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IRELAND

FINANCIAL SECTOR ASSESSMENT PROGRAM

September 2016

TECHNICAL NOTE—STRESS TESTING THE BANKING SYSTEM

This Technical Note on Stress Testing the Banking System on Ireland 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 August 2016.

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TECHNICAL NOTE

STRESS TESTING THE BANKING SYSTEM

Prepared By
Monetary and Capital Markets Department

This Technical Note was prepared by IMF staff in the context of the Financial Sector Assessment Program in Ireland. It contains technical analysis and detailed information underpinning the FSAP's findings and recommendations. Further information on the FSAP can be found at http://www.imf.org/external/np/fsap/fssa.aspx

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Glossary

ABS	Asset-Backed Securities
AFS	Available For Sale
CDS	Credit Default Swap
CET1	Common Equity Tier1
CRD	Capital Requirement Directive
EBA	European Banking Authority
ECB	European Central Bank
EDF	Expected Default Frequency
ELA	Emergency Liquidity Assistance
EU	European Union
FDI	Foreign Direct Investment
FSGM	Flexible System of Global Models
FSSA	Financial System Stability Assessment
GBP	Pound Sterling
HFT	Held For Trading
IBB	Consolidated Banking Statistics on Immediate Borrower Basis
ICAAP	Internal Capital Adequacy Assessment Process
IMF	International Monetary Fund
NFC	Non Financial Corporations
OLS	Ordinary Least Squares
PIT	Point-in-time
RAM	Risk Assessment Matrix
STeM	Stress Test Matrix (for FSAP stress tests)
TN	Technical Note
TTC	Through-the-Cycle
U.K.	United Kingdom
URB	Consolidated Banking Statistics on Ultimate Risk Basis
U.S.	United States
USD	United States Dollar
VAR	Vector Auto Regression
VIX	Chicago Board Options Exchange Volatility Index

EXECUTIVE SUMMARY

The FSAP stress testing exercise took place at a turning point for the Irish financial system. The Irish economy is quickly rebounding, the banking system returned to profitability in 2014, and banks' exposures to the volatile commercial real estate market have declined significantly. However, the banking system is still healing from the latest financial crisis, with a very large stock of non-performing loans.

The design of the stress tests incorporated the main potential external risks. These risks arise mostly from a protracted period of weak growth in advanced economies, particularly in the euro area, which would affect the Irish economy through lower investment and direct investment inflows. Moreover, a surge in global financial market volatility could increase interest rates and raise funding costs as investors may reassess underlying risks and move to safe-haven assets. Finally, the planned U.K. exit from the European Union (EU) could cause disruption to trade, labor mobility, and financial interaction with the EU and in particular between Ireland and the U.K.

The tests also incorporated potential key domestic risks. First, domestic factors could amplify the effects of external shocks, such as a domestic confidence shock translating into a consumption and investment collapse, or a house price decline bringing back prices towards those experienced during the financial crisis. Moreover, financial imbalances from protracted periods of low interest rates could eventually generate overvaluation and risks of future correction in commercial real estate prices.

The stress tests examined the resilience of the Irish banking system to *solvency*, *liquidity*, and *contagion* risks. The stress tests included top-down (TD) and bottom-up (BU) exercises based on macroeconomic scenarios and sensitivity analyses. The tests based on macroeconomic scenarios assessed the impact of these extreme but plausible external and domestic shocks on the economy over a three-year horizon (2016–2018), based on data available through June 2015, with capital figures updated based on December 2015 data. The effects of these shocks on individual banks' profitability and capitalization were assessed using satellite models and methodologies developed by the Central Bank of Ireland, the ECB and Fund staff. In addition, sensitivity stress tests assessed vulnerabilities of the banking system to individual shocks. The TD liquidity tests assessed the capacity of banks to withstand large withdrawals of funding, using a maturity ladder analysis and supervisory information, both on an aggregate basis and by currencies. The contagion tests covered interbank exposures between the three largest domestic banks, and cross-border interlinkages with the BIS International Banking Statistics and market data.

Results of the solvency stress tests reveal several sources of vulnerabilities, although these remain manageable at the macro level. In the severe stress scenario on a fully-loaded Basel III basis, two banks become undercapitalized with regard to the total CAR and Tier 1 capital ratio hurdle rates of 8 percent and 6 percent, respectively; three banks would have a leverage ratio below the hurdle rate of 3 percent in 2018, and four banks would not meet the Common Equity Tier 1 (CET 1) level of 7 percent, representing the combined minimum CET1 ratio and the capital conservation

buffer level. The results would be similar under the transitional arrangements, with a reduced capital shortfall. The higher vulnerability of the two banks mentioned above stem from different factors, including lower initial capitalization, asset quality and profitability, higher exposure to funding risks, and sensitivity to Basel III capital adjustments.

Funding and credit risks are the two main vulnerabilities. Funding costs are found to increase sharply under the adverse scenario. Moreover, loan quality is found to be very sensitive to changes in the unemployment and GDP growth rates, and, to a lesser extent, to real interest rates. In the severe stress scenario, bank loan loss provisions would rise in parallel with higher probability of default (PD) and loss given default (LGD), with negative effects on profitability. Sensitivity tests confirm the predominance of credit risks, the exposure to sovereign and real estate market risks, and also indicate that these risks are exacerbated in a bank due to its high concentration of loan portfolios, with the failure of the five largest exposures causing undercapitalization of this bank.

The global liquidity stress tests reveal that some banks in the system would be exposed to liquidity risks in the event of large deposit withdrawals, under a more severe scenario than the Basel III LCR metrics, or of a dry up of unsecured wholesale funding. In addition, some banks display material exposure to funding risks in pound sterling. By contrast, additional counterbalancing capacity would allow banks to cope with net outflows in every maturity bucket.

Banks are found to be less vulnerable to direct contagions risks through bilateral exposures or to cross-border contagion risks compared to the pre-crisis period. The contagion risk analysis reveals that the risks stemming from interbank exposures between the three largest domestic banks are limited. Given the deleveraging in recent years, cross-border bank linkages also appear to be less of a concern. Both foreign banks' exposures to Ireland and Irish domestic banks' claims to non-residents have declined dramatically. However, the tight linkages with the U.K. financial system warrant ongoing attention. Irish domestic banks have large exposures to the U.K. economy, and thus a severe distress in the neighboring country could inflict large losses on Irish banks. Based on market data, the Irish financial system can receive a lot of spillovers from U.K. and French banks, as well as from Italian and Spanish financial systems. The level of interconnectedness, however, has decreased significantly since the onset of the financial crisis.

Some suggesitons to further enhance bank stress testing and cross-border network analysis are presented in Tabel 1. The recommendations are directed at the Central Bank of Ireland, but concern also the European Central bank (ECB) in the context of the Single Supervisory Mechanism, especially when cross-border linkages and adjustment to new regulatory standards are involved.

Table 1. Ireland: Recommendations on Banking Stress Testing and Cross-border Network Analysis	Agency	Time[1]
Risk analysis		
Further develop the Central Bank of Ireland Top-Down credit risk satellite model to increase Central Bank of Ireland's ability to challenge banks' submissions in a more operational way.	Central Bank	NT
Update the Central Bank of Ireland loan-loss forecasting models calibration to make sure their out-of-sample forecasting power remains adequate.	Central Bank	NT
Carry out liquidity stress tests currency-by-currency.	Central Bank	NT
Improve surveillance further by closing data gaps on cross-border bilateral financial exposures.	Central Bank and ECB	NT
Financial sector policy		
Examine thoroughly banks' liquidity positions in pound Sterling in a stressed environment.	Central Bank and ECB	NT
Continue to review the link between sovereign and banking sector risks by reviewing the amount of banks' AFS reserves for unrealized gains on exposures to central governments.	Central Bank and ECB	MT
Continue to monitor banks' plans to meet Basel III new capital definitions and ratios throughout the transitional period.	Central Bank and ECB	MT
[1/] "NT-near-term" denotes up to 2 years; "MT-medium-term" denotes 2–5 years.		

INTRODUCTION[1]

1. The FSAP stress testing exercise took place at a turning point for the Irish financial system. Sharp ongoing economic recovery has allowed the banking system to return to profitability in 2015 but the latter is still healing from the latest financial crisis, with a very large stock of non-performing loans. Moreover, the Ireland FSAP is one of the first two mandatory FSAPs in a euro area country since the establishment of the Single Supervisory Mechanism.

2. Ireland's banking sector is open and concentrated. Total banking sector assets amount to 294 percent of GDP. The top five banks control 61 percent of system assets, with one large privately-owned bank controlling 24 percent of total assets, two state-owned banks making up 27 percent of banking system's assets, and the subsidiaries of two foreign banks controlling 10 percent.

3. In general, the objective of the FSAP stress testing exercise is to assess the capacity of the banking system to withstand *extreme* but *plausible* macroeconomic shocks. The tests are meant to explore weaknesses in the financial system and the channels through which adverse shocks are transmitted. FSAP stress tests can help to identify priorities for policy actions, such as those aimed at reducing specific exposures or building capital and liquidity buffers. The FSAP stress testing process can also help authorities to identify informational and methodological gaps, and assess their preparedness to deal with situations of financial distress.

4. FSAP stress tests may differ from stress tests conducted by central banks, including those previously undertaken by the Central Bank of Ireland. The latter, the ECB, and the FSAP team estimated separate credit risk models but common assumptions were provided to the banks. The Central Bank of Ireland carried out the tests in close cooperation with the FSAP team and provided access to a set of supervisory data in a virtual and a physical data room, either on an aggregate or individual basis. The ECB provided comments on the two adverse scenarios, provided ECB benchmark parameters for the credit risk module and was involved in some quality assurance discussions.

5. Although stress tests are useful to explore weaknesses in a financial system, results must be interpreted with caution. In all countries, the implementation of stress tests is conceptually challenging. Among other limitations, stress tests use macroeconomic and satellite models to calculate the impact of adverse scenarios or shocks on banks.[2] These models are estimated using historical data and are subject to estimation uncertainty. These limitations can be mitigated, but not eliminated, by using state-of-the-art techniques. Choices must also be made regarding the severity of shocks. In adverse scenarios, the economy is typically affected by a

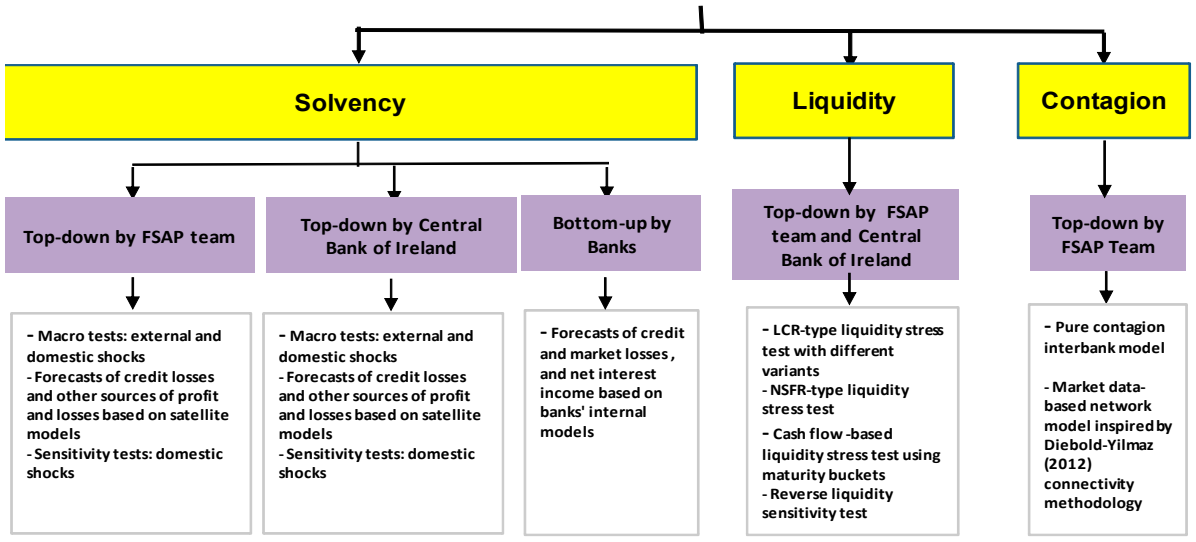
[1] This Technical Note was prepared by Cyril Pouvelle and Heedon Kang, Monetary and Capital Markets Department, IMF, in the context of the 2016 Ireland Financial Sector Assessment Program.

[2] Satellite models map the variables projected in the macroeconomic scenarios into credit factors that determine individual banks' gains or losses.

combination of external and domestic shocks that (ex ante) have a very low probability of occurrence—and could possibly materialize once every 20–40 years.[3] Hence, by construction, adverse scenarios should not be interpreted as macroeconomic "forecasts".

