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FINANCIAL SECTOR ASSESSMENT PROGRAM

June 2016

STRESS TESTING THE BANKING SECTOR—TECHNICAL NOTE

This Technical Note on Stress Testing the Banking Sector on the 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 in May 2016.

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STRESS TESTING THE BANKING SECTOR

Prepared By
Monetary and Capital Markets Department

This Technical Note was prepared in the context of an IMF Financial Sector Assessment Program (FSAP) in the United Kingdom in November 2015 and February 2016 led by Dimitri Demekas. It contains technical analysis and detailed information underpinning the FSAP findings and recommendations. Further information on the FSAP program can be found at http://www.imf.org/external/np/fsap/fssa.aspx

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Glossary

AFS	Available for sale
BoE	Bank of England
BPS	Basis Points
BU	Bottom-up (stress test)
CAR	Capital adequacy ratio
CCDS	Core capital deferred shares
CCoB	Capital conservation buffer
CCR	Counterparty credit risk
CCyB	Countercyclical buffer
CDS	Credit default swap
CET1	Core Equity Tier 1
COREP	Common Reporting
CRD	Capital Requirements Directive (EU)
CRE	Commercial real estate
CRM	Comprehensive risk measure
CRR	Capital Requirements Regulation (EU)
CVA	Credit valuation adjustment
DSGE	Dynamic stochastic general equilibrium
DWF	Discount window facility
EA	Euro area
EaD	Exposure at default
ECB	European Central Bank
EDF	Expected default frequency
EL	Expected loss
EU	European Union
FPC	Financial Policy Committee
FSAP	Financial Sector Assessment Program
FSR	Financial Stability Report
FSSA	Financial System Stability Assessment
FVO	Fair-value option
FX	Foreign Exchange
GAs	Global assumptions
GDP	Gross domestic product
G-SIB	Global Systemically Important Bank
HFT	Held for trading
HK	Hong Kong
HQLA	High-quality liquid assets
HTM	Held to maturity
HY	High yield

IFS	International Financial Statistics
IG	Investment grade
ILG	Individual liquidity guidance
IMM	Internal models (approach)
IRB	Internal ratings-based (approach)
IRC	Incremental risk change
LCR	Liquidity coverage (ratio)
LGD	Loss-given default
LIBOR	London Interbank Offered Rate
LTD	Loan-to-deposit (ratio)
LTV	Loan-to-value (ratio)
MLAR	Mortgage Lenders and Administrators Return
NII	Net interest income
NIM	Net interest margin
NPL	Nonperforming loan
P&L	Profit and loss
PCA	Principal component analysis
PD	Probability of default
PiT	Point-in-time
PNFC	Private non-financial corporation
pps	Percentage points
PRA	Prudential Regulatory Authority
PTB	Price-to-book (ratio)
PVA	Prudent valuation adjustment
RAM	Risk Assessment Matrix
ROA	Return on assets
ROE	Return on equity
RWA	Risk-weighted assets
SME	Small- and medium-sized enterprises
STA	Standardized (approach)
STeM	Stress test matrix (for FSAP stress tests)
sVaR	Stressed value at risk
TD	Top-down (stress test)
TTC	Through-the-cycle
USD	United States dollar
VAR	Vector autoregression
VaR	Value at risk
VIX	Volatility index
WEO	World Economic Outlook
Yoy	Year-on-year
YTM	Yield to maturity

EXECUTIVE SUMMARY

For the 2016 United Kingdom FSAP, a comprehensive range of stress tests were conducted to assess the resilience of the U.K. banking system. The top-down (TD) solvency stress test conducted by the FSAP covered seven major U.K. banks and building societies representing over 80 percent of Prudential Regulatory Authority (PRA)-regulated banks' lending to the real economy. The FSAP stress scenario focused on a broad-based dislocation in financial markets, with sizeable jumps in yield curves and spillovers to vulnerable emerging market economies. This scenario, which could be triggered *inter alia* by disorderly monetary normalization in the U.S., explores in some detail the market impact from severe valuation losses from internationally-correlated shocks in credit spreads and term premia. The FSAP solvency stress test complements the 2015 concurrent stress test of the Bank of England (BoE), which covered the same set of banks and focused on a different global shock. In addition, the FSAP team used its own models and analysis to cross-validate bottom-up (BU) submissions on selected portfolios for the 2015 BoE concurrent stress test. Lastly, a suite of liquidity stress tests were also conducted for 10 large firms, including three large U.K. foreign-headquartered investment banks. The variety of scenarios, cut-off dates, stress testing cycles, and analytical models addresses model risk concerns and helps assess U.K. banking system resilience against a broad range of stresses crystallizing on different horizons.

The FSAP stress test results suggest that major U.K. banks are resilient to a global economic downturn and to broad-based shocks in financial markets. Under the FSAP stress scenario, the aggregate Core Equity Tier I (CET1) ratio falls from 12.6 percent in December 2015 to a low point of 8.7 percent. The leverage ratio falls from 5.3 percent in December 2015 to a low point of 4.0 percent. In aggregate, banks incur substantial losses, amounting to GBP 35 billion, in the first two years of the stress scenario, but all covered banks continue to meet prudential requirements throughout the stress test horizon. Risk-weighted assets (RWAs) peak in 2017 with a 2.3 percentage points (pps) hike. Moreover, single-factor sensitivity tests conducted by the FSAP team in addition to the macroeconomic stress scenario reveal that risks in the U.K. mortgage book from a house price correction are contained, driven partly by the recent improvement in the distribution of loan-to-value (LTV) ratios.

A number of conservative assumptions were used in the FSAP stress tests. Key among them were the assumptions that administrative expenses would not decrease in the stress scenario; that economic hedges were not allowed to operate in the trading book; and that fee income was capped. The FSAP methodology also included an additional module to capture funding risk from the drying-up of market liquidity, with banks assumed to be unable to pass-through increases in funding cost to loan rates. Some of these assumptions were deliberately conservative choices, while others were driven by data constraints and the exigencies of a TD modeling approach.

Not surprisingly, given that the FSAP stress scenario focused on a global shock, major U.K. international banks appear relatively more vulnerable than U.K. domestic banks. The aggregate CET1 ratio of major U.K. international banks decreases by 4.3 pps at the peak of the FSAP stress scenario, compared to a decline of 2.6 pps for major U.K. domestic banks. This reflects international

banks' stressed impairment charges in their overseas exposures and larger mark-to-market losses in their securities portfolio related to sharp falls in assets prices.

A number of credit risk parameters estimated by the FSAP team are broadly comparable to those generated by participating banks under the BoE's 2015 concurrent stress test, providing some degree of independent validation of the results. The FSAP team applied an independent quantitative method to assess BU projections submitted by banks for the 2015 BoE concurrent stress test. Caution should be exercised when comparing BU and TD results due to differences in data, granularity, and modeling approach. Nonetheless, and bearing these caveats in mind, the FSAP team's analysis broadly confirms banks' BU calculations, although the FSAP team projections exhibit a somewhat more cyclical behavior.

U.K. banks' more stable post-crisis funding structures are reflected in the positive liquidity stress test results. A suite of liquidity stress tests was carried out by the BoE on scenarios calibrated by the FSAP team. The tests covered 10 large financial institutions: the seven large U.K. firms covered in the solvency stress test, plus three large U.K. subsidiaries of major foreign investment banks. All firms passed the liquidity coverage ratio (LCR) stress test under the current regulatory 80 percent hurdle rate for the standard Basel III scenario, as well as two tailored scenarios reflecting a U.K. retail deposit run and a U.K. wholesale event. All firms passed a five-day and a 30-day implied cash flow on an all-currency basis. In addition, single-currency analysis conducted by the PRA showed that all firms had sufficient liquid buffers in domestic currency and only a minor shortfall in foreign currency.

INTRODUCTION[1]

A. Stress Testing under the Financial Sector Assessment Program (FSAP)

1. The aim of the FSAP stress test is to assess the resilience of the banking sector as a whole rather than the capital adequacy of individual institutions. The FSAP approach to stress testing is essentially macroprudential: it focuses on the resilience of the broader financial system to adverse macrofinancial conditions rather than on the resilience of individual banks to specific shocks. The FSAP stress test ensures consistency in macroeconomic scenarios and metrics across firms to facilitate the assessment of the banking system as a whole. The stress test analysis is intended to help country authorities to identify key sources of systemic risk in the banking sector and inform macroprudential policies to enhance its resilience to absorb shocks. The FSAP stress test assesses solvency and liquidity risk and covers key risk types, including credit risk, market risk, sovereign risk, and funding risk.

2. The FSAP stress tests of the U.K. banking system should be seen in conjunction with the analysis undertaken by the BoE. The FSAP stress test scenarios cover the key macrofinancial risks identified in the FSAP's Risk Assessment Matrix (RAM) for the U.K., with additional scenarios or single-factor shocks included as necessary, and have a balance sheet cut-off date of December 2015. Nevertheless, to facilitate comparison between the 2015 BoE concurrent stress test result (that had a cut-off date of December 2014), the institutional perimeter of the two tests is the same.

3. As with all stress tests, the FSAP stress test results should be interpreted with caution. The FSAP stress test results on the U.K. banking system are based on data submitted by U.K. banks for FSAP purposes at the cut-off date of the stress test, December 2015. Notwithstanding the benefits from the submission of a dedicated data template, the data have not been subject to validation by the IMF. These data are complemented by market-based and publicly available data to support the FSAP team's calibration of quantitative projections. Despite the FSAP team's best efforts to build a consistent database, the cleaning, validation, matching, and reconciliation of risk data extracted from multiple data sources, and collected with different purposes and at different frequencies, is a complex exercise. This reflects the difficulties inherent in matching data from different sources. Moreover, major U.K. banks have been changing their business models relative to the crisis period to improve their profitability, enhance resilience, and comply with the new prudential regulatory framework. Structural shifts place further constraints on the reliability of past data to inform forward-looking projections. More generally, stress test scenarios typically replicate historical events or express extreme "tail events" based on an historical distribution, even though it is well known that the nature of crises is to have unanticipated shocks and unexpected interrelationships where the past offers limited guidance. While some nonlinear effects can be captured in stress tests, it is always possible that that unknown patterns emerge, especially if extreme shocks materialize.

[1] This technical note was prepared by Laura Valderrama, Monetary and Capital Markets Department, IMF.

B. Financial System Structure

4. The banking sector is a dominant part of the U.K. financial system, accounting for over 60 percent of total financial sector assets. The U.K. financial system, defined as the sum of financial assets owned by banks and nonbank financial institutions, was about GBP 20 trillion in April 2015, over 10 times U.K. annual GDP.[2] Excluding derivatives and cross-border exposures of foreign-owned bank branches, the total assets of the U.K. financial system are smaller, at GBP 13 trillion, of which GBP 8 trillion are held by banks.

5. The U.K. is a global financial hub. As of December 2015, there were 359 monetary financial institutions in the U.K., out of which 239 firms were foreign-headquartered. In terms of assets, U.K. banks' consolidated assets amounted to about GBP 5.7 trillion, whereas foreign banks' accounted for GBP 2.2 trillion, of which over GBP 1.7 trillion were foreign investment banks. In terms of exposures to the U.K. economy, U.K.-headquartered banks accounted for GBP 2.9 trillion of U.K. aggregate lending, with branches of foreign-headquartered banks contributing GBP 1.1 trillion and subsidiaries of foreign-headquartered banks about GBP 500 billion.

6. U.K.-headquartered banks feature a diverse range of business models and operate in a broad range of international markets. U.K.-headquartered banks can be categorized into three groups. The first two groups include the seven firms that took part in the 2015 concurrent BoE/PRA stress testing exercise, distinguished by geographic footprint: the first group has the major U.K. international banks (HSBC Holdings plc, Barclays plc, the Royal Bank of Scotland Group plc, and Standard Chartered plc), which accounted for GBP 4.1 trillion of aggregate assets as of December 2015; and the second group has the major U.K. domestic banks (Lloyds Banking Group plc, Santander U.K. plc, and Nationwide Building Society), with an aggregate balance sheet of GBP 1.2 trillion. All other U.K.-headquartered banks, including retail and investment banks, as well as building societies, are included in the third group, with aggregate assets of under GBP 300 billion.

7. The FSAP stress test was conducted on a global consolidated group basis,[3] (hereafter 'on a consolidated basis'). Although the Banking Reform Act of 2013 requires banking groups with core deposits[4] in excess of GBP 25 billion to ring-fence their core activities, this will not be implemented until January 2019. Therefore, for the purpose of the FSAP, the stress test was conducted on a consolidated basis.

[2] This compares with a ratio of 8.8 in the Netherlands, 5.6 in Switzerland, 6.4 in Japan, and 3.9 in the United States.
[3] Except for Santander UK plc, whose parent is supervised by a foreign authority.

[4] Core deposits include broadly deposits from individuals and small businesses.

C. FSAP Stress Testing Approach

8. The resilience of the U.K. banking system was assessed under the FSAP through both solvency and liquidity stress tests (Figure 1):

- The FSAP team performed its own TD solvency stress test, based on data submitted by the covered banks using the FSAP team's data templates as of December 2015, matched with publicly available data for the period 2016–20. This stress test complements the BoE/PRA concurrent stress test conducted in 2015 (and published in December 2015), based on end-2014 data for the period 2015–19. For details on the similarities and key differences of the BoE and FSAP solvency stress tests, see Box 1.

- The FSAP team solvency stress test includes a detailed stress test of the U.K. mortgage book drawing on estimations of outstanding balances for different LTV vintages, using a structural fair-value option Merton-based approach. The macro stress test has been complemented by single-factor sensitivity tests on a wide range of stressed U.K. residential property prices, and a stressed swap curve.

- The FSAP team applied an independent quantitative method to assess selected BU credit risk projections submitted by banks for the 2015 BoE concurrent stress test. The analysis focused on a subset of domestic and cross-border retail and wholesale portfolios.

- A battery of liquidity stress tests were performed by the BoE using scenarios and stress testing tools provided by the FSAP team to assess the resilience of large U.K. banks to a sudden withdrawal of funding. For consistency with the FSAP solvency stress test, liquidity stress tests were based on end-December 2015 data.

FSAP TEAM SOLVENCY STRESS TEST

A. Overview

9. The FSAP stress test includes all major U.K. banks, representing over 80 percent of PRA-regulated banks' lending to the real economy.[5] All major U.K. banks with total retail deposits equal to or greater than GBP 50 billion, whether on an individual or consolidated basis as of December 2015, are included. The coverage of the FSAP stress test is the same set of banks included in the 2015 BoE concurrent stress test. Specifically, seven banks and building societies are included: Barclays plc, HSBC Holdings plc, Lloyds Banking Group plc, Nationwide Building Society, the Royal Bank of Scotland Group plc, Santander UK plc, and Standard Chartered plc. This group includes two

[5] The aggregate size of banks covered in the FSAP stress test represents about 75 percent of total banking sector assets.

banks with partial government ownership, namely Lloyds Banking Group plc and the Royal Bank of Scotland Group plc.[6]

10. The stress test is based on granular data submitted by banks on the basis of a data template provided by the FSAP team. The template included granular credit risk information for exposures booked in the internal ratings-based portfolio (IRB) by Basel asset class, sectoral split, currency breakdown, and geography. In addition, the template included the breakdown of the securities portfolio at the security level, the duration of the debt portfolio, detailed information on open positions by market risk factor, the split of RWAs for market risk by category under the standardized approach (STA) and the internal models approach (IMM), projections of RWAs under the baseline and adverse scenarios, and maturity gaps for interest rate risk calculations.

11. Data submitted by banks were combined with publicly available data, drawing on a wide range of sources. To perform the stress testing analysis, the FSAP team matched banks' data at the cut-off date with a database of publicly available data to construct time series for all relevant variables feeding the stress testing models. Bank-by-bank data were sourced from individual bank Pillar 3 disclosures, Bankscope, SNL, Bloomberg, Datastream, Markit, and the 2015 EU-wide transparency exercise. Aggregate data were drawn mainly from Haver Analytics, Moody's KMV, International Financial Statistics (IFS), and the World Economic Outlook (WEO).

[6] The U.K. Government stake in the Lloyds Banking Group plc is currently below 11 percent. The Government is planning to fully return the bank to the private sector, with an anticipated sale of GBP 2 billion shares to retail investors, in spring 2016. The U.K. Government stake in the Royal Bank of Scotland Group plc is 72.9 percent, made up entirely of GPB 11.6 billion ordinary shares. The Government expects to step up the privatization of the Royal Bank of Scotland Group plc by 2020.

Box 1. The 2015 BoE Concurrent Stress Test and the FSAP Solvency Stress Tests

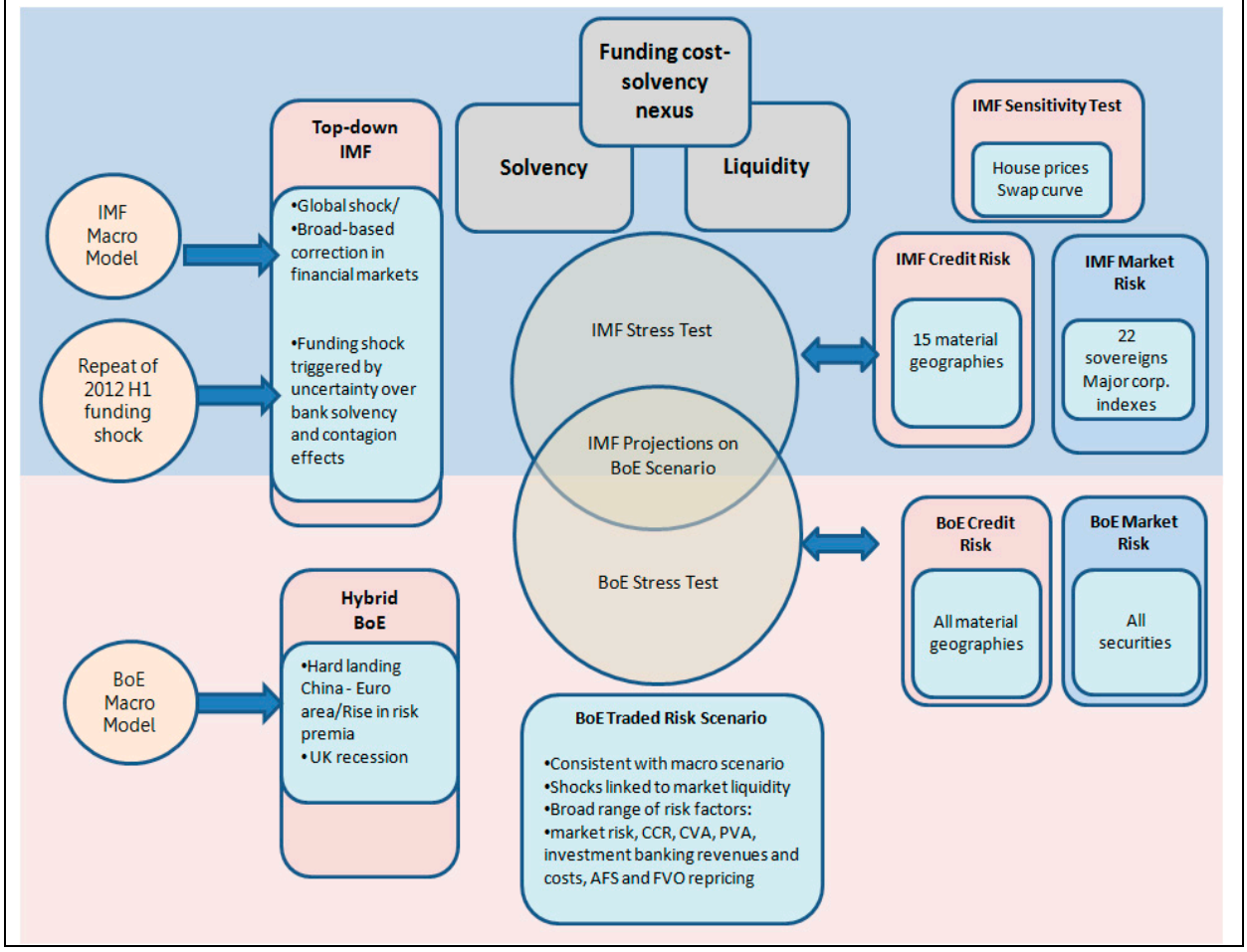
The 2015 BoE concurrent stress test and the FSAP solvency stress test share key similarities:

- Both incorporate a high degree of granularity to capture stress from international exposures. Under the FSAP stress test, key macroeconomic variables in 15 jurisdictions are modeled separately to assess the impact of all material exposures of U.K. banks. Under the BoE stress test, credit risk exposures in all jurisdictions are assessed.
- Both stress test scenarios incorporate a comparable impact on U.K. GDP, equivalent to a 2.1 standard deviation shock on two-year cumulative real GDP growth during the first two years of the test horizon.
- Both stress tests are based on a dynamic balance sheet assumption, although banks are restricted in their ability to deleverage. In the BoE stress test, this is done with the aim of ensuring that the banking system is capitalized to support the real economy in a severe stress scenario.
- Both incorporate a traded risk scenario that is linked to the macroeconomic scenario.
- Both use the same Basel III hurdle rate for the risk-weight capital metric, and a similar leverage hurdle rate.

At the same time, the BoE and the FSAP stress tests differ in a number of ways:

- *Approach*: The BoE uses a hybrid approach, challenging the banks' BU submissions and synthesizing outputs of different models; the FSAP test is based on a simple integrated TD model. The FSAP test and the BoE test use different methodologies to capture system-wide funding stress, estimate traded risk losses, and calculate stressed RWA. The two tests also use different balance sheet cut-off dates.
- *Scenarios*: The BoE scenario is characterized by long-lived shocks, featuring a U-shape in key variables; the FSAP scenario incorporates a speedier recovery, where key variables follow a V-shape path.
- *Risk coverage*: In addition to macroeconomic and traded risk elements, the BoE stress scenario incorporates stressed projections for misconduct costs, as well as pension risk. The FSAP approach does not include a misconduct stress, but the methodology used to project expenses means that the results incorporate a material impact from misconduct. The FSAP stress test includes an additional module to capture funding risk from a drying-up of money market liquidity. In the BoE stress test, banks are expected to model the impact of the scenario on money market liquidity as part of their net interest income projections. The traded risk component of the FSAP scenario is focused on market risk losses in the trading book and valuation losses from available for sale (AFS) and fair-value option (FVO) in the banking book, whereas the BoE scenario includes a broader set of risk factors, counterparty credit risk losses, stressed credit valuation adjustment (CVA), and stressed prudent valuation adjustment (PVA). The FSAP funding risk module models contagion from peer banks' funding pressures and limits the extent of pass-through of higher funding costs on bank lending rates, whereas the BoE methodology allows banks to pass-through costs to lending rates where they judge that they would be able to do so under the stress scenario.
- *Management actions*: The BoE projects capital ratios before and after the impact of strategic management actions and additional Tier 1 conversion. The FSAP stress test excludes management actions on the projections of stressed capital ratios. For consistency, comparisons of the FSAP results to the BoE 2015 results are made on a pre-management action basis.

Figure 1. United Kingdom: Overview of FSAP Stress Testing



12. The assessment criteria ("hurdle rates") include the capital standards under Basel III capital framework, implemented via the Capital Requirements Regulation (CRR) using PRA national discretions, and the PRA leverage framework. The PRA has used certain discretions in the CRR in a prudent way. For instance, the PRA has implemented an end-point definition of CET1 that does not take into account the transitional provisions for CET1, such as the phasing in of deductions.[7] Also, all additional Tier 1 instruments issued externally by U.K. banks have a trigger of 7 percent of CET1 rather than the CRR minimum of 5.125 percent.[8] Under the baseline scenario, the hurdle rate applied in the FSAP stress test was set at 7 percent CET1 ratio. Under the adverse scenario, the hurdle rate was set at 4.5 percent CET1 ratio and 6 percent Tier 1 ratio. A caveat to the hurdle rate is that it does not include the Global Systemically Important Banks' (G-SIBs') higher loss-absorbency requirements that began to be phased in January 1, 2016, with full implementation by January 1,

[7] On the other hand, in line with Basel III, the PRA has grandfathered certain state-owned ordinary shares for one bank, which do not fully comply with the CET1 criteria until end-2017.

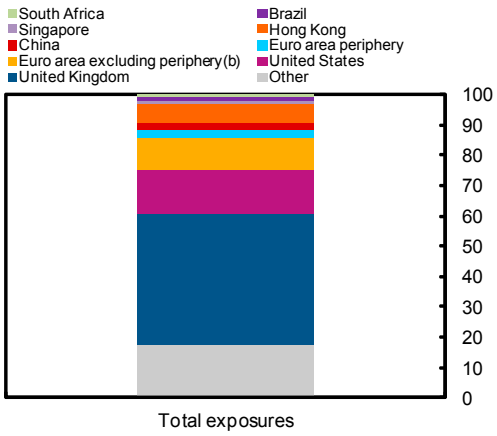
[8] Also, to ensure that the outcome is consistent with Basel III, the PRA requires banks to deduct significant investments in insurance entities, subject to threshold conditions, rather than risk-weight such investments.

2019.[9] The hurdle rate also includes a 3 percent Tier 1 ratio based on the U.K. leverage framework.[10] The U.K. leverage framework uses the CRR end-point definition of Tier 1 capital to calculate the numerator[11] with limited recognition of Additional Tier 1 capital and the CRR delegated act definition for the exposure measure.

13. The stress test examined a comprehensive range of credit risk exposures, market risk positions, and funding risk channels.

- **For IRB exposures, a separate credit risk analysis was calibrated for five Basel asset classes and the 15 most material geographies for U.K. banks.** This yielded a matrix of 75 credit risk models for IRB exposures. The Basel asset classes covered: retail unsecured exposures, including small- and medium-sized enterprises (SME) credit; retail secured exposures (that is, mortgages); corporate lending (including commercial real estate); lending to institutions; and sovereign and central bank lending. U.K. banks have significant cross-border exposures (see chart). Material geographies for IRB exposures included: the United Kingdom (60 percent); other advanced economies (30 percent) including Canada, France, Germany, Hong Kong SAR, Ireland, Italy, Korea, Netherlands, Singapore, and the United States; and emerging economies (10 percent), including China, India, and South Africa. The credit stress test included securitization and covered bond exposures.

Geographical composition of exposures
(In Percent)



Source: Bank of England

Data are as at end-2015. Geographical exposures are based on residence of immediate counterparty. Exposures includes loans and advances, claims under sale and repurchase agreements, long and short-term debt securities and claims

- **The scope of the market risk stress test included all positions exposed to risks stemming from changes in market prices.** This includes positions in Held for Trading (HFT), Available for Sale (AFS) and FVO, including sovereign and non-sovereign exposures. Positions in hedge accounting portfolios, economic hedges, and cash flow hedges were excluded. The treatment of sovereign exposures in the banking book follows the Basel III framework. The FSAP team used the IRB approach, which relies on the FSAP team risk assessments of the underlying issuers.
- **The funding risk analysis examined shocks arising from**: (i) a system-wide event related to monetary policy shocks and adverse movements in LIBOR rates; (ii) an idiosyncratic event linked

[9] In November 2014, four major U.K. banks were identified as G-SIBs by the FSB, including HSBC Holdings plc (bucket 4), Barclays plc (bucket 3), and the Royal Bank of Scotland Group plc and Standard Chartered plc (both bucket 1).

[10] For the purpose of the IMF FSAP stress test, the leverage ratio is calculated using quarter-end data as opposed to average over the quarter.

[11] With the exception of state aid capital instruments, which follow the CRR transitional provisions.

to concerns over the solvency position of each bank; and (iii) a contagion effect triggered by concerns over the solvency position of vulnerable banks within the U.K. banking system.

B. FSAP Scenarios

14. The FSAP solvency stress test examined two macroeconomic scenarios. The two hypothetical scenarios include a baseline and an adverse scenario.

- The baseline scenario draws from the October 2015 WEO projections for key variables,[12] expanded to generate additional variables that are relevant to project credit risk losses. These include real estate prices (residential and commercial real estate) for the U.K., the U.S., euro area core, and euro area periphery; U.K. Bank rate; U.K. credit growth; and equity prices for the U.K. and the U.S. These variables were projected by adjusting the baseline scenario specified for the BoE's 2015 concurrent stress test to the WEO core variables and spanning the horizon through 2020.[13] Country specific variables were complemented by global assumptions' forecasts from the IMF Global Assumptions (Gas) database, including six-month London Interbank Offered Rate (LIBOR) by major currency, and a range of commodity prices.

- Given the geographic footprint of major U.K. banks, their presence in global financial markets, and their exposure to the U.K. real estate market, the adverse scenario explores the following risks:

  - A sharp downturn in emerging markets, leading to a substantial dampening of global growth.

  - A sizeable increase in rates and steepening of the yield curve in the United Kingdom and globally, triggering broad-based abrupt price corrections across financial markets.

  - Funding risk from rising LIBOR spreads, the dry-up of issuance in money markets, and disruptions in foreign exchange (FX) swap markets.

  - A large correction in the U.K. property markets. This is a key source of credit risk for banks, as real estate is used as collateral in secured lending.

- More specifically, the adverse scenario examines the impact on U.K. banks from a balance sheet recession in the United Kingdom and financial crises in fragile emerging economies. The scenario assumes accelerated monetary normalization in the United States with a 200 basis points policy rate hike during 2016–17, induced by a stronger private domestic demand-driven macroeconomic expansion than is projected under the baseline. This is accompanied by a drying up of liquidity in money markets and the steepening of the yield curve driven by heightened monetary policy uncertainty, internationally correlated credit risk premium shocks, and duration premium shocks.

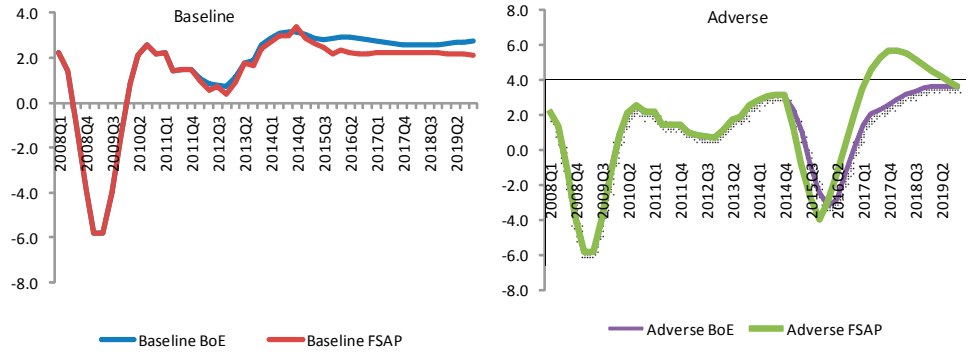
[12] Key variables used for the analysis include nominal GDP, real GDP, consumption, investment, inflation, unemployment, short-term rates, long-term rates, and FX rates. These variables are projected at the quarterly frequency over the first two years of the scenario and annually over the last three years. A subset of variables including FX rates, short-term rates, and long-term yields are only projected annually. The conversion from annual to quarterly frequency is performed using a quadratic match average approach.

[13] The BoE baseline scenario for the 2015 concurrent stress test covers the horizon 2015–19.

