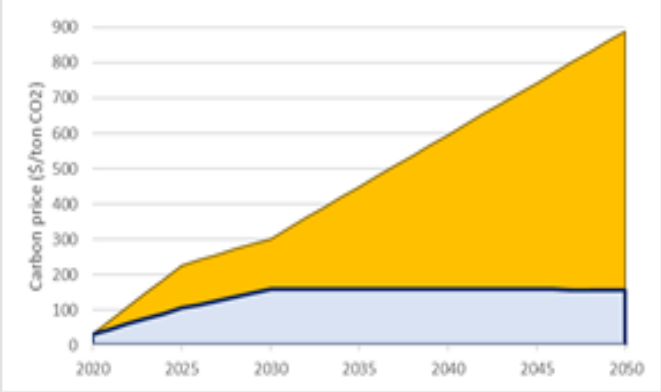
Apart from the RHI subsidy, the government also offers a Green Grant that covers up to 2/3 of the cost of chosen improvements, with a maximum government contribution of GBP 5,000.

Source: U.K. Department for Levelling Up, Housing & Communities.

Figure 25. United Kingdom: Carbon Price Paths for Analysis of Transition Risk in U.K. Residential Mortgages

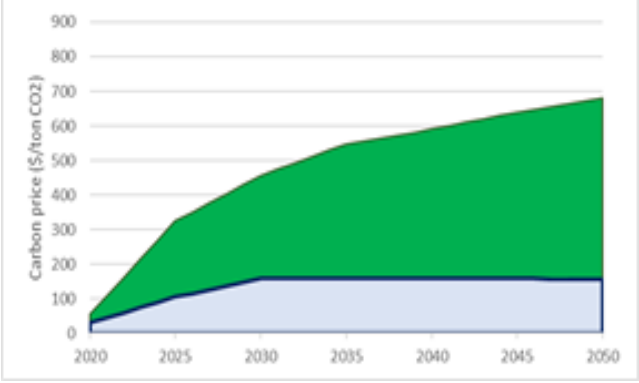
Carbon prices reach higher levels in Europe towards the end of the horizon …

Carbon Price Path in Europe: NZ2020 vs NDC



But they grow more rapidly in the first years, resulting in a stronger impact (after discounting)

Carbon Price Path in Europe: DNZ vs NDC

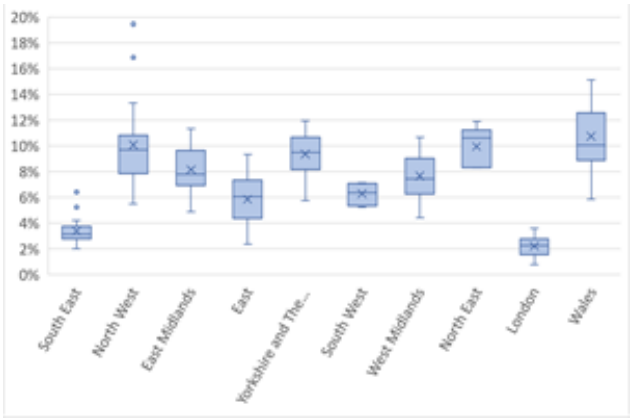


Source: NGFS.

Figure 26. United Kingdom: Impact of Carbon Prices on Residential Properties' Valuation via Energy and Energy Efficiency Costs

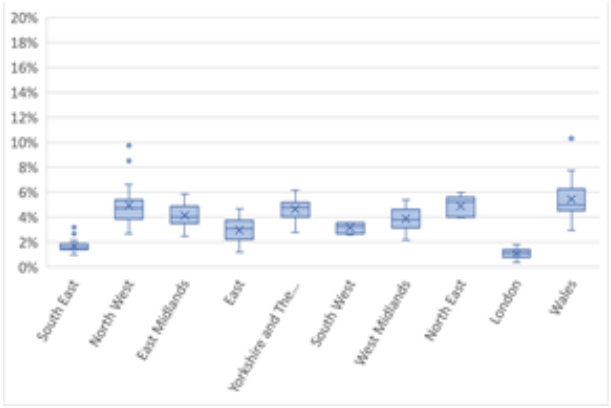
Distribution of impacts on properties' valuation across local areas (grouped by region) under the combination DNZ + MAX cost + 100% carbon price pass-through rate …

Potential House Price Drop at the Climate Minsky Point



And with the carbon price pass-through rate lowered to 50%

Potential House Price Drop at the Climate Minsky Point



Source: EPC database, IMF staff.

124. The impacts on property valuations are then mapped into banks' IFRS 9 LGD estimates. This is done by considering the distribution of mortgage loans by LtV and assuming unchanged probabilities of default (PDs). Given the relatively high degree of mortgage collateralization for the banks considered (with LtV >100 percent in less than 1 percent of the portfolios), the final impacts in terms of LGD are very small (with LGDs increasing no more than half of a percentage point) under the 'best case' combination of assumptions, and still small but non-negligible—considering the low starting point of LGDs—under the 'worst case' combination (with LGDs increasing by almost 1 percentage point, on average).[73] This would translate in an increase of loan loss provisions, in aggregate, between 5.6 percent (under the 'best case' combination) and almost 17 percent (under the 'worst case').

125. While the results of this sensitivity analysis do not appear, per se, as potentially destabilizing for the financial system, it is important to highlight some caveats. First, it is plausible that the mortgagees' PDs might increase at a climate Minsky point, thus contributing to the increase in loss provisions; however, this falls outside the current analysis, based exclusively on considerations about asset valuations. Secondly, the banks considered are national players with mortgage portfolios that are geographically well-diversified; a repetition of this analysis on banks with smaller and less diversified portfolios could be useful to explore potential concentration risks. Finally, the results are highly dependent on the degree of overcollateralization of the mortgage portfolios, which could be different outside of the sample considered.

B. Physical Risk

126. Two 'smaller scale' exercises have also been run to capture some specific, circumscribed impacts of physical risk. For 'chronic' physical risk (i.e., the reduction in GDP levels and growth rates caused by global warming), a sensitivity analysis has been run on banks' sovereign bond portfolios. For acute physical risk (intensification of natural disasters because of climate change) a sensitivity analysis has been conducted on general insurers' technical reserves (see Table 9).

Sovereign Bond Holdings

127. The sensitivity analysis on banks' sovereign portfolios is based on a simulation of the evolution of sovereign ratings up to 2050. The analysis investigates how a change in sovereign ratings under a scenario with limited CO2 emission reduction—and, hence, unmitigated climate change—could impact the banks' holdings of government bonds, following the same 'climate Minsky moment' logic of the transition risk analysis.[74] The 'adverse' scenario is represented by the Representative Concentration Pathway (RCP) 8.5, with global mean surface temperature (GMST)

[73] The average accounting LGDs of the banks in the sample are generally low, far lower than 10 percent in most cases.

[74] In this case the asset price correction affecting all marketable assets is assumed to be caused by the market agents' realization that, in the absence of more ambitious climate policies, the impact of physical risk on asset valuations is going to be (much) higher than currently incorporated in prices.

increasing up to 2.2°C above pre-industrial levels in 2050.[75] The analysis is based on a study that simulates the effect on sovereign credit ratings of chronic physical risk caused by climate change (via the increase in GMST and its variability) at various time horizons.[76] The migration to different credit ratings is then translated into changes in credit spreads, based on current rating-based country risk premia.[77] Sovereign bond holdings are then repriced by applying to their cash flows discount rates that incorporate the change in credit spreads.[78]

128. The impact on banks' sovereign bond portfolios is strongly dependent on assumptions about the future variability of global surface temperature. The change in credit spreads (because of rating migration) could determine an overall modest drop of 0.6 percent in the aggregate value of banks' sovereign bond portfolios at the climate Minsky point, with individual bank results ranging from 0.3 percent to 1.2 percent. However, if the increase in mean temperature is accompanied by an analogous increase in its variability, the average impact on sovereign bond portfolios could rise to 3 percent, with half of the banks experiencing an impact larger than 5 percent.

Insurers' Technical Reserves

129. Physical risks of climate change materialize in the insurance sector most visibly through major loss events because of natural disasters but focusing exclusively on these events underestimates the overall impact. Natural disasters are typically tail events, and climate change is seen to increase the severity and frequency of some of these perils, most notably tropical windstorms, wildfires, and coastal flooding. However, climate change also encompasses various long-term trends that challenge the pricing and reserving of general insurers, such as changes in precipitation, extreme weather variability, sea level rise, and rising mean temperatures. Additionally, climate change can also impact the value of investment assets, e.g., real estate in coastal areas. Finally, climate change is also becoming a concern for the underwriting of life and health insurers as heatwaves occur more frequently, thereby affecting mortality and morbidity, and tropical vector-borne diseases spread more widely. Given the predominantly domestic nature of U.K. life insurance business, this is less of a concern now.