6. The stress tests examined the resilience of the banking system to *solvency*, *liquidity*, and *contagion* risks (Figure 1). The stress tests included TD and BU exercises based on macroeconomic scenarios and sensitivity analyses. The tests based on macroeconomic scenarios assessed the impact of combined external and domestic shocks on the economy over a three-year horizon (2016–2018), based on data available through June 2015, with capital figures updated based on December 2015 data.[4] The effects of these shocks on individual banks' profitability and capitalization were assessed using satellite models and methodologies developed by the Central Bank of Ireland, the ECB, and Fund staff. In addition, sensitivity stress tests assessed vulnerabilities of the banking system to individual shocks. The TD liquidity tests assessed the capacity of banks to withstand large withdrawals of funding, using a maturity ladder analysis and supervisory information. The contagion tests covered interbank exposures between the three largest domestic banks, interlinkages within the domestic financial system, and cross-border exposures between Irish banks and foreign sectors.

Figure 1. Ireland: Summary of Ireland FSAP Stress Tests



Source: IMF staff

[3] The selection of the "relevant" historical episode and the length of data series used to construct adverse scenarios are among the choices that must be made in the design of stress tests. There is often a temptation to dismiss the validity of historical episodes because structural changes alter the way in which economies function. Valid stress tests, however, should not fail to incorporate history. As pointed out by Haldane (2009), stress testing exercises conducted before the global financial crisis failed to play a useful "early warning" role (in part) due to reliance on short data series—the tests underestimated true macroeconomic and financial volatility by failing to incorporate information contained in long data series, which undermined their validity and usefulness.

[4] It is common practice in FSAPs to implement the stress tests over a two- to five-year horizon. A two-year horizon is used in countries subject to a high degree of macroeconomic uncertainty at the time of the exercise. A five-year horizon is appropriate for countries subject to moderate or low macroeconomic uncertainty.

7. The TD stress test conducted by the FSAP team had the same coverage as the BU stress test but a smaller coverage than the TD test conducted by the Central Bank of Ireland. Due to a restricted access to supervisory data, combined with the need to use publically-available information, the TD stress test carried out by the FSAP team focused on the five systemically important institutions making up 61 percent of the banking sector assets and including two subsidiaries of foreign banks. The TD test conducted by the Central Bank of Ireland included six non-systemically important institutions as well.

8. The remainder of this technical note (TN) is structured as follows. The second section presents the different components of the solvency stress tests based both on macroeconomic scenarios and sensitivity analysis: their description, design, methodology for implementation, and results. The following sections present the stress tests of liquidity risk, and the analysis of contagion risks.

SOLVENCY STRESS TESTS

9. The FSAP solvency stress tests covered the main risks faced by the banking sector. They included Top-Down and Bottom-Up exercises based on macroeconomic scenarios and sensitivity analyses. The tests based on macroeconomic scenarios assessed the impact of combined external and domestic shocks on the economy over a three-year horizon (2016–2018), using data available through June 2015, with capital figures updated based on December 2015 data. Due to restricted access to supervisory data and the need to use publically-available information, the TD stress test carried out by the FSAP team focused on the five systemically important institutions making up 61 percent of the banking sector assets and including two subsidiaries of foreign banks. The BU stress test had the same coverage while the TD test conducted by the Central Bank of Ireland included six non-systemically important institutions as well.

10. The regulatory framework that was applied was Basel III, the European Union and the national frameworks, as defined by the Fourth Capital Requirements Directive (CRD IV), national law and Central Bank of Ireland regulation. Therefore, the hurdle rates for total capital adequacy, Tier 1 capital, and Common Equity Tier 1 capital were set at, respectively, 8 percent, 6 percent, and 4.5 percent, plus a capital conservation buffer of 2.5 percent. Capital shortfall calculations did not take into account the capital conservation buffer which is aimed at constraining banks' dividend payout. An additional hurdle rate was set at 3 percent from 2018 onwards for the leverage ratio. Every ratio was based on Basel III fully-loaded definitions. Some alternative results were based on the European framework in terms of phase-in of deduction from Common Equity Tier 1 and the phase-out portion of capital instruments that no longer qualify as additional Tier 1 capital or Tier 2 capital.

11. The effects of the shocks on individual bank's profitability and capitalization were assessed using the results of satellite models and methodologies developed by the Central Bank of Ireland and Fund staff. In addition, sensitivity stress tests assessed vulnerabilities of the banking system to individual shocks. Sub-section A presents the main macrofinancial risks, the

baseline and the macro scenarios that were applied for the conduct of the solvency stress test. Sub-section B describes the estimation of credit risks. Sub-section C sets out the analysis of market risks in the scenario analysis. Sub-section D provides the global results of the solvency stress tests based on scenario analysis. Sub-section E presents the results of the market risk sensitivity analysis. Sub-section F discusses the concentration risk analysis.

A. Macro-financial risks and Macroeconomic Scenarios

12. Although the country's economic structure has rebalanced and the banking system has increased its buffers, the Irish financial sector is exposed to several external risks. The risks that are most likely to materialize are the following (see also Risk Assessment Matrix in Appendix I):

- *Structurally weak growth in advanced economies, particularly in the euro area*. Protracted euro area weakness could undermine domestic confidence, investment, and direct investment inflows.

- *Sharp asset price decline and decompression of interest rate spreads as investors reassess underlying risks and move to safe-haven assets*. Ireland's high level of private and public debt makes it susceptible to financial contagion.

- *Higher-than-expected fallout from the UK referendum result on EU membership causing severe disruption to trade, labor mobility, and financial interaction with the EU and in particular between Ireland and the U.K*. Ireland's strong trade, financial and labor market links with the U.K. makes it vulnerable to adverse changes in the U.K. economy.

- *Financial imbalances from protracted period of low interest rates*. Further strong inflows into commercial real estate could eventually generate over-building and risks of future slump in prices.

13. Several features of the banking sector also increase its vulnerability to shocks:

- *Although NPLs have reduced by almost half since December 2015, the remaining stock of NPLs remains a challenge*. Despite recent efforts from the Central Bank of Ireland to accelerate the resolution of problem loans and especially mortgages and a significant decline in banks' exposures to the CRE market, property repossession has been used scarcely or the process has been very slow. Moreover, the stock of NPLs is composed to a significant degree of long-overdue mortgages, SME and CRE loans.

- *The profitability of the banking sector remains fragile*. Although the sector returned to profitability in 2014 benefitting from large provision write-backs, the change in banks' business model has not been completed and long-lasting sources of growth and profits remain to be found. Irish banks' profitability is close to euro area banks averages in 2015 but, in general, has been impacted by low interest income due to the prevalence of tracker loans indexed to the ECB

or Euribor rate in the residential mortgage book and reduced credit demand, and low non-interest income.[5]

- *The capacity of the banking system to finance the recovery is uncertain.* While the banking sector's capitalization is currently adequate, the situation is less favorable in terms of fully loaded Basel III definitions. Therefore, it might have trouble funding the recovery in the medium term once credit demand picks up.

14. Given the risks and vulnerabilities described above, the stress test examined a baseline macroeconomic scenario and two negative scenarios. All scenarios stretch over a three-year forecasting period.[6] The first year of the shock would then be 2016 and the scenario would run until 2018. The baseline macroeconomic scenario is based on a combination of forecasts from the Central Bank of Ireland and from the October 2015 IMF WEO. It forecasts favorable developments, with a very strong real GDP growth in 2015, a slowdown from 2016 onwards, and a stabilization over the medium term at 3 percent. Two adverse scenarios were developed for the FSAP stress testing exercise. The first was developed by an IMF team using the Global Macro-financial Model, a structural macro-econometric model of the world economy, disaggregated into forty national economies, documented in Vitek (2015).[7] The second was jointly developed by the FSAP team and the Central Bank of Ireland using the IMF Research Department's Flexible System of Global Models (FSGM)[8] and expert judgment. The two scenarios are in line with the scenarios applied to comparable euro area countries that are currently undergoing FSAPs. The two adverse scenarios include milder shocks in terms of GDP growth than those experienced during the 2008/2009 global financial crisis because they took into account the still negative output gap of the Irish economy in 2015; in sharp contrast, the pre-crisis period was characterized by the large over-shooting of output, which was then corrected. The adverse scenarios are severe in terms of sovereign stress and the associated impact on funding costs and asset valuations.

15. For the design of the macroeconomic scenarios, the following domestic variables had to be calibrated over a 3-year horizon: real GDP growth, CPI inflation rate, unemployment rate, the nominal government bond rate, the euro-dollar exchange rate, and the real estate price growth. The two adverse scenarios are the following (see Figure 2 and Table 2):

- **A euro area wide scenario resulting in a moderate stress,** driven by a revival in risk aversion affecting especially the European "periphery" (including Ireland) and adverse investment sentiment, and a sharp slowdown in emerging market economies. Irish growth would slow

[5] As of 2015Q3, tracker loans and standard variable rate (SVR) loans accounted for 50.4 percent and 40.1 percent of total mortgage loans, while the share of loans with fixed rates over 1 year was only 7.5 percent.

[6] A three-year projection was chosen because, at the time of the FSAP, forecast errors appeared too large over periods longer than three years.

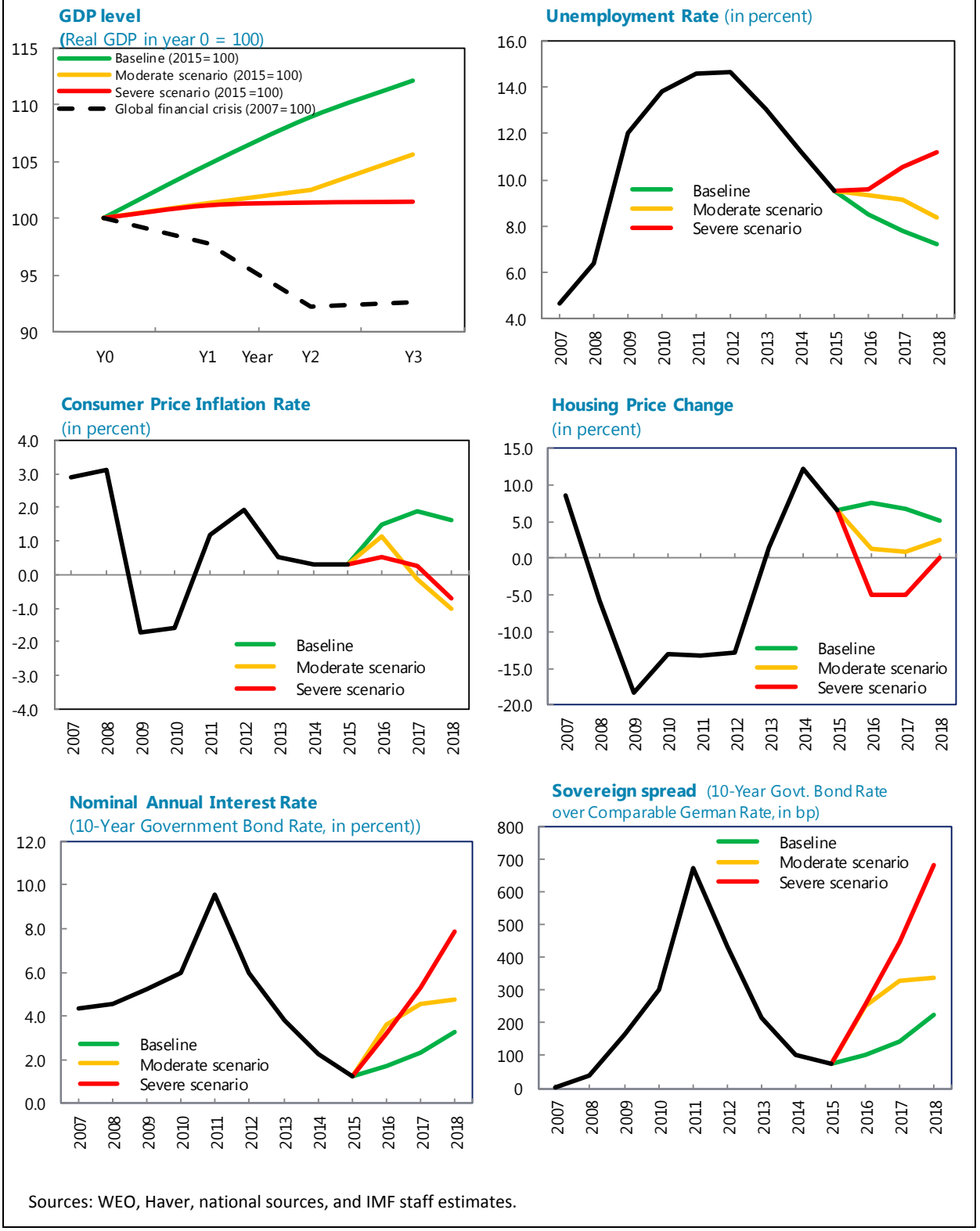
[7] Vitek, F. (2015), "Macrofinancial analysis in the world economy: A panel dynamic stochastic general equilibrium approach", International Monetary Fund Working Paper, 227.