Furthermore, there is a stock market correction triggered by equity risk premium shocks that spreads to FX markets driven by currency risk premium shocks. Vulnerable emerging economies experience sudden stops associated with a tightening of financial conditions that trigger a broad-based correction of equity markets and sharp currency depreciations. The effect of the global shock in the United Kingdom is amplified by an autonomous domestic demand shock, a confidence loss in property markets, stress in funding markets, and a decompression of the term premium in debt markets. U.K. GDP contracts by 1.6 percent in 2016, and reaches a peak deviation from baseline levels in 2017 at -7.5 percent.

15. Both the FSAP scenario and the BoE's 2015 scenario have a global focus, but triggers and transmission mechanisms across geographies in the two scenarios differ. While the 2015 BoE scenario focused on a synchronized global downturn and a correction in market risk appetite affecting mainly Asia and the euro area,[14] the FSAP scenario features a disorderly monetary normalization in the United States, triggering a broad-based dislocation in financial markets and spillovers to the most vulnerable emerging market economies.[15] Both scenarios have a major impact on the U.K. economy and share a similar degree of severity as measured by their effect on U.K. real GDP (Figure 2).

Figure 2. United Kingdom: GDP Growth Projections[1]
(In percent)



Sources: BoE, IMF, and IMF staff estimates.

[1] The IMF (BoE) scenario constitutes a 2.13 (2.04) standard deviation move in two-year cumulative real GDP growth rate over the first two years of the horizon. The standard deviation has been calculated at the quarterly frequency over 1990–2014.

16. The persistence of shocks and the channels of distress are also different. The FSAP scenario incorporates a quicker recovery toward steady state. Also, the FSAP scenario features a severe dislocation in money markets and a steepening in the yield curve (Figure 3). The diversity of

[14] This followed the 2014 BoE stress tests, in which the scenario emphasized domestic risks, especially those stemming from the U.K. housing market.

[15] Key vulnerable emerging markets include Brazil, Indonesia, South Africa, and Turkey.

scenarios allows for capturing different risks and assessing the U.K. banking system's resilience against a range of possible stresses.

C. The FSAP's Credit Risk Model Approach

17. Capital requirements are reflected in banks' regulatory RWAs.[16] After a secular decline in the risk density ratio of major U.K. firms, during which average risk weights declined from 70 percent in the mid-1990s to a trough of 29 percent in 2008:Q3, average risk weights for major U.K. banks reached 36.3 percent in December 2015. Two offsetting effects have been driving the trend in risk weights in recent years: whereas new capital rules have pushed up risk weights, including for market risk, major U.K. banks have been reducing their risky non-core asset portfolios as part of their deleveraging strategy, suggesting the possibility that a real risk reduction has taken place.

18. Credit risk accounts for the largest regulatory capital requirement faced by U.K. banks. At end-2015, RWAs of the largest seven U.K. banking groups reached GBP 1.9 trillion, of which 78 percent reflects credit risk excluding counterparty credit risk (CRR). By contrast, market risk represented just over 5 percent, with CCR amounting to over 7 percent, and operational risk under 10 percent (Figure 4).

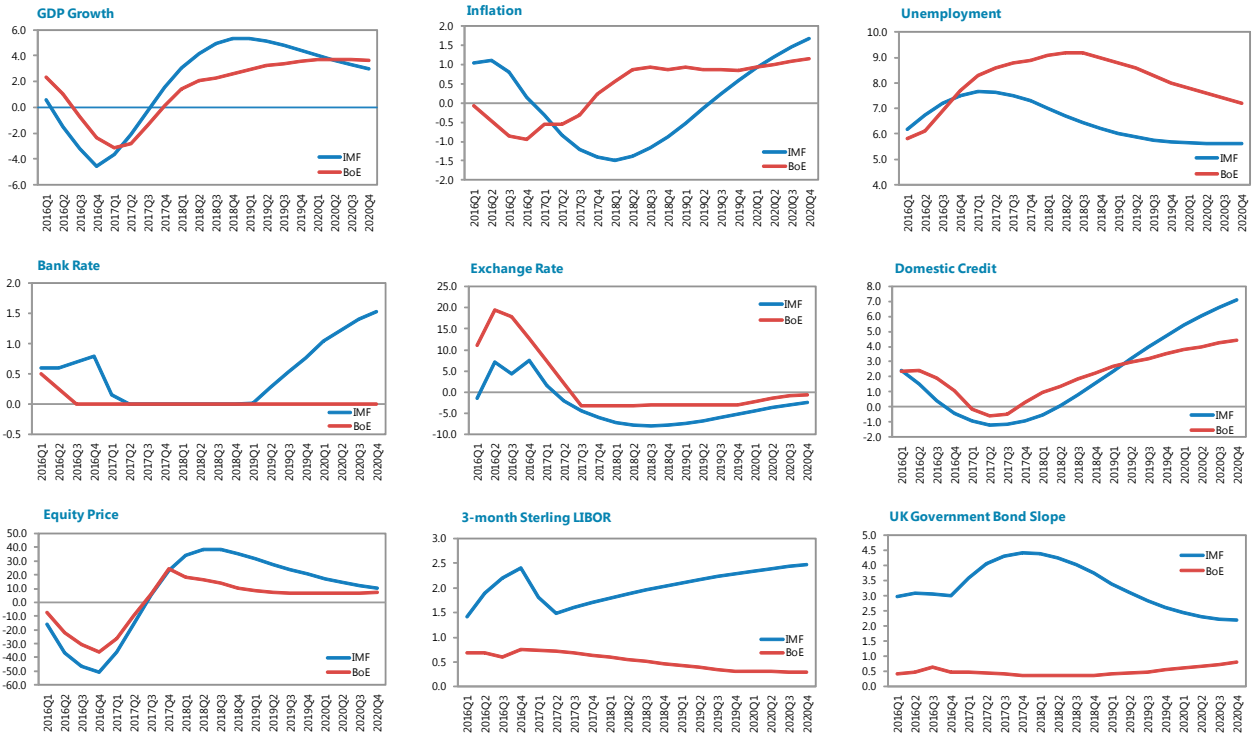
19. The impact of credit risk on banks' capital ratios depends on the regulatory approach used by banks to book credit exposures. Scenario-based stress testing of credit risk requires mapping the impact of changes in macroeconomic and financial variables onto banks' loan loss provisions and capital requirements as the level of credit risk rises. Credit risk models are used to project both actual regulatory capital and required regulatory capital (defined as 8 percent of RWA). All new or materially changed IRB capital models require PRA approval. For exposures under the IRB approach, credit risk depends on the exposure at default (EaD), the probability of default (PD), and the loss-given default (LGD). For exposures under the STA approach, risk depends on banks' loan classification and provisioning requirements set out by the U.K. authorities.

20. The larger U.K. banks rely largely on the advanced IRB approach to book credit exposures. The aggregate credit risk EaD reported in 2014 reached GBP 4.4 trillion for major U.K. banks, of which GBP 3.3 trillion was booked under the IRB approach and GBP 1.1 trillion under the STA approach. Of that GBP 1.1 trillion, GBP 400 billion was exposures to sovereign and central banks, with an asset-weighted average risk weight of under 5 percent.[17]

[16] Shortcomings in the definitions of RWAs are typically compensated in additional capital requirements under the Pillar 2 capital framework. Existing shortcomings in the definition of RWAs relate, for instance, to risks associated with defined benefit pension fund deficits. These additional minimum requirements (Pillar 2A), which vary by bank, average about 2.4 percent of RWAs in terms of Tier 1 across major U.K. banks as of end-2015.

[17] In the EU, authorities have allowed supervisors to permit banks that follow the IRB approach to stay permanently on the STA approach for their sovereign exposures. In applying the STA approach, EU authorities have set a zero risk weight not just to sovereign exposures denominated and funded in domestic currency, but also to such exposures denominated and funded in the currencies of any other member state.

Figure 3. United Kingdom: Comparison of Key Variables in BoE and IMF Adverse Scenario
(In percent)



Sources: BoE, IMF, and IMF staff estimates.

Credit Risk Model for IRB Exposures

21. The impact of stress on regulatory capital through increased provisions was computed as the level of expected losses: $EL^{j}_{i,t} = PD^{j}_{i,t} * LGD^{j}_{i,t} * EAD^{j}_{i,t}$ where *i* denotes the bank, *j* denotes the asset class, and *t* is the time dimension. The FSAP team estimated separate credit risk models by Basel asset class and geography. All material geographies for U.K. banks are covered in the credit risk analysis. Although specialized lending is subject to the slotting approach under the PRA regulatory framework, for FSAP purposes the computation of unexpected losses is treated under the corporate IRB approach.

Approach to Project Probabilities of Default (PDs)

22. The FSAP team used a two-step process to project stressed PDs. The team built a time series of bank-specific PDs by Basel asset class and geography and used it to refine projections from econometric analysis based on aggregate PD proxies. In their Pillar 3 disclosures, banks disclose information on selected portfolios' PDs calibrated using their regulatory IRB models. As regulatory capital is based on banks' IRB models, disclosed PDs provide useful information to inform regulatory capital projections. A limitation of this data is, however, that disclosures are available at annual frequency, they have a short history starting in 2008, and do not cover all relevant portfolios and geographies. The approach of the FSAP team was twofold:

- Based on the stress test scenario, a time series of PD proxies was projected for each material asset class and geography using market-based PDs (across all geographies) and write-off data (for U.K. exposures).[18] These series are available at quarterly frequency and cover all material geographies, and therefore are suited to feed the FSAP team satellite models for credit risk.

- An econometric approach was used to forecast bank-specific PDs using banks' Pillar 3 disclosures as the dependent variable and the projected series of PD proxies as the main driver.

23. For U.K. exposures, the FSAP team applied two different PD proxies to forecast expected losses. The first PD proxy was obtained from Moody's Analytics using the average one-year expected default frequency (EDF) for the corporate group, the financials group, and the consumer nondurables and services group. These categories were mapped to corporate exposures, exposures to institutions,[19] and retail unsecured exposures, respectively. The PD proxy for exposures to sovereign and central banks was extracted from sovereign yields. The second PD proxy was sourced from the BoE using write-off rates on U.K. exposures, mainly booked in the U.K., by main asset class.[20] Although the write-off rate is the closest measure to estimated portfolio loss ratio, write-off rates tend to lag defaults as defaulted exposures, and loan loss provisions remain on the books for up to about 24 months. Figure 5 shows the difference in the loss distribution across EDFs and write-off rates for selected portfolios.[21] While the write-off rate distribution shows positive skew, the EDF distribution is more neutral, with a higher spike and lower persistence, reflecting shifts to expectations at the time of deteriorating economies' conditions. Appendix I Table 1 summarizes the key variables used to inform PD projections for U.K. exposures.

24. For overseas exposures, the FSAP team applied a market-based PD proxy. The BoE publishes aggregate write-off rates for U.K. banks' domestic exposures, but similar data for cross-

[18] Data on write-offs by asset class were provided by the BoE on U.K. exposures, which are mainly booked in the U.K.

[19] In the IRB advanced approach, almost all exposures to institutions are exposures to financial institutions. See, for instance, Table 25 in HSBC Holdings plc's 2014 Pillar 3 disclosures.

[20] The PRA considers the write-off rate to be a suitable proxy for the loss rate pending the availability of annual loss rates collected on a uniform basis through Common Reporting (COREP).

[21] Note that there are not market-based proxies for default in household secured loans.

border exposures at the portfolio level are not available. Instead, the FSAP team used Moody's Analytics one-year EDF for the corporate group, the financials group, the consumer nondurables and services group, and the construction group for Canada, China, France, Germany, Hong Kong SAR, India, Ireland, Italy, Korea, the Netherlands, Singapore, South Africa, Spain, and the U.S.[22]

25. An integrated credit risk approach drawing on bilateral and multivariate vector autoregressive (VAR) estimation techniques and nonlinear principal component analysis (PCA) was used to project conditional PDs. The simultaneous behavior of credit risk, macroeconomic conditions, financial conditions, and real estate conditions was modeled explicitly in the econometric specification. In addition, global conditions and spillovers from relevant geographies were included as a factor, given the size and prominence of major U.K. banks in international markets.

26. A battery of over 900 credit risk specifications was run to obtain PD projections. The FSAP team ran a comprehensive set of over 700 bilateral VARs for all pairs of credit risk by PD proxy, asset class, and geography against each variable forecast in the macroeconomic scenario. In addition, 150 PCA analyses were conducted for each factor, PD proxy, asset class, and geography, which fed into 50 multivariate VARs for each PD proxy, asset class, and geography.[23] Appendix I gives the details of the econometric approach used to project credit risk.

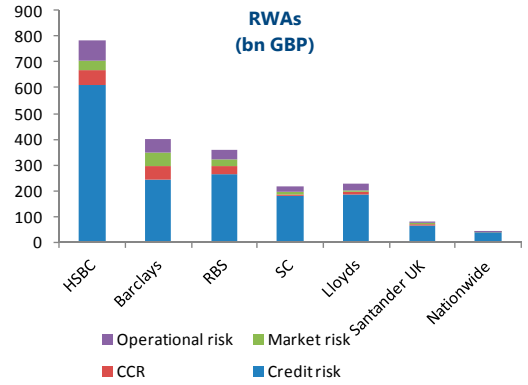
27. Credit risk in U.K. exposures is mainly driven by financial conditions. Figure 6 shows that rising spreads across money and equity markets (PC1_fin), and tight corporate credit markets (PC1_fin_c) contribute to rising corporate EDFs with a peak reached in 2017:Q2 at 5.4 percent. Whereas macro conditions are not statistically significant, an abrupt correction in the commercial real estate (CRE) market is also a driver of heightened credit risk. Write-off rates in U.K. mortgages increase with deteriorating financial conditions in secured lending markets (PC1_fin_m). Deteriorating macroeconomic conditions are also relevant to explain losses in banks' mortgage books, whereas movements in housing prices are not statistically significant.

[22] Brazil has some materiality mainly for HSBC Holdings plc. However, on August 3, 2015, HSBC Holdings plc announced that it is selling its entire business in Brazil, comprising HSBC Bank Brazil S.A., to Bradesco for a consideration of USD 5.2 billion. The sale of HSBC Brazil represents a significant step in HSBC Holding plc's stated goal to optimize its global network and reduce complexity.

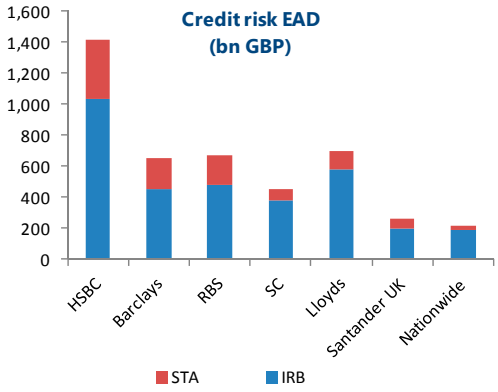
[23] For the U.K., over 170 bilateral VARs were estimated linking 2 PD proxies (i.e., EDF and write-off rate) over 4 asset classes and 24 key variables. For each overseas exposure over 14 countries, 40 bilateral VARs were estimated regressing EDFs over 3 asset classes and 14 variables (7 country-specific, 7 global variables). In addition, 24 PCAs for the United Kingdom (3 factors, 4 asset classes, 2 proxies) and 126 PCAs for overseas exposures (14 geographies, 3 factors, 3 asset classes) were conducted, and a total of 50 multivariate VARs were run.

Figure 4. United Kingdom: Credit Risk and Risk Weights for the U.K. Banking System

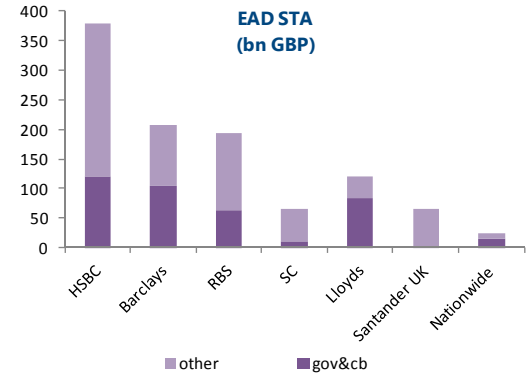
Credit risk represents the largest regulatory capital requirement of U.K. banks….



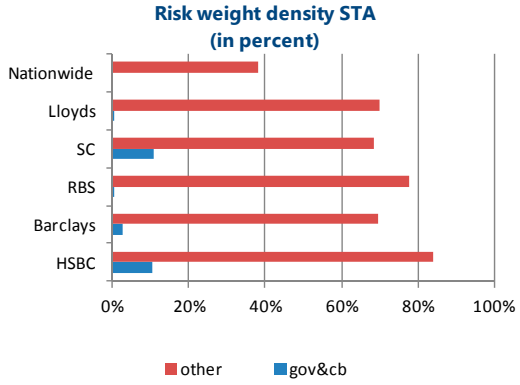
…most of the credit risk exposures follow the IRB approach for all banks.



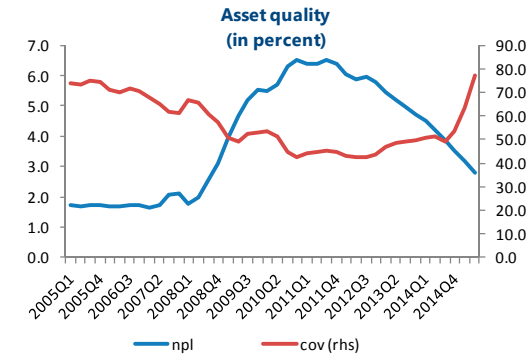
While exposures to sovereign and central banks are significant, most of the STA exposures are to the private sector…



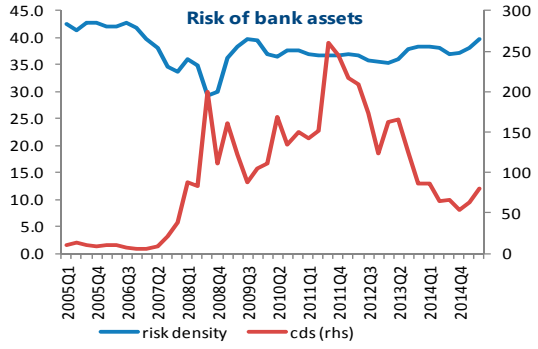
…with a 74 percent asset-weighted risk density relative to 5 percent risk density for sovereign and central bank STA exposures.



Asset quality has improved as shown by lower NPL ratios while coverage ratios have edged up…



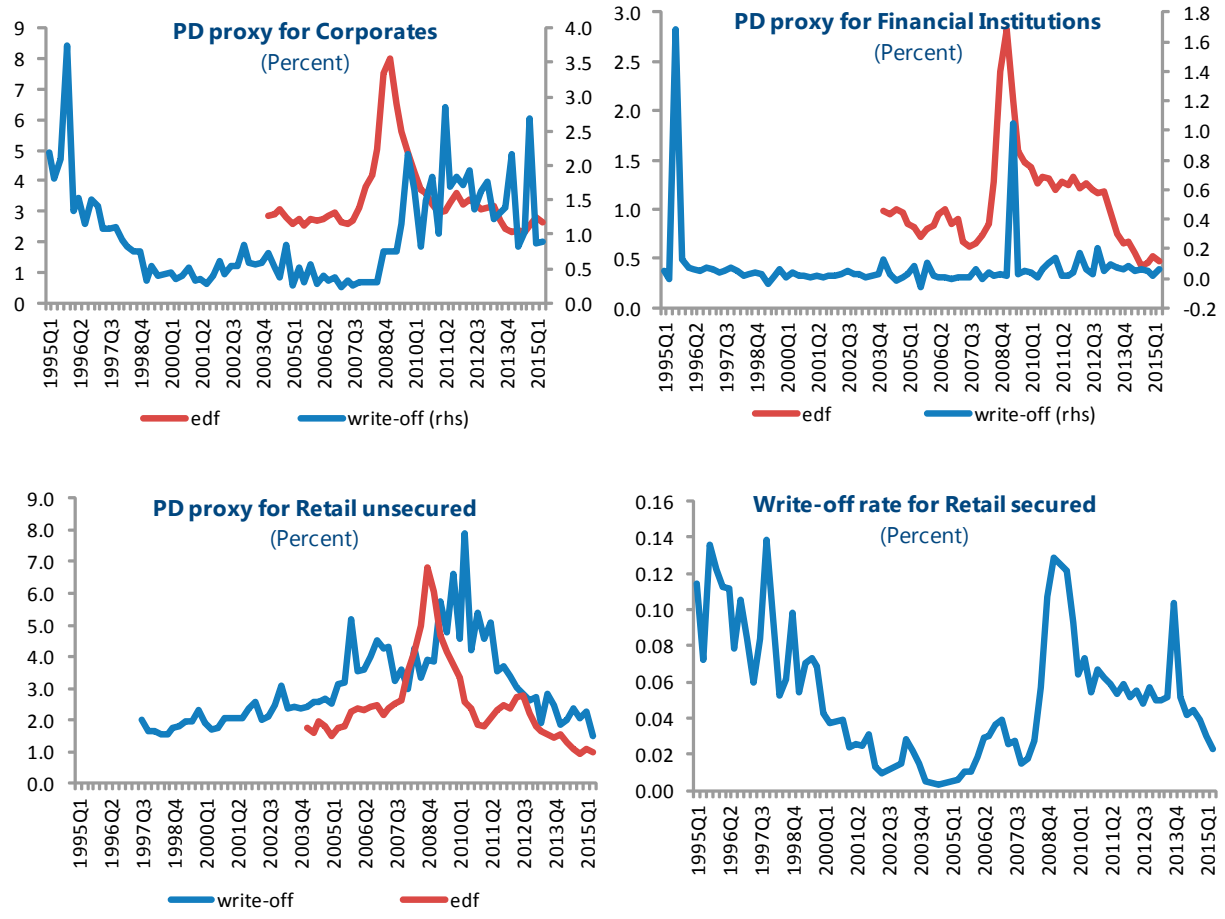
…reflected in lower market-based measures of bank risk (CDS) while regulatory risk density has increased relative to the crisis period.



Sources: Pillar 3 Disclosures, Bloomberg, and IMF staff calculations.

Note: The bottom two charts show asset-weighted averages for the largest five U.K. banks.

Figure 5. United Kingdom: Probability of Default and Credit Loss Rate Across Asset Classes
(In percent)



Sources: Moody's KMV, BoE, and IMF staff calculations.

28. The determinants of credit risk in overseas exposures differ across geographies. Figure 7 shows the key PD drivers for selected corporate exposures in France and China. While domestic macroeconomic conditions and real estate prices are drivers of corporate credit risk in France,[24] global financial conditions, particularly related to FX shocks and the steepening of the yield curve—as well as developments in oil markets—are the most significant drivers of corporate credit risk in China.

[24] Although they are not statistically significant at the 5 percent level.

Figure 6. United Kingdom: Aggregate PD Proxy Projections—Selected U.K. Exposures

The first principal component (PC1_Macro) reflects a deteriorating macroeconomic environment characterized by low growth, high inflation, and high unemployment.

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.899	1.217	0.633	1.899	0.633
2	0.682	0.263	0.227	2.581	0.860
3	0.419	---	0.140	3.000	1.000

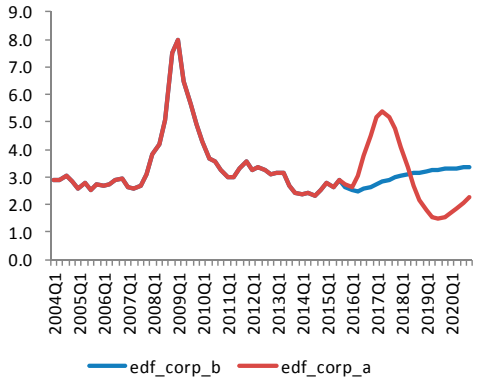
Eigenvectors (loadings):

Variable	PC 1_Macro	PC 2 _Macro	PC 3 _Macro
UK_G	-0.512	0.858	0.049
UK_INF	0.612	0.323	0.722
UK_U	0.604	0.399	-0.690

U.K. corporate EDF (first column) rises with deteriorating macroeconomic conditions, financial turmoil, and a correction in the CRE segment.

	EDF_CORP	PC1_MACRO	PC1_FIN	PC1_FIN_c	UK_CRE
EDF_CORP(-1)	0.572	0.148	0.084	-0.172	2.936
	[4.286]	[1.151]	[0.871]	[-0.718]	[2.913]
PC1_MACRO(-1)	0.087	0.913	-0.093	0.100	-1.559
	[1.201]	[13.036]	[-1.763]	[0.769]	[-2.840]
PC1_FIN(-1)	0.114	0.105	0.943	0.133	-1.028
	[2.912]	[2.805]	[33.269]	[1.894]	[-3.489]
PC1_FIN_c(-1)	0.125	-0.143	-0.158	0.876	-2.830
	[1.55]	[-1.854]	[-2.709]	[6.076]	[-4.666]
UK_CRE(-1)	-0.024	-0.013	0.008	-0.003	0.881
	[-2.152]	[-1.246]	[1.029]	[-0.133]	[10.656]
C	1.481	-0.440	-0.340	0.586	-9.452
	[3.226]	[-0.994]	[-1.019]	[0.711]	[-2.725]
R-squared	0.874	0.925	0.976	0.692	0.929
Adj. R-squared	0.859	0.916	0.973	0.653	0.920

Projections of U.K. corporate EDF peak in 2017:Q2 at 5.4 percent…



The first principal component (PC1_Fin) captures financial turmoil, featuring rising LIBOR rates, GBP depreciation, and a U.K. stock market correction.

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.428	0.338	0.476	1.428	0.476
2	1.089	0.607	0.363	2.517	0.839
3	0.483	---	0.161	3.000	1.000

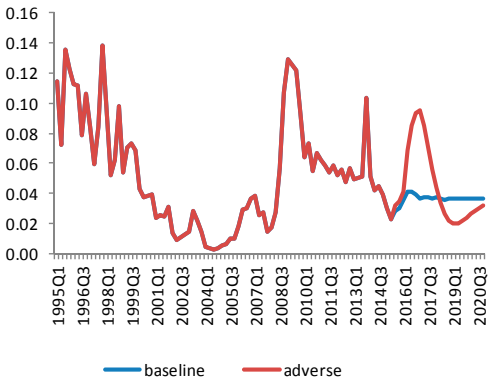
Eigenvectors (loadings):

Variable	PC 1_Fin	PC 2_Fin	PC 3_Fin
LIBOR_GBP	0.079	0.918	0.389
UK_FX	0.691	-0.331	0.643
UK_EQUITY	-0.719	-0.218	0.660

Write-off rates for U.K. mortgages (first column) increase with adverse macroeconomic conditions and tight credit conditions; but are less sensitive to a housing price correction.

	W_MOR	PC1_MACRO	PC1_FIN_m	UK_HOUSING
W_MOR(-1)	0.426	-31.173	-84.643	257.798
	[4.644]	[-2.381]	[-3.706]	[2.945]
PC1_MACRO(-1)	0.002	0.897	0.203	-0.317
	[3.372]	[11.121]	[1.444]	[-0.587]
PC1_FIN_m(-1)	0.001	-0.038	0.864	0.177
	[2.631]	[-0.806]	[10.542]	[0.562]
UK_HOUSING(-1)	0.000	-0.041	-0.027	1.067
	[-1.272]	[-3.443]	[-1.311]	[13.495]
C	0.006	0.604	0.971	-3.022
	[5.307]	[3.735]	[3.443]	[-2.795]
R-squared	0.868	0.936	0.753	0.913
Adj. R-squared	0.857	0.931	0.734	0.906

…while write-off rates for U.K. mortgages peak in 2017:Q1 at 0.08 percent, twofold baseline rate levels.



Source: IMF staff estimates.

Figure 7. United Kingdom: Aggregate PD Proxy Projections—Selected Cross-Border Exposures

In France, favorable financial conditions transmitted through the current account channel, (low short-term rates, currency depreciation, and upward sloping yield curve) are captured by a high value of PC1_FRA…

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.878	0.942	0.626	1.878	0.626
2	0.936	0.749	0.312	2.814	0.938
3	0.186	---	0.062	3.000	1.000

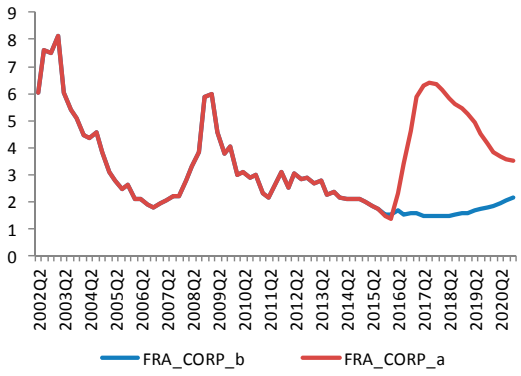
Eigenvectors (loadings):

Variable	PC 1 _FRA	PC 2 _FRA	PC 3 _FRA
FRA_FX	0.263	0.964	-0.031
FRA_SLOPE	0.685	-0.163	0.710
FRA_ST	-0.680	0.208	0.703

France corporate EDF (first column) rises with deteriorating macroeconomic conditions, tight financial conditions, and a correction in real estate markets.

	FRA_CORP	FRA_MACRO	FRA_FIN	FRA_RE	US_EQUITY
FRA_CORP(-1)	0.797	0.090	-0.039	0.158	0.880
	[10.958]	[1.3458]	[-0.830]	[3.011]	[0.77714]
FRA_MACRO(-1)	0.163	0.855	0.053	-0.193	-3.659
	[1.772]	[10.084]	[0.902]	[-2.906]	[-2.560]
FRA_FIN(-1)	-0.130	-0.099	0.909	0.015	0.194
	[-1.305]	[-1.075]	[14.323]	[0.204]	[0.126]
FRA_RE(-1)	-0.133	0.074	-0.160	0.984	0.226
	[-1.608]	[0.970]	[-3.038]	[16.529]	[0.176]
US_EQUITY(-1)	0.000	0.015	-0.005	0.019	0.781
	[0.027]	[2.423]	[-1.246]	[3.975]	[7.661]
C	0.541	-0.340	0.179	-0.545	0.484
	[2.066]	[-1.408]	[1.069]	[-2.886]	[0.119]
R-squared	0.883	0.870	0.936	0.937	0.760

Projections of France corporate EDF peak in 2017:Q3 at 6.4 percent…



…whereas, in China, distress in debt markets transmitted through the capital account channel (duration shocks, depreciation) are reflected in a low value of PC1_CHI.

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.505	0.461	0.502	1.505	0.502
2	1.044	0.592	0.348	2.548	0.850
3	0.452	---	0.151	3.000	1.000

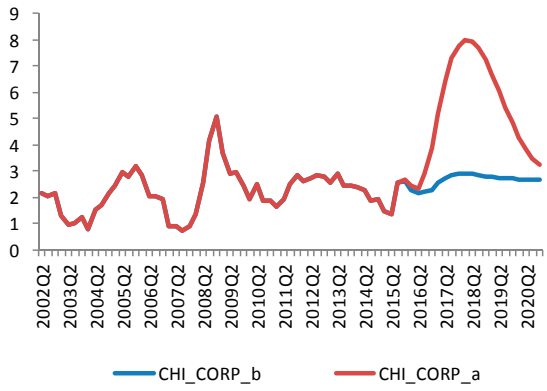
Eigenvectors (loadings):

Variable	PC 1 _CHI	PC 2_CHI	PC 3_CHI
CHI_SLOPE	0.661	-0.385	0.644
CHI_FX	0.214	0.919	0.331
CHI_ST	-0.719	-0.081	0.690

China corporate EDF (first column) rises with deteriorating macroeconomic conditions, stress in the capital account, a correction in U.S. equity markets, and rising oil prices.