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[75] The Representative Concentration Pathways (RCPs) are a set of four pathways developed for the climate modeling community as a basis for long-term and near-term modeling experiments (see van Vuuren et al. 2011, The representative concentration pathways: an overview). RCP 8.5 is the one with the steepest GMST path, with its median projection reaching more than 4°C above pre-industrial levels by 2100. It is now widely considered a very unlikely scenario, even in the absence of further ambition on decarbonization (see, for example, Hausfather and Peters, Emissions—the 'business as usual' story is misleading, 2020). However, over the 2020–2050 horizon, adopted in the present analysis, it can be considered realistic, as it produces a median GMST path that is very close to that of the NDCs or 'Current Policies' NGFS scenarios.

[76] Iusak et al. (2021), Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Credit Worthiness. The paper is largely based on a cross-country estimation of the relationship between global temperature (and its variability) and GDP levels and growth rates by Kahn et al. (2019), Long-term macroeconomic effects of climate change: A cross-country analysis.

[77] Country risk premia by rating class are drawn from A. Damodaran's 'Country Default Spreads and Risk Premiums' webpage (https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html).

[78] Changes in credit spreads are estimated at year 2030 and 2050. Linear interpolation is used for the in-between years, while sovereign spreads are assumed to not change further beyond 2050.

130. U.K. general insurers are exposed not only to domestic perils, but through their international footprint and specifically the London market to natural disasters worldwide. The largest exposures of the eight general insurers and reinsurers in the sample are towards US hurricanes and European windstorms—for those, the expected mean annual loss amounts to GBP 2.3bn and 0.8bn. However, for more extreme events with lower probability of occurrence, the loss amounts increase massively: The 1-in-200-year annual loss for a US hurricane and a European windstorm amounts to GBP 26bn and 13bn, respectively, before reinsurance. Compared to these two risks, the expected mean annual loss related to domestic floods is a more modest GBP 0.4bn (or GBP 5bn for the 1-in-200-year event) (Figure 27, left chart). It is noteworthy that a large share of extreme losses is mitigated through reinsurance or retrocession—effectively only around 30 percent of the losses of a 1-in-200-year event would be borne by the U.K. insurer who underwrote that risk (Figure 27, right chart). Most of these reinsurance contracts are with foreign reinsurers, located in Bermuda, the EU, Switzerland, or the United States.

131. The FSAP analyzed the statistical loss distribution if the severity and/or frequency of natural disaster perils were to increase. The sensitivity analysis is not linked to a specific path of climate change or carbon emissions, but instead assumes a parametric increase in the severity and/or frequency of 10/30 percent for US hurricanes, European windstorms, and U.K. floods. U.K. insurers which use an internal model for calculating their capital requirement must report certain model outputs to the PRA, which include per peril the occurrence loss and the annual loss at specific points of the tail distribution, both before and after reinsurance. Based on the model points, the full loss distribution was estimated, simulating 1,000 loss years. For the severity of each loss event, a gamma and a beta distribution were used while the estimation of the frequency followed a Poisson distribution. In a subsequent simulation, both the severity and the frequency were than adjusted to derive a new tail distribution after stress.

132. The combination of higher severity and frequency of natural disasters will considerably increase future annual losses of general insurers (Figure 28). Assuming a 30 percent increase in each of the two parameters, the mean annual loss before reinsurance would increase by up to 50 percent, without any major differences between the three perils.

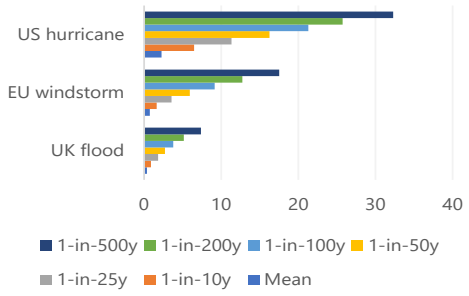
133. The net impact, after reinsurance, cannot be estimated precisely as bespoke reinsurance contracts can include various features of non-proportionality. For the U.K. flood event, general insurers tend to reinsure large shares of their risk exposure up to a very point far out in the tail. A different approach, however, is used by some insurers for the risk related to European windstorms—those use reinsurance covers with a cap which results in a higher retention rate for certain low-probability, high-impact events.

Figure 27. United Kingdom: Insurers' Exposures to Physical Climate Risks

While mean annual expected losses from natural disasters appear manageable, more remote events can become very costly, e.g., GBP 26bn for the 1-in-200-year US hurricane (before reinsurance).

Annual Expected Losses

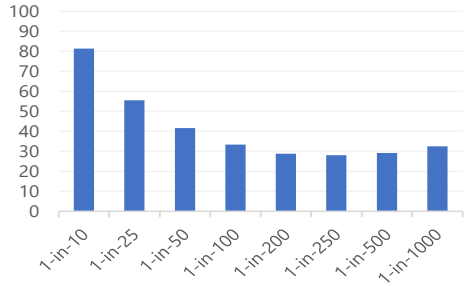
(In GBP bn., gross before reinsurance)



Risks from more frequent extreme events are retained by domestic insurers, while more than 70 percent of the losses from a 1-in-200-year event would be recovered from (mostly international) reinsurers.

Expected Annual NatCat Losses – Retained

(In percent, net to gross loss)



Sources: IMF staff calculations based on PRA data.
Notes: Stress test participants only.

Figure 28. United Kingdom: Physical Climate Risks in Insurance

The mean annual loss for the three perils would increase by up to 50 percent if the frequency and severity would increase by 30 percent each.

US Hurricane

(change in mean occurence loss, gross)

Frequency \ Severity	+10%	+30%
+10%	+9 - 10%	+28 - 29%
+30%	+9 - 10%	+30 - 31%

US Hurricane

(change in mean annual loss, gross)

Frequency \ Severity	+10%	+30%
+10%	+13 - 14%	+33%
+30%	+21 - 22%	+44 - 45%

European Windstorm

(change in mean occurence loss, gross)

Frequency \ Severity	+10%	+30%
+10%	+9 - 18%	+28 - 40%
+30%	+8 - 11%	+29 - 32%

European Windstorm

(change in mean annual loss, gross)

Frequency \ Severity	+10%	+30%
+10%	+13 - 24%	+34 - 47%
+30%	+23 - 25%	+47 - 50%

UK Flood

(change in mean occurence loss, gross)

Frequency \ Severity	+10%	+30%
+10%	+9 - 14%	+29 - 33%
+30%	+9 - 10%	+29 - 30%

UK Flood

(change in mean annual loss, gross)

Frequency \ Severity	+10%	+30%
+10%	+14 - 19%	+35 - 39%
+30%	+25%	+48 - 49%

Sources: IMF staff calculations based on PRA data.

Notes: The tables present ranges of losses, determined by two different estimates of loss distributions, a gamma, and a beta distribution.

Other Climate Risks

134. While the U.K. plays a leading role in the analysis of climate risks for the insurance sector, the global supervisory community and the insurance sector alike still face modeling challenges and a more comprehensive strategic view is required. Data gaps still exist in the supervisory world, e.g., insurance exposures split by peril and geography, as well as correlations and interdependencies. Insurers themselves often consider climate change predominantly as a catastrophe risk which is a too narrow perspective. Interdependencies and indirect risks, e.g., the impact of extreme weather variability on global supply chains, require closer attention. As a further shortcoming, many climate impact models assume that economies will fully adapt, which is a rather optimistic assumption given the current state of adaptation across the world. Climate models suggest that adapting later will be significantly more expensive and, in some cases, hardly possible. And while a growing number of insurers has adopted transition risk strategies, only few have a strategy for litigation risk or adaptation. Finally, climate risk disclosures are expanding, but due to still rather heterogenous approaches investors face difficulties in systematically incorporating those disclosures into their own investment and risk management–at the same time, many smaller companies still must catch up in their approach to disclosures.

Box 7. Flood Re

The United Kingdom's Flood Reinsurance Scheme (Flood Re) provides domestic flood reinsurance coverage. It is a joint initiative of the U.K. Government and the insurance industry, established by the Water Act 2014, and operational through its main vehicle, Flood Re Limited since April 2016. Its purpose is to promote the availability and affordability of flood insurance for eligible homes, and to manage the transition to a risk-sensitive pricing for household flood insurance which should be reached by 2039. Reinsurance cover is offered at a subsidized fixed rate to U.K. household insurers, which results for Flood Re Limited in an expected underwriting loss every year—effectively, though, the company earned profits before tax of GBP 142m and GBP 61m in the financial years 2020/21 and 2019/20, respectively. The expected loss, as well as Flood Re's cost for retrocession, is financed through a GBP 180m levy on U.K. household insurers.

As a subsidy scheme and a measure to reduce the protection gap, Flood Re has so far been quite successful. Since 2016, GBP 67m in claims were paid out, thereby benefitting more than 350,000 households. Availability of household insurance has considerably improved in flood risk areas, and 80 percent of households with previous flood claims pay now at least 50 percent less premiums.

The company's SCR ratio is very high as of March 2021, but due to the nature of the business also very volatile. At the end of the financial year 2020/21, the coverage of the SCR stood at 1,251 percent, up by more than 700 percentage points from the previous year (though partly driven by a switch from the standard formula to an internal model which led the PRA to waive the previously prescribed capital add-on). Asset-side risks are minor with cash and short-term deposits accounting for 93 percent of total assets, and regionally concentrated underwriting risks are largely mitigated through retrocession.