[8] A typical module of FSGM is a multi-region, forward-looking semi-structural global model consisting of 24 regions. See IMF working paper "The Flexible System of Global Models – FSGM", WP/15/64, March 2015.

rapidly to 1.3 percent and 1.2 percent in 2016 and 2017 respectively, before picking up to 3.1 percent in 2018, translating into a cumulative decline of GDP relative to the baseline over three years of 6.5 percentage points, equivalent to 0.6 standard deviations of the 3-year GDP growth taking the 1970–2014 period as the benchmark for GDP growth. Price deflation would become generalized; real interest rates would rise; and both bond and equity prices would fall. This scenario, which is designed by staff based on the IMF Global RAM and the EA-RAM, is comparable to that used in other concurrent EA FSAPs, and facilitates an assessment of possible non-linear effects of shocks;

- **An Ireland-specific scenario resulting in a more severe stress, with more severe disruption in Ireland's European partners in an unsupportive global environment, combined with domestic shocks**. The result would be a sharp decline in FDI inflows and a persistent recession; unemployment would go back up. Real GDP growth would average 0.5 percent per annum over 2016–2018, significantly below the potential growth rate of the economy. The cumulative decline of GDP relative to the baseline over three years would be about 9.5 percentage points, equivalent to approximately one standard deviation of the 3-year GDP growth taking the 1970–2014 period as the benchmark for GDP growth. This scenario is based on risks #1–3 of the Risk Assessment Matrix published in the 2015 Article IV report. Higher financial volatility, combined with the renewed sovereign stress in the euro area including Ireland, would bring about a sharp rise in CDS spreads and banks' funding costs, with an imperfect pass-through to lending rates, which in turn would affect the creditworthiness of corporates needing funding for investment or working capital. The decline in economic confidence and higher interest rates would dent domestic demand, resulting in a reversal in the residential and commercial real estate price recovery back towards the trough levels experienced during the last crisis. The collapse in property prices would in turn trigger adverse wealth effects, creating a negative feedback loop into domestic demand and a deflationary process.

Figure 2. Ireland: Macroeconomic Baseline and Stress Scenarios



Sources: WEO, Haver, national sources, and IMF staff estimates.

Table 2. Ireland: Macroeconomic Scenarios for Stress Tests: Assumptions for Macroeconomic and Financial Variables

(in percent)

	Est.	Projections		
	2015	2016	2017	2018
Real GDP growth				
Baseline	5.8	4.7	4.0	3.0
Severe scenario	5.8	1.1	0.3	0.1
Moderate scenario	5.8	1.3	1.2	3.1
Unemployment rate				
Baseline	9.5	8.5	7.8	7.2
Severe scenario	9.5	9.6	10.5	11.2
Moderate scenario	9.5	9.4	9.1	8.4
CPI Inflation rate				
Baseline	0.3	1.5	1.9	1.6
Severe scenario	0.3	0.5	0.3	-0.7
Moderate scenario	0.3	1.1	-0.1	-1.0
Residential real estate price annual change				
Baseline	6.5	7.5	6.7	5.1
Severe scenario	6.5	-5.0	-5.0	0.0
Moderate scenario	6.5	1.2	0.8	2.6
Commercial real estate price annual change				
Baseline	21.8	10.3	4.2	1.9
Severe scenario	21.8	-4.6	-16.1	-11.2
Moderate scenario	21.8	2.9	-5.9	-4.7
Nominal annual interest rate (10-year government bond rate)				
Baseline	1.3	1.7	2.3	3.3
Severe scenario	1.3	3.2	5.3	7.9
Moderate scenario	1.3	3.6	4.6	4.8
10-year sovereign spread (in bp, against German governemnt bond rate)				
Baseline	75	102	142	226
Severe scenario	75	255	447	683
Moderate scenario	75	251	328	339

Source: Central Bank of Ireland and IMF staff estimates and projections.

B. Credit risks in the scenario analysis

16. Credit risk in the loan book constitutes the largest risk factor for the banking system on the asset side. Total loans represent 68 percent of total banking sector assets.

17. The transmission of macroeconomic shocks to probabilities of default and loan loss provisions of individual banks was assessed by estimating specific satellite models of credit risks. Basel II IRB approach formula for expected losses was used to compute losses related to credit risk as the product of PDs, loss given default and exposure at default (EAD). The FSAP team developed times series and panel data models to project sectoral or bank-specific PDs, while LGD projections were based on house and commercial real estate price projections.[9] For the estimation of the credit risk satellite models and the conduct of the solvency stress test, the FSAP team had access to a limited set of supervisory data at the individual bank level, on solo and consolidated bases, in a physical data room only (Table 3). Therefore, it had to complete its analysis with publically-available data (from commercial providers, CreditEdge database and the EBA transparency exercise). Pre-shock LGD data was taken from banks' annual reports and from the 2015 World Bank Doing Business report, which shows a global recovery rate of 87.7 percent for Ireland. This was then used in the computation of expected losses in the stress test.

Table 3. Ireland: Summary of FSAP team access to supervisory data 1/

	Fully available	Partially available	Not available
Data at the individual bank level		✓	
Data aggregated along groups of banks	✓		
Data aggregated at the banking system level	✓		

Source: IMF staff.

Notes: 1/ This table only describes the availability of supervisory data for the stress tests conducted by the FSAP team, but does not present an assessment of data quality.

18. Probabilities of Default were projected for eight segments at the sectoral level or at the bank level. The eight segments were: Irish and U.K. household mortgage loans, Irish and U.K. non-financial corporates, Irish and U.K. financials, Irish construction and commercial real estate, and Irish sovereign exposures. For the first segment, the FSAP team estimated a panel data model as it had access to bank-by-bank supervisory data. For U.K. household mortgage loans, the FSAP team

[9] A pass-through of house price changes to LGD of 0.5 was assumed for the stress test for the Irish retail segments, based on granular data from the Central Bank of Ireland covering the 5 systemically-important banks and more than 600,000 loans. For the other segments, the recovery rate taken from World Bank Doing Business report and commercial real estate price projections were used, assuming a full pass-through.

used the write-offs series published by the Bank of England for the entire U.K. banking system. For the six other segments, it used sectoral one-year Expected Default Frequencies from the CreditEdge database. In order to ensure that the models only produce PD predictions between 0 and 1 (or, equivalently, between 0 and 100 percent) and to capture nonlinearities in the relationship between the dependent and explanatory variables, the following logit transformation was applied to the original PD:

$$Y = \ln\left(\frac{PD_{it}}{1 - PD_{it}}\right) \tag{1}$$

19. The logit-transformed PDs were modeled as a linear function of different exogenous macroeconomic and financial factors. Therefore, the estimated model for the Irish mortgage loans can be expressed as:

$$Y_{i,t} = \alpha + \mu_i + \beta X_{t-s} + \rho Z_{i,t-s} + \varepsilon_{i,t} \qquad for\ t = 1,\cdots,T \quad and \quad i = 1,\cdots,N \tag{2}$$

where $Y_{i,t}$ is the logit transform of the PD for bank i at time t, X_t is a vector of macroeconomic and financial variables, $Z_{i,t-s}$ is a bank-specific variable, s denotes time lags, μ_i denotes bank-specific fixed effects, $\varepsilon_{i,t}$ is an independent and identically distributed error-term, and α, ρ and vector β are parameters to be estimated.

For the other segments, the estimated models can be expressed as:

$$Y_t = \alpha + \beta X_{t-s} + \varepsilon_t \qquad for\ t = 1,\cdots,T \tag{3}$$

More specifically, the determinants of PDs included:

- For the Irish household mortgage loans: the contemporaneous domestic unemployment rate, the real 10-year Irish government bond rate lagged by 4 quarters, the bank-specific growth in market share lagged by 4 quarters, and bank fixed effects aimed at capturing unobserved bank-specific characteristics (such as the quality of risk management). The dependent variable was the annualized 3-month ahead PD which avoided overlaps between periods covered by consecutive PDs with quarterly frequency, and thus serial correlation of residuals. The unemployment rate was expected to have a positive effect on PDs because it is associated with lower income, which reduces borrowers' debt payment capacity. Real interest rates were expected to have a positive effect on PDs too as they increase the debt burden and deteriorate loan quality. Finally, the growth in market share has an ambiguous effect on loan quality: on the one hand, it can reduce the flow PD mechanically in the short term due to a liquidity effect, as new loans are by definition performing; on the other hand, this can reflect an aggressive lending policy with lower credit standards translating into higher credit losses when the economic cycle turns down;

- For the U.K. household mortgage loans: a Vector Auto Regression (VAR) with the quarterly write-off rates and the year-on-year growth of house prices as endogenous variables and a lag order of 2, and the year-on-year real U.K. GDP growth and the real 10-year U.K. government bond rate, as exogenous variables;

- For Irish non-financial corporate loans: the year-on-year real GDP growth rate lagged by one period, the real 10-year Irish government bond rate lagged by 6 quarters and the contemporaneous level of the euro/dollar exchange rate as Irish companies may have dollar-denominated loans or exporting-companies may have dollar-denominated income that they repatriate;

- For U.K. non-financial corporate loans: the year-on-year real GDP growth rate, the real 10-year U.K. government bond rate lagged by 6 quarters and the quarterly change in the pound/dollar exchange rate;

- For Irish financials loans: the contemporaneous year-on-year real GDP growth rate, the real 10-year Irish government bond rate lagged by 2 quarters to avoid endogeneity issues, and the level of the euro/dollar exchange rate;

- For U.K. financials loans: the contemporaneous year-on-year real GDP growth rate, the real 10-year U.K. government bond rate lagged by 6 quarters, and year-on-year growth rate of house prices lagged by 4 quarters;

- For loans to the construction and real estate sector companies: the contemporaneous year-on-year real GDP growth rate, the real 10-year Irish government bond rate, the level of the euro/dollar exchange rate and the year-on-year growth in commercial real estate prices; and

- For sovereign exposures: a VAR with the quarterly EDFs and the real 10-year Irish government bond rate as endogenous variables and a lag order of 3, and the year-on-year real GDP growth, as exogenous variable.

Then, the PDs under stress for each type of borrowers in percent were computed according to the following formula which corresponds to the inverse of the logit function:

$$PD_{type,t}^{stress} = \frac{1}{1+\exp\{-(\alpha+\beta X_{t-s})\}} * 100 \qquad (4)$$

20. PDs were projected by banks using quarterly data over the period 2002Q1–2015Q4 and estimating panel fixed-effect or time series OLS models. To minimize model error risks and for the sake of result conservatism, PD projections were based on the most severe results between four models: the banks' bottom-up submissions, ECB benchmarks, the Central Bank of Ireland loan loss forecasting models[10] and the Top-Down model developed jointly by the FSAP team and Central Bank of Ireland staff. Models differ in terms of design and explanatory variables used. The ECB uses a suite of Bayesian VARs based on time series, the Central Bank of Ireland loan-level model used highly granular data with Markov-switching transitions, while the FSAP team used Top-Down model panel data. The coefficients of the explanatory variables based on the IMF Top-Down model are

[10] For a methodological overview of the Central Bank of Ireland's loan loss forecasting models see Central Bank of Ireland Economic Letter Vol. 2014. No.13.

presented in Table 4 for the Irish mortgage loans and the non-financial corporations segment. For the Irish mortgage segment, the unemployment rate and, to a lesser extent, real interest rate, have the largest and most significant effects: when the unemployment rate increases by one percentage point, PD rises by 2 percentage points; when the real interest rate increases by 1 percentage point, PD rises by 0.5 percentage points; finally, when the bank's market share increases by 1 percentage point, PD decreases by 0.3 percentage points one year later. For the non-financial corporate loans, the year-on-year real GDP growth and the euro exchange rate have the largest effects: a 1 percentage point decline in real GDP growth increases the PD by 2 percentage points; a depreciation of the euro exchange rate against the dollar by a tenth of a point results in a rise in PD by 0.5 percentage points, as such a depreciation might increase Irish corporations' debt service and burden if they have dollar-denominated loans.

21. Potential credit risk losses in the loan book represent the largest vulnerability of the banking sector on the asset side. Top-down stress test results suggest that banks are likely to experience significant increases in PDs under adverse scenarios (see Figure 3), in contrast with the baseline scenario in which PDs remain flat. The combined effects of higher unemployment rates and interest rates and the fall in property prices increase the banking system's total PD[11] from 1.9 percent in 2015 to 4.3 percent in 2018 under the severe stress scenario, compared to a peak of 2.5 percent under the moderate stress scenario, according to IMF model results. In the residential mortgage segment, the system-wide PD projections would peak at 4.6 percent in the more severe stress scenario in 2018 (Figure 4).

22. The rise in PDs requires additional provisions that worsen bank profitability in the adverse scenarios. Credit losses in the loan book amount to EUR 7.6 bn in the severe stress scenario, equivalent to 2.2 percent of total banking system assets, as a result of the credit risk increase caused by the severe macroeconomic conditions. By contrast, in the baseline scenario, the flow of new provisions is limited to EUR 2.2 bn, equivalent to 0.6 percent of total banking system assets.

[11] Weighted by banks' total capital.