	CHI_CORP	CHI_MACRO	CHI_FIN	US_EQUITY	OIL_G
CHI_CORP(-1)	0.729	-0.048	0.038	-2.346	-4.767
	[7.089]	[-1.268]	[0.625]	[-1.280]	[-2.176]
CHI_MACRO(-1)	0.311	0.874	-0.195	-5.175	4.193
	[1.595]	[12.25]	[-1.720]	[-1.491]	[1.011]
CHI_FIN(-1)	0.237	-0.068	0.876	-0.855	-0.765
	[2.291]	[-1.803]	[14.52]	[-0.464]	[-0.347]
US_EQUITY(-1)	-0.008	0.004	0.002	0.829	0.192
	[-1.331]	[1.835]	[0.432]	[7.506]	[1.452]
OIL_G(-1)	0.008	-0.002	-0.004	-0.110	0.836
	[2.169]	[-1.708]	[-1.933]	[-1.640]	[10.46]
C	0.756	0.027	-0.084	5.996	10.971
	[2.665]	[0.261]	[-0.506]	[1.186]	[1.816]
R-squared	0.689	0.899	0.948	0.750	0.844

…while China corporate EDF peaks in 2018:Q1 at 8.0 percent.



Source: IMF staff estimates.

29. To avoid a structural shift at the cut-off date between banks' estimated PDs and FSAP team's PD projections, an econometric approach drawing on banks' Pillar 3 disclosures was used. Table 1 shows an extract from HSBC Holdings plc's Pillar 3 disclosures. The choice of HSBC is motivated by the size of the firm's balance sheet (HSBC Holdings plc accounts for one-third of U.K. major banks' assets), its broad product base, and its geographic footprint. Notwithstanding caveats related to changes in the composition of the underlying portfolios, the peak of bank estimated PDs stood at 4 percent for European unsecured retail exposures, 15 percent for the U.S. mortgage portfolio,[25] and 3 percent for both European mortgage exposures and global corporate exposures. On the other hand, PDs for exposures to institutions (mainly financial) stood at 0.5 percent at the height of the financial crisis, whereas the average PD for sovereign exposures peaked at 0.2 percent in 2008.

30. The forecast path of conditional PD proxies under the macroeconomic scenario is transformed using information embedded in bank estimated PDs, adjusting for point-in-time (PiT) parameters. There are two key reasons PD proxies and bank-specific PDs are likely to differ. First, PD proxies are calculated for the aggregate market portfolio, and hence do not necessarily reflect the underlying risk profile of banks' portfolios. Second, forecast PD proxies are either market-based (using the Merton approach) or approximate the ex post realization of credit losses (write-off rates). By contrast, bank-estimated PDs are ex ante measures computed using banks' approved IRB models for the calculation of capital requirements. For consistency with the PRA regulatory regime, the time series of bank-specific PDs by asset class and geography is regressed on the historical series of EDFs and write-off rates. The estimated coefficients were used to forecast bank-specific PDs over the stress test horizon. Figure 8 shows the aggregate PD proxies and bank-estimated PDs for selected U.K. portfolios. To compute expected losses, an adjustment to bank-specific PD projections is performed to account for the cyclicality of PiT parameters under the adverse scenario.

$$PD^{j}_{i,t} = PD^{j}_{i,t-1} + \Delta PD^{j}_{t}$$

where $PD^{j}_{i,t}$ is bank i blended PD for portfolio j (that is, including both defaulted and non-defaulted counterparties) at time t, and ΔPD^{j}_{t} is the aggregate PD shift for portfolio j at time t.

[25] HSBC Holdings plc's has a significant exposure to the U.S. subprime market followed by its acquisition of U.S. lender Household Finance.

Table 1. United Kingdom: Bank-Estimated PDs for IRB Exposures

	2008	2009	2010	2011	2012	2013	2014	2015
Retail (by region)								
Europe								
PD mortgages	1.51	1.67	1.53	1.00	0.92	3.08	0.98	1.43
PD unsecured	3.91	4.01	3.47	2.57	1.98	2.06	1.65	1.56
HK[1]								
PD mortgages	1.15	0.81	0.76	0.75	0.50	3.06	1.00	0.99
PD unsecured	1.71	1.86	1.52	1.36	0.94	1.14	1.21	1.24
Rest of Asia								
PD mortgages	2.06	2.05	1.55	1.47	1.37	3.06	1.00	0.99
PD unsecured	0.50	0.60	0.50	0.50	0.50	1.14	1.21	1.24
North America								
PD mortgages	10.27	13.39	12.92	14.65	15.01	8.48	11.54	9.66
PD unsecured	10.48	9.18	6.28	4.90	5.72	3.30	5.37	4.38
Wholesale IRB Foundation								
PD gov and central banks	0.20	0.16	0.11	0.11	0.13	0.17	0.17	0.14
PD institutions	0.47	0.49	0.36	0.46	0.39	0.46	0.36	0.18
PD corporates	2.17	3.32	2.82	2.57	2.19	2.32	1.85	2.04

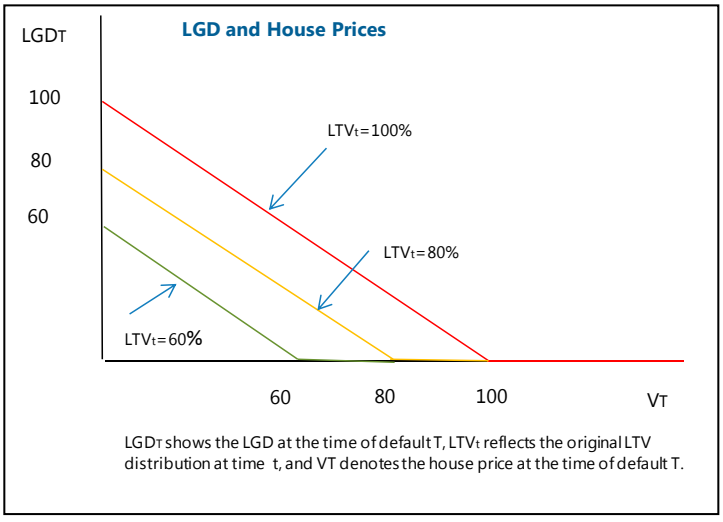
Source: HSBC Holdings plc Pillar 3 disclosures over 2008–15 and IMF staff calculations.

Note: For 2013–15, the data is for Asia (no split between HK and Rest of Asia).

Approach to LGD

Calculation of LGD for U.K. mortgages

31. The FSAP team applied a fair-value option approach to compute LGDs for mortgages. The estimated LGD on mortgages has option-like features conditional on the original LTV distribution and housing prices at default. LGD is a highly nonlinear function of the house price at the time of default V_T and the original LTV_t ratio (priced at the time of origination t) of the mortgage loan (see chart). This warrants the estimation of the initial distribution of LTV by vintage repriced at stressed house prices rather than relying on original LTV ratios.



LGDT shows the LGD at the time of default T, LTVt reflects the original LTV distribution at time t, and VT denotes the house price at the time of default T.

32. LGD projections under the stress scenario depend on four key parameters:

- The distribution of original LTV ratios by vintage;
- The outstanding value of each loan vintage net of amortization;
- The house price fall assumed under the scenario; and
- The forced sales discount on the property's market price under foreclosure.

33. The distribution of LTVs at origination has significantly improved in the wake of the financial crisis. Drawing on data on residential loans to individuals from the Mortgage Lenders and Administrators Return (MLAR) statistics, Figure 9 shows that, in the tail of the distribution (right bottom chart), only 0.1 percent of regulated mortgages[26] granted at end-2015 show LTV ratios over 95 percent relative to over 6 percent in 2007. At the same time, high-rated mortgages with LTV lower than 75 percent (left top chart) now account for over 60 percent of originated mortgages relative to just about 50 percent in 2007.

34. The volume of loans outstanding from each vintage depends on the principal rollover rate. The rollover rate was estimated for each vintage as the volume of redemptions relative to the volume of loans outstanding each period. Figure 10 (left chart) shows that the principal rollover rate has slowed down since the crisis as initial maturity has lengthened, reflecting higher reliance on fixed mortgages, as well as longer repricing periods for tracker mortgages post-crisis.

35. The property price haircut is linked to the macroeconomic scenario. The path to the U.K. residential property index draws on the 2015 BoE scenario adjusted for the time horizon under the IMF scenario. BoE's baseline projections are assumed to realize up to end-2015, and forecast projections are extrapolated in the outer years of the macro scenario. Figure 10 (right chart) shows that the largest year-on-year (yoy) decline in house prices will be achieved at end-2016, and the peak-to-trough decline in prices reaches 20 percent by 2018:Q3.

36. A conservative forced sales discount was set at 30 percent of fair-value U.K. residential property prices. This discount was derived by comparing the realized sale price with the fitted market value for houses sold in foreclosure proceedings. There is wide evidence of price discounts relative to fair-market value in the case of fire sales during crisis periods. Empirical evidence varies across countries, LTV ratios, and home quality. A recent study in European countries found a price discount between 15 percent and 36 percent of the fair-market value.[27] The estimated marginal effect for losses at foreclosure in the U.S. post-crisis is 20 pps.[28] These loans may be associated with weaker underwriting, higher expenses, weaker markets, and longer time lines. Previous studies on

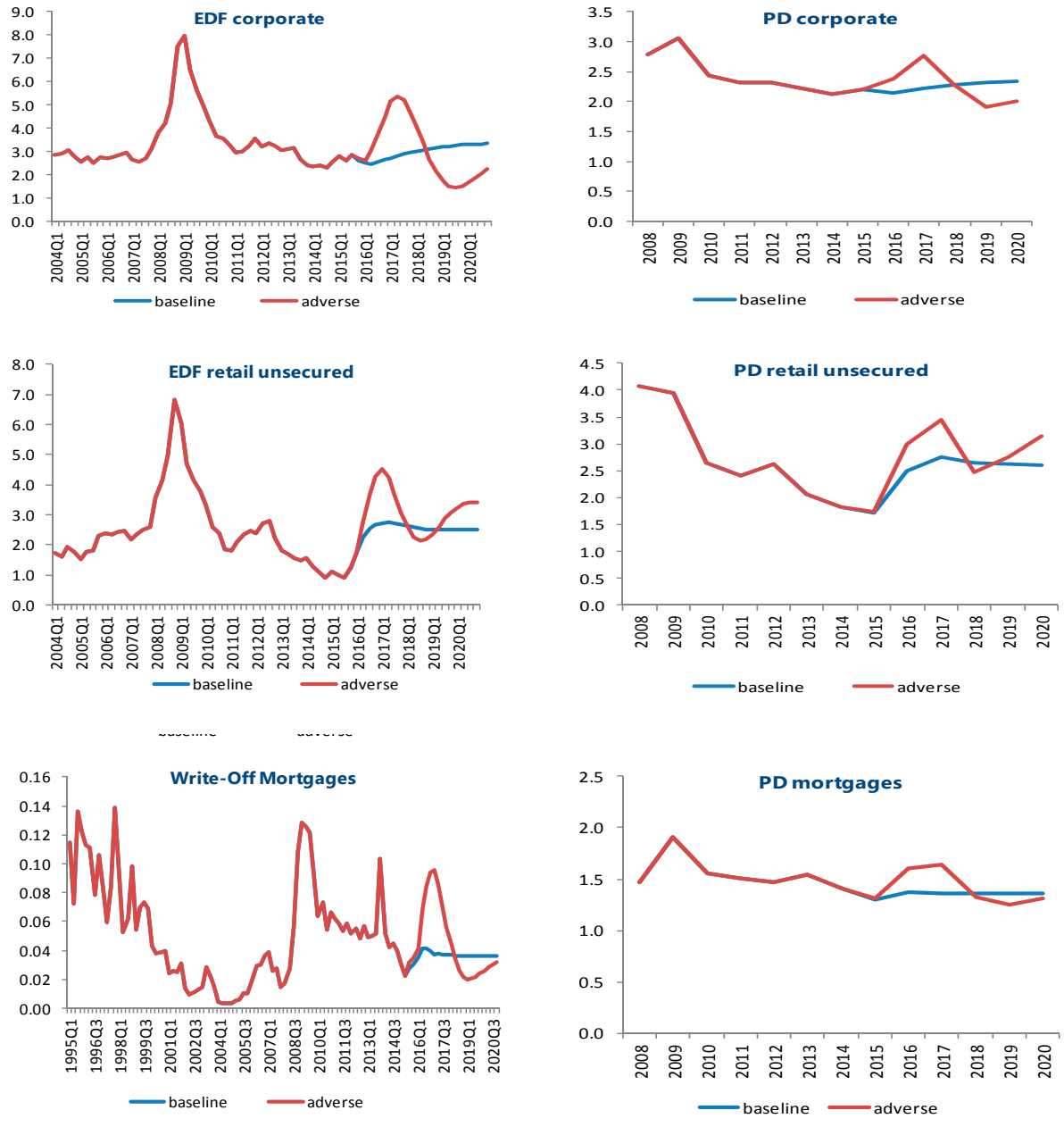
[26] Non-regulated mortgage contracts include BTL loans and other types of loans where the property is not for use by the borrower or dependents, and residential loans to individuals where the lender does not have a first charge.

[27] See Bardhan, et al. 2011 for evidence on forced sale discounts across countries.

[28] Ross, E. J., and L. Shibut, 2015, "What Drives Loss Given Default? Evidence From Commercial Real Estate Loans at Failed Banks," FDIC CFR WP 2015–03.

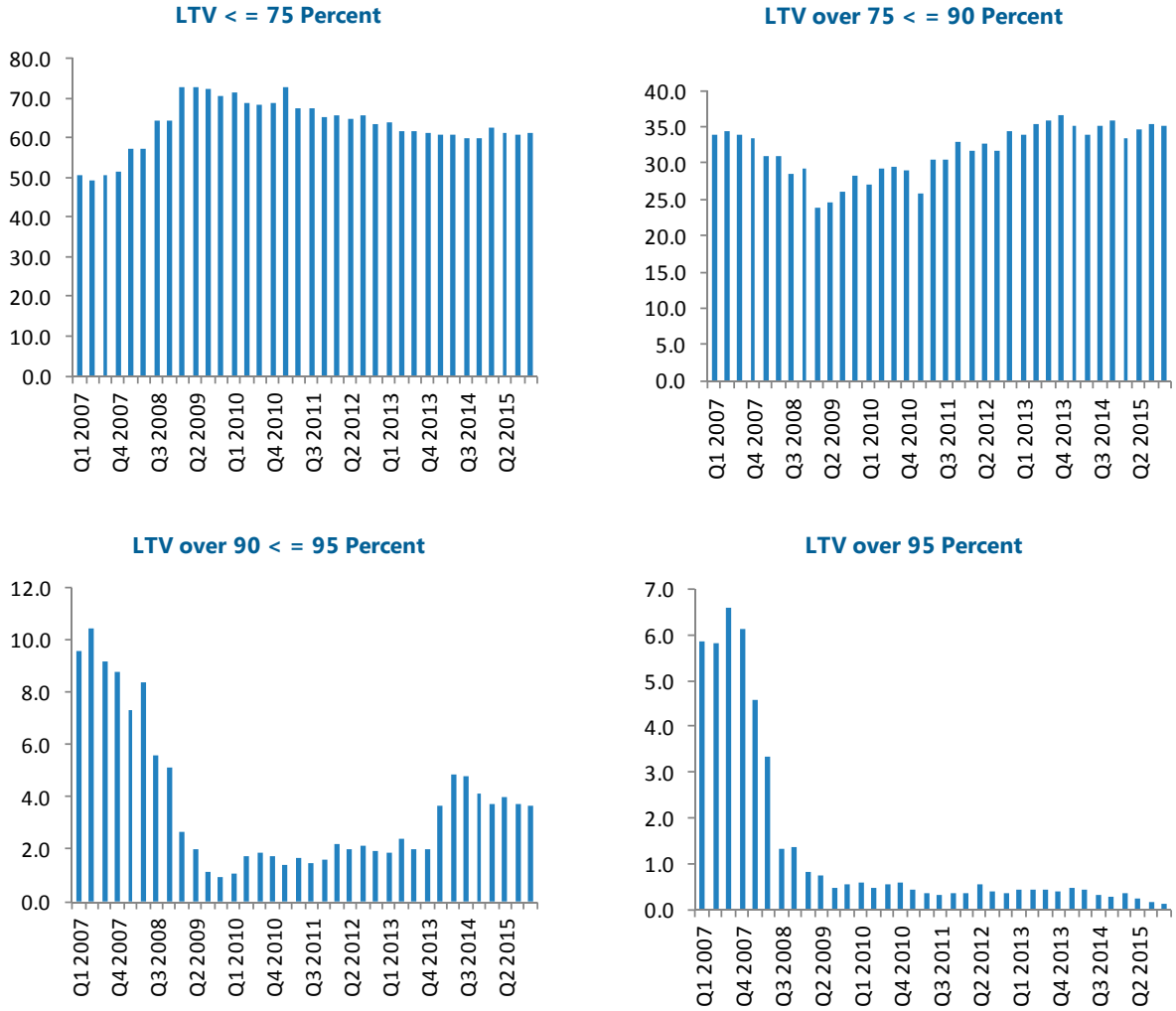
U.S. foreclosure sales had documented fire sales discounts of about 25 percent. In view of the empirical evidence, the FSAP team considered that a 30 percent discount over fair-value prices would be an appropriately conservative estimate.

Figure 8. United Kingdom: Aggregate EDFs, Write-Offs, and PDs for U.K. Exposures—Selected Portfolios
(In percent)



Sources: IMF staff estimates.

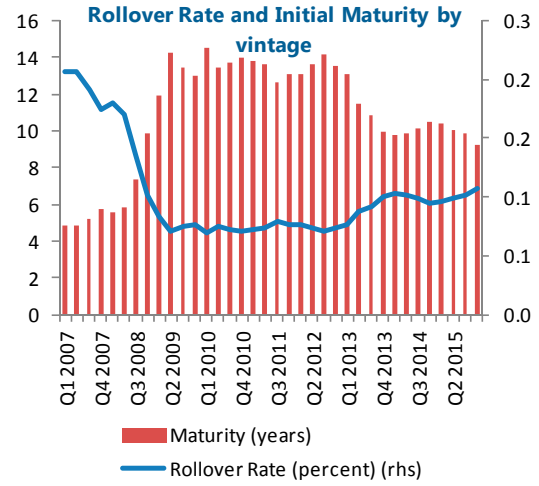
Figure 9. United Kingdom: Distribution of LTV by Vintage
(In percent)



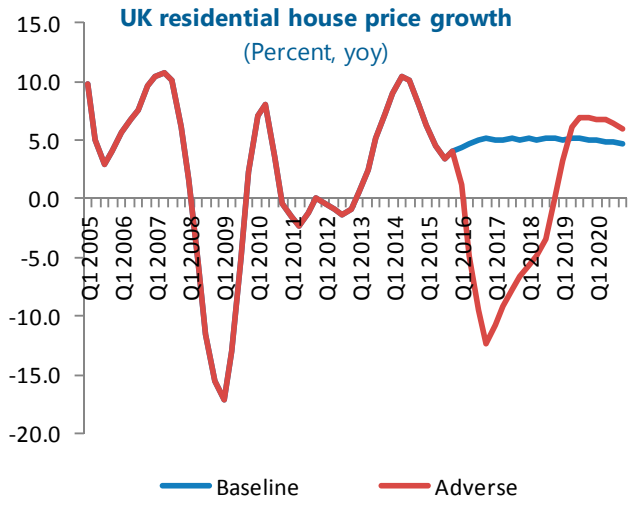
Sources: Mortgage Lenders and Administrators Statistics, 2015:Q4 for regulated institutions, and IMF staff calculations.

Figure 10. United Kingdom: Rollover Rate, Initial Maturity, and U.K. Residential Property Prices

The principal rollover rate of mortgage loan vintages has slowed down post-crisis as estimated initial maturity has lengthened....



...and U.K. residential house prices have recovered.

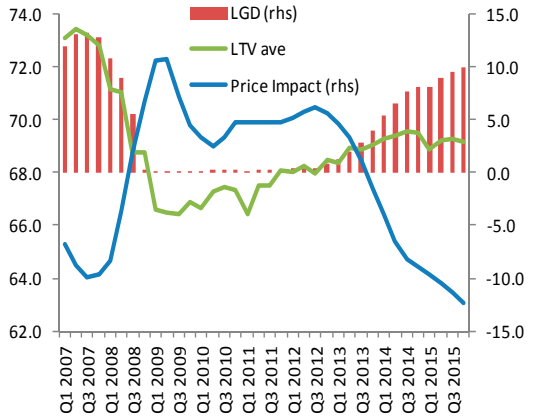


Sources: Haver Analytics, BoE, and IMF staff estimates.

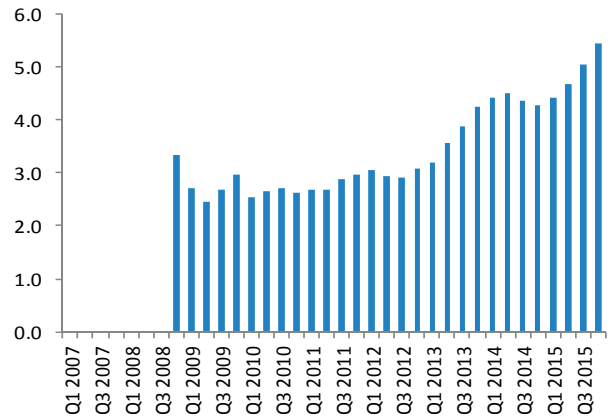
37. Under the adverse scenario, the average LGD shock was set at 3.5 percent. Figure 11 shows the LGD by vintage (left chart). Interestingly, the pattern is non-monotonic: LGD is higher for loans issued prior to the crisis or issued most recently. The former is driven by high LTV ratios (particularly at the right tail of the distribution), whereas the latter is driven by higher fair-market prices prevalent at the time of the pricing of the collateral. Multiplying the LGD ratio from each vintage by the volume of loans outstanding yields the average LGD shock of 3.5 percent. The right chart shows the estimated outstanding volume per vintage. Notably, the average estimated initial maturity for pre-crisis originated loans ranges between five and seven years, due to the prevalence of five-year fixed-rate mortgages subject to refinancing, yielding no material outstanding volume prior to 2008:Q3.

Figure 11. United Kingdom: LGD Projections by Vintage

LGD shocks arise mainly from vintages prior to the crisis driven by large LTV ratios and from recent vintages due to higher house price valuations....



...playing a greater role on current LGD projections as outstanding volumes are higher for recent vintages.



Source: IMF staff estimates.

38. For robustness, the estimated LGD shock was cross-checked against banks' reported LGDs and write-off rates on mortgages in stressed episodes. Drawing on Pillar 3's disclosures, the maximum one-year increase in IRB LGDs for U.K. mortgages in the post-crisis period is about 3 pps. (Figure 12).[29] Using write-off rate data on secured lending to individuals in U.K., the peak was reached in 1997:Q3 and 2009:Q1 at around 0.14 percent. Using an estimated PD for U.K. mortgages of 1 percent, this is equivalent to an LGD of 14 percent, which approximates the average stressed LGD projected by the FSAP team for U.K. mortgages over the stress test horizon.

Calculation of LGD for Other Asset Classes

39. To derive LGD projections for non-mortgage loans, the FSAP team drew on the macroeconomic scenario, as well as on insights from the global financial crisis and the EA sovereign debt crisis. Adverse LGDs were calibrated for the first two years of the scenario, given the recovery path assumed over the outer three years of the horizon. LGD projections were derived bank by bank, using initial bank-specific LGD ratios and shocks to LGD linked to the scenario:

where $LGD_{i,t}^{j}$ is bank *i* post-credit risk mitigation LGD for portfolio *j* at time *t*, and ΔLGD_{t}^{j} is the aggregate LGD shift for portfolio *j* at time *t*.

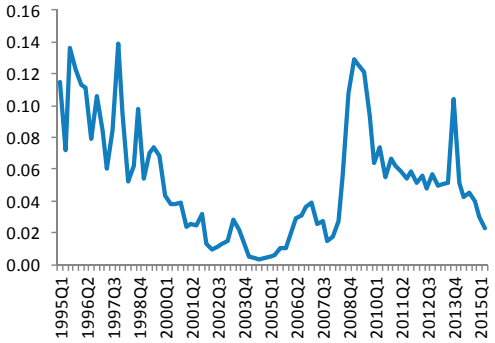
[29] For mortgage exposures, the peak LGD was reached for the U.S. mortgage portfolio in 2012, representing an increase of 5.5 pps from baseline levels.

Figure 12. United Kingdom: Write-Off Rates and LGDs for U.K. Mortgages

Twin peaks of write-off rates for U.K. mortgages were reached in 1997:Q3 and 2009:Q1 at 0.14 percent and 0.13 percent, respectively….

Write-Off Rate for U.K. Mortgages

(In Percent)



…while the largest one-year increase in HSBC Holdings plc's IRB estimated LGD on U.K. mortgage exposures in the recent period reached 3 pps in 2012.

LGD Mortgage by Geography, HSBC

(In Percent)

	2012	2013	2014	2015	max Δ
U.S.	64.7	59.6	56.4	59.2	5.5
U.K .	12.7	16.4	15.5	13.4	3.0
Hong Kong SAR	10.1	10.1	10.1	10.1	0

Sources: BoE, HSBC Holdings plc Pillar 3 disclosures, and IMF staff calculations.

- To compute LGD shocks, information was drawn from banks' disclosed IRB-based estimates for LGDs during stressed periods. For instance, the average peak LGD in HSBC Holdings plc's Pillar 3 disclosures for wholesale IRB corporate portfolio is reached in 2011 at 39.2 percent (Table 2), which represents an increase of about 3.6 pps over 2015 LGD levels. LGD floors were applied to central bank and Government exposures in 2013 and to institutions in 2014, and were kept under the adverse scenario.

- Projected increases in corporate LGDs were cross-checked against the drop in nominal GDP forecast under adverse conditions. For retail unsecured exposures, the increase in LGD was matched with rising unemployment by IRB jurisdiction, including a rise of over 2 pps in the U.K. unemployment rate in 2017.

Table 2. United Kingdom: LGD Calibration for Non-Mortgage Portfolios

(In Percent)

LGD Global Portfolios

	2008	2009	2010	2011	2012	2013	2014	2015	max
LGD gov and central banks	20.3	19.9	20.9	20.3	19.6	45.0	45.0	45.1	flo
LGD institutions	29.6	32.5	29.5	32.5	32.1	33.6	42.0	42.0	flo
LGD corporates	37.8	38.9	38.4	39.2	37.8	38.5	36.0	35.6	

Source: HSBC Holdings plc Pillar 3 disclosures.

Note: LGD floors applied to central Government and central banks since 2013 and to institutions since 2014.

40. The projection of EAD was driven by balance sheet assumptions, structural FX risk in foreign currency loans, and triggered credit lines and guarantees. Specifically, changes to EAD in the IRB portfolio are governed by:

$$EAD^{j}_{i,t} = EAD^{j}_{i,t-1} \cdot \left(1 + g_{i,t} + f^{j}_{i,FX} \cdot \Delta FX_{t}\right) \cdot \left(1 - PD^{j}_{i,t-1}\right) + \Delta L^{j}_{i,t} \cdot UCL^{j}_{i,t-1}$$

where *i* denotes the bank, *j* denotes the asset class, and *t* is time, $g_{i,t}$ is the growth rate of the IRB portfolio, $f^{j}_{i,FX}$ is the fraction of foreign currency loans. The FSAP team considers two major currency pairs by bank, namely EUR and USD for GBP-reporting banks; and EUR and GBP for USD-reporting banks. ΔFX_{t} is the shock to foreign currency under the macro scenario, $\left(1 - PD^{j}_{i,t-1}\right)$ represents the non-defaulted portfolio, $\Delta L^{j}_{i,t}$ is the shock to triggered credit lines and guarantees, and $UCL^{j}_{i,t-1}$ is the amount of undrawn guarantees.

41. The FSAP scenario assumed constrained balance sheets by geography. Bank credit supply behavior is constrained through the activation of macroprudential policy tools to avoid credit supply rationing.[30] Under the FSAP scenario, credit growth is determined by credit demand shocks triggered by negative consumption and investment shocks that lead to a slowdown of credit under the adverse scenario. Given the geographic footprint of U.K. banks, the growth rate of credit varies across banks. It was computed as the EAD-weighted nominal GDP growth across relevant jurisdictions. Data on FX structural effects from foreign currency loans were provided by firms. When there were data gaps, it was assumed that loans are denominated in the domestic currency of the overseas exposure. To calibrate the shock to triggered credit lines and guarantees, the FSAP team used the maximum increase in the off-balance sheet exposures to EAD ratio for corporates reported by banks in their Pillar 3 disclosures over 2008–15, which is about 40 percent.

42. To compute capital requirements, regulatory risk parameters were considered and the Basel III formula for IRB exposures was applied. The derivation of RWAs is dependent on estimates of PD, LGD, EAD, correlation assumptions, and effective maturity for each exposure. According to the Basel III framework, RWAs were computed after applying the scaling factor of 1.06 to credit RWAs. Also, a multiplier of 1.25 was applied to the correlation parameter of all exposures to large regulated financial institutions and to all unregulated financial institutions.

Credit Risk Model for STA Exposures

43. Expected losses for STA banking book exposures rise due to the impact of migrations from performing to nonperforming loans (NPLs), as well as to migration effects across rating grades within NPLs. The first effect was estimated by running a panel regression of NPLs on key macrofinancial variables. A caveat is that NPL ratios are not disaggregated between IRB and STA exposures. For large international banks, NPLs can be larger among STA exposures if the STA approach is used to book exposures warehoused in overseas subsidiaries subject to higher credit

[30] This assumption is embedded in the structural dynamic stochastic general equilibrium(DSGE) model used by the FSAP team to generate the stress scenario.

risk. The second effect was calibrated using Basel findings on NPL coverage ratios during the global financial crisis, which stood at about 65 percent on average.

44. To compute the impact of migration on capital requirements, the FSAP team used a two-prong approach:

- The risk weight of NPL was set at an average 130 percent, partly informed by banks' reported average risk weight of corporate exposures under special management. The difference between 130 percent and the average risk weight of each bank STA exposures (excluding sovereign and central bank exposures) multiplied by the nominal amount of NPLs under the scenario (driven by the balance sheet dynamics and the forecast of the NPL ratio) represents the increase in risk weights attributed to the STA exposures in default.

- The non-defaulting portfolio was assumed to downgrade two notches under the adverse scenario. The asset-weighted risk weight of major U.K. banks' STA exposures (net of sovereign and central bank claims) stands at about 75 percent, corresponding to a Basel III credit assessment for corporate claims between A+ to A- (50 percent) and BBB+ to BB- (100 percent). A two-notch downgrade in the BBB+ to BB- category represents an increase of 16.67 percent in the average risk weight of the non-defaulted portfolio. Table 3 shows the increase in RWAs due to migration effects.