Going forward, it will be critical to introduce increasingly risk-sensitive elements to avoid cliff effects at the end of the scheme's projected lifetime in 2039. Flood Re evaluates its strategy and the effectiveness of the regime every five years in consultation with external stakeholders and public bodies. The last review in 2019 proposed new mechanisms which Flood Re expects to incentivize the implementation of property flood resilience measures more widely, including:

'Build Back Better', i.e., claims payments would include an additional amount for resilient repair, which would typically exceed the cost of the original damage.

Discounted premiums to reward households that have adapted their homes to be more resilient to flooding.

Furthermore, the levy on ceding insurers could be reviewed on a three-year cycle in line with the procurement of Flood Re's reinsurance program, which might potentially reduce the levy in the future. In response to the review, the Department for Environment, Food and Rural Affairs (DEFRA) has initiated and consulted an amendment of the Flood Re scheme in early 2021.

Sources: IMF staff based on Flood Re's disclosures.

C. Recommendations

135. To remain at the frontier of climate-related analyses in the financial sector, the Bank of England should accelerate the development of its own analytics. In the past years, the BOE has led the global effort to fully incorporate the consideration of climate change in the financial industry and in the day-to-day activity of central banks and financial regulators. Since the pathbreaking speech of then Governor Carney at Lloyd's in September 2015,[79] through the launch of (and significant support to) the Network for Greening the Financial Sector (NGFS), up to the ongoing Climate Biennial Exploratory Scenario, it has often blazed the trail for the international central bank and financial regulatory community. It can remain at the frontier of the increasingly intense dialogue on climate-related risks in the financial system by complementing its current framework with more investments on its own internal analytical tools: in particular, it could equip itself with a suite of in-house models (at macro, sectoral, and micro level), allowing to run independent (top-down) scenario-based analyses of the impact of climate-related risks on financial institutions—as a few other central banks have recently done—and, in perspective, their propagation across the whole financial system. It will also be important to deepen the understanding of how financial firms' climate-related risks will be influenced by public policies, particularly for transitions risks (e.g., use of revenues from carbon taxes, energy efficiency measures, other decarbonization policies), but also for physical risks (e.g., future role of Flood Re and general disaster prevention policies).

136. The PRA should develop further guidance for insurance companies on the risks that should be considered in their Own Risk and Solvency Review (ORSA), which should include indirect climate risks and litigation risks. Indirect effects of climate change are still to be fully understood both by insurers and supervisors. An important aspect which is relevant for the U.K.—being a reinsurance hub—is the vulnerability of global supply chains to more frequent or more severe weather events. Second-order effects of such disruptions could lead to substantial claims in business interruption policies and even have significant macroeconomic implications. Additionally, as U.K. insurers are also very active in liability insurance, it is crucial to fully understand the climate-related risks covered by corporate liability insurance as well as Directors and Officers (D&O) policies. Litigation risks are difficult to quantify for insurance supervisors in a top-down climate stress test, and hence were excluded from this FSAP's stress test. Industry practice needs to emerge on how to measure litigation risks—as a stand-alone risk or as a component of transition risk— how to adequately reserve for it, considering recent developments in jurisprudence, and how to disclose it.

137. DEFRA should further promote the transition of Flood Re with a view to reward investments in flood resilience measures with premium reductions, and to introduce a build-back-better policy. Such policies normally require the definition of best-practice standards and certifications which should also be widely promoted.

[79] M. Carney (2015), The Tragedy of the Horizons.

Annex I. Risk Assessment Matrix

Risks[1]	Likelihood	Expected Impact of Risk
Conjunctural Shocks and Scenarios		
Global resurgence of the COVID-19 pandemic. Local outbreaks lead to a global resurgence of the pandemic (possibly due to vaccine-resistant variants), which requires costly containment efforts and prompts persistent behavioral changes rendering many activities unviable.	Medium	Demand for contact-intensive sectors remains low for longer. Firms face a prolonged increase in production costs. Corporate bankruptcies and longer-term unemployment increase, causing persistent scarring effects. Bank losses on domestic and cross-border exposures materialize due to higher debt service to income ratio for leveraged corporations and households. Banks' capital declines, in turn depressing the economic recovery with weaker credit growth for a prolonged period (second-round effects).
Disorderly transformations. COVID-19 triggers structural transformations, but the reallocation of resources is impeded by labor market rigidities, debt overhangs, and inadequate bankruptcy resolution frameworks. This, coupled with a withdrawal of Covid-19-related policy support, undermines growth prospects, and increases unemployment, with adverse social/political consequences. Adjustments in global value chains and reshoring (partly driven by geostrategic and national security concerns) shift production activities across countries.	Medium	Reshuffling of global value chains increases production costs and contributes to inflation. Permanent reshoring and less trade reduce potential output. Prolonged unemployment and protracted corporate insolvencies weigh on banks' asset quality.

Risks	Likelihood	Expected Impact of Risk
De-anchoring of inflation expectations in the U.S. leads to rising core yields and risk premia. A fast recovery in demand (supported by excess private savings and stimulus policies), combined with Covid-19-related supply constraints, leads to sustained above-target inflation readings and a de-anchoring of expectations. The Fed reacts by signaling a need to tighten earlier than expected. The resulting repositioning by market participants leads to a front-loaded tightening of financial conditions and higher risk premia, including for credit, equities, and emerging and frontier market currencies.	Medium	Higher debt service and refinancing costs lead to increasing defaults among corporates and households and mounting credit losses. A severe price correction in the real estate market leads to losses on residential and commercial real estate loans. Higher interest rates could lead to mark-to-market losses on debt securities.
Rising commodity prices amid bouts of volatility. Commodity prices increase by more than expected against a weaker U.S. dollar, post-pandemic pent-up demand and supply disruptions, and for some materials, accelerated plans for renewable energy adoption. Uncertainty surrounding each of these factors leads to bouts of volatility, especially in oil prices.	Medium	A persistent rise in the price of imports passes through to U.K. domestic inflation. Volatility in financial markets and a rise in risk premia leads to an increase in debt service burden for banks' counterparts and losses in banks' bond portfolios
Structural Risks		
Cyber-attacks on critical infrastructure, institutions, and financial systems trigger systemic financial instability or widespread disruptions in socio-economic activities and remote work arrangements.	Medium	Disruptions in the real economy and in financial services undermine consumer and business confidence and negatively affect asset quality. Amid concerns about counterparty risk funding market freeze and risk premia spike.
Higher frequency and severity of natural disasters related to climate change cause severe economic damage to smaller economies susceptible to disruptions and accelerate emigration from these economies. A sequence of severe events in large economies reduces global GDP and prompts a recalculation of risk and growth prospects. Disasters hitting key	Medium	Damages from increasingly frequent and severe hazards (esp. floods in the U.K.) and from increasing surface temperatures and extreme weather events (out of the U.K.) affect the probabilities of default of corporates and

infrastructure or disrupting trade raise commodity price levels and volatility.		households and the value of their collateral, leading to an increase in banks' credit losses. The global policy response to mounting evidence of climate change impact on the economy leads to a sharp acceleration of the transition to a low-carbon economy, determining a drastic reassessment of asset values and causing significant losses in equity and bond portfolios with large concentrations in high-carbon sectors.
Stronger impact from Brexit. Greater implementation disruptions in the short term, and greater trade frictions with the EU (due to perceived regulatory divergence and EU location policies) and loss of financial and professional service business in the medium term.	Medium	Market fragmentation increases the cost of financial services and the continuing uncertainty about the adjustment path leads to a decrease in business investment and weighs on potential growth.

[1]The Risk Assessment Matrix (RAM) shows events that could materially alter the baseline path. The relative likelihood is the staff's subjective assessment of the risks surrounding the baseline ("low" is meant to indicate a probability below 10 percent, "medium" a probability between 10 and 30 percent, and "high" a probability between 30 and 50 percent). The RAM reflects staff views on the source of risks and overall level of concern as of the time of discussions with the authorities. Non-mutually exclusive risks may interact and materialize jointly. The conjunctural shocks and scenario highlight risks that may materialize over a shorter horizon (between 12 to 18 months) given the current baseline. Structural risks are those that are likely to remain salient over a longer horizon.

Annex II. Dynamics of Corporate Balance Sheets

Corporates' key financial indicators are summarized on three financial statements: i) income statement, ii) cash flow statement, and ii) balance sheets, as shown in Table A1. Financial indicators are based on availability in the ORBIS data and follow ORBIS definitions. Table A2 describes the approaches in determining major financial indicators and calculating liquidity and equity gaps, with firm-level regression analysis presented in Table A3. Table A2 also reflects the accounting identities and connections among three financial statements in Table A1.