Table 4. Ireland: Results from the Estimation of the IMF Credit Risk Satellite Models (Equations [2] and [3])

(Dependent variable: logit transform of the PD)

Type of borrowers	Irish Mortgages	Irish NFCs
YoY real GDP growth (in log) (lagged by 1 period)	-	-8.0412*** (-8.42)
Unemployment rate (in percent)	0.2015*** (11.24)	-
Real interest rate (in percent) (lagged by 4 periods/6 periods)	0.0204** (3.18)	0.0151* (1.64)
EUR/USD exchange rate level 1/	-	-1.6414*** (4.43)
Bank's yoy growth in market share (in percent, lagged by 4 periods)	-0.0113** (-2.79)	-
Constant	-5.3984*** (-32.24)	-1.0298** (2.06)
R-square	0.71	0.55
# of observations	206	54

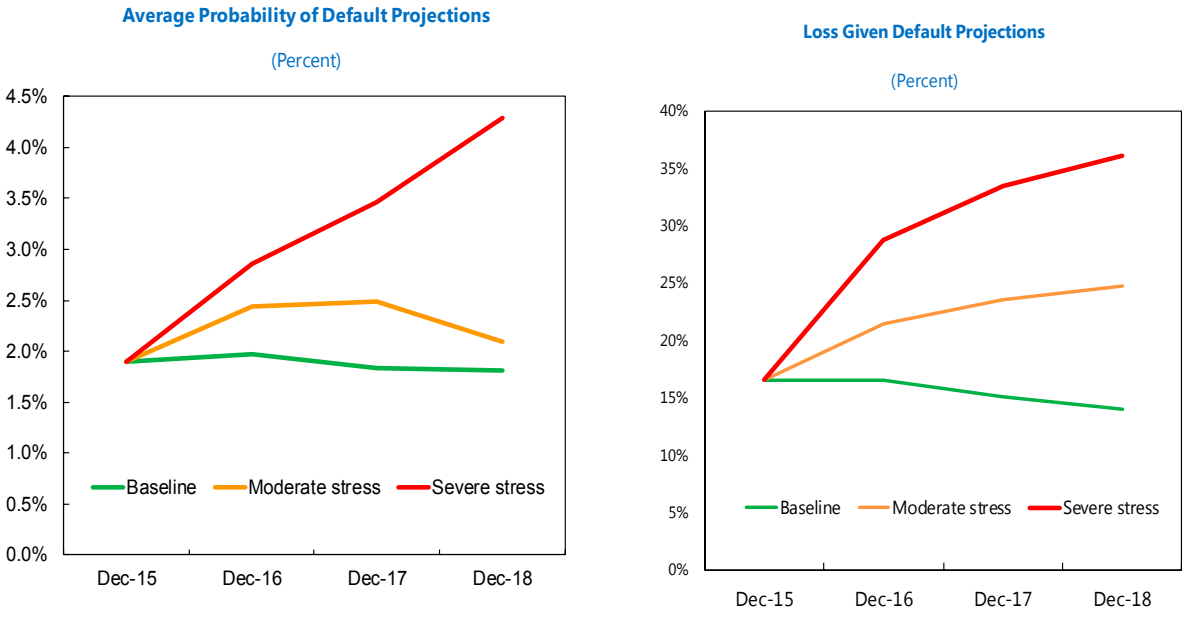
Source: IMF staff calculations

Notes: 1/ An increase in this variable denotes an appreciation of the euro against the dollar.

t-statistics in parentheses.

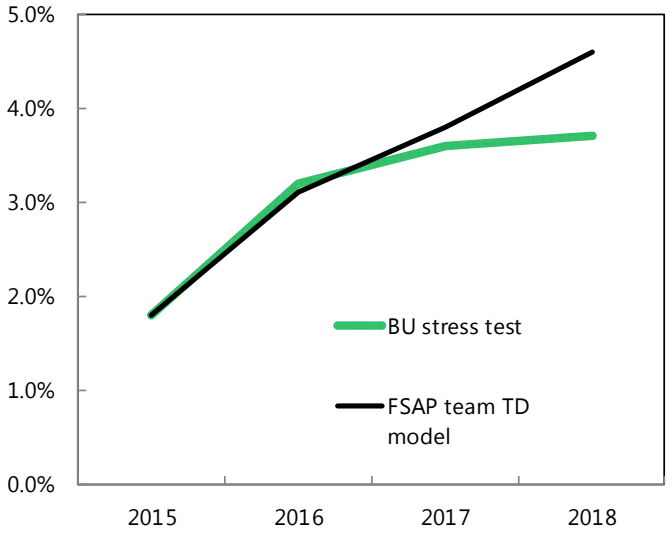
* Denotes significance at the 10 percent level; ** at the 5 percent level; and *** at the 1 percent level.

Figure 3. Ireland: PD and LGD Projections in the Baseline and Adverse Macroeconomic Scenarios—IMF model



Source: IMF staff calculations

Figure 4. Residential Mortgage PD Projections in the Severe Stress Scenario—BU and FSAP TD stress tests



Source: Central Bank of Ireland, and IMF staff calculations.

C. Market risks in the scenario analysis

23. Stress tests also assessed the resilience of banks when facing different sources of market risk. In addition to credit risk related losses, banks can experience large losses due to changes in market variables (for instance, exchange rates and interest rates). These losses or gains might be due to the existence of "open positions" in banks' balance sheets (due to e.g., currency, maturity, time-to-repricing mismatches between assets and liabilities) or to valuation changes in the different securities (Available For Sale and Held For Trading) held by the banks. Interest and exchange rate risks were the two market risks included in the stress tests. Risks related to equity investments were not dealt with, as equity investments make up a negligible part of banks' assets and capital.

Interest rate risk

24. The impact of interest rate risk on net interest income was assessed using time-to-repricing buckets. Different interest rate sensitive assets and liabilities are grouped together in different buckets depending on their time-to-repricing. For instance, a loan and a deposit whose effective interest rate can change within the next month would be placed in the same bucket; their difference would represent the "time-to-repricing gap".[12] The expected losses—or gains—on interest income are simply computed as the product of this gap and the changes in the interest rate. This particular analysis only deals with the direct effect of interest rate risk. Indirect effects, that is through credit risk and the effect on asset quality in the loan portfolio, were dealt with in the credit risk section.

25. In the severe stress scenario, Irish banks lose a small amount of net interest despite the sharp rise in interest rates. Banks are usually exposed to a rise in interest rates because they are performing maturity transformation. Banks' net interest income is a main source of profits for banks and is sensitive to changes in interest rates, as these could reduce the interest margin depending on the time to asset and liability repricing. Therefore, a maturity ladder approach was used to project net interest rate income in the baseline and adverse macroeconomic scenarios. Three out of the five banks composing our stress test sample display a negative time-to-repricing gap (i.e. liabilities are repriced faster than assets), leading them to lose interest income when interest rates rise. Indeed, equal increases in deposit and lending rates raise banks' interest payments by a larger amount and faster than interest receipts. At the aggregate level for the 5 banks, the repricing gap amounts to EUR -8.1 bn euro as of June 2015 for maturities below one year. In the severe stress scenario, the aggregated loss directly due to the change in interest rates amount to EUR82 mn, with no material effect on the CAR over the entire stress horizon.

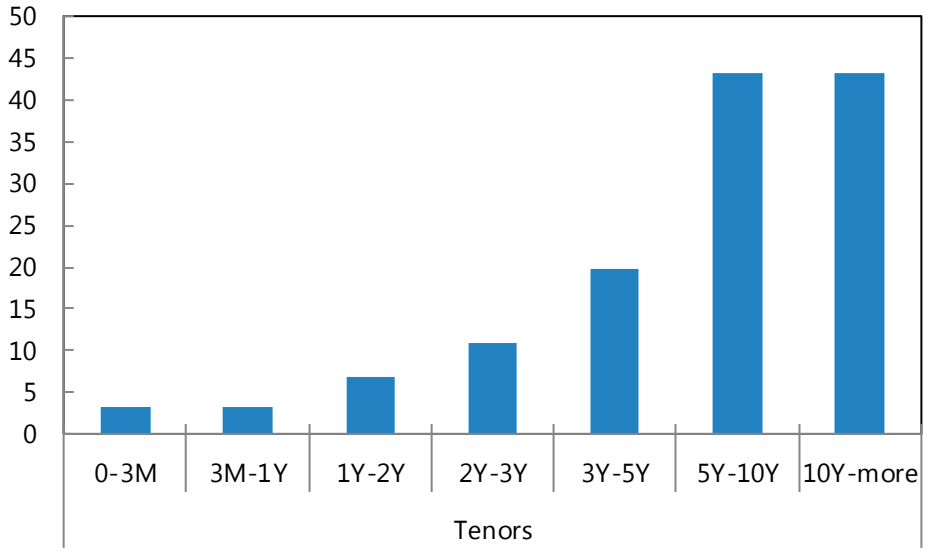
[12] Data were available for the following time-to-repricing buckets: less than one month; 1 to 2 months; 2 to 3 months; 3 to 6 months; 6 to 12 months; and more than 12 months. Conservatively, the largest net losses on any gap with a time-to-repricing less than 12 months were considered as representing the "instantaneous loss" due to the interest rate shock.

26. Interest rate risk was also assessed through valuation effects on debt instrument holding. The other potential source of gains or losses related to changes in interest rates are valuation changes on domestic government and corporate bond holdings. First, the duration of each of these holdings is computed. Second, for each portfolio, the average duration is calculated as the weighted average of the individual durations weighted by the amount (in euro) of each individual bond holding. Finally, using a modified duration approach, the expected gains or losses due to valuation changes are computed as the product of the size of the bond portfolio, its average modified duration, and the change in the relevant interest rate (i.e. the bond yield). An increase in interest rates translates into a valuation loss in the bond portfolio, and vice versa.

27. Potential valuation losses on own-sovereign debt remain significant. In the severe stress scenario, losses due to a decline in the price of domestic sovereign securities in the Available-for-Sale and Held-for-Trading portfolios amount to EUR2.7 bn, contributing by 1.6 percentage points to the decline in the CAR over the entire stress horizon. Three factors contribute to this result: (i) the significant exposure of Irish banks to their own sovereign, with an average AFS exposure of 4.3 percent of total assets and ratios at individual banks ranging between 2 percent and 8.5 percent; (ii) the moderate duration of Irish banks' own sovereign AFS bond portfolio, averaging 5 years; and (iii) the large increase in the Irish government bond rates under the adverse scenario (6.6 percentage points for the 10-year rate), resulting in large haircuts on bond prices (Figure 5).

Figure 5. Ireland: Haircuts on Irish Sovereign Bonds

(Percent)



Sources: CBI; and IMF staff estimates.

Foreign exchange rate risk

28. The direct effects of exchange rate risks were assessed based on banks' net open FX positions. Data on net open FX positions were grouped by currency along the following three categories: USD, GBP, and "other currencies". The implied gains or losses on these positions were computed as the product of the net open position and the expected change in the euro exchange rate in each of the scenarios.[13]

29. The positive net foreign exchange position at the banking system level means that the banking system experiences direct market gains in the case of a euro depreciation. Assets denominated in foreign currency outweigh liabilities denominated in foreign currency in each of the five banks. The net open FX position for the banking system amounts to EUR 330 mn as of June 2015, equivalent to 0.1 percent of assets and 0.4 percent of capital.

30. Losses on banks' net foreign exchange positions are very small in the severe stress scenario. In this scenario, the euro is expected to rise against the US dollar and the pound sterling over the whole period, which results in an aggregated loss of EUR 2 mn.

D. Results of the solvency stress tests based on macro scenarios

31. In the stress scenarios, the materialization of risks affects the banking system through several channels. The relative importance of the different channels described above can be seen in terms of their contributions to the changes in Common Equity Tier 1 capital ratio in Figure 6.

32. In all the scenarios, a number of adjustments and assumptions were made to track the change in individual banks' balance sheets and profits over time.

- *Growth of banks' balance sheets.* Banks' balance sheet size was projected to grow in line with nominal GDP. Thus, the size of the banking system in terms of assets remains constant relative to the size of the economy. This assumption has two advantages. First, it guarantees that banks do not meet capital requirements simply by shrinking their balance sheets—which could also reduce their RWAs (i.e. the denominator of the CAR ratio)—in adverse scenarios. Second, it ensures that banks that pass the tests remain sufficiently capitalized to support lending in a severe downturn. For this reason, this assumption reduces the need to quantify the second round effects triggered by banks' behavioral responses to the initial shocks. It should be noted that in adverse scenarios, the growth of net assets (total assets net of loan loss provisions) is usually lower than the growth of total assets because provisions are higher.

- *Projection of risk-weighted assets.* As large banks in Ireland operate under Basel II Internal Rating-Based approach, risk weights are projected using the corresponding Basel II formula for credit risk whereby the capital requirement ratio depends on the value of PD, LGD and asset

[13] For the currencies other than USD and GBP, the path for the NEER was used.

correlation. This means that typically risk weights should rise in a stress scenario. Therefore, RWAs are exogenously constrained not to decrease over the stress period.