45. Capital requirements for STA exposures were driven by changes in provisioning rates, growth of EAD, structural FX risk, triggered credit lines and guarantees, and migration effects. The equation below shows four main components driving RWAs in the STA portfolio. The first component reflects the motion of RWAs generated by the flow of provisions, the growth rate of the portfolio, and FX effects. The second component shows the increase in risk weights resulting from triggered off-balance sheet credit lines and guarantees. The third component reflects the increase in risk density from the transition of loans from the performing to nonperforming category. Finally, the fourth component denotes the change in risk density from the transition matrix estimated for performing exposures:

$$RWA_{i,t} = \left(RWA_{i,t-1} - \Delta \Pr_{i,t}\right) * \left(1 + g_{i,t} + f_{i,EUR} \cdot \Delta FX_{EUR} + f_{i,USD} \cdot \Delta FX_{USD}\right) +$$
$$+ \left(RWD^{STA}_{i,t-1} - RWD^{OBS}_{i,t-1}\right) \cdot \Delta L^{STA,OBS}_{i,t} + \left(RWD^{NPL}_{i,t-1} - RWD^{PL}_{i,t-1}\right) \cdot \Delta NPL_{i,t} + \left(RWD^{s}_{i,t-1} - RWD^{b}_{i,t-1}\right) \cdot PL_{i,t}$$

where $\Delta \Pr_{i,t}$ is the increase in provisions in the STA book, $g_{i,t}$ is the growth of STA exposures, $f_{i,EUR}$ ($f_{i,USD}$) is the fraction of RWAs in STA exposures denominated in EUR (USD), ΔFX_{EUR} (ΔFX_{USD}) is the FX shock to EUR (USD), $RWD^{STA}_{i,t-1}$ is the average risk-weight density of on-balance sheet STA exposures, $RWD^{OBS}_{i,t-1}$ is the average risk weight density of off-balance sheet STA exposures, $\Delta L^{STA,OBS}_{i,t}$ is the increase in loans triggered by unused credit lines and guarantees, $RWD^{NPL}_{i,t-1}$ is the average risk weight density of the nonperforming portfolio, $RWD^{PL}_{i,t-1}$ is the average risk-weight density of the performing portfolio, $\Delta NPL_{i,t}$ is the increase of NPLs in the STA portfolio, $RWD^{s}_{i,t-1}$ (

$RWD^{b}_{i,t-1}$) is the average risk-weight density of the performing portfolio under stressed (baseline) conditions due to credit risk migration effects.

Table 3. United Kingdom: EAD and Risk Weights of STA Exposures
(In millions of British Pounds)

	HSBC	Barclays	RBS	SC	Lloyds	San UK	Nationwide
IRB EAD	1,037,673	449,608	478,572	384,837	580,080	199,100	193,889
STA EAD	378,332	207,328	193,869	66,160	119,956	64,600	23,911
of which gov&cb	121,284	104,499	63,596	11,088	83,617	...	14,423
of which other	164,690	102,829	130,273	35,285	36,339	64,600	9,488
Total EAD	907,230	656,936	672,441	288,953	700,036	263,700	217,800
STA (in percent of total EAD)	41.7%	31.6%	28.8%	22.9%	17.1%	24.5%	11.0%
RWA STA total	228,665	74,540	101,496	38,874	25,444	37,500	3,621
of which gov&cb	12,622	2,828	84	1,180	11	...	0
of which other	138,418	71,712	101,412	24,151	25,433	37,500	3,621
RW density gov&cb	10.4%	2.7%	0.1%	10.6%	0.0%	...	0.0%
RW density excl gov&cb	84.0%	69.7%	77.8%	68.4%	70.0%	40.0%	38.2%
Δ RWAs due to Δ NPL	46.0%	60.3%	52.2%	61.6%	60.0%	90.0%	91.8%
Δ RWAs due to rating effects on PL	16.7%	16.7%	16.7%	16.7%	16.7%	16.7%	16.7%

Sources: Pillar 3 disclosures and IMF staff calculations.

Notes: The figures for HSBC Holdings plc and Standard Chartered plc were originally reported in USD. The risk-weight density for Santander U.K. plc was estimated drawing on inference from Nationwide Building Society.

D. The FSAP Team's Approach to Market Risk

46. Market liquidity risks on the grounds of higher fragility of liquidity in some fixed income markets have been recently exposed in several advanced markets. Market liquidity using different measures such as bid–ask spreads, imputed round-trip costs, and Corwin and Schultz's high-low spreads among others, is not low in most markets when compared to historical averages.[31] But there are reasons to believe that the current level has been supported by benign cyclical conditions, including accommodative monetary policy in most advanced economies. In addition, the resilience of market liquidity has been challenged by recent structural changes in financial markets, including the increased footprint of and concentration among asset managers, a retrenchment of banks from trading activities and a reduction of their balance sheet space to support market making in credit markets, and the proliferation of smaller issues or issues by unseasoned or higher credit risk issuers.

47. The FSAP solvency stress test explores in some detail market risks from valuation losses in bond markets. The analysis covers shocks to sovereign debt securities in 22 jurisdictions and market stress in 4 non-sovereign corporate bond indices, that is, EU investment grade, EU high-yield, U.S. investment grade, and U.S. high-yield. Banks' corporate fixed income securities are mapped into

[31] *Global Financial Stability Report* (2015), Chapter 2: "Market Liquidity—Resilient or Fleeting," October, International Monetary Fund.

these corporate indices to cover the whole debt securities portfolio. Exposures arise from an immediate borrower basis. They do not include exposures to other counterparties with government guarantees.

48. Shocks to the securities portfolio are consistent with the macroeconomic scenario and hit banks throughout the five-year stress test horizon (Figure 13). This is a particularly severe assumption, especially for the trading book, as rebalancing of the portfolio is disallowed. Shocks to risk factors impact the fair valuation of securities under both the baseline and the adverse scenario. This contrasts with the methodology applied in the 2016 EU-wide stress test, whereby no changes for the baseline scenario were required. This also differs from the BoE stress test, whereby market risk in the trading book (along with CVA movements, PVA movements, and counterparty credit defaults) was incurred in the first year of the stress test horizon. In the FSAP stress test, the market shock was applied as an instantaneous shock to all the positions covered by the market risk analysis each year of the horizon, with losses fully recognized each year of the stress test:

- In line with the constrained balance sheet assumption for credit risk, the notional values of the securities portfolio grow according to:

$$B^{j}_{i,t} = \left(B^{j}_{i,t-1} - \Pr^{j}_{i,t}\right) * \left(1 + g_{i,t} + f_{i,EUR} \cdot \Delta FX_{EUR} + f_{i,USD} \cdot \Delta FX_{USD}\right)$$

  where $\Pr^{j}_{i,t}$ is the level of provisions for asset class *j*, by bank *i*, at time *t*; $g_{i,t}$ is the growth of interest-bearing assets for bank *I*; $f_{i,EUR}$ ($f_{i,USD}$) is the fraction of bank's *i* portfolio denominated in EUR (USD), and ΔFX_{EUR} (ΔFX_{USD}) is the FX shock to EUR (USD). On the other hand, no portfolio rebalancing or liquidation of positions was allowed throughout the stress test horizon.

- The calibration of market risk factors was consistent with the macroeconomic scenario. Changes to baseline sovereign yield to maturity (YTM) rates were extracted from WEO projections for 10-year bond yields. Levels of projected yields were adjusted using Bloomberg generic bond rates for the relevant residual maturity and jurisdiction. Shocks to yields under the adverse scenario were calibrated using the IMF in-house structural model. Adverse shifts to risk factors (including risk-free rates and credit spreads) stem from monetary policy shocks and internationally correlated term premium shocks.

- The model assumes no flight-to-quality effects, with all sovereign yields edging up relative to December 2015 rates across sovereign curves. Compared to the distribution of bond yields observed during the global financial crisis and the EA sovereign debt crisis, the projected adverse shocks look quite severe. The largest yoy hikes in yields under the adverse scenario are for the United States (310 bps), Ireland (205 bps), Hong Kong SAR (192 bps), and the U.K. (168 bps) by 2017. The largest two-year cumulative shocks over 2015–20 range between 133 and 164 bps.

49. Shocks to corporate bonds were calibrated using BoE's projections for corporate spreads, adjusted for market yields observed in 2015 (Table 4). Under the baseline scenario, a decompression of credit spreads across U.K. investment grade, U.K. high yield, U.S. investment grade, and U.S. high yield corporates was assumed as the credit cycle turns. Under the adverse scenario, U.K. corporate spreads reach levels seen at the height of the financial crisis with spreads rising

between 353 basis points (for U.S. investment grade) and 1,463 basis points (for U.K. high yield) by 2016.

Table 4. United Kingdom: Shocks to Corporate Spreads
(In percent)

		Baseline Yields					Adverse Yields				
	Dec-15	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
UK IG	3.26	3.48	3.63	3.78	3.92	4.04	7.80	6.05	4.59	4.33	4.32
UK HY	6.15	6.75	7.21	7.67	8.11	8.56	20.78	12.86	8.48	8.53	8.83
US IG	3.50	4.22	4.94	5.56	6.12	6.37	7.03	7.13	6.56	6.49	6.44
US HY	8.33	9.39	10.21	10.94	11.60	11.95	17.97	14.33	11.94	11.97	12.02

Sources: BoE, Bloomberg, and IMF staff calculations.

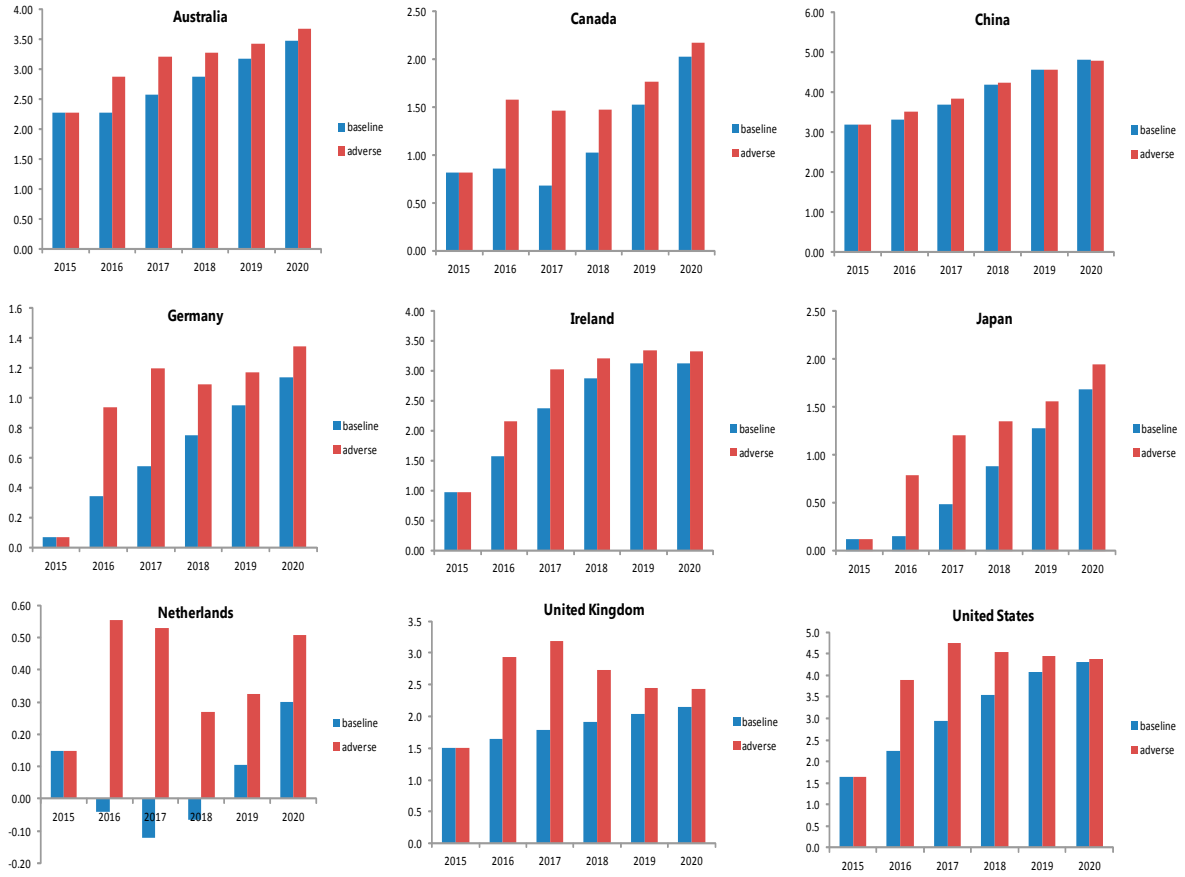
50. The impact of market risk on HFT, AFS, and FVO was assessed through a full revaluation of securities. The FSAP team applied a granular approach for market risk, which relies on full revaluation of securities to all firms, including those whose market risk capital requirement is lower than 5 percent of the total capital requirement. Banks are not allowed to rebalance their portfolios, and the mitigating effect of hedge accounting portfolios, designed to hedge positions at fair value, is excluded. Also, the offsetting impact from derivatives classified as economic hedges on related positions is excluded. This is a particularly severe assumption, as banks rely on fair-value hedges to hedge interest rate risk on AFS. Also, prudential filters are excluded, which implies that where a position has a prudential filter that eliminates its impact from capital, such position has nevertheless been included.[32]

51. Figure 14 shows the distribution of fixed income securities in the banking system by regulatory treatment and asset class. As of December 2015, fixed income securities booked in the AFS portfolio accounted for 67 percent of the aggregate debt securities portfolio for U.K. major banks, with HFT securities representing 26 percent of the portfolio, and held to maturity (HTM) securities accounting for 7 percent. Relative to bank total assets, the average size of the AFS portfolio reached 9.7 percent of total assets, compared to 3.8 percent of assets for the trading book, and 1.0 percent for HTM securities. By asset class, U.K. sovereign securities accounted for 2.6 percent of assets, while other sovereign securities accounted for 8.5 percent and corporate securities for 3.4 percent.

[32] Under Basel III, the AFS filter allows a partial pass-through of unrealized mark-to-market gains and losses in the AFS portfolio to regulatory capital. This will be gradually phased out by 2019.

Figure 13. United Kingdom: Projections of Five-Year Yields for Selected Sovereigns—IMF Adverse Scenario

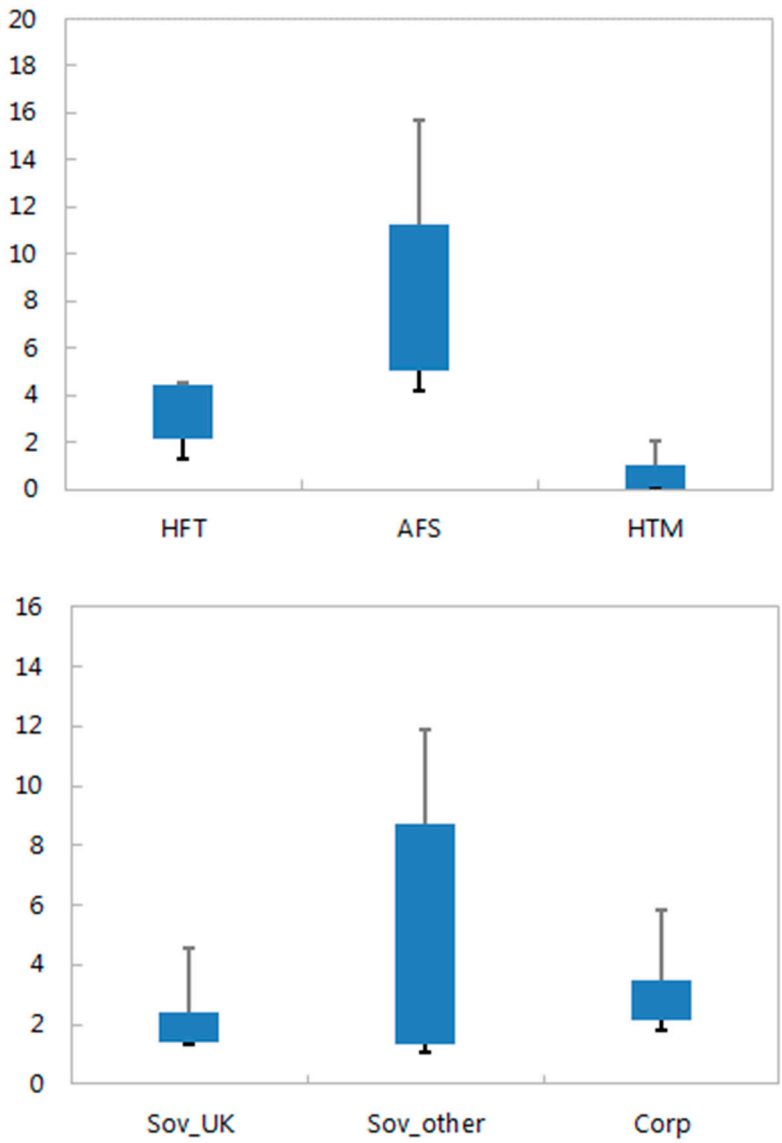
(In percent)



Source: IMF staff calculations.

Note: The chart shows yield to maturity (YTM) projections for five-year government securities in domestic currency under the baseline scenario (blue bars) and the adverse scenario (red bars).

Figure 14. United Kingdom: Distribution of Debt Securities Portfolio
(In percent of Assets)



Source: IMF staff calculations.

Note: Boxplots include the 25th and 75th percentiles of the distribution (blue shaded area) and the 10th and 90th percentiles (whiskers).

52. Other risk factors include rates risk, FX risk, and commodity risk. Table 5 reports shocks to other risk factors, including interest rates for currencies, exchange rates for nine major currency pairs showing a sharp appreciation of U.S. dollar in 2016–17 across all currencies, and shocks to commodity prices for metals and fuel plunging by 2017. Shocks to risk factors other than sovereign yields were also linked to the macroeconomic scenario and calculated for every year of the scenario. Other risk factors, including volatility risk, correlation risk, inflation risk, and basis risk, were excluded

from the P&L sensitivity of the trading book. Credit counterparty risk and credit valuation adjustments were also excluded to compute expected losses.

53. The impact of traded risk stress test on P&L differentiates between the general interest rate impact and the credit spread impact. The FSAP team calculated a haircut for each fixed income instrument under stressed conditions as the result of multiplying the maximum modified duration for each residual maturity by a change in the yield to maturity at stress test levels. Shocks to market yields stem from (1) the general interest rate impact assumed under the scenario; and (2) the credit spread impact for each individual security. In addition to the impact of market stress on the fair-value of the securities portfolio, the impact of the traded risk scenario was applied by relevant risk factors on banks' reported net open positions.

Table 5. United Kingdom: Shocks to Other Risk Factors

(In percent)

FX shocks (- denotes appreciation of USD relative to FX)

Country	Currency	Baseline					Adverse				
		2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Hong Kong	HKD	-0.09	0.56	0.69	0.51	1.26	-0.43	0.19	0.45	-0.22	-0.19
Canada	CAD	0.49	0.74	0.41	0.67	0.95	-7.04	-7.33	-4.21	-2.46	-2.51
China	CNY	0.18	0.30	0.56	0.96	0.87	-4.65	-4.59	-2.06	-0.48	-0.24
France	EUR	2.33	1.11	0.80	1.17	1.47	-7.28	-6.19	-2.30	0.59	1.25
Singapore	SGD	0.56	0.22	-0.03	0.28	0.55	-5.10	-4.79	-1.37	0.94	1.42
South Africa	ZAR	-0.94	-3.38	-3.14	-3.19	-2.72	-16.26	-15.10	-4.83	2.48	3.89
Korea	KRW	1.33	1.38	1.04	1.31	1.57	-7.29	-7.08	-2.92	-0.60	-0.63
India	INR	-2.06	-3.35	-3.02	-2.71	-1.39	-9.99	-9.85	-4.46	-1.39	-1.43
UK	GBP	1.17	1.65	1.31	1.58	1.85	-7.64	-6.57	-0.08	5.05	6.75

	Shock to U.K. Risk-Free Interest Rate					Shock to Gold				
	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
baseline	0.33	0.25	0.16	0.10	0.14	-1.52	1.19	1.40	1.70	2.18
adverse	0.33	-1.16	-0.22	0.99	0.95	-8.65	-14.15	-9.07	-2.89	-0.98

	Shock to Oil				
	2016	2017	2018	2019	2020
baseline	15.55	11.52	6.76	2.75	0.33
adverse	-10.43	-20.54	-12.56	-1.93	1.33

Source: IMF staff estimates.

54. The calculation of RWAs for market risk drew on firms' projections for the 2015 BoE stress test. These projections were adjusted for changes in the IMF market scenario relative to the BoE traded risk scenario. RWAs projections for market risk include VaR, Stressed Value at Risk (sVaR),

incremental risk charge (IRC), comprehensive risk measure (CRM), structural FX risk, CVA, PVA, and CCR.[33]

E. The FSAP Team's Approach to P&L

55. U.K. banks' profitability is driven partly by structural factors. While U.K. banks have continued to deleverage their balance sheet in an effort to mitigate underlying risks, profits of major U.K. banks have been notably lower than they were before the crisis.[34] Unquestionably, part of the pre-crisis profitability was driven by excessive risk-taking and was therefore unsustainable. To improve profitability, some banks have been exiting businesses with lower returns, including their global investment banking activities and their non-core operations in foreign jurisdictions.[35] Also, they have reduced their exposures to other financial institutions through repo lending and securities lending transactions, reducing their interconnectedness relative to 2008. Accumulated charges relating to past misconduct have also weighed on profitability. Structural factors are likely to be reflected in banks' interest income base, non-interest income, and non-interest expense.

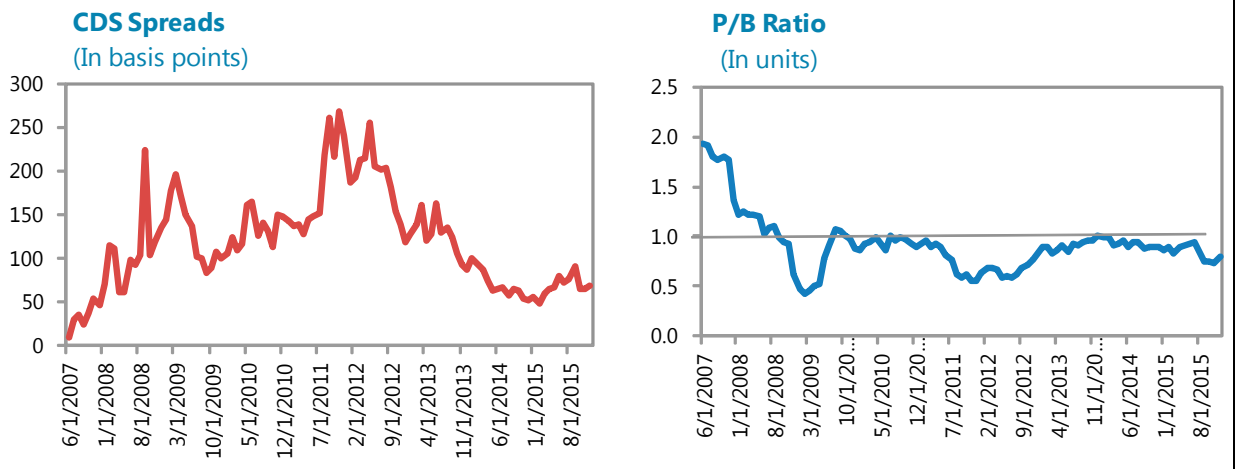
56. Cyclical factors are also key contributors to U.K. banks' profitability. Until recently, U.K. banks were facing pressures from the sluggish economic recovery and a sustained period of low interest rates. Whereas the impact of low policy rates on major U.K. banks' net interest margins (NIMs) has not been material, due in part to banks' management of interest rate risk through hedging practices, banks' low returns are reflected in market-based indicators with below par price-book value ratios. Most U.K. banks' shares continue to trade below their book value, indicating investors' expectations of subdued future profitability. At end-2015 the asset-weighted average price-to-book ratio (P/B) for major U.K. banks stood at 0.8 from a peak of 1.9 in July 2007 (Figure 15). At the same time, five-year credit default spreads (CDS) stood at 69 basis points.

[33] The CCR approach set by the 2015 BoE stress test includes losses from portfolio-wide default losses across cohorts of SME clients and additional losses from the default of large vulnerable counterparties. For uncollateralized exposures, the two most vulnerable counterparties amid the top 10 Asian counterparties are assumed to default, as well as the most vulnerable counterparty amid the top 10 European counterparties. For collateralized exposures, the most vulnerable exposures among the global top 20 exposures are assumed to default. See BoE (2015), "Stress Testing the U.K. banking system: guidance on the traded risk methodology for participating banks and building societies".

[34] Major U.K. banks' average return on assets (ROA) in 2014 was less than a third of its average level between 1987–2007. Average post-tax return on equity (ROE) fell from 17 percent in 2006 to 6 percent in March 2015 (BoE's Governor Mark Carney speech "Redeeming an unforgiving world," 8th Annual Institute of International Finance G20 conference, Shangai, February 26, 2016.)

[35] Divestment in noncore operations affect particularly Barclays plc (which has reduced exposure to periphery Europe, and announced on March 1, 2016, plans to divest part of its shareholding in Barclays Africa over the next two to three years), the Royal Bank of Scotland Group plc (which will reduce its geographic footprint from 38 to 13 countries), and Lloyds Banking Group plc (which has reduced its international presence from 30 countries in 2011 to seven countries).

Figure 15. United Kingdom: Banking System—Market-Based Indicators



Source: Bloomberg.

Note: The sample of U.K. banks includes HSBC Holdings plc, Barclays plc, the Royal Bank of Scotland Group plc, Lloyds Banking Group plc, and Standard Chartered plc.

57. Adverse macroeconomic conditions and stress in money markets were used to project net interest income. Banks that rely on net interest income to generate profits are particularly exposed to low NIMs. The ability of banks to pass-through higher funding costs to consumers is likely to depend on macroeconomic conditions. Under stressed conditions, deteriorating creditworthiness among borrowers is likely to limit the extent of pass-through to keep credit risk at bay. Also, the income base is expected to shrink under stress as performing loans migrate into exposures at default. At the same time, the decline in asset prices and the sharp increase in loan delinquencies are likely to increase charge-offs and loan-loss provisions, reducing banks' profits and generating solvency concerns among bank creditors. This may lead to a spike in bank funding costs. Banks with unstable funding structures are particularly exposed to credit sensitive investors.

58. Net interest income is driven by cyclical shocks to funding costs, including dislocations in money markets, shocks to NIMs, interest income from securities, and interest rate risk in the banking book. The FSAP team's approach to net interest income is summarized here:

- Funding costs were proxied by changes to deposit rates that are determined by macrofinancial conditions (that is, policy rates and LIBOR rates), as well as by firm specific conditions, including bank asset quality, bank capital adequacy, and contagion effects from funding stress in peer U.K. banks. As the capital adequacy of the U.K. banking system improves over the outer years of the scenario, bank funding costs edge down. An additional add-on funding cost reflecting dislocations in money markets was calibrated to the funding stress observed during the Eurozone crisis in H1 2012.

- NIMs were projected on the basis of the policy rate, money market rates, and the term structure assumed under the macroeconomic scenario. Given banks' traditional role of maturity transformation, when the yield curve steepens, banks' NIMs are expected to rise. Conversely,

when the yield curve flattens, banks' NIMs are likely to fall. Yet, if the yield curve steepens during crisis periods due to a spike in the term premium, as discussed earlier, banks may be reluctant to increase lending rates to rein in credit risk.

- Interest income that banks earn on other interest-earning assets, including assets held for trading purposes and liquid buffers, was projected by regulatory book.

- The impact of shocks to short-term interest rate risk in the banking book was computed using a gap risk approach to capture the risk arising from the timing on instruments' rate changes as bank assets and liabilities turn over or reprice at different times.[36] Although banks can hedge their interest rate risk or alter their operations in other ways so that interest rate changes may have little effect on overall bank profitability, bank hedges were excluded for stress test calculations.

59. The key driver of deposit rates is the money market rate. Deposit rates were projected at the bank level as:

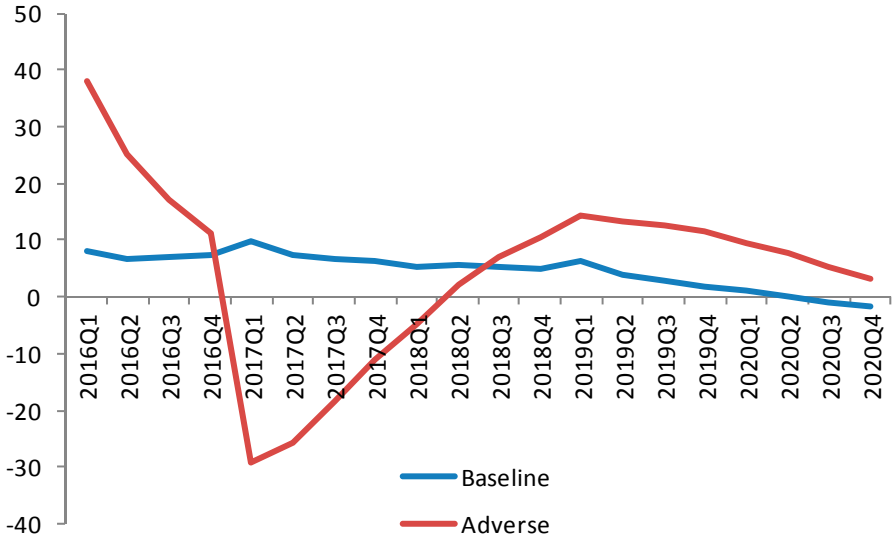
$$D_{i,t} = D_{i,2015} + \sum_{s=1}^{T-t} \Delta D_{t+s}$$

where $D_{i,2015}$ is the implicit deposit rate of bank *i* at the cut-off date December 2015 and $\sum_{s=1}^{T-t} \Delta D_{t+s}$ is the sum of accumulated funding shocks throughout the stress test horizon. Banks' initial funding costs differ across U.K. banks owing to their different funding models, liquidity management, and bank soundness. Changes to deposit rates are determined by two key drivers. First, changes to LIBOR 6m rates, with elasticity of 0.5.[37] Figure 16 plots the projection of deposit rates with their confidence interval. Second, by bank aggregate capital adequacy reflecting the linkages between solvency and funding risk (see Section F).

[36] In the BoE's capital framework, interest rate risk in the banking book is s part of Pillar 2, in line with the 2015 Basel standards on interest rate in the banking book.

[37] The regression period runs from 1999 Q1 through 2015 Q4. The R2 is 0.63. Regression results suggest that the policy rate is not statistically significant. While both series are non-stationary I (1), they are not linked by a cointegrating vector of coefficients, which would reduce their common order of integration.

Figure 16. United Kingdom: Projected Changes to Deposit Rates
(In basis points)



Source: IMF staff estimates.