Annex II. Table A1. Key Financial Indicators

Income Statement	Cash Flow Statement	Balance Sheets
Operating revenue (sales)	Cash from operation	Assets
Cost of goods sold	Net income	Current assets
Intermediate inputs	Depreciation	Fixed assets
Cost of labor	Change in receivable	Liabilities
Other operating expense	Change in payable	Current liabilities
Depreciation	Change in inventory	Non-current liabilities
Net interest expense	Cash from investment	Equity
Taxation	Change in fixed assets	
Net income	Change in financial assets	
	Cash from financing	
	New financing	
	Dividend / stock buyback	
	Debt principal payment	

Source: ORBIS

Annex II. Table A2. Estimation of Key Financial Indicators

Cash flow items	Balance sheets items	Estimation approach (No policy)	Adjustment for policy or crisis impact
Net income		Regression*	CJRS**, grant, and business rates relief
Depreciation	Fixed assets	Firm-specific historical pattern (ratio to fixed assets)	
Change in receivable	Current assets	No change	
Change in payable	Current liabilities	No change	
Change in inventory	Current assets	No change	
Debt principal payment	Liabilities	Firm-specific historical pattern (ratio to total liabilities)	
Change in fixed assets	Fixed assets	Firm-specific historical pattern (ratio to total assets)	Match to depreciation if negative cash flow
New financing	Liabilities/Equity	Regression*	Adjust new financing based on the growth rate of MFIs' gross lending to NFCs by sector
Dividend / stock buyback	Equity	No change	
Change in financial assets	Current assets	Match to residual cash flow	

Source: IMF

* The growth rate of operating revenue (sales) is projected to match the sectoral GVA growth rate. Then, firm-specific indicators related to sales are calculated accordingly.

** Labor cost is estimated based on firm-specific historic pattern on cost to sales ratio. If missing, this item is proxied by sectoral averages.

Annex II. Table A3. Firm-Level Regressions

	Return on assets (ROA)		Liability to assets ratio (Lev)	
	(1)	*(2)*	*(3)*	*(4)*
lag ROA	0.596***	0.548***	-0.117***	-0.174***
lag Lev	-0.0211***	-0.0689***	0.656***	0.620***
relative size	-0.000485***	-0.0000206	-0.000419***	0.0000884**
fixed asset	-0.0445***	-0.000332	0.0104	-0.0191**
gen sales		0.0751***		0.0757***
lag gen sales	0.00500***		0.00914***	
sales growth		0.186***		0.0429***
lag sales growth	-0.0894***		-0.0820***	
sectoral GVA growth	0.221***	0.190***	0.132**	0.110**
NEER growth	0.0121	0.00233	-0.0732	0.255**
FTSE index growth				0.398***
inflation	1.429**	1.262***	1.912**	1.025*
oil price growth	-0.0522**	-0.0515**	-0.0617*	
lending rate	-0.0720**	-0.0663**	-0.0682	-0.111**
FCI	-0.00367		-0.00788	0.0970***
policy rate	0.0823**	0.0720**	0.0782*	0.107**
house price growth				0.00791***
Constant	0.0412***	-0.0785***	0.162***	0.0578**
Observations	1,508,768	1,508,768	1,508,768	1,508,768
R-squared	0.427	0.528	0.452	0.504
Fixed effect	By sector	By sector	By sector	By sector
Standard errors	Robust Clustered by year	Robust Clustered by year	Robust Clustered by year	Robust Clustered by year

Source: IMF staff calculations.

Note: *** (**) (*) denotes 1 (5) (10) percent significance level.

Annex III. Banking Sector Stress Test Matrix

Banking Sector: Solvency Test			
Domain		**Framework**	
		Top-down by FSAP Team	**Bottom-up by Bank of England[1]**
1. Institutional perimeter	Institutions included	Eight major banks and building societies.	Eight major banks and building societies.
	Market share	Approximately 75 percent of PRA-regulated banks' lending to the United Kingdom real economy.	Approximately 75 percent of PRA-regulated banks' lending to the United Kingdom real economy.
	Data and baseline date	Effective date: end-December 2020. Data: Banks' submissions as part of the Annual Cyclical Scenario (ACS), performed by the BOE, FINREP, COREP, HBRD. [2] Scope of consolidation: Global consolidated group basis, except for Santander U.K. plc, whose parent is supervised by a foreign authority[1].	Effective date: end-December 2020. Data: Banks' submissions as part of 2021 solvency stress test but banks will not be requested to submit baseline projections. Scope of consolidation: Global consolidated group basis, except for Santander U.K. plc, whose parent is supervised by a foreign authority.
2. Channels of risk propagation	Methodology	IMF Solvency Stress Test Workbox (Balance-sheet based approach)	Standard BOE approach that uses a dynamic balance sheet approach. Solvency stress test also includes a traded risk stress that is calibrated to be consistent with the shocks in the macro scenario.
	Satellite Models for Macrofinancial linkages	A comprehensive battery of econometric models. Credit Risk: Satellite models that link credit risk variables with macroeconomic variables per asset class for domestic exposures and per geographical location for foreign exposures. Different sample periods are considered in the estimations, including, and excluding 2020. When 2020 is	Banks use their own models to comprehensively project their P&L and capital results. The Bank also uses its own set of econometric models to form a judgment around

		included a dummy variable for the quarters affected by the pandemic is added as a regressor. Selected models are used to project loan losses under various scenarios. The estimates are augmented with the output of the corporate stress testing exercise. Market risk: valuation losses from full revaluation of sovereign securities, corporate fixed income debt securities and equity holdings are calculated using a Mark to Market (MTM) approach for fair-valued securities. Valuation losses of securities held at amortized cost are calculated using a credit risk approach. Valuation changes in open positions in foreign currency, commodities and equities are estimated based on fluctuations in the exchange rate, the commodity prices, and the equity prices under the scenarios. Interest rate risk: A gap analysis is conducted based on data on the asset/liability structure of individual banks broken into types of funding sources and time to re-pricing buckets. Interest margin shocks vary per scenario. Other P&L components: Interest income is calculated via estimation and projection of lending/borrowing rates (via satellite models), applied to new and variable rate loans. Residual income components (e.g., net fee and commission income) are either estimated via satellite models. Non-performing loans do not generate any income. Macrofinancial feedback effects. The team developed a parallel exercise that accounts for macrofinancial feedback effects following a framework similar to Catalan and Hoffmaister (2020). The exercise is comprised of two modules that are integrated with the Workbox: Credit Growth model: Elasticities of credit growth to macroeconomic variables and bank sector variables (CAR and NPL).	reasonableness of banks' results. These will be used for the 2021 solvency stress test. Credit Risk: A range of internal stress test models are used to project credit losses. The mechanics of the individual models vary, but each one takes various economic scenario variables as inputs, and ultimately aims to project credit impairment charge over the horizon. Model outputs are not necessarily used directly, but instead help us to form judgements on results, and the reasonableness of submissions received from participating firms. Three internal models cover U.K. mortgages (each designed differently, and so giving alternative views). Two alternate models cover corporate exposures, again primarily focusing on U.K. exposures. Interest rate risk: A gap analysis is conducted based on granular data on asset/liability structure of individual banks and time to re-pricing buckets. Net interest income: Net interest income will be calculated via estimation and projection of lending/borrowing rates. Other P&L components: Residual income components (e.g., net fee and commission income) will be either estimated/projected or assumed to stay at the level observed for 2020. Non-performing loans will not generate any income.

		SVAR (Structural Vector Auto Regression): Elasticities of macroeconomic variables to aggregate bank loan.	
	Stress test horizon	5 years (2021-2025)	5 years (2021-2025)
3. Tail shocks	Scenario analysis	Three macroeconomic scenarios (baseline and two adverse) agreed with the authorities The baseline scenario is based on the October 2021 WEO projections. Scenario 1: Adverse with scarring. The pandemic recedes in the first half of 2021 as vaccination campaigns pick up, yet later in the year it becomes clear that new variants of the virus will continue to emerge across the world with increasing frequency. The new strains prove to be even more contagious or pathogenic, and resistant to existing vaccines and therapies. With the adaptation of vaccines taking longer than anticipated the pandemic is assumed to be under control not earlier than late 2022 for advanced economies, including The United Kingdom., and by the end of 2023 for the rest of the world. Global trade is depressed as asynchronous resurgences of the pandemic disrupt international supply chains and precipitate an acceleration of de-globalization (e.g., permanent reshoring, vaccine nationalism, long-lasting travel bans). Weaker global economy activity prompts sharp increases of risk premia, which in turn expose financial and fiscal vulnerabilities. Domestically, difficulties in adjusting to the new U.K.-EU agreement prove to be more severe than expected and further lower GDP growth over the short-term. Over the medium and long term, further market fragmentation increases the cost of financial services in the EU and the United Kingdom. The continuing uncertainty about the adjustment path leads to a decrease in business investment and weighs on potential growth. Despite the brief easing of COVID-related restrictions in the middle of the year, the compound effects of the pandemic and the post-Brexit adjustments results in real GDP growth of only 0.5 percent in	One macroeconomic scenario. The adverse scenario used for the 2021 solvency stress test is a severe path for the economy in 2021–25 on top of the economic shock associated with the COVID pandemic that occurred in 2020. It is broadly consistent with the 'double-dip' scenario generated in the FPC's reverse stress test of August 2020 and represents an intensification of the macroeconomic shocks seen in 2020. The traded risk stress will be consistent with the macroeconomic scenario – but there will be no separate traded risk scenario. The global stress causes financial market participants' perceptions of risk to increase, and their risk appetite to diminish. Credit risks rise in several markets. As in previous tests, participating banks will be asked to submit stressed misconduct costs for known issues.