- *Evolution of profits*. In regards to the income statement, non-interest profit items and lines such as operational and administrative expenses, and net fee and commission income, were projected to grow in line with nominal GDP, with a floor set at 0 for the growth of operational and administrative expenses. However, it was assumed that income from extraordinary items did not recur again during the 2016-2018 period in the baseline and the adverse scenarios. Moreover, non-performing loans were assumed to provide no accrued income. Lending rates were assumed to follow the path of the 3-month Euribor rate due to the large share of tracker loans indexed to the ECB policy rate or the Euribor rate in banks' residential mortgage portfolios. Finally, banks' funding costs were projected based on an econometric model estimating the annual change in Irish banks' average interest expense to total funding ratio, with annual data over 2000-2014. Explanatory variables were: the annual change in the 3-month money market interest rate, the annual change in the VIX index, and the annual change in the amount of interbank deposits in percent. By doing so, we were able to capture the relationship between banks' funding cost and availability, and solvency, establishing a link between the solvency and liquidity stress test. The projection of interbank deposits was aligned with the parameter set for the liquidity stress test. The coefficient on the change in the interbank rate was found to be equal to 0.4.

- *Distribution of dividends*. Banks satisfying capital requirements during the whole period of the stress test in a given scenario were assumed to distribute 25 percent of their after-tax profits. Undercapitalized banks in any year of a given scenario were not allowed to distribute dividends.

33. As a result of the materialization of the different risks set out above, the banking system would be very significantly affected by the severe scenario (Figure 6). Under a fully-loaded Basel III definition, the aggregate Common Equity Tier 1 ratio would drop by 8 percentage points compared with the starting point and would be 7.2 percentage points below the baseline in 2018. The main drivers of the change in capitalization in this scenario are the following: (i) funding costs (-4.8 percentage points of RWAs); (ii) loss provisions (-4.4 percentage points of RWAs); (iii) other comprehensive income linked to valuation losses in the AFS portfolio (-2 percentage points over the whole stress horizon); and (iv) Basel III capital adjustments (-3.7 percentage points). Two banks would see their total CAR and Tier 1 ratios fall below the hurdle rates of 8 and 6 percent, translating into a capital shortfall of 0.2 and 0.1 percent of GDP, respectively. Four banks would have their Common Equity Tier 1 ratios falling below 7 percent, representing the combined minimum CET1 ratio and the capital conservation buffer If transitional arrangements towards Basel III were used in line with European rules instead, results would be similar on aggregate but the capital shortfall would be limited to 0.1 percent of GDP. In the baseline and moderate stress scenarios, every bank would stay above the regulatory minima.

34. Results measured in terms of the leverage ratio are similar. In the adverse scenario, three banks would see their leverage ratio fall below the hurdle rate of 3 percent in 2018, translating into

a capital shortfall of 0.1 percent of GDP.[14] However, in every scenario, the leverage ratio at the banking system level, measured as Tier 1 capital to total assets, remains largely above 3 percent in 2018, with a ratio of 7.4 percent in the baseline, 6.5 percent in the moderate stress, and 5.2 percent in the severe stress scenario, from an initial level of 9.6 percent in 2015. The similar results in terms of leverage ratio compared to those based on RWAs suggest that given that Irish banks' business model is simple, their RWA calculations based on internal models are suitably conservative.

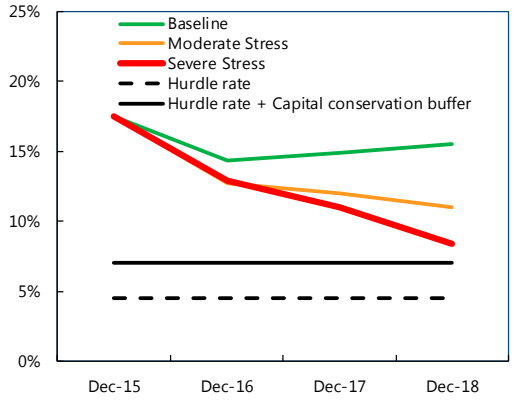
35. One caveat that should be borne in mind is that our credit loss estimates and solvency projections in the adverse scenario may be biased. First, the top-down stress test carried out by the FSAP team did not take into account loan write-offs and cures. Second, some assumptions had to be made in terms of Loss Given Default and other supervisory parameters as the FSAP team's access and use of supervisory data was constrained to a large extent.

36. The results of the Top-Down solvency stress test carried out by the FSAP team are more severe than the results of the bottom-up stress test (Table 5). According to banks' Bottom-Up submissions, no bank would be undercapitalized under the adverse scenario, and only one would not be able to meet the conservation capital buffer level. Credit risk loss estimates by most banks were large and based on severe PD projections. However, the Central Bank of Ireland had to apply more conservative adjustments on top of the results of some banks in terms of credit benchmarks, funding shock estimate, interest income, and RWA projection. Moreover, banks followed a dynamic balance sheet approach in their bottom-up stress test under which they could restructure their balance sheets. By contrast, the IMF Top-down stress test followed a static balance sheet approach whereby banks' balance sheet grows in line with nominal GDP. Furthermore, banks projected the banks' pension scheme balances as part of the solvency stress testing exercise, which the FSAP team did not.

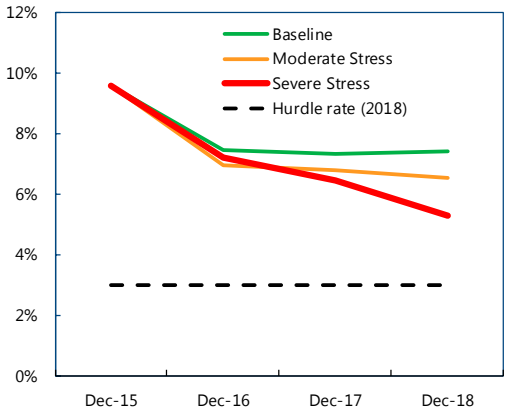
[14] It should be noted that the total assets used for the leverage ratio calculation differ from the European Banking Authority's definition of total leverage ratio exposures, as they correspond to balance sheet total assets. If the EBA definition was used instead, only two banks would see their leverage ratio fall below the hurdle rate of 3 percent in 2018.

Figure 6. Ireland: Bank Solvency Stress Test Results

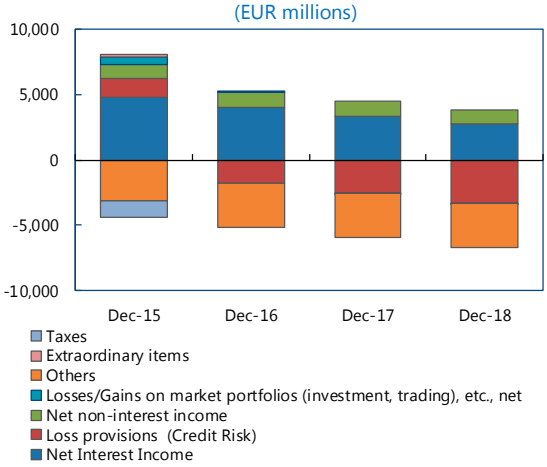
Core Tier 1 Capital Ratio
(fully-loaded, in percent)



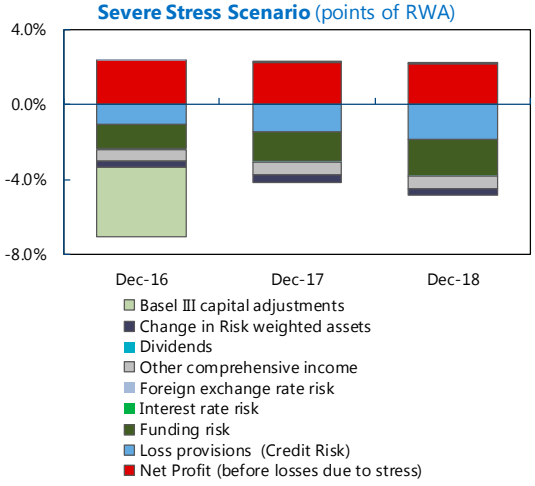
Leverage Ratio
(fully-loaded Tier 1/Total assets, in percent)



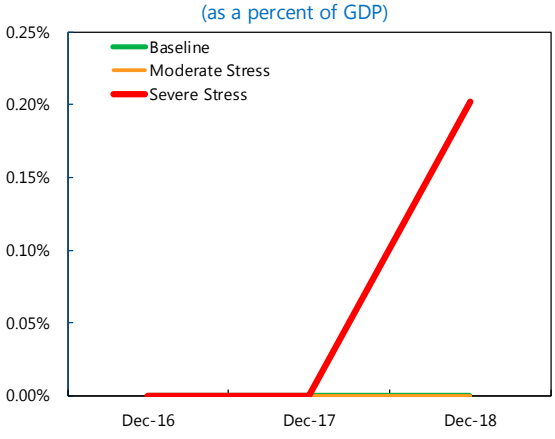
Net Profit Components in the Severe Stress Scenario
(EUR millions)



Contribution to Change of Capitalization Ratio in the Severe Stress Scenario (points of RWA)



Capital Needs
(as a percent of GDP)



Distribution of Banks' CET1 Capital in the Severe Stress Scenario (percent of banking system's assets)

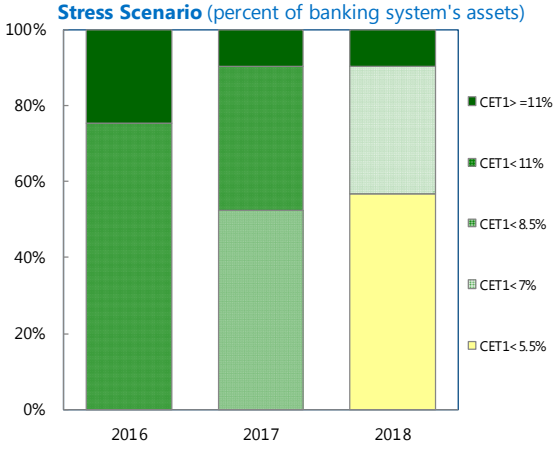


Table 5. Ireland: Results of the Bottom-Up and Top-Down Solvency Stress Tests (adverse scenario)

	Banking system's CET1 ratio (in percent)	Number of banks with 4.5%<CET1<7%	Number of undercapitalized banks (CET1<4.5%)	Number of undercapitalized banks (leverage ratio<3%)	Max. capital shortfall in terms of CAR, T1, CET1 or leverage ratio (percent of GDP)
Fully-loaded Basel III					
Bottom-Up Stress Test	12.4	1	0	-	0.00
CBI Top-Down Stress Test	10.1	1	1	-	0.05
IMF Top-Down Stress Test	8.3	4	0	3	0.20
European framework for transitional arrangements					
Bottom-Up Stress Test	14.3	1	0	-	0.00
CBI Top-Down Stress Test	11.9	0	1	-	0.04
IMF Top-Down Stress Test	9.4	4	0	2	0.10

Sources: Central Bank of Ireland and IMF staff calculations

37. Differences in results between the Central Bank of Ireland TD model and the IMF's model are mostly due to differences between methodological assumptions. The Central Bank of Ireland based its results on banks' submissions adjusted by more conservative parameters. Central Bank of Ireland adjustments lowered banks' CET1 ratio projections by a range of 1 to 3 percentage points of RWAs and resulted in one bank being undercapitalized under the adverse scenario in terms of CET1 ratio and another bank under the capital conservation buffer level. FSAP team and Central Bank of Ireland methodologies differed mostly in terms of net interest income projections as the FSAP team conservatively assumed no accrued interest on non-performing loans, whereas the Central Bank of Ireland allowed discount unwind in line with EBA methodology. The estimates of the shock on the AFS portfolio were also larger in the FSAP team top-down model as the FSAP team adopted a point in time shock versus the dynamic approach assumed in the Central Bank of Ireland approach. The Central Bank of Ireland also allowed changes in pension fund balances in its approach, while this was absent from the IMF methodology. The less systemically-important institutions were not covered by the IMF Top-Down model but were included in the Top-Down test conducted by the Central Bank of Ireland. The results show that LSIs' CET1 ratio falls by 4 percentage points under the adverse scenario but remains largely above the minimum requirement and the capital conservation buffer, at 18.6 percent. The less systemically-important institutions were not covered by the IMF Top-Down model but were included in the Top-Down test conducted by the Central Bank of Ireland. The results show that LSIs' CET1 ratio falls by 4 percentage points under the adverse scenario but remains largely above the minimum requirement and the capital conservation buffer, at 18.6 percent.

E. Market and macro risks based on sensitivity analysis

38. In addition to stress scenario analysis, sensitivity stress tests assessed vulnerabilities of the banking system to key individual shocks. These included: an increase in the unemployment rate; a decline in the prices of domestic sovereign securities; an increase in interest rates that affects banks' net interest income; an increase in interest rates that worsens the credit quality of bank loans; a decline in house prices that lowers the recovery rate of bank loans; a depreciation or appreciation of the euro nominal effective exchange rate that triggers direct gains or losses in banks with net open FX positions; and a nominal depreciation of the euro that worsens the credit quality of certain types of borrowers. Unlike macroeconomic stress tests, sensitivity tests are static: they assessed the instantaneous impact of different shocks on the banks' balance sheet positions as of June 2015. In all the sensitivity tests, banks' risk-weighted assets are assumed to stay constant after the application of the shocks.