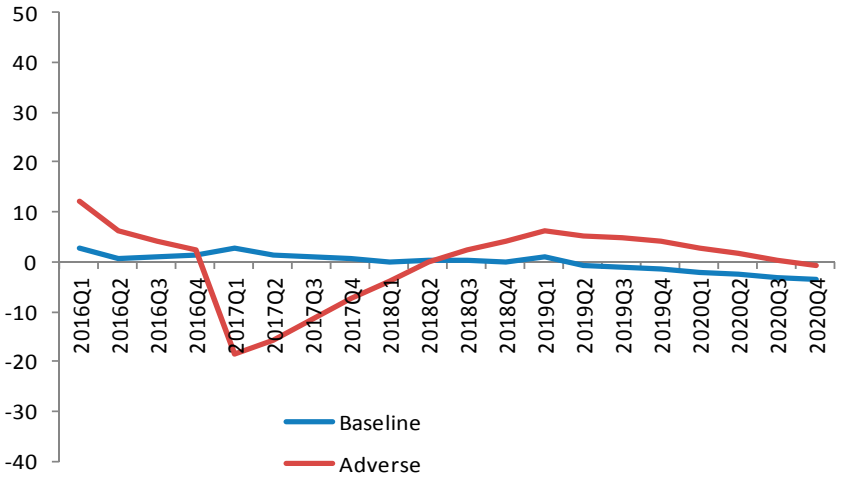
60. NIMs were regressed on money market rates and the slope of the yield curve. NIMs were projected at the bank level as:

$$NIM_{i,t} = NIM_{i,2015} + \sum_{s=1}^{T-t} \Delta NIM_{t+s}$$

where $NIM_{i,2015}$ is bank i's reported NIM in December 2015 and $\sum_{s=1}^{T-t} \Delta NIM_{t+s}$ is the sum of accumulated NIM shocks. There is cross-sectional variation of NIMs across banks. The variation in business models across the U.K. banks is the biggest driver. The weighted average NIM of U.K. major banks was around 2.8 percent in December 2015. Changes to NIMs are explained mainly by changes to LIBOR 6m rates (with elasticity 0.2) and the slope of the yield curve (with elasticity -0.1).[38] Again, both series are found to be non-stationary I (1), but there is no cointegrating vector. Figure 17 plots the projection of NIMs with their confidence interval.

[38] The regression period runs from 1999:Q1 through 2015"Q4. The R2 is 0.4. The unexpected negative sign of the slope of the yield curve can be explained by the limited pass-through during the global financial crisis due to the deteriorating creditworthiness of borrowers. A caveat of the analysis is that shocks to lending rates are proxied by changes to corporate rates which may not be perfectly aligned with changes to mortgage rates.

Figure 17. United Kingdom: Projected Changes to NIM
(In basis points)



Source: IMF staff estimates.

61. Lending rates are driven by shocks to funding costs and shocks to NIMs.

$$L_{i,t} = L_{i,2015} + \sum_{s=1}^{T-t} \Delta D_{t+s} + \sum_{s=1}^{T-t} \Delta NIM_{t+s}$$

During the first year of the adverse scenario, lending rates were projected to outpace baseline projections due to a rise in funding costs and increase in NIMs. This effect is mitigated in the second year of stress, as NIMs compress due to borrowers' creditworthiness downgrade, reflected in changes to the slope of the yield curve (Table 6). Interest accrued on defaulted loans is not recognized under the baseline and adverse scenario.[39]

Table 6. United Kingdom: Nominal Shocks to Rates
(In basis points)

	2016	2017	2018	2019	2020
ΔD_{t-2015}					
Baseline	14	16	13	12	8
Adverse	51	17	42	51	44
ΔNIM_{t-2015}					
Baseline	3	4	3	2	0
Adverse	15	-1	13	17	13
ΔL_{t-2015}					
Baseline	17	20	16	14	8
Adverse	67	16	55	68	58

Source: IMF staff estimates.

Note: The chart shows nominal shocks to rates, in the form of deviations from their end-2015 value.

[39] This differs from the 2016 EU-wide stress methodology, which allows the recognition of interest accrued on defaulted assets in line with standing accounting practices under the baseline scenario.

62. To compute interest income from the securities portfolio, banks' implicit interest rate was calculated. Using banks' reported information, yields were computed for the HFT, AFS, and HTM regulatory books by asset class, that is, own sovereign bonds, foreign sovereign bonds, corporate bonds, and other securities. The implicit interest rate was projected forward, assuming no changes in portfolio composition during the stress test period.[40] This is a conservative assumption, given the extent to which the low interest rate environment prevailing at end-2015 was pushing down market yields.

63. Interest rate in the banking book is driven by policy rate shocks and banks' repricing gaps in assets and liabilities. Interest rate gaps by time to repricing across six maturity buckets were computed for each bank, that is, <1m, 1m-2m, 2m-3m, 3m-6m, 6m-12m, and >12m, and net income is calculated as:

$$income_{i,t} = \sum_b gap_{i,t}^b \cdot \left(\frac{365 - mid^b}{365} \right) \cdot \Delta i_t^f$$

where $gap_{i,t}^b$ is the gap of bank *i* in bucket b and time *t*, mid^b is the mid-point in bucket *b* (in days), and Δi_t^f is the shock to risk free rates at *t*.

64. The bank tax rate is driven by the macroeconomic scenario. Econometric analysis suggests that the effective bank tax rate fluctuates with changes in the macroeconomic environment, in particular with changes to GDP growth and money market rates.[41] The projected tax rate declines by 4 pps in 2017 under the adverse scenario (relative to baseline) before picking up by 2019, driven by the quick recovery of the U.K. real economy.

65. Other P&L items were projected drawing on the 2016 EU-wide stress test methodology:

- The non-interest income ratio to total assets (which includes dividend income and net fee and commission income) was kept constant at its 2015 value under the baseline. Under the adverse scenario, the minimum between the 2015 ratio and the average of the two years with the smallest value over the past five years $r_i^{\min}$ was considered as the projected ratio. The weighted average ratio for U.K. banks in December 2015 was 0.82 percent of total assets, down from 0.91 percent in June 2015. The growth rate of non-interest income $g_{i,t}^{non-ii}$ was thus adjusted on the basis of the projected balance sheet growth g_t^{bs} and the lower bound ratio $r_i^{\min}$ according to:

$$g_{i,t}^{non-ii} = \frac{r_i^{\min}}{r_{i,2015}} \cdot \left(1 + g_t^{bs}\right) - 1$$

- Non-interest expenses, including administrative expenses and operating expenses, were kept constant relative to total assets under the baseline scenario. This constraint is binding for four U.K. banks in 2016. Under the adverse scenario, their value could not be below the value reported at 2015. This is a conservative assumption. The 2015 value for non-interest expense

[40] This is a reasonable assumption supported by findings by Covas, F., M. Rezende, and C.M. Vojtech, 2015, "Why Are Net Interest Margins of Large Banks So Compressed?" FEDS Notes, October 5. They show that recent contributions to NIM are mainly driven by changes to yields rather than changes to portfolio composition.

[41] A panel regression is conducted on effective tax rates of major U.K. banks, excluding the intervened banks, that is, Lloyds Banking Group plc and the Royal Bank of Scotland Group plc, over 2005–14, using data from Bloomberg.

contains material misconduct costs and, in addition, a number of U.K. banks incurred significant restructuring costs during 2015. This constraint is binding for all U.K. banks over 2016–17.

66. The dividend payout rule was fixed throughout the stress testing horizon. The FSAP team considered three options to set payout ratio projections:

- *Econometric approach:* A panel of bank payout ratios was regressed on key macrofinancial variables projected under the macro scenario. Econometric results suggest that, on average, the dividend payout ratio increases when the U.K. FTSEE index softens and LIBOR rates increase.[42] This suggests that U.K. banks might be targeting a ROE ratio that calls for an increase of the payout ratio when net profits are eroded under stressed conditions. Under this approach, the payout ratio would peak at about 80 percent in 2017 in the adverse scenario before converging to baseline levels at about 50 percent by 2020. However, the feasibility of this approach is limited by the Capital Requirement Directive (CRD) restrictions on dividend payments under thin capital buffers, and banks' declared dividend policies under stress.

- *The 2016 EU-wide stress test approach*: Under the 2016 EU-wide stress test methodology, if no publicly declared dividend policy is available, the payout ratio is the maximum of 30 percent and the median of the observed payout ratio in profitable years over the past five years. This rule has limited applicability in the U.K., as the Royal Bank of Scotland plc has not paid a dividend on its ordinary shares since it received a capital injection from the U.K. Government in 2008.[43] While in May 2015, Lloyds Banking Group plc paid its first dividend on its ordinary shares since its capital injection from the U.K. Government. Also, Nationwide Building Society is a mutual society that operates as a member-owned business model and profits are typically returned to members through better savings, loan, or mortgage rates.[44] The implementation of this approach would generate substantial variability in dividend policies across banks (with 17 percent standard deviation in payout ratios).

- A *fixed dividend payout rule* of 30 percent: This rule reflects the lower bound of the 2016 EU-wide stress test methodology, and ensures a level playing field for all U.K. banks.

F. The FSAP Team's Approach to Funding Costs

67. While U.K. banks have shifted their funding mix away from wholesale funding sources toward deposits, a market liquidity shock could lead to strains in funding markets. After the crisis, banks have shown more stable funding structures. Major U.K. banks' funding from customer deposits has increased by about GBP 250 billion since 2008, while wholesale funding has declined by over GBP 1.3 billion over the same period. In December 2015, the asset-weighted average loan-to-

[42] The regression is performed over 2005–15. The elasticity of stock market returns is -0.6 and that of LIBOR rates 2.2. The R2 of the regression is, however, low, at 0.3.

[43] The Royal Bank of Scotland Group plc has earmarked 2017 for the resumption of dividend payments or share buybacks.

[44] Starting in 2013, Nationwide has also issued core capital deferred shares (CCDS) to institutional investors.

deposit (LTD) ratio stood at 92 percent. However, a generalized sell-off in fixed-income securities spurred by uncertainty over bank solvency valuation could put pressure on funding schemes as risk sentiment among investors' turns, leading to escalating bank funding costs and amplified stress across markets.

68. The FSAP team used an econometric approach to drill down on the key drivers of U.K. banks' funding costs. The risk factors examined fall in three main categories (Appendix II, Table 1): (1) bank-specific variables, including asset quality, leverage, regulatory capital, funding structure, business model, and earning capacity; (2) country-specific variables, including macro variables, real estate prices, equity prices, corporate spreads, and credit growth; and (3) global variables, including world GDP growth, commodity prices, volatility index (VIX), U.S. equity prices, and emerging market exchange rates.

69. The analysis incorporates explicitly contagion from peer banks' funding pressures. For the same set of fundamentals, contagion can occur if funding stress in one U.K. bank is a signal to investors that other banks in the same U.K. banking system are likely to be in financial trouble. Contagion can result in the restriction of liquidity to other U.K. banks as possible counterparties shy away. To capture contagion, a two-prong approach was followed:

- For each U.K. bank, a peer group was defined as the U.K. banking system, excluding each bank in turn. The average funding costs for the peer group was regressed against the set of explanatory variables for the individual U.K. bank, that is, the U.K. bank-specific variables, country-specific variables, and global variables.

- The orthogonal residuals of the aforementioned regression were identified as a proxy of contagion from funding pressures in other U.K. banks.[45] Notably, the value of the contagion variable differs across banks.

70. The main model defines funding costs as the implicit interest rate paid in interest-bearing liabilities, and uses a panel model approach. A key challenge was to identify a proxy for bank funding costs. The key reference variable used for the main model is effective interest paid on interest-bearing liabilities. The effective interest rate reflects the P&L impact of funding stress, taking into account banks' funding structure. Alternatively, bank funding costs can be proxied by five-year senior single name CDS spreads. While this is a reasonable proxy for unsecured term wholesale funding costs, as CDS market liquidity on referenced major U.K. banks' is usually high, CDS liquidity for specific banks (for example, Nationwide Building Society) and over stressed periods might be limited. Also, it is unlikely to be representative of U.K. bank funding costs, as their main funding base is retail deposits.[46] For robustness, the analysis was replicated using five-year CDS as a proxy for

[45] This approach builds on Longstaff, F., J. Pan, L.H. Pedersen, and K.J. Singleton, 2011, "How Sovereign is Sovereign Credit Risk?" *American Economic Journal: Macroeconomics 3,* April 2011: 75–103.

[46] In addition, short-term funding can also be substituted by central bank funding, which limits the variation and information content of wholesale funding costs as proxy for banks' marginal funding costs. Finally, CDS spread may reflect counterparty concerns of the issuer of credit protection.

funding costs. The data was sourced from Bloomberg over 2000:Q1 through 2015:Q2.[47] The econometric analysis was based on a panel model with fixed effects and robust standard errors estimates. Interest payments were computed on a biannual basis.

71. The results of regressing U.K. banks' funding costs on a broad range of determinants suggest that (Table 7):

- **The most significant macroeconomic variable is unemployment.** The effect of unemployment on funding costs depends crucially on the econometric specification. When the specification controls for the BoE policy rate or conditions in the interbank market, funding costs rise with unemployment. Results show that a 1 percentage point rise in unemployment pushes up bank funding costs by around 26 bps (13 bps bi-annual).
- **Money market conditions are key determinants of bank interest payments.** The policy rate and the LIBOR rate are the most significant financial variables. A decrease in the policy or LIBOR rate by 1 percentage point reduces interest payments by about 44 bps (22 bps biannual). On the other hand, bank soundness proxied by regulatory bank capital, leverage, short-term borrowings, and asset quality are not statistically significant. As with any empirical analysis, a number of caveats apply, including changes in the definition of regulatory capital over the sample period, the impact of capital injections during the financial crisis, and recent changes in the funding model of U.K. banks toward lower reliance on wholesale markets.
- **By contrast, asset quality is a significant determinant of CDS spreads.** Asset quality is the only bank- specific indicator that drives CDS spreads across all specifications. A rise of one percentage point in the NPL ratio leads to a rise of CDS by around 12 basis points. This result suggests that investors are more credit sensitive than depositors. Improved sentiment in the U.K. residential real estate market, a boost in the U.K. equity market, and a reduction of investors' risk aversion also contribute to softening bank CDS spreads.
- **While contagion from other U.K. banks is a key driver of CDS spreads, it is not a significant driver of effective interest rates across banks.** First, the explanatory power of the CDS regression increases when the specification allows for contagion effects. Second, the coefficient for the contagion variable with a positive sign is robust across specifications and statistically significant at the one percent level. For the average bank, a rise in 100 CDS spreads in the rest of the U.K. system is associated with a rise in bank spreads of 63 bps. This result is consistent with the presence of common factors that affect all banks' credit spreads, but are not captured by the other explanatory variables, including bank- specific drivers. By contrast, contagion is not a significant determinant of effective interest rates once money market rates are included in the econometric specification.

72. A bank-by-bank econometric analysis reveals a diversity of funding cost drivers across different types of banks. For robustness, the analysis was replicated using funding costs on a range

[47] The data are sourced from Bloomberg at the biannual frequency. A cubic spline method is used to convert biannual data at the quarterly frequency in line with macroeconomic data.

of bank-by-bank individual regressions. This approach allows distilling cross-sectional variation in the determinants of funding costs. The results show that:

- **The impact of bank specific determinants on funding costs differs across types of banks** (Appendix II, Table 2). This reflects the diversity in banks' liability structure, capital retention, and recapitalization efforts in publicly intervened banks.

- **The effect of the U.K. housing market is broadly significant.** Rising prices in the U.K. residential real estate market tend to push down funding costs, except for U.K. banks with significant operations outside the U.K.

- **The effect of contagion from peer banks' funding pressure is robust for specific banks.** Even after controlling for conditions in money markets, contagion from peer banks' funding costs affects interest payments of selected U.K. banks, with an elasticity of about 0.9. This analysis may help identify banks that are potentially exposed to funding pressures in peer banks.

73. To project an add-on to funding costs, the FSAP team considered the market stress prevailing in H1 2012, banks' funding structure, and the capital adequacy of the U.K. banking system:

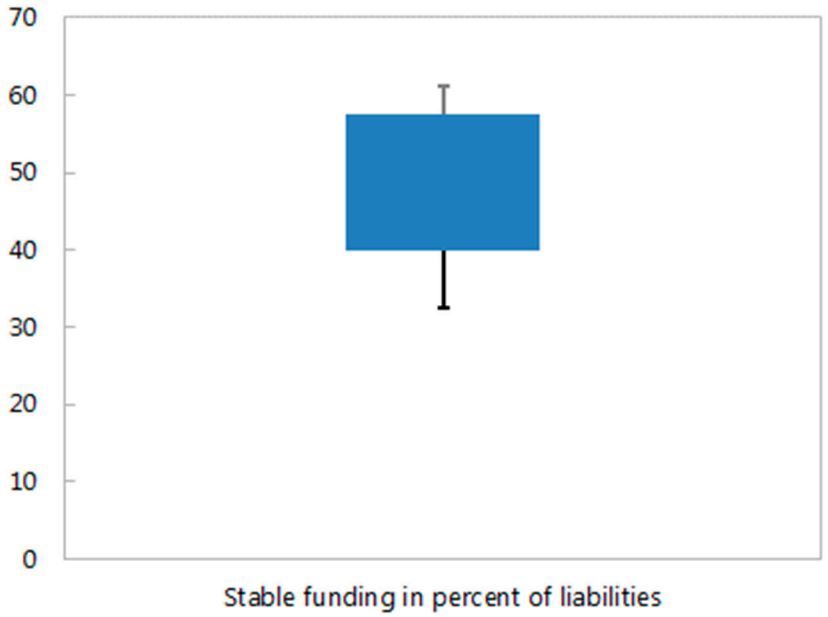
- **Under the adverse scenario, a funding shock was applied to less stable liabilities.** The funding model varies across banks. The median value of the most stable source of funding, that is, small, insured deposits, is estimated at 46 percent of interest-bearing liabilities as of end-2015 (Figure 18).

- **The magnitude of the funding shock replicates the funding stress observed at the height of the European sovereign crisis.** Financial turmoil is likely to change the average relationship between funding costs and bank-specific variables.[48] This was observed during the first half of 2012, when market concerns about a potential break-up of the euro area created strains in money markets. This benchmark period is more relevant for U.K. banks than the global financial crisis, given post-crisis changes in U.K. bank funding models with lower dependence on short-term wholesale funding. Under the adverse scenario, the margin paid on less stable liabilities was assumed to rise by the maximum increase observed in H1 2012, that is, 52 basis points annually. The funding shock is applied over the first two years of the horizon.

- **Funding costs edge down in the outer years of the stress test horizon as the banking sector rebuilds its capital buffers.** The gradual improvement in bank solvency and asset quality during 2018–19 pushes down funding costs in 2019 and 2020. The magnitude of this effect is around 38 bps in 2019 and 33 bps in 2020, respectively.

[48] See Babihuga, R., and M. Spaltro, 2014, "Bank Funding Costs for International Banks," IMF Working Paper 14/71.

Figure 18. United Kingdom: Banks' Stable Funding (Small Insured Deposits)
(In percent)



Source: IMF staff calculations.

Note: Boxplots include the 25th and 75th percentiles of the distribution (blue shaded area) and the 10th and 90th percentiles (whiskers).

G. Solvency Stress Test Results

74. The IMF stress test results suggest that major U.K. banks are resilient to a global economic downturn and to broad-based corrections in financial markets.

- Based on IMF's baseline projections, aggregate CET1 ratios stabilize at around 12.6 percent by 2020 as capital buffers grow in line with regulatory balance sheet exposures, well above fully loaded Basel III regulatory minima (Figure 19). The aggregate Tier 1 leverage ratio hovers around 4.8 percent over the stress test horizon.[49]
- Under the stress scenario, the aggregate CET1 ratio falls from 12.6 percent in December 2015 to a low point of 8.7 percent in 2017 (Figure 20), still above regulatory minima. The aggregate Tier 1 leverage ratio falls from 5.3 percent in December 2015 to a low point of 4.0 percent in 2017.
- In the aggregate, banks incur substantial losses in the first two years of the scenario amounting to GBP 35 billion. RWAs peak in 2017 with a 2.3 pps hike.

[49] The IMF leverage ratio is defined as Tier 1 (end-point CET1 and transitional additional Tier 1) relative to total assets. In contrast, the PRA leverage framework uses the CRR definition for the exposure measure.

Table 7. United Kingdom—Determinants of U.K. Banks' Funding Costs

Dependent Variable	Interest	Interest	Interest	Interest	Interest	Interest	Interest	Interest	CDS	CDS	CDS	CDS	CDS	CDS
Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
ct1	-0.065***	-0.067***	0.005	0.004	-0.004	0.001	-0.006	-0.002	0.202	0.184	9.805**	6.525	5.260	4.666
	(0.012)	(0.013)	(0.015)	(0.016)	(0.017)	(0.017)	(0.017)	(0.017)	(2.237)	(2.274)	(3.452)	(4.165)	(4.528)	(4.841)
lev					-0.010	-0.009	-0.011	-0.010			-0.710	-0.857	-0.578	-0.567
					(0.010)	(0.009)	(0.010)	(0.010)			(0.596)	(0.581)	(0.699)	(0.685)
npl	-0.014	-0.013	-0.003	-0.003	-0.000	-0.000	-0.000	-0.001	11.558**	11.356*	7.099**	7.255**	6.463**	6.524**
	(0.010)	(0.010)	(0.016)	(0.016)	(0.013)	(0.014)	(0.014)	(0.015)	(3.520)	(3.709)	(2.359)	(1.904)	(1.919)	(1.789)
stb_tf	0.001	0.001	-0.002	-0.002	-0.003	-0.003	-0.003	-0.003	0.036	0.037	0.649	0.858	0.303	0.386
	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.215)	(0.213)	(0.471)	(0.536)	(0.574)	(0.575)
unem	-0.084*	-0.096	-0.241***	-0.223**	0.083**	0.128*	0.068*	0.123*	33.951*	27.702*	39.346**	26.736*	39.349**	26.197*
	(0.040)	(0.049)	(0.056)	(0.061)	(0.031)	(0.051)	(0.029)	(0.051)	(11.864)	(10.049)	(9.764)	(10.678)	(10.144)	(10.839)
housing	-0.003	-0.002	-0.008	-0.010	-0.005	-0.008*	-0.003	-0.006	0.383	0.488	-2.482**	-1.849**	-2.184**	-1.427*
	(0.004)	(0.003)	(0.006)	(0.006)	(0.004)	(0.003)	(0.003)	(0.003)	(0.395)	(0.363)	(0.724)	(0.572)	(0.741)	(0.603)
equity	-0.001	-0.000	0.001	0.001	-0.001	-0.002*	-0.001	-0.002*	-1.302	-1.020	-0.649**	-0.415	-0.628*	-0.384
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.561)	(0.496)	(0.251)	(0.249)	(0.288)	(0.268)
vix	-0.003	-0.001	0.006*	0.004	-0.001	-0.006	-0.003	-0.008*	-0.343	0.468	0.175	1.344***	0.047	1.392**
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.298)	(0.484)	(0.214)	(0.323)	(0.227)	(0.404)
pol					0.220***	0.230***					13.108	7.287	8.195	4.722
					(0.033)	(0.033)					(7.788)	(7.657)	(6.431)	(7.204)
libor							0.204***	0.216***						
							(0.030)	(0.031)						
oil		0.001		-0.001		-0.003		-0.003		0.492**		0.715***		0.699***
		(0.001)		(0.002)		(0.002)		(0.002)		(0.152)		(0.146)		(0.171)
cont_spec *j*			0.950***	0.947***	0.458	0.368	0.563	0.493	0.603*	0.563			0.680**	0.635**
			(0.209)	(0.212)	(0.258)	(0.203)	(0.285)	(0.249)	(0.250)	(0.256)			(0.188)	(0.209)
Constant	2.103***	2.056***	2.217***	2.249***	0.075	0.009	0.223	0.148	-168.313**	-185.252**	-305.483**	-258.988*	-239.077*	-227.685
	(0.342)	(0.316)	(0.367)	(0.343)	(0.367)	(0.374)	(0.346)	(0.358)	(51.810)	(56.581)	(104.911)	(113.107)	(110.619)	(117.599)
Fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	292	292	292	292	292	292	292	292	172	172	276	276	273	273
R-squared	0.506	0.509	0.691	0.692	0.731	0.735	0.724	0.727	0.849	0.850	0.727	0.751	0.800	0.801
Banks	6	6	6	6	6	6	6	6	4	4	6	6	6	6

Robust standard errors

*** p<0.01, ** p<0.05, * p<0.1

Estimation period: 2000:Q1-2015:Q2

75. The IMF results are largely comparable to the stress test results reported by the BoE for the 2015 BoE concurrent stress test. In both stress tests, the global shocks have a major impact on bank capitalization, but all banks remain well above regulatory minima throughout the stress test horizon. The differences in starting dates, nature of shocks, transmission channels, and in-house models between the two stress tests notwithstanding, the results in terms of impact on aggregate system capital are similar.

- In the FSAP stress scenario, the aggregate CET1 ratio of U.K. major banks falls by 3.9 pps in the low point of the scenario. The Tier 1 leverage ratio falls from 5.3 percent to a low of 4.0 percent in 2017.
- In the BoE stress scenario, on a pre-management actions basis[50], the aggregate CET1 ratio falls by 4.0 pps (from 11.2 percent at end-2014 to a low point of 7.2 percent in 2016), and the PRA Tier 1 leverage ratio falls to a low of 3.4 percent (Figure 21).

76. Comparing the impact of stress across types of banks, both stress tests suggest that major U.K. international banks appear relatively more vulnerable to global shocks than major U.K. domestic banks. Under a global economic downturn scenario, internationally active banks are hit by larger impairment charges and larger mark-to-market losses in their securities portfolio. Also, they are relatively more affected by sharp corrections in asset prices and by a rise in counterparty credit risk, as they are more active in financial markets and more interconnected:

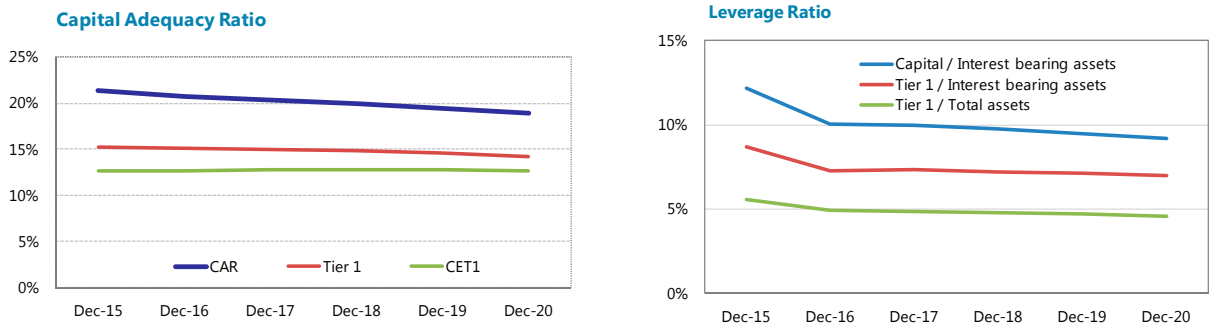
- As a result, the asset-weighted CET1 ratio of major U.K. international banks under the FSAP stress test decreases by 4.3 pps at the peak of the stress relative to the December 2015 ratio, compared to a decline of 2.6 pps for major U.K. domestic banks.
- This is similar to BoE's stress test results by type of bank, showing decreasing CET1 ratios of major U.K. international banks by 3.7 pps at the peak of the stress, compared to 2.6 pps for U.K. domestic banks.[51]

[50] The pre-management actions basis shown in the BoE 2015 Results document shows the minimum stressed ratio before the impact of strategic management actions proposed by firms and accepted by the BoE.

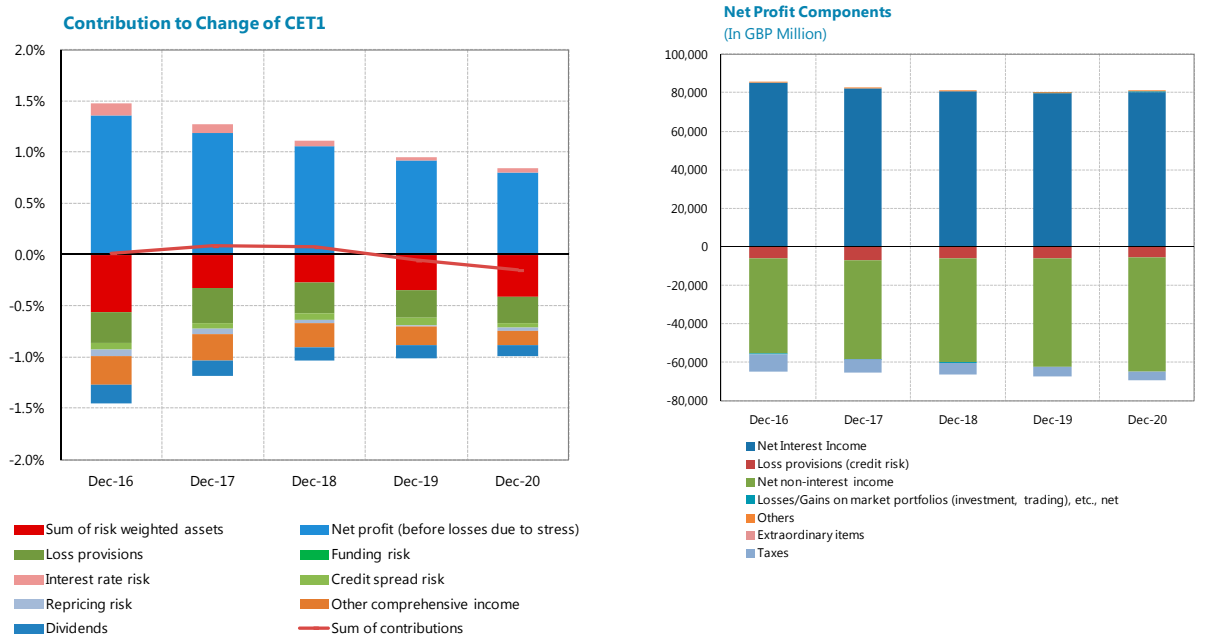
[51] This contrasts with the results of the 2014 BoE stress test, which showed domestic banks being relatively more impacted, given the focus of the 2014 scenario on domestic risks, particularly those stemming from the housing market.

Figure 19. United Kingdom: IMF Solvency Stress Test Results: Baseline Scenario

Aggregate Capitalization Charts



Aggregate Risk Drivers Charts

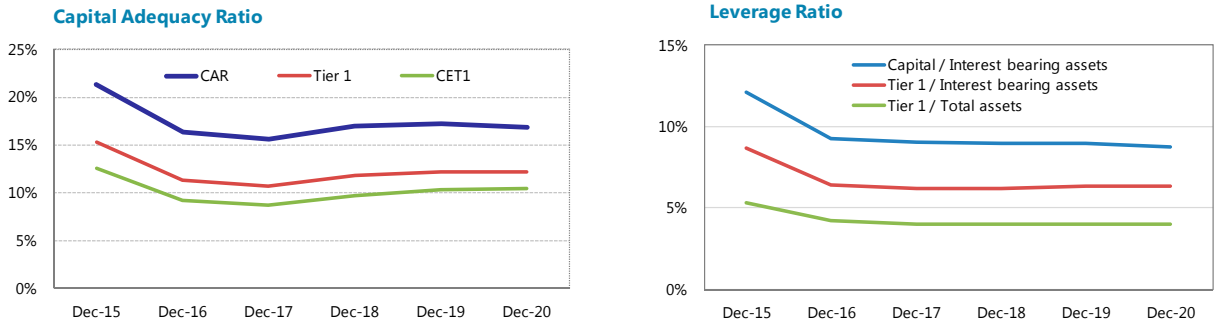


Source: IMF staff estimates.