		2021. Amid the intensifying pandemic real GDP recovers by only 1.6 percent in 2022. The scenario is also characterized by an increase in unemployment and a drop in residential and commercial real estate prices. Scarring in the medium term is manifested by lower potential output growth by 0.3 percent with respect to the pre-COVID period and higher natural unemployment rate. Scenario 2. Adverse with sudden tightening of global financial conditions. With the pandemic in the global rearview mirror, consumer spending picks up, supported by the drawdown of savings accumulated during the pandemic (for continuously employed workers) and by government support that is receding only gradually (for workers in industries affected by lockdowns). Meanwhile, low investment during the pandemic, business failures, as well as skill mismatches on the labor market reduce global spare capacity. As the global recovery proceeds, energy and commodity prices rise on a sustained basis. The push by many countries to localize key value chains (including but not limited to medical products) reduces the role of globalization as a driver of productivity gains and disinflation. Cautious not to stifle the nascent recovery, major central banks around the world accommodate rising inflationary pressures in the near term, with the Fed showing the greater inflation tolerance among AE central banks in line with its new monetary policy framework. Thus, while policy rates remain near zero, term premia rise sharply as markets revisit inflation expectations, leading to an abrupt increase in the borrowing cost of corporates and sovereigns. This tightening of global financial conditions weighs further on already-low post-pandemic investment while unemployment, despite some initial improvement resulting from the relaxation of containment measures, remains elevated. Central banks finally raise short term rates rapidly [by 2022/2023] while uncertainty about the pace of quantitative tightening creates upwards pressure on	

		term premia and long-term rates, exerting financial strains on households with variable rate mortgages. Equity prices, which are flat over the near term due to the improvement in economic prospects counterbalancing the rise in long-term rates, decline as policy tightening becomes inevitable. In the United Kingdom, a reduction is risk appetite of foreign investors leads to sterling depreciation and further contributes to goods price inflation. Like the baseline, potential output recovers as pandemic-related supply restriction ease, yet intensifying supply-side snags prevent its full recovery to the pre-COVID path. The adverse scenarios are simulated using the IMF's Global Macro financial Model (GFM).	
4. Risks and buffers	Positions/risk factors assessed	<u>Credit risk (provision costs)</u> Estimated according to Basel III framework. Credit risk includes: (i) lending risk from exposures to sovereign, public entities, financial institutions, corporates, and other; (ii) mortgage-related lending. Positions include cross-border loan exposures; (iii) retail lending. <u>Sovereign risk</u> Mark-to-market valuation of securities (from shocks to interest rates and credit spreads) in trading book and Available for Sale/Fair Value Option (AFS/FVO) linked to macro scenario. <u>Market risk other than sovereign risk</u> Market stress from shocks to changes in interest rates, credit spreads, exchange rates, commodities, and equity prices. <u>Profits</u> Interest income declines for lost income from defaulted loans. Interest rate risk in the banking book Interest expenses increase due to rising funding costs linked to the macroeconomic scenario with empirically estimated pass-through. Net fee and commission income, other income and non-interest expense evolve with macroeconomic conditions.	<u>Credit risk (provision costs)</u> Estimated according to Basel III framework. Credit risk includes all credit risk exposures to ensure the entirety of balance sheet is captured. <u>Market risk</u> Direct losses due to market moves for fair valued banking book positions and on trading book positions Equity and debt including leveraged loans underwriting positions. Investment banking revenues. Losses from large single name defaults and defaults in specific groups of smaller counterparties. Changes in valuation adjustments, principally CVA, FVA and PVA. Changes to market risk, counterparty credit risk and CVA RWAs. <u>Profits</u>

		No change in business models (no rebalancing of portfolio)	Banks' submissions should reflect their corporate plans, including any cost or business changes. These should be adjusted appropriately to reflect changes in the expected performance and execution of these plans in the stress scenario, including business-as-usual management actions 2021 solvency stress test will include a comprehensive of banks' profit projections that will include: Net interest income. Investment banking income. Net fee and commission income and other income expenses. Misconduct costs and other non-underlying costs.
	Behavioral adjustments	Balance sheet growth assumptions: Loan portfolios are assumed to grow uniformly across the in-scope banks at the nominal GDP growth rate of the scenarios, with no change in composition (except for new NPLs). Balance sheet composition remaining constant over the stress test horizon. Banks can only accumulate capital through retained earnings. Maturing assets are replaced by exposures of the same type and risk. Statutory tax rates. Dividends are linked to banks' net profits. Under positive profits and capital ratios above hurdle rates, the dividend payout is set at 30 percent. Otherwise, no dividend payout is assumed. If a bank's capital ratio falls below regulatory minimum during the stress test horizon, no prompt corrective action is assumed.	Balance sheet size and composition is dynamic. Banks' submissions should reflect their corporate plans, including any cost or business changes. These should be adjusted appropriately to reflect changes in the expected performance and execution of these plans in the stress scenario, including business-as-usual management actions and strategic management actions. Banks' stock of secured lending to U.K. individuals, consumer credit to U.K. individuals and lending to U.K. PNFCs should increase in each year of the stress projection by at least the growth rates provided by the Bank for these asset

		Management actions are not incorporated.	classes. The published growth rates assume there are no provisions or write-offs during the stress period. Effective tax rates. In the 2021 stress test, banks should include ordinary dividend payments that they project their boards would approve in the stress scenario There is no mechanical link between the stress test results and the setting of capital buffers or other regulatory response, the Bank will consider each bank's capital low point against their hurdle rates.
5. Regulatory and market-based standards and parameters	Calibration of risk parameters	<u>Parameter definition</u> Point-in-Time (PiT) PDs and LGDs for expected losses (numerator of the capital ratio) and Through-the-Cycle TtC PDs and LGDs for RWA (denominator). Transition rates between stages 1-2-3 (under IFRS 9) are inferred from available information. Domestic Corporate PDs are also derived from the output of the corporate stress test exercise, as a robustness check. <u>Parameter calibration</u> PDs and LGDs evolve with the macroeconomic and financial variables of the scenario.	<u>Parameter definition</u> Internal credit models will project PiT PDs and LGDs. Risk weighted assets are not modelled internally, and we do not have internal projections of regulatory parameters (TTC PDs, downturn LGDs etc.). However, participating firms do model these aspects, submit them as part of their projections. IFRS 9 stage transitions are again not modelled internally, and we do not request them as part of the results submission. <u>Parameter calibration</u> PDs and LGDs evolve with the macroeconomic and financial variables of the scenario.
	Regulatory standards	Capital definition according to Basel III/PRA rulebook, including CET1, Tier 1, and total CAR. Hurdle rates: Pillar 1 and 2A CET1 Requirements plus systemic buffers (G-SIB, O-SII, and SRB); leverage ratio requirements.	Capital definition according to Basel III/PRA rulebook – CET1, Tier 1 and Total capital ratios as defined in the CRR and end-point Tier 1

		Results are reported on a fully loaded basis, i.e., IFRS9 transitional arrangements are not accounted for.	leverage ratio as per the U.K. leverage ratio framework Banks are required to apply IFRS 9 in their starting position and throughout the projection period. Hurdle rates/Reference points: Pillar 1 and 2A CET1 Requirements plus systemic buffers (G-SIB and SRB).
6. Reporting format for results	Output presentation	Evolution of CET1, Tier 1, CAR for the aggregate banking system. Decomposition of key drivers to aggregate net profits and aggregate CET1 capital ratios. Cumulative impairment charges by bank for The United Kingdom. and other specific countries impacted by the scenario. Number of banks and share of total assets below hurdle rates.	Individual firm-by-firm results from the stress test will published in Q4 2021. As in previous years, the Bank is committed to disclosing as much information as necessary to explain the results of the stress test. This will include at least as much bank-specific information about the headline impact of the stress on capital adequacy as was in the 2019 stress-test results publication (e.g., bank specific impairment charges and traded risk losses) Aggregate information will also be published in Summer 2021. The Q4 publication will also include details of the impact of the stress on the U.K. banking system in aggregate, including a decomposition of key drivers to aggregate changes in the CET1 and Tier 1 leverage ratio and further details of aggregate impairments by asset class and geography.

Refers to the 2021 Solvency Stress Test exercise rather than Annual Cyclical Scenario (ACS). Key differences with respect to the ACS are that the latter includes baseline projections and the approach to traded risk is different.

[1] Santander UK is the only subsidiary of foreign G-SIBs included, given its important domestic footprint, particularly in retail banking, with its assets largely funded locally and relatively limited integration with the rest of the group.

[2] de-Ramon, S., Francis, W., Milonas, K. (2017) An overview of the U.K. banking sector since the Basel accord: Insights from a Regulatory Database. Bank of England Staff Working Paper SWP 652, March 2017.