An increase in the unemployment rate

39. Sensitivity tests assessed the impact of a higher unemployment rate increase than in the adverse macroeconomic scenario. Every model used as part of the FSAP (ECB benchmark, Central Bank of Ireland and IMF Top-Down credit risk satellite model) showed the crucial impact of the unemployment rate for the level and change in Probabilities of Default in the residential mortgages segment. To assess the sensitivity of the credit loss estimates to changes in the unemployment rate projections, a single factor test was carried out based on an increase of the unemployment rate up to 12.7 percent, i.e. 3.2 percentage points higher than in 2015, 1.5 percentage points higher than the peak of the macro scenario and in line with the 2016 EBA stress test scenario. The results from the credit risk model developed by the IMF team (also used in the tests based on macroeconomic scenarios) suggest that a 3.2 percentage point increase in the unemployment rate would increase the global PD in the system by 1.6 percentage points (from 1.9 percent to 3.5 percent). This would result in credit loss provisions expenses equal to EUR1.5 bn and a decline in total CAR by 0.9 percentage points. This shock taken in isolation would not be large enough to cause undercapitalization in any of the five banks. Moreover, the FSAP team informally communicated the results of the stress test based on the 2016 EBA adverse scenario using the FSAP Top-Down model to the Central Bank of Ireland.

A decline in the prices of domestic sovereign securities

40. Sensitivity tests assessed the impact of increases in domestic yields by type of instruments on exposures in the trading book. The tests assessed the sensitivity of banks' domestic bond AFS and HFT portfolios to a 500 bp increase in interest rates. Losses were calculated using a modified duration approach as the product of the size of the bond portfolio, its average modified duration, and the change in the interest rate.

41. The results show that some Irish banks are significantly exposed to domestic sovereign bond risks. The partial impact of domestic sovereign bond portfolio losses would be significant. Specifically, the CAR in the system would decline by 2 percentage points due to these losses taken

in isolation (assuming that no other shocks trigger simultaneous losses for these banks). However, the comfortable initial capitalization of most Irish banks on a transitional basis would provide them a large enough buffer to avoid undercapitalization as a result of this shock (Figure 7).

Interest rate risk: net interest income effects

42. A sensitivity test based on a maturity ladder (gap) analysis suggests that the banking system would lose a small amount of net interest income in the event of an interest rate increase. The gap analysis assesses the effect of an increase in interest rates by 500 basis points on banks' net interest income, taking into account the maturity transformation performed by banks. Changes in net interest income stem from the temporal dynamics of deposits, loans, and securities with maturities of up to one year. In the analysis, deposits maturing within one year must be rolled over at higher deposit rates, implying higher bank interest payments. Loans with maturities of less than one year are also renewed at higher interest rates, increasing bank interest income. Finally, treasury instruments with maturities of less than one year are reinvested at higher yields, earning higher interest income for part of the year. This shock taken in isolation would lower the total banking system's net interest income by EUR 403 mn euro, and the aggregate Tier 1 capital ratio by 0.2 percentage points. It would not cause undercapitalization in any of the five banks.

Interest rate risk: effects on credit quality

43. An increase in domestic interest rates could lead to a deterioration in the credit quality of loans, with a moderate effect on bank capitalization. A tightening of domestic monetary conditions may be the result of a sovereign stress or may be required to contain inflationary pressures or prevent capital outflows. Sensitivity tests based on credit risk models developed by the IMF team (also used in the tests based on macroeconomic scenarios) suggest that a 500 basis point increase in domestic real interest rates would increase the global PD in the system by 1.4 percentage points (from 1.9 percent to 3.3 percent). This would result in credit loss provisions expenses equal to EUR 1.5 bn and a decline in total CAR by 0.9 percentage points. This shock taken in isolation would not cause undercapitalization in any of the five banks.

44. This result shows only the partial impact of changes in interest rates on credit quality and bank capitalization. This test assumes that banks earn no-pre-impairment profits under stress; also, the increase in interest rates is sustained for one year and only affects banks' PD and credit losses directly, with output assumed to stay constant.[15] By definition, it may be limited as a measure of the overall impact as banks are likely to continue earning positive (or negative) pre-impairment profits that are not included in the analysis. This test also ignores second-round effects through which higher interest rates could be transmitted to banks. For instance, a monetary tightening could

[15] We noted above that, in contrast to macroeconomic tests, sensitivity tests are "static". However, the credit risk model used to assess the effect of a rise in interest rates on PD is dynamic and estimated based on quarterly data. This implies that the interest rate effects are fully transmitted to PD only with the passage of time. These tests are still considered "static" because banks' balance sheets do not adjust over time, and are taken as observed in June 2015.

help contain deposit or capital outflows; it could also slow down output growth in the short term, exacerbating credit losses in the banking system.

Foreign exchange rate risk: direct effects on banks with net open FX positions

45. A separate sensitivity test assessed how banks would be affected by *market* risk in a scenario with euro depreciation or appreciation. Setting the effect of the euro depreciation on credit losses aside, separate sensitivity tests were undertaken to assess how profits would be affected as a result of banks' net open foreign currency exposures. For the banking system as a whole, the net open FX position is positive, amounting to EUR219 mn as of June 2015 and equivalent to 0.05 percent of assets. For the five largest banks, the corresponding amount is EUR330 mn. Each of these five banks has a net long position in foreign currencies. The test indicates that a 30 percent appreciation of the euro nominal effective exchange rate would cause a loss of EUR99 mn and lower the CAR in the system by 0.1 percentage points. This shock, taken in isolation, would not cause undercapitalization in any of the five banks. Conversely, a 30 percent depreciation of the euro nominal effective exchange rate would cause a gain of EUR99 mn and increase the CAR in the system by 0.1 percentage points.

Foreign exchange rate risk: indirect effects of a nominal depreciation of the euro on credit quality

46. A sensitivity test assessed potential losses from *credit* risks as a result of a single factor shock with euro depreciation. A depreciation of the euro would increase the debt burden and reduce the debt-repayment capacity of unhedged foreign currency borrowers. Hence, the depreciation would damage the credit quality of banks' foreign currency loan portfolios. Credit models developed by the IMF team (also used in the macroeconomic scenarios) suggest that the credit quality of Irish non-financial corporations and financials is sensitive to the level of the exchange rate. A 30 percent depreciation of the euro against the US dollar would increase the total PD in the system by 0.7 percentage points (from 1.9 percent to 2.6 percent). The test indicates that this would cause a loss of EUR1.1 bn, lower the CAR in the system by 0.7 percentage point, but would not cause undercapitalization in any bank. As in the case of the interest rate sensitivity test, the result shows only the partial impact of a depreciation of the euro on credit quality and bank capitalization; it does not factor in the positive effects of euro depreciation on the domestic economic situation. It is therefore limited in scope and subject to caveats, including the fact that banks are assumed to earn no pre-impairment profits under stress and output is assumed to remain constant.

A decline in real estate prices: effects on credit quality

47. A sensitivity test assessed potential losses from *credit* risks in a scenario with a decline in real estate prices. For banks, a decline in the real estate prices increases credit risks in two ways: through its macroeconomic effects and through the loan recovery rate in case of default. First, real estate price fluctuations might entail wealth effects and affect investment and consumption in the economy. Second, if borrowers can no longer service their debt payments due to unemployment or

a rise in interest rates in case of floating interest rate loans, this would lead the bank to repossess collateral. However, the value of the collateral in such a situation might not cover the full amount of loan balance remaining to be repaid, translating into credit losses for the bank. A 30 percent decline in domestic real estate (housing and CRE) prices would have large effects: it would bring about a rise in LGD in the system by 16 percentage points (from 16½ percent to 32½ percent). This would cause aggregate loss provisions of EUR1.7 bn. The loss of CAR in the system would be equivalent to 1 percentage point. As in the case of the interest rate sensitivity test, the result shows only the partial impact of a real estate price decline on credit quality and bank capitalization

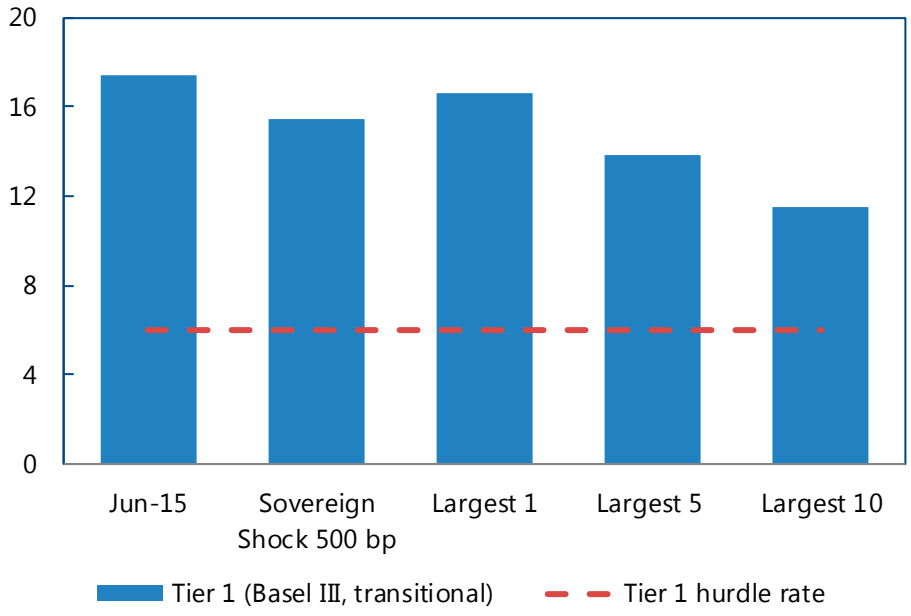
F. Concentration risk: Failure of a number of large corporate exposures

48. Name concentration risk was tested by assessing the impact of the default of the largest exposures. Supervisory data on the largest bank exposures were used to perform this sensitivity analysis type of stress test. They included exposures to non-financial corporations, credit institutions other than self, and financial corporations other than credit institutions, but excluded sovereign exposures. The test assesses the impact of the hypothetical default of up to ten of the largest borrowers, and computes the implied losses for various assumptions on the recovery rate. In our first scenario, we used the recovery rate calculated by banks within the national regulation framework, but alternative assumptions were also made.

49. Sensitivity test shows that an Irish bank is particularly exposed to credit concentration risks. On average, the size of the net largest exposure (after application of the conversion factors) is limited at 4.9 percent of total regulatory capital. Under the national regulation, the default by the largest exposure of each of the five largest banks in the system would cause no undercapitalization (Figure 7). However, the simultaneous default by the five to ten largest would cause undercapitalization in one bank. In the event of the default of the five largest exposures, the Tier 1 capital shortfall with regard to the 6 percent hurdle rate would amount to EUR 167 mn, equivalent to 0.1 percent of GDP. In the event of the default of the ten largest exposures, the Tier 1 capital shortfall would amount to EUR639 mn, equivalent to 0.3 percent of GDP.

Figure 7. Ireland: Sensitivity Analyses for Sovereign and Credit Concentration Risks

(Banking system's T1 capital in percent of RWA)



Source: CBI; and IMF staff calculations

G. Operational risks

50. Losses associated with operational risks taken in isolation would be moderate. In collaboration with the FSAP team, the Central Bank of Ireland's staff calculated loss estimates linked to operational risks using a sample of severe historical operational risk incidents across the five largest institutions. Such losses would amount to 0.73 percent of total assets on aggregate. However, it would not be possible to include large scale operational incidents (for example technology related or cyberattacks) within a macroeconomic stress test scenario because it would be difficult to quantitatively assess such a scenario based on historic loss data but that could lead to a certain impact.

LIQUIDITY STRESS TESTS

51. Liquidity stress tests were based on the national transposition of the Liquidity Coverage Ratio, Net Stable Funding Ratio (NSFR), and a cash flow-based analysis by maturity bucket. The LCR measures the bank's ability to meet its liquidity needs in a 30 calendar day liquidity stress scenario by using a stock of unencumbered high-quality liquid assets (HQLA).[16] Banks must maintain an LCR above 60 percent from October 2015 and 100 percent from 2018. Specific deposit run-off rates, roll-off rates for cash inflows and assets haircuts are included to simulate stressed conditions in three different scenarios. The national transposition of the LCR under the European Commission Regulation differs from the Basel III LCR on two main points: (i) it includes a larger range of high quality liquid assets, but subject them to high haircuts (e.g., equity is assigned a haircut of 50 percent); and (ii) the granularity of deposits is higher under the Commission Regulation. It also has an accelerated phase-in timetable relative to the Basel III LCR reaching the 100 percent hurdle in 2018 rather than 2019. The NSFR will require banks to maintain a stable funding profile in relation to the composition of their assets and off-balance sheet activities at a one-year horizon from 2018 in order to curb excessive maturity transformation and resulting liquidity mismatches.[17] Finally, the maturity bucket liquidity stress test is based on the analysis of the full temporal structure of cash flows generated by different assets and liabilities.