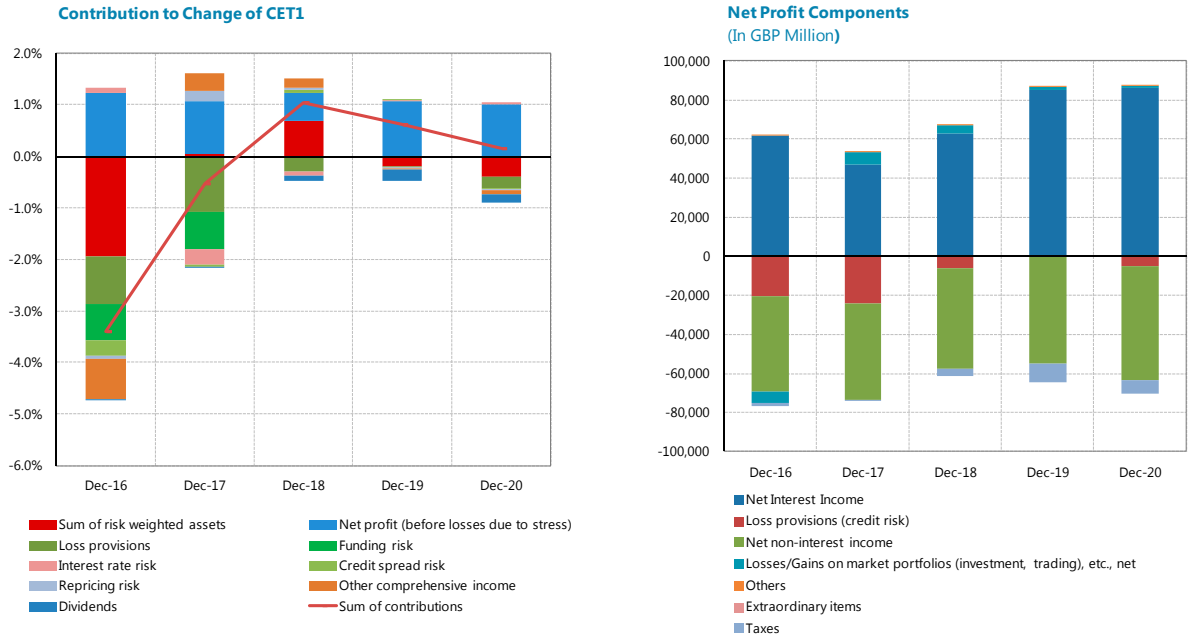
Note: Results are based on banks' submitted confidential data at the cut-off date, matched with publicly available data drawing on a wide range of sources to build a database used to perform the empirical analysis using IMF in-house models. The results for HSBC Holdings plc and Standard Chartered plc, which are reported in USD, have been converted into GDP using the FX at the cut-off date.

Figure 20. United Kingdom: IMF Solvency Stress Test Results: Adverse Scenario

Aggregate Capitalization Charts



Aggregate Risk Drivers Charts

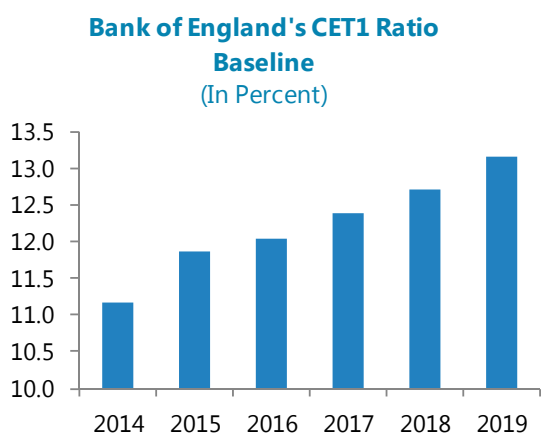


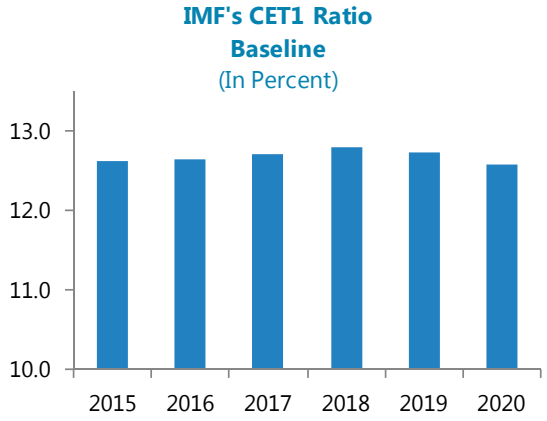
Source: IMF staff estimates.

Note: Results are based on banks' submitted confidential data at the cut-off date, matched with publicly available data drawing on a wide range of sources to build a database used to perform the empirical analysis using IMF in-house models. The results for HSBC Holdings plc and Standard Chartered plc, which are reported in USD, have been converted into GDP using the FX at the cut-off date.

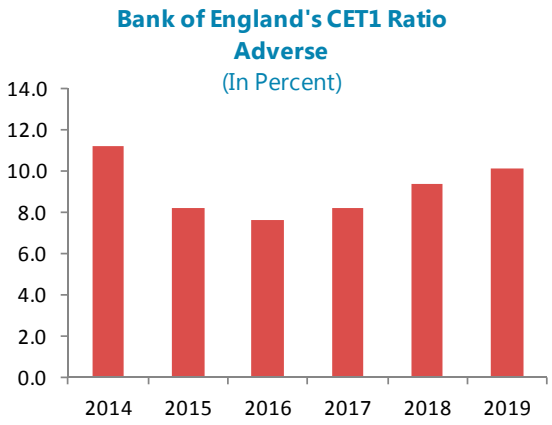
Figure 21. United Kingdom: IMF and BoE Stress Test Results

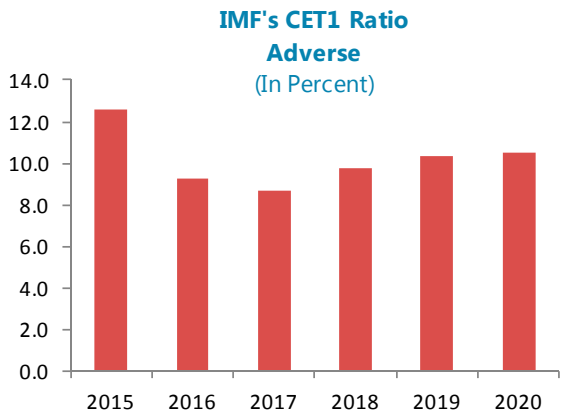
Baseline Projections





Adverse Projections





Sources: BoE (left charts) and IMF staff estimates (right charts).

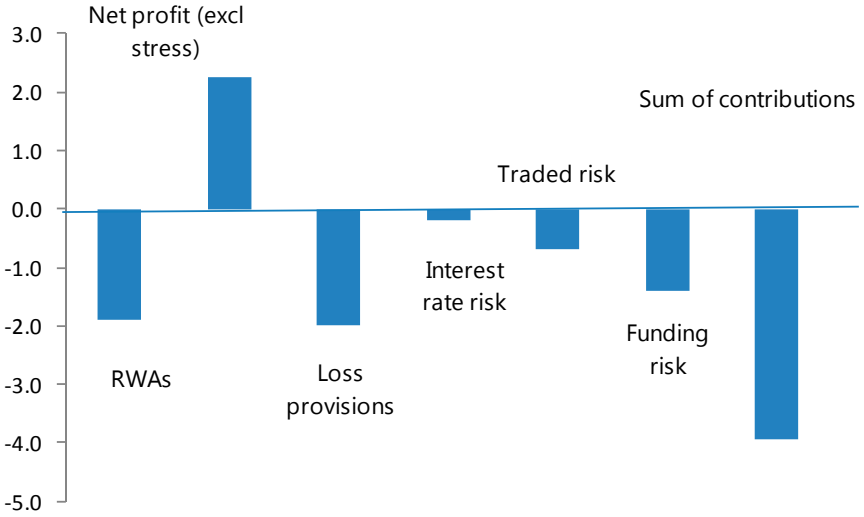
Notes: The CET1 capital ratio is defined as CET1 capital expressed as a percentage of RWAs, where these are defined in line with the U.K. implementation of the CRR via the PRA Rulebook. IMF results use banks' submitted confidential data at the cut-off date, matched with publicly available data to construct a database used to perform the empirical analysis using IMF credit risk models and P&L model-based estimates. The results for HSBC Holdings plc and Standard Chartered plc, which are reported in USD, have been converted into GDP using the FX at the cut-off date.

77. Zooming into the contributing factors to the shortfall in the aggregate CET1 reveals the impact of the various individual risks explored in the IMF stress test (Figure 22):

- The fall in aggregate capital ratios over the first two years of the FSAP stress test is mainly driven by stressed credit losses, RWAs, and funding costs.
- At the low point of the stress, the cumulative impact on aggregate CET1 relative to end-2015 capital ratios is 2.0 pps from loss provisions and 1.9 pps from shifts to RWAs. The similarity in the impact of both credit risk measures is partly driven by the methodological approach used by the FSAP team to compute unexpected losses, which draws mainly on point-in-time projections.
- The aggregate impact of funding risk is around 1.4 pps, driven by the add-on funding cost induced by money market stress. Banks are not allowed to pass-through this additional funding shock to customers.

78. In addition to the scenario-based stress test, the FSAP team conducted a separate single-factor sensitivity test on the impact of a correction of U.K. residential real estate prices on banks' capital ratios. The adverse scenario includes a cumulative peak-to-trough reduction in residential property prices of 20 percent in 2018:Q3 that is estimated to reduce recovery rates by 3.5 pps. These estimates were used to assess LGD projections for U.K. mortgage portfolios in the scenario-based stress test. To understand the sensitivity of banks' capital ratios to corrections in the U.K. housing market, an additional sensitivity test stressed the U.K. mortgage portfolio by applying a wider range of LGD shocks. Results show that the impact is broadly linear on the size of the shock. An increase of 20 pps in LGD would depress the aggregate CET1 ratio by 120 bps. The most significant contributor to the decline of capital buffers is a widening of required regulatory capital through a spike in RWAs, as shown in Figure 23 (upper chart).

Figure 22. United Kingdom: Decomposition of First Two Years' Cumulative Impact on CET1
(In percent)



Source: IMF staff estimates.

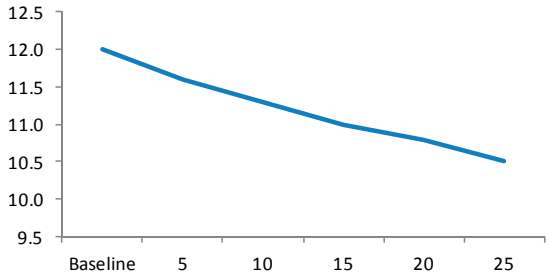
Note: The contribution to the shortfall of aggregate capital ratios is relative to initial capital ratios at end-December 2015.

79. A sensitivity assessment on the impact of a sharp move up the sterling swap curve shows that repricing risk is moderate. The scenario stress test includes projections of an adjustment to policy rates consistent with macroeconomic conditions. To test the impact of further moves on aggregate capital ratios, a separate sensitivity test was conducted to assess banks' resilience to shocks in the swap curve at the one-year maturity. The transmission of the shock operates through two channels. First, through the repricing of the AFS and trading-book portfolio. Second, through maturity gaps for interest rate risk calculations. Both effects net out somewhat. The net effect is shown in Figure 23 (lower chart). The chart shows a concave and a convex section, with an inflection point at about a 200 bps increase. An increase of 250 bps in risk-free rates would depress aggregate CET1 ratio by about 120 basis points driven by a decline in retained capital. A caveat worth noting is that this is a sensitivity test and, thus, does not take into account propagation effects from the swap curve to other asset classes or broader risk types.

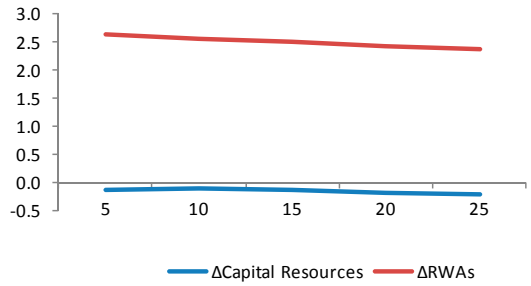
Figure 23. United Kingdom: Sensitivity Stress Test Results

House Price Shock

CET1 Ratio and LGD Shocks (pps) to U.K. Mortgages
(In Percent)

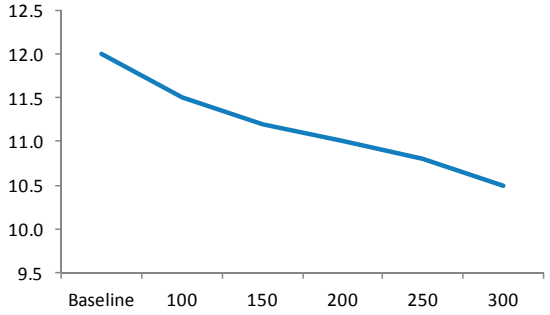


CET1 Contribution
(Change, yoy)

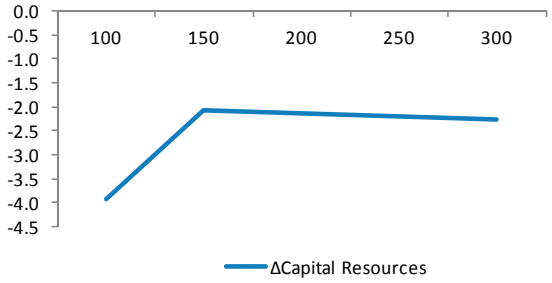


Swap Rate Shock

CET1 Ratio and Swap Rate Shocks (bps)
(In Percent)



CET1 Contribution
(Change, yoy)



Source: IMF staff estimates.

Note: The impact on aggregate CET1 ratios is immediate. No further propagation effects are considered.

FSAP TEAM ANALYSIS OF BU PROJECTIONS

A. Overview and Key Findings

80. The FSAP team applied a quantitative tool to assess BU projections generated by banks in the context of the 2015 BoE concurrent stress test. The BoE uses a hybrid approach to concurrent stress testing in which both TD models and BU banks' models play an important role to inform stress test results.[52] Banks' BU submissions are used as the starting point for the stress test projections. The BoE uses a suite of in-house models to inform judgments on where banks' BU submissions should be adjusted.[53] The FSAP team used its own TD models to assess selected BU projections. Using publicly available data, a simplified analysis was performed to cross-validate aggregate BU projected credit risk parameters for unexpected losses under the 2015 BoE scenario. The FSAP team projections were compared to banks' BU aggregate projections submitted for the 2015 BoE stress test. Specifically, the focus of the FSAP team analysis was on stressed PDs and LGDs for selected IRB exposures that are particularly relevant to major U.K. banks across the following geographic regions:

- U.K. exposures, including retail secured lending and corporate exposures; and
- Non-U.K. exposures, including corporate exposures in China, Hong Kong SAR, Ireland, and the U.S.

81. Caution should be exercised when comparing BU and FSAP team results, due to differences in data, granularity, and modeling approach. There are three main reasons BU and FSAP team projections may differ. First, FSAP projections are based on risk-neutral default measures extracted from market prices or on ex post write-off rates for selected exposures rather than on physical default probabilities of banks' portfolios. Second, FSAP results provide aggregate estimates of credit risk, while BU projections are based on granular risk characteristics of the loan portfolio, at the individual borrower or loan level, and on the diversification structure of the portfolio. Banks are able to compute detailed projections of grade migration in credit quality as a result of borrower characteristics or loan structure, including LTV, credit risk mitigation provisions, or other factors affecting expected losses. In contrast, FSAP projections use a TD approach based on the historical behavior of PD proxies or on the information embedded in corporate spreads. Third, there are key differences in the modeling approach used to inform projections. While FSAP projections are based on IMF in-house models, BU projections are calculated using banks' PRA-approved IRB models. Also, FSAP projections use PiT estimates for both PD and LGD, while BU projections reflect regulatory calibrations required for capital calculation as set out in the European Capital Requirements

[52] See 2016 U.K. FSAP Technical Note on *The BoE's Stress Testing Framework* for a detailed overview of the BoE/PRA stress testing program.

[53] BoE, 2015, "The BoE's approach to stress testing the U.K. banking system."

Regulation, which include a long-run average calibration for PD and a downturn calibration for LGD.[54]

82. Bearing these caveats in mind, the FSAP team's analysis broadly confirms banks' BU calculations, although FSAP projections exhibit a more cyclical behavior. Two features of the comparison are worth highlighting. First, the peak of stressed PDs between the two sets of projections is similar: the average maximum PD across portfolios reaches the same value, although with some variation across portfolios. BU estimates of LGD for corporate exposures reflect a weighted average of FSAP team LGD projections for investment grade (IG) and high yield (HY) corporate bonds. Overall, while FSAP team projections are more conservative for cross-border exposures, they are relatively less conservative for U.K. exposures. Second, the variable paths underlying FSAP team estimates are relatively more cyclical: FSAP team projections are relatively front-loaded during the first period of stress and rebound in the outer years of the horizon. This is explained partly by the PiT approach applied by the FSAP team, as well as by the use of market-based data used to generate projections. Both the modeling choice and the data sources used by the FSAP team are likely to reflect to larger extent nonlinear effects from cyclical shocks on credit risk parameters, relative to the long run PD and downturn LGD estimates provided by firms.

B. Framework and Analytical Approach

83. Figure 24 summarizes the framework and main steps involved in the FSAP team credit risk analysis. There are two steps involved in forecasting PDs for each portfolio. First, a set of regression equations were used to project aggregate PD proxies. Second, a time series regression comparing PD proxies and bank reported PDs was run, and the average forecast across banks was used to compute aggregate PD projections. To forecast LGDs, a structural approach was applied to extract losses from corporate spreads using the 2015 BoE scenario. The structural approach yields a set of expected losses by asset class that is a function of both corporate PDs and LGDs. Aggregate BU PD estimates were then used to back out the implied LGD projections underlying the projected expected losses.

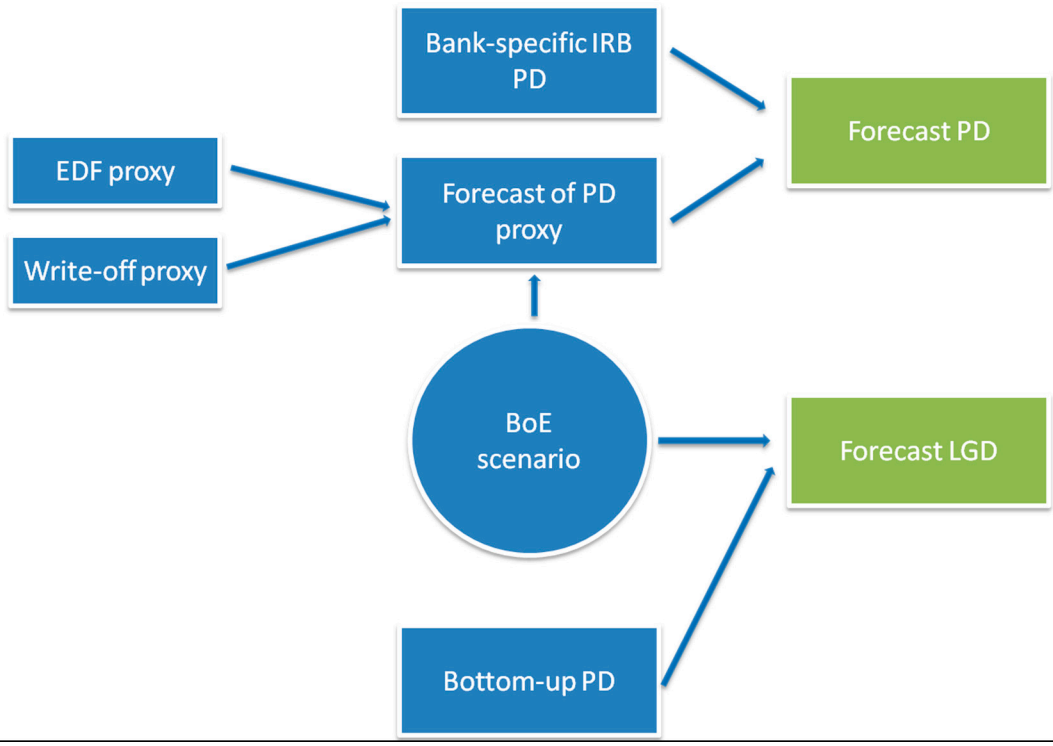
Data

84. To estimate the credit risk equations, three types of data were combined. First, macroeconomic and financial market variables drawing on the 2015 BoE scenario. The data were provided at a quarterly frequency over 2000:Q1 through 2019:Q4. The variables used in the FSAP team credit risk model are a subset of those included in the scenario. Second, aggregate credit risk data sourced from write-off data provided by the BoE on U.K. exposures by asset class. The data runs over 1995:Q1 through 2014:Q4. For banks' non-U.K. exposures, Moody's EDF rates are used as a PD proxy. The estimation period starts in 2004:Q1 for U.K. exposures and in 2002:Q1 for non-U.K.

[54] PRA, 2013, "Internal Ratings Based Approached," Supervisory Statement SS11/13.

exposures, and ends in 2014:Q4. Third, credit risk data at the bank level, drawing on banks' Pillar 3 annual disclosures over 2008–14.

Figure 24. United Kingdom: Framework of FSAP Credit Risk Analysis



85. The 2015 BoE scenario explored a deterioration of global economy over 2015–19. Economic output falls across a number of regions including the U.K., the euro area, and emerging markets.[55] In the U.K., growth turns negative in 2015:Q3 as export demand falls and higher risk premia push up banks' funding costs and credit growth contracts. U.K. inflation turns negative for the first seven quarters of the scenario, and the Bank rate is set at the zero bound.[56] Aggregate euro-area real GDP growth troughs at -2.1 percent in 2016:Q1, real GDP growth in China falls to a rate of 1.7 percent in 2015:Q4, and Hong Kong SAR are particularly impacted, with real GDP growth reaching about -6 percent at its trough. Appendix III, Figures 1–2 show the distribution of core variables under the 2015 BoE adverse scenario.

86. The BoE scenario also included detailed projections of financial variables and a traded risk scenario. Key financial variables include the U.K. yield curve, the German yield curve, average euro area excluding periphery (ex-Germany) government bond spreads, the average European periphery (ex-Greece) government bond spreads, the U.S. yield curve, 3 million LIBOR rates across major currencies, the Sterling LIBOR swap rates, the EURIBOR swap rates, and the U.S. dollar LIBOR

[55] BoE, 2015, "Stress testing the U.K. banking system: key elements of the 2015 stress test," March.

[56] The 2015 scenario places more emphasis on risks from U.K. corporate exposures than the 2014 scenario, which explored the risks from U.K. retail exposures.

swap rates. The traded risk scenario spans shocks to risk factors on FX, equities, credit spreads, commodities, rates, FX volatility, equity volatility, rates volatility, and structured finance shock across currencies, maturities, and liquidity horizons.

Methodology

87. For U.K. exposures, the econometric approach used to project PDs drew on a VAR model combined with PCA analysis. The structure of the VAR expresses each variable as a linear function of its own past values, the past values of all other variables being considered, and a serially uncorrelated error term. For each asset class, the VAR involved four equations reflecting four factors: credit risk, macroeconomic conditions, financial conditions, and real estate conditions.[57] The PCA analysis was used as a data dimensionality reduction technique to gain insight into which variables in the 2015 BoE scenario accounted for the maximum variability in the data with the minimum number of factors.[58] The PCA analysis used different sets of variables across portfolios. For instance, the macro risk factor used to explain credit risk in the mortgage book included household income, whereas the macro factor affecting credit risk in the corporate portfolio included corporate profits. Likewise, key variables loading into the financial risk factor included on the one hand, residential prices and credit growth in secured lending to individuals for the mortgage book, and on the other hand, commercial real estate prices and credit growth in corporate lending for the corporate portfolio. The econometric results suggest that mortgage loss rates are driven mainly by tight financial conditions for households, whereas corporate risk rises with a widening of corporate spreads and a correction of the CRE segment.

88. The same econometric strategy was applied to project PDs for overseas corporate exposures in advanced countries, that is, Ireland and the U.S. Results suggest that shocks to residential prices and monetary policy shocks are the key drivers of corporate stress in Ireland. PDs in U.S. corporate exposures are explained mainly by shocks to IG credit spreads, suggesting a stronger role of corporate credit markets in the U.S. Across the spectrum of loan categories, credit risk is highly autoregressive.

89. Projections for credit risk in Asian exposures were based on a quantile regression approach to capture the tail of the distribution. Because the historical period provided in the 2015 BoE scenario does not contain a severe macroeconomic downturn in emerging Asia, a quantile regression approach performs better in identifying stress than classical linear estimation techniques based on conditional means. The FSAP team chose a semi-parametric estimation at the 70th percentile to capture the tail of extreme PD realizations over the sample period. Results suggest that while distress in China is driven mainly by volatility in U.S. markets and FX depreciation, credit risk in Hong Kong SAR is impacted by corporate distress in mainland China. This suggests sizable spillover effects from global markets to emerging markets, as well as across emerging market countries. A

[57] The number of lagged values to include in each equation was determined by a number of different methods, including the Akaike (AIC) and Bayes (BIC) information criteria.

[58] The extraction of common factors to reduce the dimensionality of variables in stress test scenarios is used by Pritsker (2015) to design robust supervisory stress test scenarios.

caveat of the analysis is, however, the large confidence intervals associated with the quantile regression approach due to forecast uncertainty in the tail of the conditional distribution.

90. The FSAP team used the path of corporate spreads projections under the BoE scenario to inform LGD projections. The BoE adverse scenario projects a sharp increase in corporate bond spreads, in line with the broad-based increase in risk premia across asset classes. The spike in corporate bond spreads is particularly large for riskier asset classes, with yields on high-yield U.K. corporate bonds widening by over 1,000 bps in 2015. At the same time, safe-haven capital flows to low-risk U.S. assets compress the increase in U.K. investment grade corporate spreads to about 100 bps. Corporate spreads factor in the expected default loss of the portfolio.

91. The FSAP team applied a Merton structural model approach to extract corporate default risk. The approach relates credit spreads for the broad range of asset classes defined under the BoE scenario to corporate default rates and loss rates. Changes in the yield spread between risky and risk-free bonds should reflect changing expectations about the likelihood of loss from default, which is determined by changes to the probability of default or the expected recovery upon default. The Merton approach used by the FSAP team is described in Box 2.[59]

92. To back out LGD projections from expected losses, aggregate BU PD estimates were used in the FSAP team analysis. The structural model approach allows calibrating expected losses changes in corporate yields. Plugging the path of BU PDs in the estimated path of expected losses yields the path of estimated LGDs. When the recovery is nonzero, the credit spread is a nonlinear function of the cumulative probability of default. Using a five-year time to maturity assumption, the procedure was applied to estimate the path of LGDs for sterling IG corporate bonds, sterling HY corporate bonds, U.S. dollar IG corporate bonds, and U.S. dollar HY corporate bonds. Using the BU cumulative LGD shock to the U.K. (U.S.) corporate portfolio, the FSAP team could back out the implicit rating of the U.K. (U.S.) loan portfolio, which is consistent with FSAP team projections for U.K. (U.S.) corporate bonds.

93. Results suggest that LGD shocks are significant for low-rated asset classes but relatively moderate for investment grade bonds. The application of the structural approach is revealing: shocks are front-loaded during the first year of the scenario, with a quick recovery in the outer years. This is partly explained by the path of corporate spreads under the scenario and by the cyclical behavior of PD projections. Two caveats are worth noting. First, the theoretical relationship between credit spreads and expected losses may be hindered by the existence of liquidity premia, which would impose a yield premium to compensate lack of liquidity. Also, the differential tax treatment of corporate relative to risk-free bonds may explain variation in credit spreads. Second, idiosyncratic default risk on individual corporate issuers is not priced-in in the projection, as the BoE scenario focuses on corporate bond indices rather than on single name issuers.

[59] Manning, M.J., 2004, "Exploring the relationship between credit spreads and default probabilities," BoE WP No. 225, shows that a Merton-style structural model is more supportive for lower investment-grade issues in the IG category, i.e., BBB, than for higher rated issuers for a sample of IG bonds issued by U.K. industrial firms.

Box 2. A Structural Model to Extract LGD Estimates from Corporate Spreads

Traded securities should have a risk-neutral expected return equal to the risk-free rate. Otherwise, arbitrage opportunities would arise and the market would be out of equilibrium. If we denote by $r_{t,T}$ the risk-free rate at time *t* on a *T*-period bond, $B_{t,T}$ the value at *t* of a *T*-period zero-coupon risk-free bond, and D_T its face value at maturity:

$$B_{t,T} = D \cdot e^{-r_{t,T} \cdot (T-t)}$$

The yield on a *T*-period zero-coupon risky bond defined by $r_{t,T} + s_{t,T}$. This is the rate that is used to discount the face value at time *t* to determine the price of the security denoted by B_t^*:

$B_{t,T}^* = D \cdot e^{-(r_{t,T}+s_{t,T})(T-t)}$; replacing the above equation: $B_{t,T}^* = B_{t,T} \cdot e^{-s_{t,T} \cdot (T-t)}$.

The debt holder's payoff is of a risky zero-coupon bond is the sum of a safe claim payoff and a short position in a put option written on the firm's assets. The debt holder of a risky security holds a portfolio that is long in the default-free bond $B_{t,T}$ and short in a put option on the firm's assets with current value $V_{t,T}$, strike price *D*, volatility σ_t, and maturity *T* (or, in other words, the bond can be hedged by buying a put). Thus, the put option represents the expected loss:

$B_{t,T}^* = B_{t,T} - Put_t(D, V_t)$, rearranging we obtain $Put_t(D, V_t) = B_{t,T} - B_{t,T}^*$

The expected loss includes the probability of default of the bond and the extent of loss given default. If $PD_{t,T}$ is the risk-neutral cumulative probability of default over the remaining life of the bond, and LGD_T the loss given default:

$PD_{t,T} \cdot LGD \cdot B_{t,T} = B_{t,T} - B_{t,T}^*$, or equivalently $PD_{t,T} \cdot LGD = 1 - \frac{B_{t,T}^*}{B_{t,T}}$

The FSAP team used the BoE projected credit spread to back out the compensation for expected loss. The no- arbitrage condition implies that:

$$PD_{t,T} \cdot LGD = 1 - e^{-s_{t,T} \cdot (T-t)}$$

Using U.K. banks' submitted average PD by portfolio, the FSAP team solved for the estimated LGD embedded in the BoE scenario:

$$LGD = \frac{1 - e^{-s_{t,T} \cdot (T-t)}}{PD_{t,T}}$$

LIQUIDITY STRESS TESTS

94. The LCR for credit institutions came into effect on October 1, 2015. On that date, the PRA revoked the liquidity standards in the U.K. liquidity regulation, including firms' individual liquidity guidance (ILG). Yet firms will continue to submit the ILG reporting returns during an interim period until at least October 2016. The LCR ratio was set at 80 percent until end-2016, when it will rise to 90 percent, and it will reach 100 percent in January 2018, as required by the CRR. The 80 percent starting point is above the 70 percent ratio set out by the CRR on the basis of the narrower range of liquid assets allowed by the PRA's former regime. Box 3 provides some detail on the former ILG regime and how it compares to Basel III LCR.

95. A suite of liquidity stress tests were carried out by the BoE on scenarios calibrated by the FSAP team, drawing on the interim LCR report and a PRA liquidity return. The PRA ILG return PRA 048 will run in parallel to the COREP LCR returns until at least October 2016. Both liquidity returns were used to populate the IMF liquidity stress test templates. The PRA run specified liquidity stress tests against a sample of firms. The sample was agreed with the PRA to provide at least 80 percent coverage of total U.K. banking assets as measured by the PRA liquidity returns, and to include a diversified sample of firms. The sample consists of 10 large financial institutions, including the seven large U.K. firms covered in the solvency stress test, plus three large U.K. subsidiaries of major foreign investment banks:

- To populate the data in the LCR liquidity stress test, the interim LCR return as of end-December 2015 was used. The PRA ensured a consistent mapping of the asset haircuts, outflows, and inflow rates between the IMF template and the EU LCR template.
- The implied cash flow tests and the maturity mismatch test rely on PRA 048 returns as of January 1, 2016.
- The single currency analysis is based on PRA ILG returns.