Annex IV. Liquidity Stress Test—Assumptions

Annex IV. Table 1. Stressed LCR: Haircut Scenarios (percent)

	Scenario 1	Scenario 2	Scenario 3
Total Unadjusted Liquid Assets			
Total Unadjusted Level 1 Assets			
Total unadjusted level 1 assets excluding extremely high-quality covered bonds			
Coins and banknotes	100	100	100
Withdrawable central bank reserves	100	100	100
Central bank assets	100	100	100
Central government assets	100	100	95
Regional government / local authorities' assets	100	95	90
Public Sector Entity assets	100	95	90
Recognizable domestic and foreign currency central government and central bank assets	100	100	100
Credit institution (protected by Member State government, promotional lender) assets	100	100	100
Multilateral development bank and international organizations assets	100	100	90
Qualifying CIU shares/units: underlying is coins/banknotes and/or central bank exposure	100	100	100
Qualifying CIU shares/units: underlying is Level 1 assets excluding extremely high-quality covered bonds	95	95	85
Alternative Liquidity Approaches: Central bank credit facility	100	100	100
Central institutions: Level 1 assets excl. EHQ CB which are considered liquid assets for the depositing credit institution			
Alternative Liquidity Approaches: Inclusion of Level 2A assets recognized as Level 1	80	80	80
Total unadjusted level 1 extremely high-quality covered bonds			
Extremely high-quality covered bonds	93	90	85
Qualifying CIU shares/units: underlying is extremely high-quality covered bonds	88	80	80
Central institutions: Level 1 EHQ covered bonds which are considered liquid assets for the depositing credit institution		80	80
Total Unadjusted Level 2 Assets			
Total unadjusted level 2A assets			
Regional government / local authorities or Public Sector Entity assets (Member State, RW20)	85	75	70
Central bank or central / regional government or local authorities or Public Sector Entity assets (Third Country, RW20)	85	80	70
High quality covered bonds (CQS2)	85	70	50
High quality covered bonds (Third Country, CQS1)	85	80	60
Corporate debt securities (CQS1)	85	80	70
Qualifying CIU shares/units: underlying is Level 2A assets	80	70	60
Central institutions: Level 2A assets which are considered liquid assets for the depositing credit institution			
Total unadjusted level 2B assets			
Asset-backed securities (residential, CQS1)	75	70	60
Asset-backed securities (auto, CQS1)	75	70	60
High quality covered bonds (RW35)	70	60	50
Asset-backed securities (commercial or individuals, Member State, CQS1)	65	60	55
Corporate debt securities (CQS2/3)	50	40	30

Annex IV. Table 1. Stressed LCR: Haircut Scenarios (concluded)

	Scenario 1	Scenario 2	Scenario 3
Corporate debt securities - non-interest-bearing assets (held by credit institutions for religious reasons) (CQS1/2/3	50	30	30
Shares (major stock index)	50	25	0
Non-interest-bearing assets (held by credit institutions for religious reasons) (CQS3-5)	50	50	50
Restricted-use central bank committed liquidity facilities	100	100	100
Qualifying CIU shares/units: underlying is asset-backed securities (residential or auto, CQS1)	70	60	50
Qualifying CIU shares/units: underlying is high quality covered bonds (RW35)	65	60	55
Qualifying CIU shares/units: underlying is asset-backed securities (commercial or individuals, Member State, CQS1)	60	60	60
Qualifying CIU shares/units: underlying is corporate debt securities (CQS2/3), shares (major stock index) or non-interest-bearing assets (held by credit institutions for religious reasons) (CQS3-5)	45	40	35
Deposits by network member with central institution (no obligated investment)	75	75	75
Liquidity funding available to network member from central institution (non-specified collateralization)	75	75	75
Central institutions: Level 2B assets which are considered liquid assets for the depositing credit institution			

Annex IV. Table 2. Stressed LCR: Outflows Scenarios 1-4 (percent)

		Scenario 1	Scenario 2	Scenario 3	Scenario 4
		Regulatory	Retail	Wholesale	Retail & Wholesale
Outflows					
Outflows from Unsecured Transactions/Deposits					
Retail deposits					
deposits where the payout has been agreed within the following 30 days		100	100	100	100
deposits subject to higher outflows					
deposits subject to higher outflows	category 1	10	20		20
	category 2	15	30		30
stable deposits		5	10	5	10
derogated stable deposits		3	5	3	5
deposits in third countries where a higher outflow is applied					
other retail deposits		10	20	20	20
Operational deposits					
maintained for clearing, custody, cash management or other comparable services in the context of an established operational relationship					
maintained for clearing, custody, cash management or other comparable services in the context of an established operational relationship	covered by DGS	5	10	15	15
	not covered by DGS	25	25	35	35
maintained in the context of IPS or a cooperative network					
maintained in the context of IPS or a cooperative network	not treated as liquid assets for the depositing institution	25	35	25	35
	treated as liquid assets for the depositing credit institution	100	100	100	100
maintained in the context of an established operational relationship (other) with non-financial customers		25	25	35	35
maintained to obtain cash clearing and central credit institution services within a network		25	25	25	25
Non-operational deposits					
correspondent banking and provisions of prime brokerage deposits		100	100	100	100
deposits by financial customers		100	100	100	100
deposits by other customers					
deposits by other customers	covered by DGS	20	20	40	40
	not covered by DGS	40	40	60	60
Additional outflows					
collateral other than Level 1 assets collateral posted for derivatives		20	30	30	30
Level 1 EHQ Covered Bonds assets collateral posted for derivatives		10	25	25	25
material outflows due to deterioration of own credit quality		100	20	20	20
impact of an adverse market scenario on derivatives, financing transactions and other contracts					
impact of an adverse market scenario on derivatives, financing transactions and other contracts	hlba approach	100	100	100	100
	amao approach	100	100	100	100
outflows from derivatives		100	100	100	100
short positions					

Annex IV. Table 2. Stressed LCR: Outflows Scenarios 1-4 (continued)

			Scenario 1	Scenario 2	Scenario 3	Scenario 4
			Regulatory	Retail	Wholesale	Retail & Wholesale
short positions	covered by collateralized SFT		0	0	0	0
	other		100	100	100	100
callable excess collateral			100	100	100	100
due collateral			100	100	100	100
liquid asset collateral exchangeable for non-liquid asset collateral			100	100	100	100
loss of funding on structured financing activities						
loss of funding on structured financing activities	structured financing instruments		100	100	100	100
	financing facilities		100	100	100	100
assets borrowed on an unsecured basis			100	100	100	100
internal netting of client´s positions			50	50	50	50
Committed facilities						
credit facilities						
	to retail customers		5	10	5	10
	to non-financial customers other than retail customers		10	10	20	20
	to credit institutions					
		for funding promotional loans of retail customers	5	10	10	10
		for funding promotional loans of non-financial customers	10	20	20	20
		other	40	60	60	60
	to regulated institutions other than credit institutions		40	75	75	75
	within a group or an IPS if subject to preferential treatment					
	within IPS or cooperative network if treated as liquid asset by the depositing institution		75	100	100	100
	to other financial customers		100	100	100	100
liquidity facilities						
	to retail customers		5	15	10	15
	to non-financial customers other than retail customers		30	40	50	50
	to personal investment companies		40	50	50	50
	to SSPEs					
		to purchase assets other than securities from non-financial customers	10	10	10	10
		other	100	100	100	100
	to credit institutions					
liquidity facilities		for funding promotional loans of retail customers	5	15	10	15
		for funding promotional loans of non-financial customers	30	40	50	50
		other	40	50	50	50
	within a group or an IPS if subject to preferential treatment					
	within IPS or cooperative network if treated as liquid asset by the depositing institution		75	100	100	100
	to other financial customers		100	100	100	100
liabilities resulting from operating expenses			0	0	0	0
in the form of debt securities if not treated as retail deposits			100	100	100	100
others			100	100	100	100

Annex IV. Table 2. Stressed LCR: Outflows Scenarios 1-4 (concluded)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Regulatory	Retail	Wholesale	Retail & Wholesale
Outflows From Secured Lending and Capital Market-Driven Transactions				
Counterparty is central bank				
level 1 excl. EHQ Covered Bonds collateral	0	0	0	0
level 1 EHQ Covered Bonds collateral	0	0	0	0
level 2A collateral	0	0	0	0
level 2B asset-backed securities (residential or automobile, CQS1) collateral	0	0	0	0
level 2B covered bonds	0	0	0	0
level 2B asset-backed securities (commercial or individuals, Member State, CQS1) collateral	0	0	0	0
other Level 2B assets collateral	0	0	0	0
non-liquid assets collateral	0	0	0	0
Counterparty is non-central bank				0
level 1 excl. EHQ Covered Bonds collateral	0	0	0	0
level 1 EHQ Covered Bonds collateral	7	7	7	7
level 2A collateral	15	15	15	15
level 2B asset-backed securities (residential or automobile, CQS1) collateral	25	25	25	25
level 2B covered bonds	30	30	30	30
level 2B asset-backed securities (commercial or individuals, Member State, CQS1) collateral	35	35	35	35
other Level 2B assets collateral	50	50	50	50
non-liquid assets collateral				0
non-liquid assets collateral — counterparty is central govt, PSE<=RW20, MDB	25	25	25	25
non-liquid assets collateral — another counterparty	100	100	100	100