52. Top-down liquidity stress tests were conducted jointly by Central Bank of Ireland staff and the FSAP team. Cash-flow based liquidity stress tests were implemented through a Top-Down approach, using supervisory information on maturity structures of assets and liabilities at June 2015. The tests were carried out at the aggregate level, i.e. combining every currency including the euro, and with a separate test on pound sterling (GBP) positions. These tests assessed banks' resilience to strong shocks characterized by run-off rates on funding sources calibrated by type, and liquidation of assets subject to valuation haircuts. Specifically, the exercise captured: (i) a bank's liquidity need derived from outflows; (ii) its available standby liquidity from inflows; and (iii) its buffers available to counterbalance liquidity gaps. The LCR-based analysis also included an alternative, more severe scenario in terms of deposit withdrawals and a third scenario featuring a dry-up of unsecured wholesale funding, calibrated to meet very severe stress test conditions, such as those experienced during the 2008/2009 global financial crisis in some countries. It should be noted that common practice in FSAPs is to implement the liquidity tests assuming an underlying environment in which funding pressures are sizeable but limited to a number of banks (not systemic).[18]

[16] See Basel Committee on Banking Supervision (2013), "Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools", January.

[17] See Basel Committee on Banking Supervision (2014), "Basel III: The Net Stable Funding Ratio", October.

[18] The underlying environment in which a bank's resilience to liquidity shocks is tested should affect the calibration of deposit run-off rates and asset haircuts. Under generalized banking panics (bank runs affecting many banks, including important ones), the scramble for liquidity usually results in fire sales of assets, and hence, larger haircuts. Similarly, run-off rates on deposits should be higher when a panic sets in and triggers widespread bank runs.

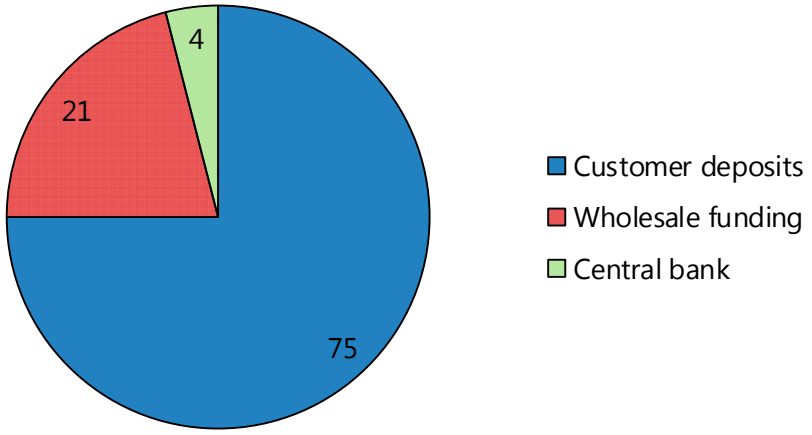
A. LCR-based stress test

53. The LCR-based stress test was based on three scenarios, with various parameters in terms of deposit run-off rates, roll-off rates for cash inflows, and asset haircuts. These rates, together with the assumed asset haircuts, are presented in Table 6. Potential sources of funding pressures for banks consist mainly of deposits from individuals, businesses, and large corporations. Cash outflows are generated by the need to pay contracted and contingent liabilities under specific assumptions regarding the capacity of banks to re-issue liabilities in adverse conditions. The funding structure of the banking system (excluding capital and including contingent credit lines) as of June 2015, can be described as follows (Figure 8):

- 77 percent of funding comes from customer deposits;
- 19 percent is wholesale funding (Debt Capital Markets 11 percent , Interbank deposits and Repo 8 percent; and
- 4 percent of funding comes from central banks.

Figure 8. Irish Banks' Funding Structure – June 2015

(Percent)



Source: Central Bank of Ireland.

54. Funding pressures were captured through specific time profiles of run-off rates for different funding sources. A set of general principles guided the choice of run-off rates for the computation of the LCR. First, more informed and sophisticated depositors withdraw funding more rapidly than less informed ones. That is why run-off rates applied to wholesale funding sources are higher than those applied to retail funding sources. Second, run-off rates on secured funding sources are lower than those applied to unsecured funding sources.

55. Banks' standby liquidity inflows stem mostly from maturing loans, deposits and credit facilities. Assets that can generate cash inflows over one month include: maturing loans from retail counterparties, and level 1 assets.

56. For different assets and maturity buckets, specific roll-off rates were applied to convert the maturing amounts into cash inflows. Specifically, 50 percent rates were applied to inflows from retail and nonfinancial wholesale counterparties, i.e. to performing loans to non-financial customers, and 100 percent rates were applied to maturing loans to financial institutions. These represent the cash inflows that a bank can generate under the going concern assumption: its actions do not compromise banking relations with important borrowers and cause no significant business disruptions.

57. Banks can counterbalance negative funding gaps by using their cash holdings and standard operations of the Eurosystem. In the tests, banks were allowed to cover negative balances of cash inflows relative to cash outflows by using their sovereign securities as collateral to obtain liquidity through the standard operations of the Eurosystem. At the banking system level, liquid assets make up 20 percent of total assets (including both on- and off-balance sheet items).

Table 6. Ireland: LCR-based Stress Test Assumptions on Run-off, Roll-off Rates and Haircuts
(in percent)

	LCR - Delegated Act	FSAP scenario with retail shock	Dry-up of unsecured wholesale funding
Run-off rates on potential outflows			
Retail Deposits			
Deposits subject to higher outflows - Category 1	10%-15%	20%	10%-15%
Deposits subject to higher outflows - Category 1	15%-20%	25%	15%-20%
Stable deposits	5%	10%	5%
Other retail deposits	10%	15%	10%
Operational Deposits			
Covered by DGS	5%	5%	50%
Not covered by DGS	25%	50%	100%
Non-financial customers	25%	30%	25%
Deposits for cash clearance purposes	25%	50%	100%
Non-operational Deposits			
Covered by DGS	20%	20%	50%
Not covered by DGS	40%	60%	100%
Committed Facilities			
Credit facilities to retail customers	5%	10%	5%
Credit facilities to non-financial customers other than retail customers	10%	30%	10%
Inflows	As per LCR	As per LCR	As per LCR
Haircuts on Liquid Asssets			
Level 1 assets	As per LCR	Additional 5% haircut	As per LCR
Level 2a assets	As per LCR	Additional 15% haircut	As per LCR
Level 2b assets	As per LCR	Additional 25%-50% haircut	As per LCR

Source: CBI

58. The LCR-based stress tests reveal that several banks in the system would be exposed to liquidity risks in the event of large deposit withdrawals or a dry-up of unsecured wholesale funding (Table 7 and Figure 9). Liquidity stress test results suggest that aggregate LCR using the European Commission Regulation parameters is 124 percent at June 2015. Every bank passed the 60 percent hurdle rate, which is the initial rate imposed by national regulation in 2015 according to the LCR phase-in agenda, and four of the five banks are above the 100 percent hurdle rate, which will be the binding level in 2018.

59. In the first alternative more adverse scenario, a number of banks would see their LCR fall below 100 percent. Higher run-off rates were applied in this scenario, especially to retail deposits, as well as higher roll-off rates for cash inflows. Indeed, the LCR standard establishes a minimum level of liquidity, but national authorities may impose higher minimum requirements. However, it should be noted that the severity of this scenario exceeds the one experienced during the 2008/2009 financial crisis as the peak of monthly funding withdrawals has been 2.4 percent for retail deposits since 2003 in Ireland. Under this adverse scenario, banks lose 10 to 15 percent of their retail deposits, including sight deposits and term deposits with a residual maturity below 30 days, and 10 to 60 percent of their non-financial corporate deposits in a month. The results of this adverse liquidity stress test suggest that aggregate LCR would fall to 87 percent, translating into a liquidity shortfall of EUR 7.1 bn, equivalent to 3.3 percent of GDP.

60. The second adverse scenario including a dry-up of unsecured wholesale funding provides similar results. Banks were assumed to face 100 percent run-off rates on unsecured wholesale funding, operational outflows rates (corporate and deposits through custody or clearing arrangements) were assumed to increase by 45 percentage points, non-operational outflows covered by a deposit guarantee scheme (DGS) by 30 percentage points and those not covered by DGS by 60 percentage points. The results show that the aggregate LCR would fall to 87 percent, as in the second scenario including a retail shock. The total liquidity shortfall would amount to EUR 7.4 bn, equivalent to 2.8 percent of these banks' assets.

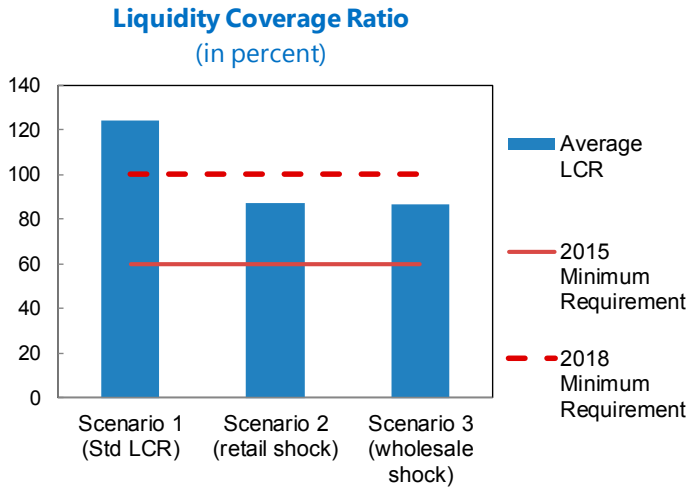
61. A separate liquidity stress test on pound sterling positions reveals large exposures. The aggregate liquidity shortfall in pound sterling would range between EUR1.7 bn and 6.0 bn, i.e. 0.8 percent and 2.8 percent of GDP, in the various LCR scenarios.

Table 7. Ireland: Summary of the Liquidity Stress Test Results

	LCR - Ireland Delegated Act	LCR Scenario with retail shock	LCR Scenario with wholesale shock	GBP LCR retail shock	NSFR
System-wide liq. ratio (in percent)	124	87	87	79	108
Liquidity shortfall 1/					
EUR billions	0.3	7.1	7.4	5.3	7.4
as a percent of GDP	0.1	3.3	3.4	2.5	3.4

Sources: Central Bank of Ireland and IMF staff calculations
1/ Liquidity shortfall is the amount required so that the Liq. Ratio in each bank in the sytem be equal to or above 100 percent.

Figure 9. Ireland: LCR-based stress test results



Source: Central Bank of Ireland

B. NSFR-based stress test

62. The liquidity stress test results based on the NSFR do not suggest large maturity transformation by Irish banks in aggregate. Under the NSFR methodology, available stable funding for the 5 largest banks amounts to EUR211.3 bn in June 2015 and the required stable funding to EUR196.4 bn, resulting in an aggregate NSFR of 107.6 percent. Nevertheless, some banks have a NSFR below 100 percent due to a larger gap between their assets and liabilities maturities, resulting in an aggregate liquidity shortfall of EUR7.4 bn, equivalent to 3.4 percent of GDP.

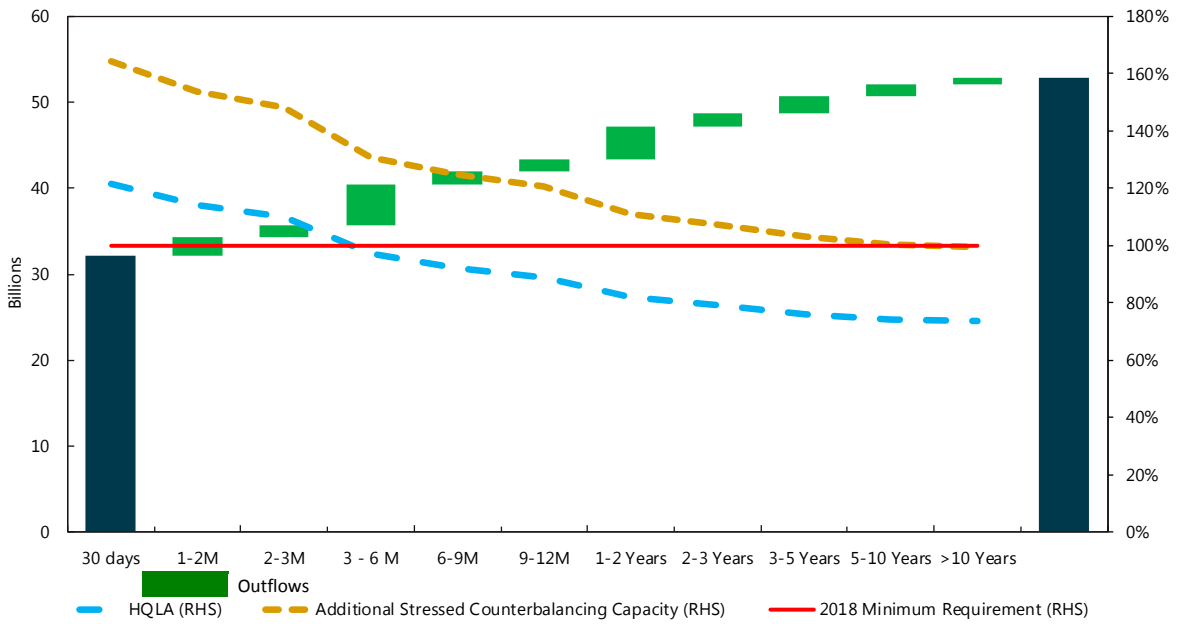
C. Outflow analysis stress test

63. The outflow analysis was based on eleven maturity buckets aimed at capturing the comprehensive time structure of banks' cash in- and outflows. The maturity ladder was

composed of the following buckets: below 30 days, between 1 and 2 months, 2–3 months, 3–6 months, 6–9 months, 9–12 months, 1–2 years, 2–3 years, 3–5 years, 5–10 years, and above 10 years. The deposit outflows were mapped by banks to LCR categorization. Then, the LCR parameters previously defined were used, including a 50 percent allowance on inflows for retail and corporate obligations. Inflows were capped at 75 percent of outflows as is the case in the LCR. For each bucket, the amount of net outflows was compared to the sum of the amount of HQLA buffer and an expanded counterbalancing capacity (stressed buffer), comprising banks' retained securitized assets. The stress of counterbalancing capacity was based on: (i) haircuts derived from sovereign yields in Irish sovereign stress test; (ii) haircuts on asset-backed securities (ABS) and Asset Covered Securities (ACS) based on downgrade using ECB collateral schedule; (iii) haircuts on retained ABS and ACS based on historic pricing; and (iv) pool of securities stressed using increased PD and house price decrease in Irish solvency stress test.