Box 3. The PRA Liquidity Regime

The PRA revoked the liquidity standards contained in the Prudential sourcebook (BIPRU 12) in October 2015. The BIPRU 12 liquidity regime became effective in mid-2010 for the largest U.K. banks and building societies on a firm-by-firm basis. The regime included reporting obligations and quantitative elements in the form of an ILG to hold a liquid buffer against stressed outflows.

The Basel III LCR came into effect in October 2015 at a transitional starting point of 80 percent. This requirement will rise to 90 percent in 2017 and 100 percent in 2018. The quantitative elements of the PRA regime and the European Commission implementation of the Basel III LCR share a similar approach, as they require firms to hold sufficient liquid buffers to withstand stressed cash flows over a sustained period with some key differences:

- The PRA regime used three liquidity horizons for the stress test: a two-week horizon, a one-month horizon, and a three-month horizon, whereas the LCR uses a single one-month horizon.
- The PRA scenarios are not fully prescribed, but vary according to the funding vulnerabilities exposed in U.K. banks' supervisory review process and PRA's risk appetite. By contrast, LCR stress scenarios are almost fully prescribed.
- The PRA counterbalancing capacity includes a narrower range of eligible liquid assets than the LCR. Liquid assets are broadly confined to LCR's Level 1 assets.
- PRA's buffer requirement applies a suite of "add-ons" to capture risks not included in the LCR. These include intraday risk (material for major U.K. banks). These have been carried forward as part of interim Pillar 2 requirements for LCR.
- The ILG regime was somewhat stricter than the LCR, as it applied stresses to retail deposits maturing beyond the LCR's 30-day time horizon, with all retail and corporate lending rolling over in the stress.

The PRA has adopted an interim Pillar 2 approach to reflect risks not captured in the LCR, based on firms' existing ILG add-ons. The PRA's Pillar 2 regime for liquidity risk is currently under review. It includes an add-on for risks not reflected in the LCR using PRA's liquidity regime.

Sources: EBA, 2013, "Report on impact assessment for liquidity measures under Article 509(1) of the CRR," December, and PRA, 2015, "CRD IV: Liquidity," Policy Statement PS11/15, June.

A. Liquidity Stress Test Scenarios

96. To assess the short-term resilience of large banks to an abrupt withdrawal of funding, the LCR stress tests include scenarios that are more severe than those prescribed by Basel III LCR (Appendix IV, Tables 1-2). The LCR liquidity stress tests cover three predefined scenarios, including two scenarios tailored to stresses based on local assumptions and characteristics of the liquidity practices of major U.K. banks:

- A *LCR scenario,* with standard parameters set out by Basel III LCR 2013.

- A *U.K. retail stress scenario.* This scenario replicates a "Northern Rock event," with a deposit run-off as the key source of funding stress. Key assumptions include: (1) run-off rates of up to 15 percent for retail deposits; (2) rates of 60 percent for corporate deposits; (3) rates of 50 percent for operational deposits generated by clearing, custody, and cash management activities (material for U.K. banks); (4) trade finance contingent liabilities of 10 percent; and (5) an increase of outflows from retail and corporate committed but undrawn credit and liquidity facilities of up to 50 percent.

- A *U.K. wholesale stress scenario.* This scenario is a repeat of the liquidity stress observed during the global financial crisis through a freeze of wholesale funding on the interbank market, the secured funding market via repo and covered bonds, and the commercial paper market; and sizable margin calls related to secured funding, derivatives, and foreign currency funding. Key assumptions include: (1) run-off rates of up to 100 percent for corporate deposits; (2) rates of 75 percent for operational deposits generated by clearing, custody, and cash management activities; (3) outflows of secured funding backed by level-2B assets of up to 100 percent; and (4) an increase of contingent funding liabilities of up to 75 percent.

97. Two implied cash flow tests, simulating a gradual outflow of funding over five consecutive days and over a 30-day time horizon, include comparable stressed flow assumptions to those under the PRA ILG (Appendix IV, Table 3). The stressed parameters were calibrated under more severe assumptions than the money market conditions observed during the 2008 financial crisis. Assumptions on the 30-day test include:

- Haircuts of up to 60 percent for securities and bank loans that can be mobilized in repo transactions backed by other than general government collateral.

- No issuance of new unsecured funding and freeze of securitization markets.

- Callback rates of 100 percent on expected cash inflows related to credit extension without liquid financial assets as collateral, and no offsetting cash inflows from renewed wholesale lending.

- Cash outflows of up to 75 percent of maturing and non-maturity funding without liquid financial assets as collateral, and no renewal of term retail and wholesale deposits.

98. The maturity mismatch test is calibrated on six different maturity buckets, ranging from less than one week to over one year. Key assumptions include: (1) all outflows with no maturity (that is, retail accounts, derivative outflows, and corporate current accounts) are classified in the "less than one week" bucket; (2) half of the deposits maturing in less than two weeks are reported in the "deposit under one week" bucket; and (3) all securities are classified according to their residual maturity, including highly rated long-term tenor gilts.

99. The single currency analysis is based on an internal measure used by the PRA as part of the supervisory monitoring under the previous PRA liquidity regime. The scenario replicates

very severe wholesale stress, with no rollover of contractual maturities and immediate withdrawal of all on-call wholesale funding. The counterbalancing capacity is very narrowly defined, including only cash and the highest quality of liquid assets. The analysis is conducted by significant currency (that is, those comprising more than 20 percent of the balance sheet). For the sample of banks, the three significant currencies are British pounds, the euro, and the U.S. dollar.

B. Liquidity Stress Test Results

100. The results suggest that the largest U.K. banks are resilient to sudden, sizeable withdrawals of funding:

- All firms passed the LCR stress test for all three scenarios under the current 80 percent LCR hurdle rate requirement in the United Kingdom (Table 8). The results are aggregated for all currencies, as the interim LCR reporting regime is based on an all-currency basis only. The aggregate LCR ratio under the standard Basel III assumptions stands at about 140 percent. Under more stressed conditions captured by the "U.K. retail" scenario and the "U.K. wholesale" scenario, the average ratio declined to about 95 percent. The LCR ratio's sensitivity to a retail event and a wholesale event was similar, reflecting the recent change in U.K. banks' funding models towards more stable sources of funding.

Table 8. United Kingdom: Liquidity Stress Test Results—LCR Test
(In billion of British pounds)

	LCR Scenario	U.K. Retail Scenario	U.K. Wholesale Scenario
Banks Passing	10	10	10
Banks Not Passing	0	0	0
Net Cash Outflows	510	722	745
Value of Liquid Assets, After Haircuts	701	701	701
Aggregate Coverage Ratio (percent)	138	97	94

Source: BoE estimates.

- **All firms passed the five-day and 30-day implied cash flow tests** (Table 9). The average liquidity risk-bearing counterbalancing capacity to stressed cash flows stood at over 180 percent for the five-day test, and under 150 percent for the 30-day test. Results suggest that protracted noncumulative stressed cash flows over a longer time horizon would weaken banks' liquid buffers to a larger extent than cumulative stress over a shorter period. The distribution of results is shown in Figure 25. There is more variation among banks' resilience to a short-lived episode of stress than to sustained stress over a long time period, reflecting more variability in banks' funding models at the short end. Results are particularly sensitive to assumptions related to retail cash outflows. Under a scenario of stress with no retail deposit run, the average counterbalancing capacity would rise to over 325 percent (five-day test) and 250 percent (30-day test).

Table 9. United Kingdom: Liquidity Stress Test Results—Implied Cash-Flow Tests
(In billion of British pounds)

Test 1a: Implied Cash Flow Test (5 Days)

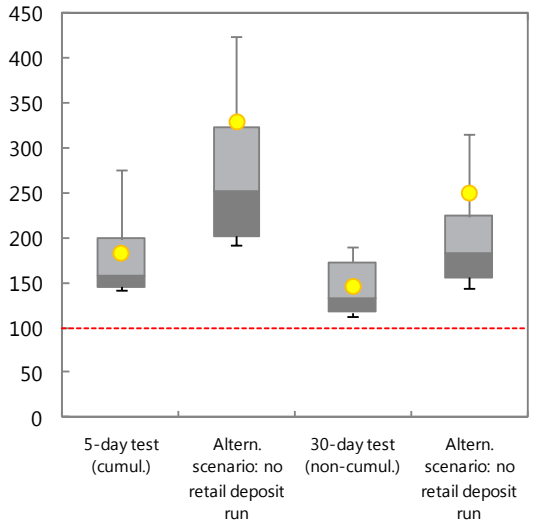
	Cumulative loss of unsecured funding (up to 1 week) (percent)	Cumulative loss of secured funding (up to 1 week) (percent)	Minimum number of days of survival	Banks illiquid (number)	Banks illiquid (percent of banking system assets)	Net cash shortfall relative to total liquid assets (percent)	Net cash shortfall relative to total assets (percent)
Day 1	5.2	5.4	1	0	0	0	0
Day 2	10.6	10.2	2	0	0	0	0
Day 3	16.4	14.5	3	0	0	0	0
Day 4	22.4	18.5	4	0	0	0	0
Day 5	315.0	243.7	5	0	0	0	0

Test 1b: Implied Cash Flow Test (30 Days)

	Cumulative loss of unsecured funding (percent)	Cumulative loss of secured funding (percent)	Survival	Banks illiquid (number)	Banks illiquid (percent of banking system assets)	Net cash shortfall relative to total liquid assets (percent)	Net cash shortfall relative to total assets (percent)
30 Days	27.5	100.0	No	0	0.0	0.0	0.0

Source: BoE estimates.

Figure 25. United Kingdom: Implied Cash Flow Tests—Distribution
(In percent, solo basis)



Source: BoE estimates.

Note: The sample of banks included in the IMF TD implied cash flow stress test includes the seven largest U.K. banks and three large subsidiaries of foreign banks representing 80 percent of the banking sector on a PRA liquidity reporting basis. Boxplots include the mean (yellow dot), the 25th and 75th percentiles (gray box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers). The red line indicates the lowest acceptable ratio value (threshold).

- **Five of the ten covered firms show a shortfall in the one- to four-week bucket in the maturity mismatch analysis.** This result is explained by the maturity gap featured by retail-focused commercial banks and building societies that focus on long-term lending funded with

short-term deposits. The scenario is very severe, as it assumes that all securities-related flows, including HQLA, can only be realized when the securities mature.

- **Single currency analysis reveals that all firms have sufficient liquid buffers in domestic currency and only a minor shortfall in foreign currency.** The results are robust to the two-week point and the one-month point of the analysis. No U.K. firm has a shortfall in GBP. Only one firm out of 10 firms in the sample has a negative position in EUR. Two firms show a slight negative shortfall in USD.

OVERALL ASSESSMENT

101. The FSAP stress test results suggest that major U.K. banks are resilient to a global economic downturn. The FSAP macroeconomic stress scenario would reduce the aggregate CET1 ratio from 12.6 percent to a low point of 8.7 percent, still above regulatory minima for all covered banks. The leverage ratio would fall from 5.4 percent in December 2015 to a low point of 4.0 percent. The results reflect first, strong initial positions, as U.K. banks have more than doubled their risk-weighted capital ratios from pre-crisis levels; and second, de-risking in banks' balance sheets through reductions in banks' international exposures, including their global investment bank activities and their non-core operations in foreign jurisdictions, improved LTV distributions in U.K. mortgages, more stable funding structures, and reduced leverage.

102. Banks' more stable funding structures are also reflected in the positive liquidity stress test results. All firms pass the LCR stress test under the current regulatory 80 percent hurdle rate for the standard Basel III scenario, as well as two tailored scenarios reflecting a U.K. retail deposit run and a U.K. wholesale event. All firms pass a five-day and a 30-day implied cash flow on an all-currency basis. Single currency analysis conducted by the PRA reveals that all firms have sufficient liquid buffers in domestic currency and only a minor shortfall in foreign currency.

103. The FSAP stress test results should be interpreted with caution. The FSAP stress test results on the U.K. banking system are based on banks' submitted data at the cut-off date, complemented by market-based and publicly available data to support stress test projections. The matching and reconciliation of risk data extracted from multiple data sources is a complex exercise and caveats are in place. Moreover, major U.K. banks have been changing their business models relative to the crisis period to improve their profitability, enhance their resilience, and comply with the new prudential regulatory framework. Structural shifts place additional constraints on the reliability of past data to inform forward-looking projections. A caveat specific to the U.K. banking system relates to uncertainties associated with the projected path of nominal bilateral exchange rates between the GBP and the USD over the stress test horizon, as two major U.K. banks report regulatory balance sheets in USD.

Appendix I. IMF Credit Risk Model for IRB Exposures

104. The FSAP team ran a battery of credit risk models to project PDs using a multivariate VAR approach combined with PCA analysis. VAR modeling is a useful approach to estimate and evaluate economic-wide models. It provides a flexible forecasting tool, it forms the basis of Granger causality testing, and it can be used to compute impulse responses. The key characteristics of this system of equations is that each equation is expressed as a function of its own lags, and other lags including lagged values of all the other variables of the system. For a multivariate VAR consisting of K variables $\{Y_{1,t,}Y_{2,t},...,Y_{K,t}\}$, the VAR is given by:

$$
\begin{aligned}
Y_{1,t} &= f_1\left(Y_{1,t-1},Y_{1,t-2},Y_{2,t-1},Y_{2,t-2},...,Y_{K,t-1},Y_{K,t-2},\right)+e_{1,t}\\
Y_{2,t} &= f_2\left(Y_{1,t-1},Y_{1,t-2},Y_{2,t-1},Y_{2,t-2},...,Y_{K,t-1},Y_{K,t-2},\right)+e_{2,t}\\
&...\\
&...\\
&...\\
Y_{K,t} &= f_K\left(Y_{1,t-1},Y_{1,t-2},Y_{2,t-1},Y_{2,t-2},...,Y_{K,t-1},Y_{K,t-2},\right)+e_{K,t}
\end{aligned}
$$

Where $\{e_{1,t,}e_{2,t},...,e_{K,t}\}$ is a vector of non-correlated error terms with zero mean and covariance matrix Ω.

105. The FSAP team constructed a series of conditional PDs, using VAR-estimated coefficients on credit risk, and using the scenario-based exogenous forecast for the rest of the system. The series are denoted by $\left\{PD^{j}_{i,t,s}\middle|s\in\{b,a\}\right\}$ at time *t,* for country *i*, asset class *j*, and scenario *s=b* for baseline and *s=a* for adverse. The VAR approach is extended to forecast credit risk based on an exogenous scenario built with the paths of the key macroeconomic and financial variables projected under the baseline and adverse scenario. Two methods were used:

- The FSAP team constructed a comprehensive range of bilateral VARs for all pairs of credit risk and each variable projected in the macroeconomic scenario. The average forecast of credit risk across all specifications was considered to reflect deterioration conditions in credit markets. Specifically, for U.K. exposures, over 170 VARs were estimated linking a PD proxy (that is, EDF or write-off rate) for each corporate class (mortgages, corporate, retail unsecured, and financial) and a set of macroeconomic and financial variables generated by the scenario (24 key variables). Separate estimations and forecasts were built for the baseline and the adverse scenario. The team followed the same approach for all international exposures located in 14 geographies. Appendix II, Table 1 shows the summary descriptive statistics of the sample of key variables used to feed the battery of U.K. credit risk models.

- A multivariate VAR, broken down by asset class and geography, and combined with a factor model reflecting deteriorating conditions in four categories of variables (macroeconomic variables, financial variables, real estate prices, and global conditions) was estimated. Again, an exogenous scenario built with projections from the baseline and adverse macroeconomic

scenario was formulated, and the credit risk proxy was projected over the stress test horizon using the estimated VAR coefficients and the first loading factor of each principal component.

106. The factor model approach allows extracting systematic risk factors from major macrofinancial variables and incorporates them into the VAR specification. The composition of each factor is informed by the following set of variables:

- *The macro factor* is linked to macroeconomic developments related to GDP growth, inflation, unemployment, FX rates, and policy rates.
- *The financial factor* captures financial conditions related to money markets (LIBOR rates), public debt markets (term structure), corporate markets (credit spreads), equity markets (returns), and credit markets (credit availability and cost of credit).
- *The real estate factor* includes developments in residential housing and CRE.
- *The global factor* reflects conditions in interest rate swap markets, U.S. equity markets, and commodity prices (fuel and nonfuel).

107. The set of variables feeding into each principal component can be regarded as a system containing N variables $v_t = \{v_{1,t}, v_{2,t}, ..., v_{N,t}\}$ and $K \leq N$ factors $s_t = \{s_{1,t}, s_{2,t}, ..., s_{K,t}\}$, with:

$$v_t - \mu = \beta \cdot s_t + u_t$$

Where μ_{it} is the mean of v_{it}, and the vector of factors (s_t) and the vector of disturbances (u_t) have the properties $E[u_t] = 0$, $E[u_t u_t'] = \Omega$, $E[s_t] = 0$, $E[s_t s_t'] = I$. The equation shows that $v_t - \mu$ can be decomposed into a systematic component $\beta \cdot s_t$ and an idiosyncratic component (u_t). Given the properties of s_t and u_t, the covariance structure of v_t can be decomposed as $\text{cov}(v_t) = \beta\beta' + \Omega$ where $\beta\beta'$ captures the systematic factors.

108. For each asset class and geography, a different set of factor analysis is conducted and underlying drivers identified. For instance, key financial conditions driving credit risk in U.K. corporate exposures include corporate lending credit growth and corporate lending rates, whereas default in U.K. mortgages is explained by credit supply in secured lending and floating rates in mortgages. On the other hand, financial conditions driving risk in U.K. financial exposures are linked to money market rates across currencies, given the geographic footprint of international banks.

109. To reduce the dimensionality of the multivariate VAR, the first factor of each principal component is included as an endogenous driver. The first factor explains about 65 percent of macroeconomic conditions, 50 percent of financial conditions, 90 percent of real estate conditions, and over 70 percent of global conditions for the United Kingdom. Similar variation is explained by the first factor of the PCA in foreign jurisdictions.

Table 1. Summary Statistics—U.K. Scenario

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
PD proxy									
EDF corp	3.417	2.994	7.989	2.304	1.272	2.203	7.426	74.733	0.000
EDF fin	1.060	0.965	2.830	0.431	0.478	1.649	6.587	45.500	0.000
EDF cons	2.480	2.312	6.827	0.921	1.258	1.645	5.712	34.848	0.000
write-off corp	0.256	0.209	0.709	0.060	0.175	0.758	2.708	4.572	0.102
write-off fin	0.017	0.009	0.263	-0.014	0.039	5.608	35.835	2307.495	0.000
write-off mor	0.012	0.012	0.032	0.001	0.008	0.855	3.306	5.777	0.056
write-off unsec	0.888	0.840	1.979	0.370	0.326	1.058	4.440	12.556	0.002
Global									
libor euro	1.802	1.405	5.085	-0.002	1.529	0.700	2.291	4.716	0.095
libor gbp	2.805	1.179	6.340	0.537	2.195	0.319	1.305	6.288	0.043
libor usd	1.988	0.816	5.600	0.299	1.888	0.803	2.057	6.649	0.036
US equity	8.283	11.450	38.462	-40.030	16.282	-1.466	5.368	27.220	0.000
non fuel g	6.274	7.780	31.823	-18.391	14.151	-0.133	1.959	2.213	0.331
oil g	11.756	15.696	47.728	-47.225	26.093	-0.657	2.601	3.614	0.164
oil	78.468	77.009	108.132	33.384	22.901	-0.236	1.759	3.379	0.185
UK financial									
credit corp	4.659	-0.200	18.400	-4.400	8.505	0.531	1.580	6.029	0.049
credit mor	5.257	1.700	15.300	0.600	5.198	0.567	1.620	6.110	0.047
credit unsec	4.580	4.850	14.000	-2.300	4.826	0.503	2.447	2.528	0.282
lending corp	4.519	3.208	7.277	2.657	1.713	0.330	1.265	6.605	0.037
lending sec	4.332	3.630	5.950	3.107	1.076	0.278	1.233	6.574	0.037
lending unsec	7.944	7.715	9.133	6.987	0.703	0.181	1.542	4.326	0.115
slope	0.991	1.276	3.067	-2.019	1.394	-0.337	1.932	6.910	0.032
UK_equity	6.598	9.806	36.833	-35.344	14.803	-1.005	4.253	10.758	0.005
UK real estate									
cre	1.466	4.666	15.045	-31.178	12.743	-1.213	3.508	11.783	0.003
housing	3.691	4.743	19.792	-17.103	8.045	-0.538	3.557	2.814	0.245
UK macroeconomic									
FX	1.147	0.034	38.668	-13.885	11.011	1.643	6.366	42.419	0.000
growth	1.437	2.131	4.174	-5.823	2.295	-1.865	6.144	45.616	0.000
inf	2.476	2.413	4.876	0.000	1.099	0.185	3.060	0.269	0.874
yield	3.685	3.675	5.046	1.817	1.024	-0.310	1.790	3.543	0.170
policy	2.372	0.500	5.700	0.400	2.173	0.340	1.218	6.967	0.031
libor 3m	2.670	0.890	6.291	0.428	2.256	0.330	1.293	6.420	0.040
unem	6.457	6.150	8.400	4.700	1.310	0.064	1.333	5.355	0.069

Sources: Moody's KMV, WEO, GAS, Haver Analytics, and BoE.

Note: Summary descriptive statistics of U.K. key variables used for the FSAP team's credit risk model of U.K. exposures. The data run from 1995:Q1 to 2015:Q2. PD proxies include 1y EDF for U.K. corporate group (EDF corp.), U.K. financial group (EDF fin), U.K. consumer nondurable and services group (U.K. unsec), write-off rates on sterling loans to corporations (write-off corp.), financial institutions (write-off fin), secured lending to individuals (write-off mor), and unsecured lending to individuals including SME (write-off unsec). Global variables include the 6m libor euro, libor gbp, libor usd, the yoy growth of S&P 500 (US equity), of nonfuel commodity prices (non fuel g), and of oil (oil g), and the price level of oil prices (oil). U.K. financial variables include the yoy credit growth to corporates (credit corp.), mortgages (credit mor), and retail unsecured (unsec); the lending rate for corporates (lending corp.), mortgages (lending mor), and retail unsecured (lending unsec); the slope of the yield curve (10y-3m), and the yoy growth of the FTSE 100 (U.K._equity). U.K. real estate variables include yoy changes to the Investment Property Databank price index (cre), and to the Halifax and Nationwide Building Society residential house prices (housing). U.K. macroeconomic variables include yoy growth rate of the nominal exchange rate gbp to usd (FX), GDP growth (growth), inflation (inf), 10y sovereign yield (10y yield), the Bank's rate (policy) the libor 3m in sterling (libor 3m), and the unemployment rate (unem).

Appendix II. Funding Cost Variables and Bank-Specific Results

Table 1. Funding Cost Variables

Category	Indicator	Variable
Dependent variable		
Funding cost	Inerest expense to interest-bearing liabilities	interest
	5 year single name CDS spread	CDS
Contagion	Orthogonalized residual of regressing the rest of the UK banking system funding costs on all fundamental drivers given specification j	cont_spec j
Bank specific variables		
Asset quality	NPL ratio	npl
	Loss provision to total loans	loss_r
	Loss provision to NII	prov_nii
	Loan loss coverage ratio	cov
Leverage	Tangible equity to total assets	te_ta
	Leverage	lev
Capital	RWAs to total assets	rwa_a
	CT1 ratio	ct1
Funding model	Short-term borrowing to total funding	stb_tf
	LTD ratio	ltd
Business model	Trading profit to total revenue	tprof_rev
	VaR to equity	vte
Earning capacity	Pre-provision operating revenue to total assets	pre_rev_a
	ROA	roa
Country specific variables		
Real economy	GDP growth	g
	Inflation rate	inf
	Unemployment rate	unem
	Corporate profit growth	corp_g
	Household income growth	inc_g
Real estate market	Residential property price growth	housing
	Commercial real estate price growth	CRE
Equity market	FTSE price index growth	equity
Money market	Policy rate	pol
	3m LIBOR GBP	libor
Credit market	Corporate spread - IG	spread_ig
	Corporate spread - HY	spread_hy
	Credit growth - mortgages	g_sec
	Credit growth - retail unsecured	g_unsec
	Credit growth - corporate	g_corp
Global variables		
Real economy	GDP growth - world	g_w
Commodity market	Oil price	oil
Financial market		
FX market	G20 EE USD exchange rate growth	fx_em
Equity market	S&P 500 price index growth	equity_us
	VIX	VIX

Table 2. United Kingdom—U.K. Bank-by-Bank Results

Bank	Bank 1		Bank 2		Bank 3		Bank 4		Bank 5		Bank 6	
Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ct1	-0.008	-0.004	0.003	-0.011	-0.096***	-0.051*	-0.009	-0.018**	-0.049	-0.019	0.090**	0.111***
	(0.010)	(0.010)	(0.036)	(0.032)	(0.023)	(0.027)	(0.008)	(0.007)	(0.060)	(0.061)	(0.033)	(0.033)
lev	-0.017***	-0.015***	-0.003	-0.005	-0.071***	-0.051***	-0.019***	-0.020***	-0.110**	-0.097**	0.027*	0.038**
	(0.002)	(0.002)	(0.029)	(0.029)	(0.015)	(0.018)	(0.004)	(0.005)	(0.047)	(0.047)	(0.014)	(0.016)
npl	-0.004	-0.006	-0.096	-0.073	-0.166***	-0.117***	-0.029**	-0.048**	-0.065***	-0.078***	0.220***	0.226***
	(0.012)	(0.012)	(0.094)	(0.088)	(0.035)	(0.035)	(0.011)	(0.018)	(0.012)	(0.012)	(0.052)	(0.047)
stb_tf	-0.001	-0.001	-0.003	-0.001	0.012***	0.007*	-0.000	-0.000	-0.008	-0.007	0.114***	0.114***
	(0.001)	(0.001)	(0.008)	(0.008)	(0.003)	(0.004)	(0.001)	(0.001)	(0.017)	(0.017)	(0.039)	(0.035)
unem	0.013	0.061***	0.109**	0.033	0.488***	0.452***	0.032**	0.051***	0.017	0.136***	-0.040	-0.044
	(0.018)	(0.019)	(0.049)	(0.070)	(0.072)	(0.065)	(0.012)	(0.011)	(0.031)	(0.032)	(0.066)	(0.099)
housing	-0.005**	-0.006***	-0.004	-0.001	-0.024***	-0.018***	-0.012***	-0.012***	0.005	0.001	-0.020*	-0.026**
	(0.002)	(0.002)	(0.004)	(0.005)	(0.007)	(0.006)	(0.002)	(0.002)	(0.007)	(0.007)	(0.011)	(0.011)
equity	-0.000	-0.001	-0.003	-0.002	0.001	0.000	0.001*	0.001	-0.001	-0.004**	0.002	0.001
	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.004)	(0.004)
vix	0.001	-0.004**	-0.006	-0.000	0.002	-0.003	-0.000	-0.001	0.006	-0.008*	-0.002	-0.006
	(0.002)	(0.002)	(0.009)	(0.008)	(0.005)	(0.005)	(0.001)	(0.002)	(0.004)	(0.004)	(0.004)	(0.006)
oil		-0.003***		0.003		-0.003*		0.000		-0.008***		-0.001
		(0.000)		(0.003)		(0.002)		(0.001)		(0.001)		(0.003)
libor	0.162***	0.164***	0.204***	0.189***	0.190***	0.230***	0.111***	0.085***	0.222***	0.250***	0.089	0.031
	(0.016)	(0.016)	(0.032)	(0.034)	(0.037)	(0.031)	(0.013)	(0.018)	(0.021)	(0.021)	(0.073)	(0.096)
cont_spec *j*	0.668***	0.648***	-0.141	0.286	-0.083	0.043	0.386***	0.355***	1.172***	0.893***	1.343***	1.306***
	(0.095)	(0.103)	(0.342)	(0.302)	(0.236)	(0.226)	(0.072)	(0.066)	(0.258)	(0.281)	(0.461)	(0.461)
Constant	0.686***	0.576**	-0.011	0.223	1.018**	0.249	0.719***	0.856***	2.643*	2.207	-1.604**	-1.965***
	(0.226)	(0.222)	(0.600)	(0.528)	(0.494)	(0.538)	(0.161)	(0.195)	(1.398)	(1.380)	(0.638)	(0.656)
Observations	56	56	54	54	44	44	44	44	58	58	36	36
R-squared	0.960	0.961	0.845	0.867	0.902	0.911	0.982	0.984	0.880	0.898	0.914	0.922