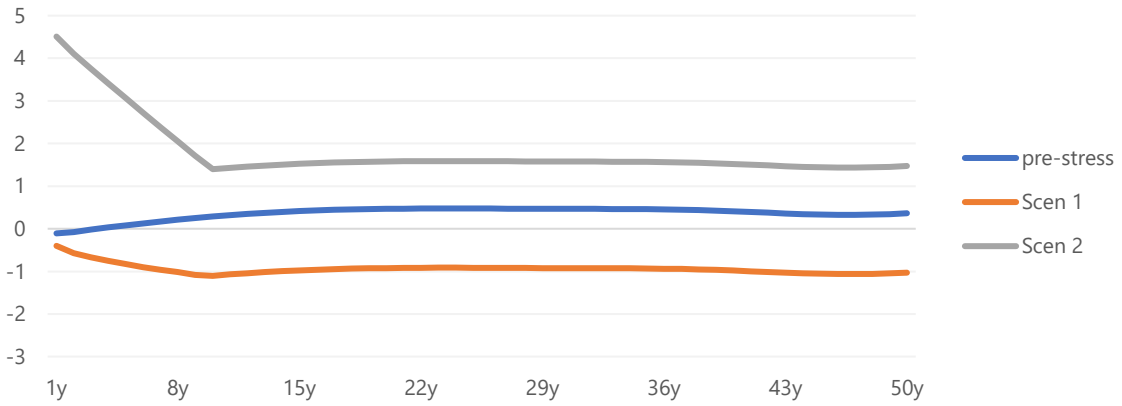
		Top-Down by IMF
Insurance Sector: Solvency Risk		
1. Institutional perimeter	Institutions included	• 8 life insurance groups. • 6 general insurance groups.
	Market share	• Life: 71 percent (gross premiums written) • Non-life: 70 percent (gross premiums written)
	Consolidation	• Group level
	Data	• Regulatory reporting
	Reference date	• December 31, 2020
2. Channels of risk propagation	Methodology	• Investment assets: market value changes after price shocks, affecting the solvency position • Insurance liabilities: impact on value of the best estimate by changing discount rate of future cash flows, proportionate change also for the risk margin • Recalculation of required capital after stress: approximated by the Solvency II standard formula also for internal model users
	Time horizon	• Instantaneous shock
3. Tail shocks	Scenario analysis	• Scarring scenario: o risk-free interest rates (without volatility adjustment) -29 bps (1y GBP), -139 bps (10y GBP); -44 bps (1y EUR), -180 bps (10y EUR); -12 bps (1y USD), -143 bps (10y USD). o sovereign bond spread +80 bps (domestic), +70 bps for other low-yield advanced economies, up to +160 bps for emerging and developing economies. o stock prices -19.5 percent (domestic), -25.0 percent (United States and Euro area), -15.0 percent (other advanced economies), -25.0 percent (emerging and developing economies). o property prices -14.6 percent (domestic, residential), -29.7 percent (domestic, commercial), -10.0 percent (foreign, residential), -18.0 percent (foreign, commercial). o corporate bond spreads between +70 bps (AAA, non-financials) and +290 bps (B and lower, non-financials), and between +85 bps (AAA, financials) and +320 bps (B and lower, financials) • Tightening of financial conditions: o risk-free interest rates (without volatility adjustment) +462 bps (1y GBP), +111 bps (10y GBP); +335 bps (1y EUR), +61 bps (10y EUR); +240 bps (1y USD), +68 bps (10y USD). o sovereign bond spread +50 bps (domestic), +30 bps for other low-yield advanced economies, up to +180 bps for emerging and developing economies. o stock prices -15.8 percent (domestic), -15.0 percent (United States and Euro area), -15.0 percent (other advanced economies), -30.0 percent (emerging and developing economies). o property prices -8.4 percent (domestic, residential), -20.1 percent (domestic, commercial), -6.0 percent (foreign, residential), -8.2 percent (foreign, commercial).

		Top-Down by IMF
Insurance Sector: Solvency Risk		
		○ corporate bond spreads between +40 bps (AAA, non-financials) and +320 bps (B and lower, non-financials), and between +70 bps (AAA, financials) and +360 bps (B and lower, financials)
	Sensitivity analysis	• Default of largest financial counterparty
4. Risks and buffers	Risks/factors assessed	• Market risks: interest rates, share prices, property prices, credit spreads • Credit risks: default of largest financial counterparty • Summation of risks, no diversification effects
	Buffers	• Solvency II long-term guarantee measures and transitionals: ○ Matching Adjustment (MA) ○ Transition on Technical Provisions (TMTP) • Unit-linked life insurance: Investment losses borne by policyholders
	Behavioral adjustments	• None
5. Regulatory standards and parameters	Regulatory/ accounting standards	• Solvency II • National GAAP
6. Reporting format for results	Output presentation	• Impact on valuation of assets and liabilities • Impact on solvency ratios (including and excluding the effect of long-term guaranteed measures and transitionals) • Contribution of individual shocks to changes of eligible own funds • Dispersion measures of solvency ratios • Capital shortfall and possible de-risking of investment assets to re-establish a full coverage of solvency requirements
Insurance Sector: Liquidity Risk		
1. Institutional perimeter	Institutions included	• 5 life insurance groups: Aviva Group, Legal & General Group, M&G Group, Royal London Group, Scottish Widows Group
	Market share	• Life: 51 percent (balance sheet assets)
	Data	• Regulatory reporting
	Reference date	• December 31, 2020
2. Channels of risk propagation	Methodology	• Revaluation of derivative positions after interest rate shock,
	Time horizon	• Instantaneous (1 day, 5 days)
3. Tail shocks	Scenario analysis	• None
	Sensitivity analysis	• Parallel shift of the interest rate term structure (for all currencies): +25 bps, +50 bps, +100 bps
4. Risks and buffers	Risks/factors assessed	• Liquidity risk: Margin calls for interest rate swaps
	Buffers	• None
	Behavioral adjustments	• None

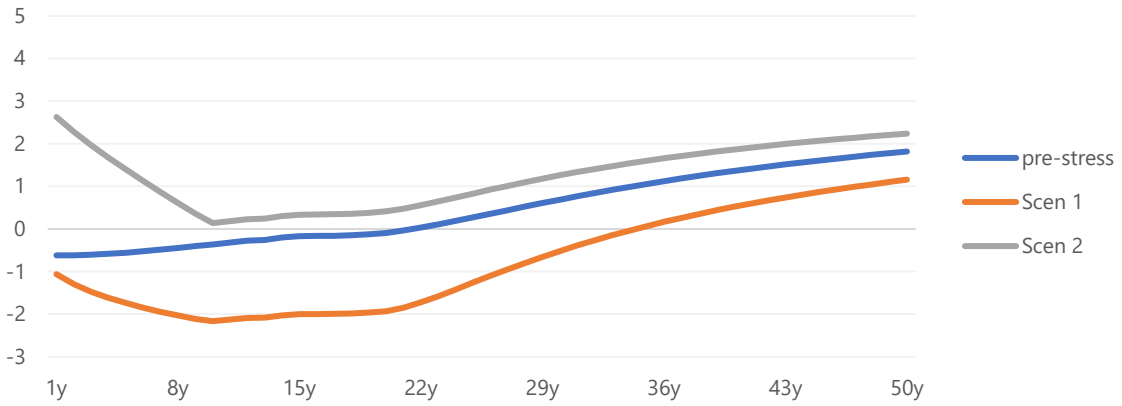
		Top-Down by IMF
Insurance Sector: Solvency Risk		
5. Regulatory standards and parameters	Regulatory/ accounting standards	• Solvency II • National GAAP
6. Reporting format for results	Output presentation	• Total amount of variation margin calls • Variation margin as percent of cash holdings • Variation margin as percent of high-quality liquid assets

Annex VI. Insurance Interest Rate Scenarios

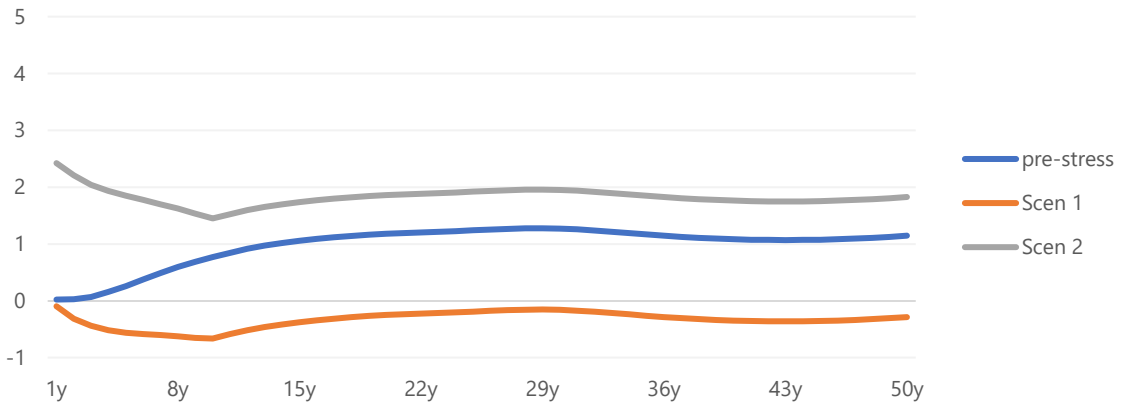
Risk-free Rate Term Structure - GBP
(in percent, without volatility adjustment)



Risk-free Rate Term Structure - EUR
(in percent, without volatility adjustment)



Risk-free Rate Term Structure - USD
(in percent, without volatility adjustment)



Source: IMF staff.