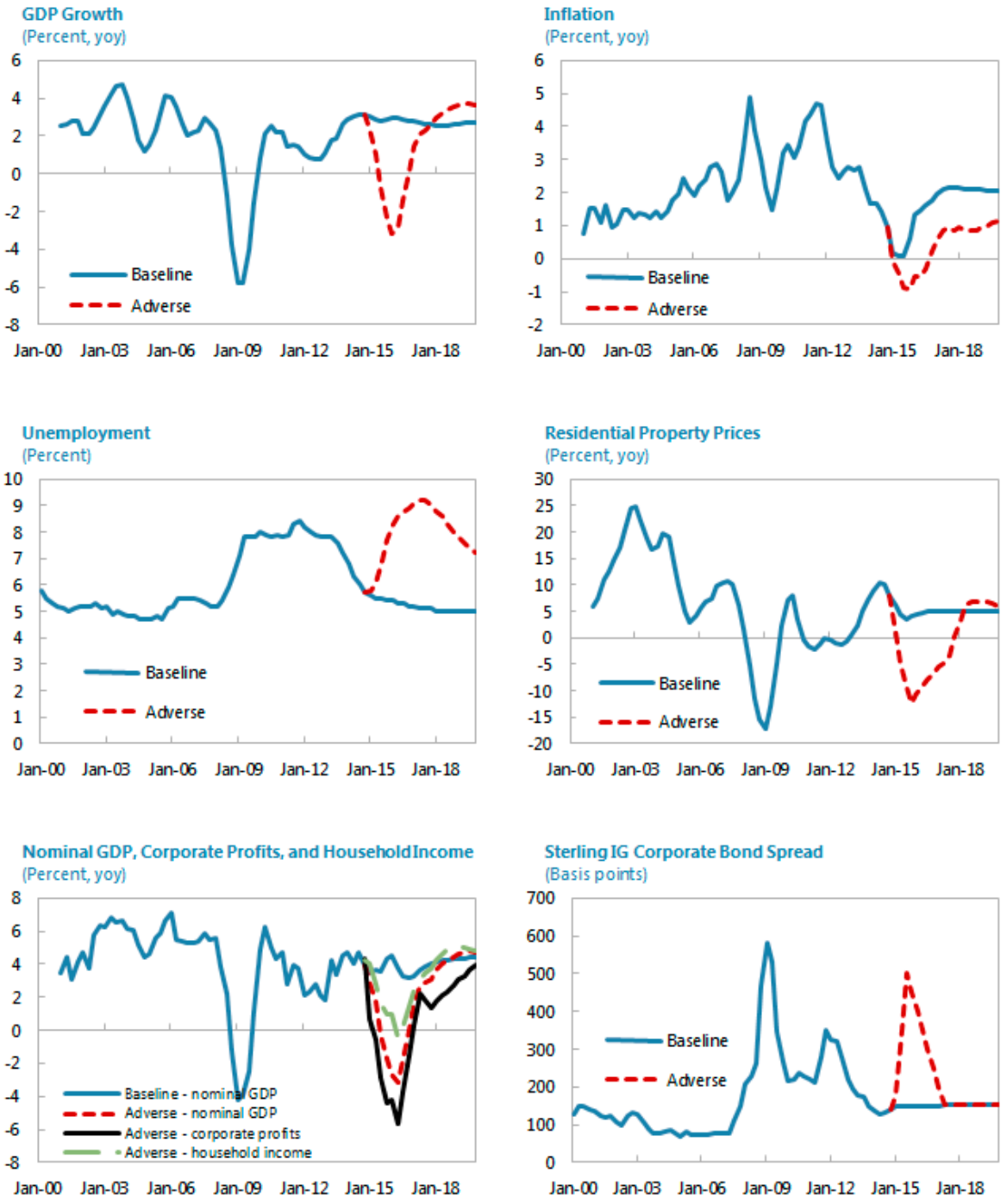
Robust standard errors

*** p<0.01, ** p<0.05, * p<0.1

Estimation period: 2000Q1-2015Q2

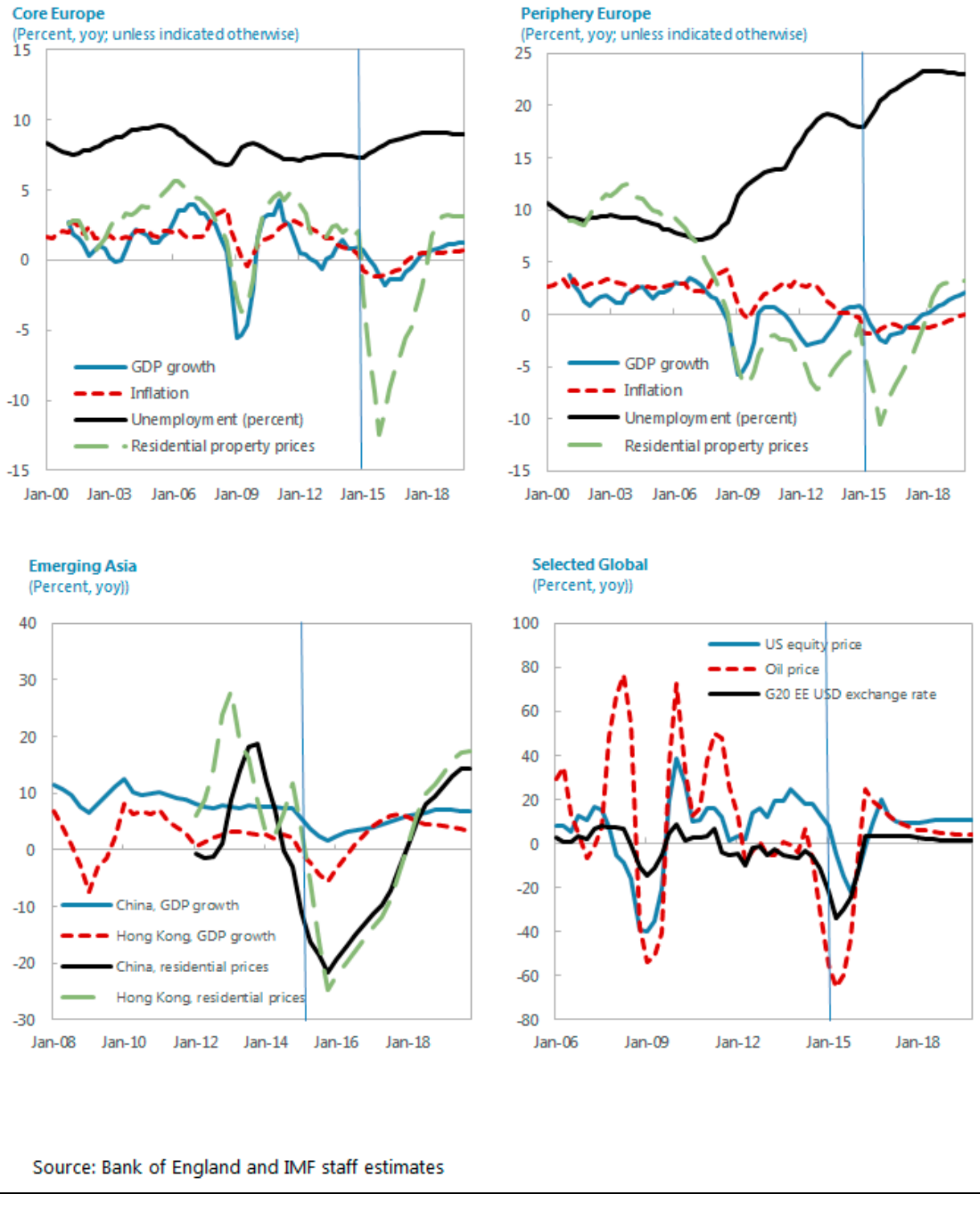
Appendix III. BoE Scenario

Figure 1. BoE Scenario—U.K. Projections



Source: Bank of England and IMF staff estimates.

Figure 2. BoE Scenario—Foreign Adverse Projections



Source: Bank of England and IMF staff estimates

Appendix IV. LCR Scenarios and Implied Cash-Flow Assumptions

Table 1. LCR Scenario—Inflows

A. Eligibility of liquid assets

	LCR Scenario	U.K. Retail Scenario	U.K. Wholesale Scenario
Level 1 Assets	100%	100%	100%
Coins and bank notes			
Qualifying marketable securities form sovereigns, central banks, PSEs, and			
Qualifying central bank reserves			
Domestic sovereign or central bank debt for nonzero risk-weighted entities			
Level 2a Assets	85%	85%	85%
Qualifying marketable securities form sovereigns, central banks, PSEs, and			
Qualifying corporate debt securities rated AA- or higher			
Qualifying covered bonds rated AA- or better			
Level 2b Assets			
Qualifying Mortgage Backed Securities	75%	75%	75%
Qualifying corporate debt securities rated between A+ and BBB-	50%	50%	50%
Qualifying common equity shares	50%	50%	50%

B. Haircuts on Inflows of liquid assets (over 30 days)

	LCR Scenario	U.K. Retail Scenario	U.K. Wholesale Scenario
Level 1 assets	0%	0%	0%
Level 2a assets	15%	15%	15%
Level 2b assets			
Eligible RMBS	25%	25%	25%
Other	50%	50%	50%
Margin lending backed by all other collateral	50%	50%	50%
All other assets	100%	100%	100%
Credit or liquidity facilities	0%	0%	0%
Operational deposits held at other financial institutions	0%	0%	0%
Other inflows, by counterparty			
Retail counterparties	50%	50%	50%
Nonfinancial wholesale counterparties, transactions not listed above	50%	50%	50%
Financial institutions and central banks, transactions not listed above	100%	100%	100%
Net derivative cash inflows	100%	100%	100%
Other (contractual) cash inflows	100%	100%	100%

Table 2. LCR Scenario—Outflows

C. Outflows of liquid assets (over 30 days)

	LCR Scenario	U.K. Retail Scenario	U.K. Wholesale Scenario
Retail Deposits			
Demand deposits			
Stable deposits	5%	10%	5%
Less stable retail deposits	10%	15%	10%
Term deposits, residual maturity > 30d	0%	0%	0%
Unsecured Wholesale Funding			
Demand and term deposits, residual maturity < 30d, small business			
Stable deposits	5%	10%	5%
Less stable deposits	10%	15%	10%
Operational deposits generated by clearing, custody, and cash management activities	25%	50%	75%
Portion covered by deposit insurance	5%	5%	50%
Cooperative banks in an institutional network	25%	25%	100%
Nonfinancial corporates, sovereigns, central banks, multilat development banks, PSEs			
Fully covered by deposit insurance	20%	20%	50%
Not fully covered by deposit insurance	40%	60%	100%
Other legal entity customers	100%	100%	100%
Secured Funding			
Secured funding with a central bank, or backed by Level 1 assets	0%	0%	0%
Secured funding backed by Level 2A assets	15%	15%	15%
Secured funding backed by non-Level 1 or non-Level 2A asset, with domestic sovereign, mu	25%	25%	50%
Funding backed by RMBS eligible for Level 2B	25%	25%	50%
Funding backed by other Level 2B assets	50%	50%	100%
Other secured funding transactions	100%	100%	100%
Additional Requirements			
Valuation changes on non-Level 1 posted collateral securing derivatives	20%	20%	20%
Excess collateral held by bank related to derivate transactions that could be called anytime	100%	100%	100%
Liquidity needs related to collateral contractually due on derivatives transactions	100%	100%	100%
Increased liquidity needs related to derivative transactions allowing collateral substitution	100%	100%	100%
ABCP, SIVs, conduits, SPVs, or similar			
Liabilities from maturing	100%	100%	100%
Asset backed securities	100%	100%	100%
Undrawn but committed credit and liquidity facilities			
Retail and small business	5%	10%	5%
Nonfinancial corporates, sovereigns, central banks, multilat dev. banks, PSEs			
Credit facilities	10%	30%	10%
Liquidity facilities	30%	50%	30%
Supervised banks	40%	50%	50%
Other financial institutions			
Credit facilities	40%	50%	50%
Liquidity facilities	100%	100%	100%
Other legal entity customers, credit and liquidity facilities	100%	100%	100%
Other contingent funding liabilities			
Trade finance	5%	10%	5%
Customer short positions covered by customers' collateral	50%	75%	75%
Additional contractual outflows	100%	100%	100%
Net derivate cash outflows	100%	100%	100%
Any other contractual cash outflows (not listed above)	100%	100%	100%

Table 3. Implied Cash Flow Assumptions

Test	Definition	Basic Assumptions		Other Assumptions
		Assets (cash inflows)	Liabilities (cash outflows)	
5-day implied cash flow (ICF) test	cumulative inflow and outflow over 5 consecutive days	Liquid financial assets: (i) cash and cash balances with central banks [**haircut**: 0 percent], (ii) securities and bank loans eligible at major central banks [0-15], (iii) securities and bank loans which can be mobilized in repo transactions (or another type of lending against financial collateral) [5-30], and (iv) marketable securities [10-35]; Cumulative cash inflows: (i) expected cash inflows related to credit extension without liquid financial assets as collateral [**call-back rate**: 20 percent per day], (ii) expected inflows of cash and liquid assets related to maturing transactions with liquid securities and bank loans (e.g., reverse repo and securities borrowing transactions) [20], (iii) expected and potential net cash flows related to derivatives (excl. credit derivatives) – net contractual cash flows [20], and (iv) potential inflows from committed/uncommitted credit lines to related and third parties [5/3].	Cumulative cash outflows: (i) maturing and non-maturity funding without liquid financial assets as collateral [**discount factor**: 5 percent per day] (i.e., all deposits and funding from financial and non-financial corporates as well as private households and SME clients) with the exception of sovereign and other public sector and central bank clients [0], (ii) expected outflows of cash and liquid assets related to transactions with liquid securities and bank loans (e.g., repo and securities lending transactions) [20], (iii) maturing outflows to related parties [20], and (iv) committed/uncommitted contingent claims to related and third parties [5].	A ratio lower than 100 percent implies a liquidity shortage if the stress scenario would materialize at the reporting date (i.e., potentially required liquidity > potentially available liquidity); only unencumbered liquid assets (generating cash inflows), i.e., assets used as a collateral to receive funding (with the exception of cash/cash-equivalents) are included in the test ("liquidity scope"); new unsecured financing and securitization impossible within the time horizon; no offsetting cash inflows from new or renewed (secured/unsecured) wholesale lending (at contractual maturities) but full renewal of secured retail lending (e.g., secured lending with illiquid collateral (residential mortgages); central bank eligible collateral can be monetized at appropriate haircuts; repo markets are open at appropriate haircuts; fire-sale of assets possible at appropriate haircuts; no consideration of funding via potentially re-usable securities received as collateral ("rehypothecation"); limited potential unsecured support in convertible currencies from related and third parties (e.g., in the form of committed lines); no renewal of term retail and wholesale deposits; and full convertibility between currencies (within one week).
30-day implied cash flow (ICF) test	non-cumulative	Liquid financial assets: (i) cash and cash balances with central banks [0], (ii) securities and bank loans eligible at major central banks [0-20], (iii) securities and bank loans which can be mobilized in repo transactions (or another type of lending against financial collateral) [10-60], and (iv) marketable securities [20-70]; Non-cumulative cash inflows: (i) expected cash inflows related to credit extension without liquid financial assets as collateral [**call-back rate**: 100 percent], (ii) expected inflows of cash and liquid assets related to maturing transactions with liquid securities and bank loans (e.g., reverse repo and securities borrowing transactions) [100], (iii) expected and potential net cash flows related to derivatives (excl. credit derivatives) – net contractual cash flows [100], and (iv) potential inflows from committed/uncommitted credit lines to related and third parties [23/12].	Non-cumulative cash outflows: (i) maturing and non-maturity funding without liquid financial assets as collateral [10-75] (i.e., all deposits and funding from financial and non-financial corporates as well as private households and SME clients) with the exception of sovereign and other public sector and central bank clients [0], (ii) expected outflows of cash and liquid assets related to transactions with liquid securities and bank loans (e.g., repo and securities lending transactions) [100], (iii) maturing outflows to related parties [100], and (iv) committed/uncommitted contingent claims to related and third parties [23].	

Appendix V. Stress Test Matrix (STeM): Solvency and Liquidity Risks

Banking Sector: Solvency Test			
Domain		**Framework**	
		BU/TD by Authorities	**TD by FSAP Team**
1. Institutional perimeter	Institutions included	• Seven major banks and building societies: Barclays plc, HSBC Holdings plc, Lloyds Banking Group plc, Nationwide Building Society, the Royal Bank of Scotland Group plc, Santander UK plc, and Standard Chartered plc. • The criteria used to determine the institutional perimeter include: firms' balance sheet, firms' role in the U.K. payment system, and firms' plans to grow their balance sheet.	
	Market share	• Approximately 80 percent of PRA-regulated banks' lending to the UK real economy.	
	Data	• Effective date: end-December 2014. • Effective date for market risk: February 20, 2015. • Data: Stress testing templates and associated documents submitted by participating banks for the 2015 Stress Test. • Scope of consolidation: Global consolidated group basis, except for Santander UK plc, whose parent is supervised by a foreign authority. Perimeter of the banking group (CRD IV). Insurance activities are excluded, but firms have to assess the impact of the scenario on insurance activities and model the impact on dividends, holdings or minority interests, capital deductions, and risk weightings.	• Effective date: end-December 2015. • Effective date for market risk: end-December 2015. • Data: Firm-by-firm confidential data at the cut-off date, BoE data on aggregate write-off rates for UK exposures, and publicly available data (Pillar 3 disclosures, Bloomberg, Datastream, Markit, 2015 EU-wide transparency exercise, Haver Analytics, Mortgage Lenders and Administrators Statistics, Moody's KMV, Bankscope, SNL, International Financial Statistics [IFS], IMF Global Assumptions (GAS), and IMF WEO). • Scope of consolidation: Global consolidated group basis, except for Santander UK plc, whose parent is supervised by a foreign authority. Perimeter of the banking group (CRD IV). Insurance activities are excluded, but firms have to assess the impact of the scenario on insurance activities and model the impact on dividends, holdings or minority interests, capital deductions, and risk weightings.
	Stress testing process	• The U.K. stress test is a hybrid process that includes the following steps: - Scenarios are designed by the BoE and approved by the FPC and PRA Board. - Each participating firm generates additional scenario variables as required for its modeling across its geographies and asset classes. - Firms perform constrained BU stress tests based on their internal risk-management infrastructure and tools. - The BoE runs its own in-house challenger models to cross-validate firms' results from both a micro and macro perspective.	• The FSAP team conducted its own TD macroprudential stress test based on IMF generated scenarios. • For IRB exposures, a separate credit risk model is calibrated for 5 Basel asset classes and 15 geographies. • For STA exposures, stressed NPL ratios, stressed coverage ratios, and a transition matrix for performing exposures are projected. • For market risk, stress to 22 sovereign issuers and major corporate indices is modeled separately. • The TD stress test includes a detailed stress test of the UK mortgage book by LTV vintage, using a structural Merton-based approach.

Banking Sector: Solvency Test			
Domain		**Framework**	
		BU/TD by Authorities	**TD by FSAP Team**
		- Aggregation of results by BoE, including adjustments from peer comparison, challenger models, and BoE judgment.	• The FSAP team used its own credit risk models to project stressed credit risk parameters based on the 2015 BoE scenario in banks' key selected portfolios. • FSAP projections were compared against banks' BU projections. • Sensitivity tests included a range of stressed UK residential house prices and shocks to the swap curve.
2. Channels of risk propagation	Methodology	• Risks are projected using a variety of models, approaches and judgments from the banks and BoE/PRA. • Banks' internal risk management models translate the scenario into credit risk losses across their asset classes and geographies. • Banks model the traded risk elements of the stress, including: the impact on their market risk positions depending on the liquidity of those positions; the valuation adjustments (FVO, CVA, PVA, and bid/offer reserve); and a prescribed number of counterparty defaults in geographies impacted by the stress. • Banks model the impact on their funding costs, and how the increase in funding costs is passed on to customers. • BoE in-house suite of supervisory risk models to challenge banks' projections and macro models to provide system-wide view of risk propagation. • Supervisory input to take account of individual banks' business models.	• A comprehensive battery of econometric and structural models were specifically developed and calibrated for the 2016 U.K. FSAP. • Over 75 credit risk models and 900 econometric specifications for PDs based on vector autoregressive models (VAR), principal component analysis (PCA), and quartile-based regressions, and a structural Merton-based approach for LGDs. • Lending rates linked to shocks to deposit rates (projected in line with the macro scenario, bank-specific solvency ratios, and funding stress in peer banks) and shocks to NIMs (affected by the base rate, money market shocks, and the slope of the yield curve), with pass-through estimated empirically. • Add-on funding shock related to funding shock in H1 2012 with disallowed pass-through. • Mark-to-market losses from full revaluation of sovereign securities (22 jurisdictions), and corporate fixed income debt securities, excluding hedges, under each scenario.
3. Tail shocks	Scenario analysis	• This scenario is characterized by a broad-based global recession with major adverse implications for China and the euro area. This impacts the U.K. and generates a domestic recession, affecting particularly corporate exposures, amid the build-up of disinflationary pressures. • U.K. real GDP growth contracts by 2.3 percent year-on-year from 2014:Q4 to 2015:Q4, and reaches a peak deviation from baseline in 2017 at -7.7 percent. Unemployment rises by 3.5 pps by 2017:Q3, equity prices decline by 36 percent peak-to-trough, and residential property prices fall by 20 percent.	• This scenario is calibrated using IMF in-house model and auxiliary assumptions drawing on historical crisis-episodes. This scenario is characterized by a disorderly accelerated monetary normalization in the U.S., which triggers an abrupt asset price correction across markets and generates financial crises in fragile emerging economies. • This scenario constitutes a 2.1 standard deviation move in two-year cumulative real GDP growth rate for 2016–17.

Banking Sector: Solvency Test			
Domain		**Framework**	
		BU/TD by Authorities	**TD by FSAP Team**
		• Euro area year-on-year real GDP growth troughs at -2.1 percent in 2016:Q1. Emerging economies experience a large downturn in economic activity with year-on-year real GDP growth in China falling to 1.7 percent in 2015:Q4. The peak-to-trough fall in real GDP is about 7 percent in Brazil and 4 percent in South Africa. • The VIX peaks at 46 pps in 2015, the oil price troughs at USD 38, the renminbi depreciates 10 percent against the USD by end-2015, and the euro depreciates by about 25 percent against the USD and by 15 percent against sterling in 2015.	• U.K. GDP growth contracts by 1.6 percent in 2016, and reaches a peak deviation from baseline in 2017 at -6.9 percent. There is a large housing market correction, with real house price falling by 40 percent in 2016 and 2017. In addition, the real equity price falls by 40 percent during 2016. The deep recession increases funding costs that induce a rise in banks' lending rates by 1.1 pps by 2017, and bank credit falls by 6.7 percent. • Output falls by 11.9 percent in the fragile three (Brazil, South Africa, and Turkey), and by 1.3 percent in other emerging economies. • The scenario includes an additional idiosyncratic and system-wide funding risk shock triggered by dislocation of money markets and linked to banks' capital ratios under stress.
	Sensitivity analysis	• Stressed projections for misconduct costs.	• Shocks to U.K .residential house prices affecting stressed LGDs. • Shocks to swap curve.
4. Risks and buffers	Positions/risk factors assessed	<u>Credit risk</u> • Estimated according to Basel III framework, under IRB advanced approach, IRB foundation approach, and Standardized approach. • Positions include cross-border loan exposures, including interbank and public sector loans. • Covered bonds and securitization exposures are included. • Off-balance sheet exposures using baseline and stressed Credit Conversion Factors (CCFs) are included. <u>Sovereign risk</u> • Issuer risk from shocks to yield curves across material advanced and emerging economies of banks' exposure (IRB sovereign exposures). • Mark-to-market valuation of securities in trading book and AFS/FVO linked to macro scenario. <u>Market risk other than sovereign risk</u> • Market stress from shocks to asset prices in FX markets, corporate spreads, commodities, and money markets (IMF stress test).	

Banking Sector: Solvency Test			
Domain		**Framework**	
		BU/TD by Authorities	**TD by FSAP Team**
		• Market stress from shocks to asset prices and volatilities in a broad set of core risk factor shocks calibrated by the BoE and all other relevant risk factors to which banks are exposed calibrated by firms and applied in line with the liquidity of the position (BoE stress test). • Counterparty credit risk losses covering all trading book and banking book derivatives and securities financing transactions, as well as CVA (BoE stress test). • Shocks to PVA for own funding costs (BoE stress test). <u>Profits</u> • Income from investment banking activities. • Interest income declines for the amount of lost income from defaulted loans. • Interest income from non-defaulting loans is estimated according to satellite models (IMF stress test). • Interest expenses increase due to rising funding costs linked to the macroeconomic scenario with empirically estimated pass-through, and add-on funding stress from a market event with no pass-through to lending rates (IMF stress test). • Banks project interest income and interest expense in the stress scenario taking account of balance sheet evolution, funding evolution, product interest rate and margin movements, foreign exchange movements, and structural hedging programs (BoE stress test). • Net fee and commission income and other income evolve with macroeconomic conditions and banks' balance sheets. • No change in business models (no rebalancing of portfolio) (IMF stress test). Business models and balance sheets evolve over the stress horizon per the banks' corporate plans, adjusted for the scenario (BoE stress test). <u>Regulatory impact</u> • The effects of the phase-out of no-longer-eligible additional Tier 1 and Tier 2 capital are included. No conversion of additional Tier 1 capital is assumed during the stress horizon (IMF stress test). Additional Tier 1 instruments can convert if their trigger level is breached after management actions are taken into account (BoE stress test).	
	Behavioral adjustments	<u>Dynamic balance sheets</u> • The balance sheet evolves under stress per each bank's corporate plan, adjusted for the scenario. • The BoE scenario includes paths for U.K. lending to individuals and private non-financial corporations (PNFCs) in the stress, calibrated to reflect the reduced credit demand in the scenario. Guidance is provided that individual banks' market share of lending in these assets classes should not decline under stress. The BoE ensures	<u>Dynamic balance sheets</u> • Credit supply effects are disallowed to calibrate credit risk projections. • Balance sheets evolve with key macroeconomic aggregates in material jurisdictions and FX effects and, thus, vary across banks. • EAD under stress from off-balance sheet exposures increases about 5 percent on average, reflecting higher use of committed but previously unused credit lines.

Banking Sector: Solvency Test			
Domain		**Framework**	
		BU/TD by Authorities	**TD by FSAP Team**
		that, in aggregate, banks' lending projections are consistent with the U.K. lending paths. • The size and composition of BSs for non-U.K. lending are allowed to vary as follows: (i) if non-U.K. lending has positive growth under baseline, slower growth is allowed under stress but no contraction; and (ii) if non-U.K. lending has negative growth under baseline, no further contraction is allowed under stress. • The dividend payout in stress is in line with banks' publicly disclosed dividend policies. Further dividend cuts can be proposed as strategic management actions. • Banks may propose strategic management actions to improve their capital position as it falls in the stress. The BoE assessed both timing and benefit of the actions proposed and only accepts realistic management actions. Any proposed management actions are expected to be part of banks' recovery and resolution plans.	• Maturing assets are replaced by exposures of the same type and risk. • Dividends are linked to banks' net profits. Under positive profits, the dividend payout is set at 30 percent. Otherwise, no dividend payout is assumed. • The effective tax rate evolves with the macro scenario. • Losses are recognized in the same year that a shock hits. • If banks' capital ratio falls below regulatory minimum during the stress test horizon, no prompt corrective action is assumed.
5. Regulatory and market-based standards and parameters	Calibration of risk parameters	<u>Parameter definition</u> • Banks project PDs and LGDs across the stress scenario for both expected loan losses (impairment charges) and capital requirements. • PDs and LGDs are projected by asset class and geography for defaulted and non-defaulted exposures. • Changes in capital requirements (RWAs) driven in part by banks' PRA approved regulatory IRB models. <u>Parameter calibration</u> • PDs and LGDs evolve with the macroeconomic and financial variables of the scenario, per banks' models.	<u>Parameter definition</u> • PiT PDs and LGDs for both expected and unexpected losses. • PDs are blended PDs (i.e., include both defaulted and non-defaulted counterparties) by asset class and geography. • LGDs are calculated post credit risk mitigation by asset class and geography. <u>Parameter calibration</u> • For IRB exposures, changes in PDs are proxied by shocks to write-off rates for U.K. exposures, Moody's EDFs for cross-border exposures, and banks' computed PDs in historical stressed episodes. • Shocks to LGDs are projected using a Merton-based approach for mortgage exposures, shocks to

Banking Sector: Solvency Test			
Domain		**Framework**	
		BU/TD by Authorities	**TD by FSAP Team**
			unemployment for retail unsecured exposures, and shocks to GDP for corporate exposures. • PDs and LGDs evolve with the macroeconomic and financial variables of the scenario. • For STA exposures, inflows into NPL categories are based on panel regression, including risk migration for performing exposures.
	Regulatory standards	• Capital definition according to Basel III/CRD IV/PRA rulebook, including CET1, Tier 1, and total CAR. • The CET1 ratio is computed using CRD IV end-point definition. This follows PRA's decision not to make use of transitional provisions for CET1. Specifically, unrealized gains/losses in AFS and equities and reserves arising from revaluation of property are recognized since January 2015. • Capital components that are no longer eligible for additional Tier 1 and Tier 2 capital components follow CRD IV transitional path. • CET1 ratio hurdle rate are 4.5 percent of RWAs in stress and 7% in the baseline (BoE stress test). Hurdle rates follow Basel III (including Capital Conservation Buffer under the baseline) (IMF stress test). • Leverage ratio (3 percent hurdle rate met with Tier 1 capital) using two definitions: (i) the leverage ratio set out by the PRA in SS3/13 (BoE stress test): - Tier 1 (end-point definition as set out in CRR). - Leverage exposure (CRR delegated act definition). (ii) a Tier 1 (CET1 end-point definition and Additional Tier 1 transitional definition) ratio relative to interest-bearing assets (IMF stress test).	
6. Reporting format for results	Output presentation	• Minimum stressed CET1, Tier 1, CAR, and leverage ratio by bank. Evolution of stressed CET1 and leverage ratio for aggregate of all seven banks (BoE stress test). • Evolution of CET1, Tier 1, CAR, and leverage ratio, for the aggregate banking system and type of bank, i.e., major U.K. international banks and major U.K. domestic banks (IMF stress test). • Contribution of key drivers to aggregate net profits and aggregate CET1 capital ratios. • Cumulative impairment charges by bank for the U.K. and specific other countries impacted by the scenario (BoE stress test). Number of banks and share of total assets below hurdle rates (IMF stress test).	

Liquidity Stress Testing Matrix		
Domain		**IMF designed stress test undertaken by the BoE on behalf of the FSAP team**
1. Institutional perimeter	Institutions	• Number of firms: 10, consisting of seven major banks and building societies, and the 3 largest subsidiaries of foreign investment banks. • Selection criteria: The sample firms have been selected to provide 80 percent coverage of total U.K. banking assets as measured by the PRA048 liquidity returns.
	Market share	• About 80 percent of banking sector total assets.
	Data and base date	• The LCR Liquidity Stress Test is based on the data as of December 31, 2015, received by the PRA as Interim LCR reporting from U.K. firms on an all-currency basis. This PRA return is based on the EU Delegated Act (Commission Delegated Regulation (EU) no 2015/61), which implements LCR in the United Kingdom. • The cash flow liquidity stress test relies on the PRA048 return as of January 1, 2016.
2. Channels of risk propagation	Methodology	• Basel III measures of liquidity risk—the LCR on three scenarios. • Two implied cash flow tests: 5 days (cumulative) and 30 days (noncumulative). • A general maturity mismatch analysis by maturity bucket. • A single currency analysis based on PRA's ILG regime.
3. Risks and buffers	Risks	• Funding liquidity risk, rollover risk, and market liquidity risk.
	Buffers	• HQLA securities assessed at market values net of haircut on a security-by-security basis.
4. Tail shocks	Size of the shock	A range of adverse scenarios • LCR Scenario under standard assumptions calibrated by BCBS. • An LCR "U.K. retail stress" scenario. The calibration of this deposit run-off scenario replicates the peak stress during the 2007 Northern Rock run, with run-off rates for retail deposits of up to 15 percent and for corporate deposits of 60 percent, and with liquidity risk from committed but undrawn liquidity facilities of 50 percent. • An LCR "U.K. wholesale stress" scenario. This scenario replicates the liquidity stress observed during the global financial crisis. It is characterized by: (i) a freeze of wholesale funding on the interbank market, secured funding market via repo and covered bonds, and the commercial paper market (with run-off rate for operational deposits of 75 percent and for not-fully covered corporate deposits of 100 percent), and (ii) liquidity risk from sizeable margin calls related to secured funding, derivatives and foreign currency funding due to market liquidity shocks, derivative assignments, and unwinds and disruptions in the FX swap market (with rollover of secured funding backed by other than Level 1 and Level 2A assets of up to 0 percent). • Implied cash flow assumptions include haircuts of up to 60 percent for securities and bank loans that can be mobilized in repos, no issuance of new unsecured funding and freeze of securitization markets, call-back rates of up to 100 percent, and cash outflows of up to 75 percent.
5. Regulatory standards	Regulatory standards	• Counterbalancing capacity above net cash outflows under stress scenario. • The PRA's transitional arrangement for the LCR ratio, which is more front-loaded than that prescribed by the CRR (Art. 460). It is set at 80 percent in October 2015 above the 60 percent threshold under the CRR.
6. Reporting format for results	Output presentation	• Changes in average liquidity position and counterbalancing capacity for each scenario. • Distribution of banks' liquidity position for each scenario. • Number of banks with counterbalancing capacity below net cash outflows. • Banks' post-shock net liquidity position.

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