Annex VII. Integration of Models for Transition Risk Analysis and Mapping to Financial Institutions' Credit and Market Losses

138. The integration of results between the GTAP-E and CCA simulations is obtained as follows.

- Gross Value Added by sector ('s') and country ('c') at each time ('t') over the horizon is obtained, in CCA, by aggregation of proxy company-level GVA, both for BASE and ADV scenarios:

- [1],[2]

$$GVA_{s,c,t}^{BASE,CCA} = \sum_{i \in s \cap c} GVA_{i,t}^{BASE,CCA}$$

$$GVA_{s,c,t}^{ADV,CCA} = \sum_{i \in s \cap c} GVA_{i,t}^{ADV,CCA}$$

- Sector-wide GVA under the ADV scenario is adjusted by applying the percentage deviation from the baseline, for each sector/country at any given time, obtained from GTAP-E:

$$\overline{GVA}_{s,c,t}^{ADV,CCA} = GVA_{s,c,t}^{BASE,CCA} \cdot \Delta\%GVA_{s,c,t}^{ADV vs BASE,GTAP-E}$$

- The difference between the GTAP-E-adjusted GVA and the GVA originally calculated in CCA for the sector/country is then calculated:

$$\Delta GVA_{s,c,t}^{ADV} = \overline{GVA}_{s,c,t}^{ADV,CCA} - GVA_{s,c,t}^{ADV,CCA}$$

- This GVA difference at the sector/country level is then allocated back to the companies within the sector/country in proportion to the company revenues. The original stress GVA and this new

[1] The proxy for GVA at company level is obtained by adding estimated employee costs to the company level EBITDA. Employee costs are estimated since they are not commonly reported separately in corporate financials and are based on average ratios with respect to GVA by industry and region. The impact of any bias from the approximation is mitigated using deviations between two GVA proxies calculated the same way – as opposed to the absolute values.

[2] 'Country' is to be interpreted as single country (U.K., US, China, Japan), jurisdiction (EU), or wider area (rest of Asia and rest of the World), with the aggregation decided based on the relevance of different countries/areas for U.K. financial institutions. For the sake of simplicity, the term 'country' (and suffix 'c') is used indistinctively for countries and areas.

adjusted stress GVA are then compared to compute a company-level scaling factor for each company ('i'):[3]

$$sf_{i,t}^{ADV} = \frac{\overline{GVA}_{i,t}^{ADV,CCA}}{GVA_{i,t}^{ADV,CCA}}$$

- The scaling factor is then applied to the free cash flows to equity (FCFEs) calculated in CCA for each company, to obtain adjusted FCFEs. These are then discounted back to the climate Minsky point (cMp), with the discount factor dependent on each company' sector (for the risk premium) and country (for both risk-free rate and risk premium). The discount factors are kept constant throughout the evaluation horizon, at the current (i.e., end-2020) level.[4] A terminal value (TV) at 2050 is calculated for each company as the book value of the company equity in the terminal year, projected by CCA.

- Finally, the net present value (NPV) of FCFEs is obtained, at the cMp, as the sum of discounted cash flows and the discounted terminal value.

$$NPV_{i\,(i\in s\cap c),t=cMp}^{ADV} = \sum_{t=cMp}^{2050} \frac{FCFE_{i,t}^{ADV} \cdot sf_{i,t}^{ADV}}{\left(1+rfr_c+RP_{s,c}\right)^{t-cMp}} + \frac{TV_{i,2050}^{ADV}}{\left(1+rfr_c+RP_{s,c}\right)^{2050-cMp}}$$

- An equivalent calculation is performed for the NPV under the BASE scenario, by using FCFEs and TVs under the BASE and with no scaling factors applied.

139. The difference between the NPV under ADV and BASE scenarios represents the estimated change in the market value of equity (ΔMVE) for each firm at the cMp. To obtain a percentage change in MVE (Δ%MVE), a 'calculation hierarchy' is applied: it gives priority to market capitalization, when available, as the denominator; then to the book value of equity when market capitalization is not available; then to the calculated NPV under BASE (if positive) when neither market capitalization nor book value of equity are available. Finally, in the residual cases (i.e., when NPV is negative under the BASE), the percentage change in MVE is either set at -100 percent (when NPV under ADV is negative and lower than NPV under BASE) or equaled to the sectoral average (when NPV under ADV is positive).[5] All percentage changes in MVE are floored at -100 percent

[3] Note that in some cases a company may belong to multiple sectors. Here, where possible, the financials are separated between the sectors and separate scaling factors are calculated for each sector of business activity. This is done for companies within the oil and gas sector.

[4] The only exception being the sensitivity analysis mentioned in the main text, in which all risk premia are increased by ½.

[5] A negative NPV for an existing and active company under the BASE scenario at the cMp is not necessarily to be interpreted as a sign of negative equity, as it could be the result of differences in the valuation of the company with respect to that implicit in market quotations.

(which corresponds to a situation where the whole equity value is wiped out) and capped at a calibrated cap.[6]

140. The percentage change in MVE directly represents the expected impact on equity holdings at the cMp. Financial institutions' equity holdings are shocked individually (when the issuing company is modelled in CCA) or, alternatively, based on the sector/country average percentage change in MVE. The share of firms in a country/sector that would experience a -100 percent change in the market value of their equity (considered as defaulting), represents the new probability of default, which, combined with the existing LGD, determines the extra credit losses to be expected at the cMp in loan portfolios.

141. For corporate bond holdings, a Merton-like extension is adopted to infer the change in credit spreads at the cMp. The percentage change in MVE is used to update the estimate of the market value of assets (MVA), which, in turn, leads to a recalculation of the 'distance to default' (DtD), assuming an unchanged volatility of MVA and default point (DP). The relationship between the market value of equity and the market value of assets (given a certain volatility of MVA and default point, linked to the company's debt) is based on Merton's intuition that the value of a firm's equity can be interpreted as a call option on the underlying market value of the company's assets, with a strike price linked to the company's debt (a threshold below which the company would become insolvent, i.e. the option would be 'exercised'):

$$MVE_{i,t} = f\left(MVA_{i,t}; \overline{DP}_{i,t}, \bar{\sigma}_{i,t}^{MVA}\right)$$

The inverse of the function linking MVE to MVA is used to infer the value of MVA, under both the BASE and ADV scenario:

$$MVA_{i,t=cMp}^{BASE} = f^{-1}\left(MVE_{i,t=cMp}^{BASE}; \overline{DP}_i, \bar{\sigma}_i^{MVA}\right)$$

$$MVA_{i,t=cMp}^{ADV} = f^{-1}\left(MVE_{i,t=cMp} \cdot \left(1 + \Delta\%MVE_{i,t=cMp}\right); \overline{DP}_i, \bar{\sigma}_i^{MVA}\right)$$

The 'distance to default' is a synthetic measure of a company's MVA distance from the default point, standardized for the volatility of MVA, and is computed under both scenarios:

$$DtD_{i,t=cMp}^{BASE} = \frac{MVA_{i,t=cMp}^{BASE} - \overline{DP}_i}{\bar{\sigma}_i^{MVA} \cdot MVA_{i,t=cMp}^{BASE}}$$

$$DtD_{i,t=cMp}^{ADV} = \frac{MVA_{i,t=cMp}^{ADV} - \overline{DP}_i}{\bar{\sigma}_i^{MVA} \cdot MVA_{i,t=cMp}^{ADV}}$$

Finally, the change in DtD is calculated as the difference between DtD under the ADV and BASE scenarios:

[6] The cap is calibrated to compensate for the -100 percent floor and approximately align the average change in MVE with the sum of the discounted GDP deviations between ADV and BASE scenarios.

$$\Delta DtD_{i,t=cMp} = DtD^{ADV}_{i,t=cMp} - DtD^{BASE}_{i,t=cMp}$$

The change in the distance to default determines a new market-based probability of default and a potential migration to a new credit rating. When a rating migration happens, the corporate spread is assumed to adjust to reflect the new credit rating, determining a change of credit spread that is used to reprice, via full revaluation, the financial institutions' holdings of corporate bonds.

142. In particular, the credit risk impact linked to a specified climate Minsky moment scenario was obtained through the following steps:[7]

i) Estimation of the current (implied) Merton-like Distance to Default (DtD) - by inverting the long-term PD/DtD relationship historically observed over the past 20 years; this relationship can be leveraged also to estimate a current DtD for private companies.

ii) Estimation of the new DtD, based on the current DtD and the market value of equity (MVE) impact linked to the chosen scenario: for this, an approach developed and patented by S&P Global Market Intelligence's Analytical Development Group was employed. Essentially, the approach calibrates a parametric relationship between the DtD impact and the change in market capitalization, based on a large, simulated dataset of public companies, under multiple changes in market capitalization and corresponding change in DtD. This relationship is then used to estimate the future DtD of a company (public or private), based on its current DtD and future change in equity value.

iii) The future PD was calculated by using the relationship between PD and DtD.

[7] The FSAP team would like to express its gratitude to Giorgio Baldassarri (Standard & Poor's) for the support provided in these calculations.