64. The results of the outflow analysis suggest that the banking system as a whole would have enough buffers to counterbalance net outflows for a wide range of maturity buckets, if an expanded range of counterbalancing capacity is included. Irish banks would be able to survive the assumed stress conditions of the stated analysis for maturities up to 10 years with a counterbalancing capacity expanded to securitized, stressed assets but would experience liquidity shortfalls for maturities beyond 3 months in a stress event with standard high-quality liquid assets only (Figure 10).

Figure 10. Ireland: Outflow Analysis-based Stress Test Results



Source: Central Bank of Ireland.

INTERCONNECTEDNESS ANALYSIS AND CONTAGION RISKS

A. Domestic interbank contagion risks

65. The risk of interbank contagion between the three largest domestic banks are assessed using a network model of contagion based on Espinosa-Vega and Solé (2010). The analysis is based on a matrix of bilateral domestic interbank gross exposures to the three largest banks composing our sample, with information as of end-June 2015.[19] Interbank exposures are taken from the quarterly large exposures return;[20] and are mainly composed of exposures on the asset side of banks' balance sheets, and not on the funding side. The analysis includes pure contagion arising from default of institutions-whereby failure of a bank triggers direct credit and capital losses in other banks-and the subsequent fire sales caused by funding shocks (assuming a 50 percent haircut in the fire sale of assets and a 65 percent roll-over ratio of interbank debt). The stress test assumes the hypothetical default of each bank, one at a time, on all its interbank obligations, and assesses the impact on other banks. If the default of any given bank on its interbank obligations implies the default of another bank in the system, a subsequent round must be calculated in order to assess the impact of the second bank's default on all other banks, and so on (i.e. "cascade effects"). With regard to funding shocks, in addition to the direct loss of capital, a bank needs to replace a fraction of the funding lost due to the default. It does so by selling other assets at deep discounts in the market, and these fire sales cause further losses of capital.

66. The analysis reveals that contagion risks stemming from purely domestic interbank exposures are very limited. In Ireland, interbank positions between the three largest domestic banks are found to be small, especially compared to these banks' capitalization. For the three largest banks in the system, the sum of their gross exposures to the other two banks is smaller than their regulatory capital. Therefore, no single failure of a domestic bank would trigger the failure of another domestic bank, and thus no "cascade effect" would take place through this three-bank market. Moreover, as of end-June 2015, none of the three largest banks is found to be undercapitalized with regard to the regulatory minimum after a shock on one or several of its interbank exposures to the other two domestic banks. Nevertheless, one of the three largest banks presents a significantly higher level of vulnerability to spillovers from the two others. For this bank, the index of vulnerability, which is the percentage of loss at a single institution due to the default of all other institutions,[21] is twice and four times as high as for the other two banks, respectively, although it remains at a very low level, below 9 percent.

[19] In a system with 3 banks, the interbank exposure matrix is a square matrix of size 3x3.

[20] See Articles 387–403 of the Capital Requirements Regulation (CRR) 575/2013 and http://www.eba.europa.eu/regulation-and-policy/large-exposures for details of the large exposures regime.

[21] See Espinosa-Vega and Solé (2010) for further details on the methodology.

B. Cross-border contagion and interconnectedness analysis

Recent developments in cross-border financial linkages

67. The global financial crisis highlighted the potential risks from financial contagion across borders. International financial integration from 1990s supported economic efficiency and growth by allowing risk sharing beyond national territories. As a side effect, however, it increased the probability of international spillovers of national shocks. Global banks' leveraged and interlinked balance sheets acted as transmission channels of the shocks within an intricate web of bilateral exposures, generating an unprecedented level of distress during the crisis.

68. The surge of banking inflows cultivated the core of the crisis in Ireland. Before the financial crisis, low-cost funding available in international wholesale markets channeled into Ireland by banks active in the domestic retail market, fuelling the credit and housing boom (Honohan, 2009; Everett, 2015).[22] Foreign banks increased exposures by about seven-fold from 2002 to 2008Q2 (Figure 11). A number of factors contributed: greater financial integration within the euro area; rapid expansion of financial markets such as the securitization market; a low-risk environment with innovative financial instruments; and a permissive regulatory framework (Coates and Everett, 2013).

Figure 11. Growth of Foreign Banks' International Claims

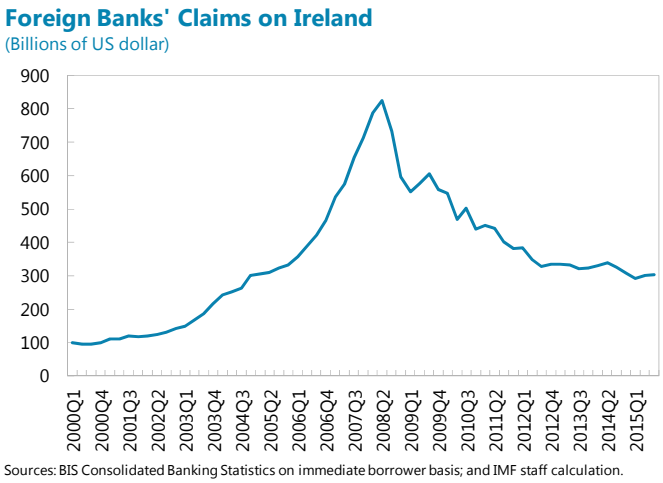
Sources: BIS Consolidated Banking Statistics on immediate borrower basis; and IMF staff calculation.

69. Currently, foreign banks are much less exposed to Ireland relative to the pre-crisis period (Figure 12). Since the onset of the global financial crisis, the Irish economy has experienced strong capital outflows, with the deleveraging of European banks that have faced credit and liquidity shocks. Relative to the peak, foreign banks' claims on Ireland, measured by the Consolidated

[22] The paper employs cross-border banking data on a residency basis, while our analysis uses the BIS Consolidated Banking Statistics.

Banking Statistics on the immediate borrower basis (CBS-IBB) had plummeted more than 60 percent by 2015Q3.[23]

Figure 12. Ireland: Foreign Banks' Claims on Ireland (Billions of US dollar)



Sources: BIS Consolidated Banking Statistics on immediate borrower basis; and IMF staff calculation.

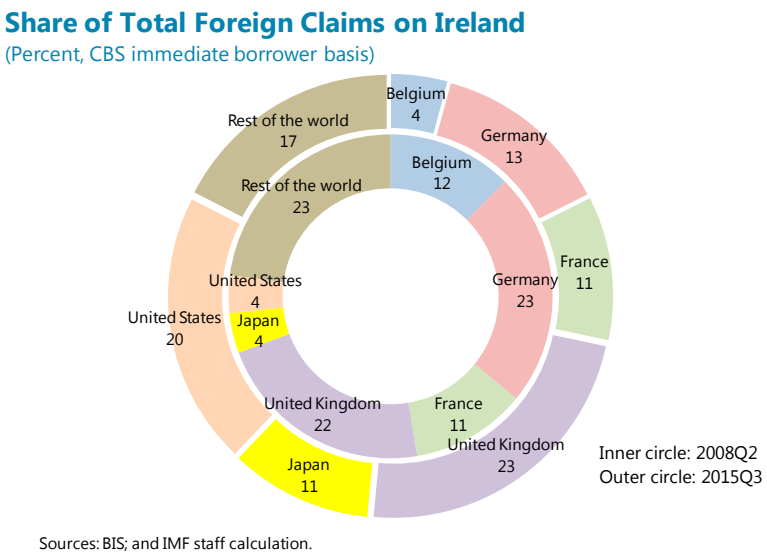
70. While U.K. banks have also retrenched they continue to be closely integrated with Irish financial markets. Banks headquartered in the U.K. had large exposures (US$235 billion) on Ireland in 2008Q1. About 54 percent of the exposures were international claims, and the rest were local claims in local currency booked by subsidiaries of U.K. banks. The size of exposures has decreased since then, to US$87 billion by 2015Q3, but amounted to 23 percent of total foreign claims (figure 13). Claims on non-bank private sectors in Ireland accounted for about 90 percent of these exposures in 2015Q3. There were also other exposures held by U.K. banks, such as derivative contracts, guarantees extended, and credit commitments, amounting to US$26 billion.

71. While other European banks have significantly reduced their role in providing funding to Ireland, the share of U.S. and Japanese banks has increased. European banks, especially those headquartered in Germany, have mainly retreated from Ireland. In 2008, German banks accounted for 23 percent of total foreign claims on Ireland, including exposures to Irish-resident Depfa bank (a subsidiary of the German Hypo Real Estate Group) (Coates and Everett, 2013). After Depfa bank transferred a large portion of its balance sheet to a German resolution vehicle in 2011, German bank claims decreased sharply to US$50 billion in 2015Q3 based on the CBS-IBB (US$36 billion based on the Consolidated Banking Statistics on the ultimate risk basis, CBS-URB) and the share of total foreign claims on Ireland dropped by more than 10 percentage points. On the other hand, financial links with U.S. and Japanese banks have strengthened since the financial crisis, with their shares increasing by 16 and 7 percentage points of total foreign claims on Ireland. U.S. banks hold US$30.5

[23] See Box 1 for information of the BIS International Banking Statistics.

billion worth of other exposures (derivative contracts, guarantees extended, and credit commitment) to Irish counterparties (mostly domestic banks).

Figure 13. Ireland: Share of Total Foreign Claims on Ireland (Percent, CBS immediate borrower basis)

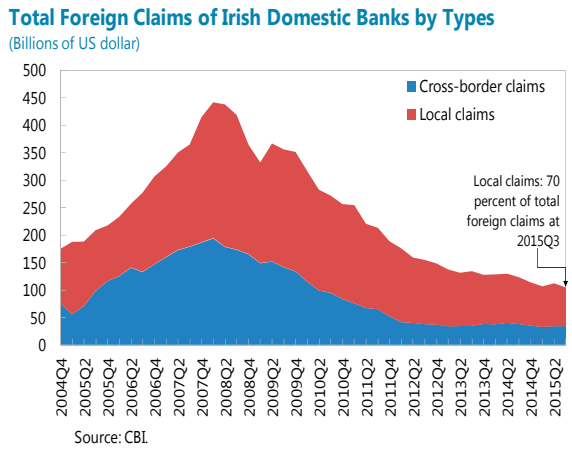


Sources: BIS; and IMF staff calculation.

72. Domestic banks headquartered in Ireland significantly reduced exposures to non-residents by asset sales and loan retrenchment in the wake of the crisis (Figure 14). Relative to the peak in 2008Q1, their foreign claims have decreased by 76 percent, bringing the outstanding amount from US$441 to US$105 billion in 2015Q3 (Table 8). The massive deleveraging by Irish domestic banks lowered their loan-to-deposit (LTD) ratios: top three banks' LTD ratio dropped from 181 percent at end-2010 to 107 percent in June 2015. But they have maintained relatively tight linkages with U.K. residents. Claims on the U.K. residents decreased the most (minus US$173 billion), accounting for half of the reduction. However, Irish banks' largest foreign claims continue to be on the U.K. residents with 71 percent of exposures to non-residents.

73. Exposures to non-bank private sectors, mostly in the form of local claims, accounted for a vast majority of the foreign claims held by Irish domestic banks. According to the CBS-URB, claims on non-resident private sectors accounted for 76 percent, and those on foreign banks and public sectors were 11 and 13 percent of total foreign claims in September 2015, respectively. They were mainly local claims (70 percent), held by the U.K. subsidiaries of Irish Banks. The claims are mostly in the form of mortgage loans, exposing them to the U.K. property cycle.

Figure 14. Ireland: Composition of Total Foreign Claims of Irish Domestic Banks



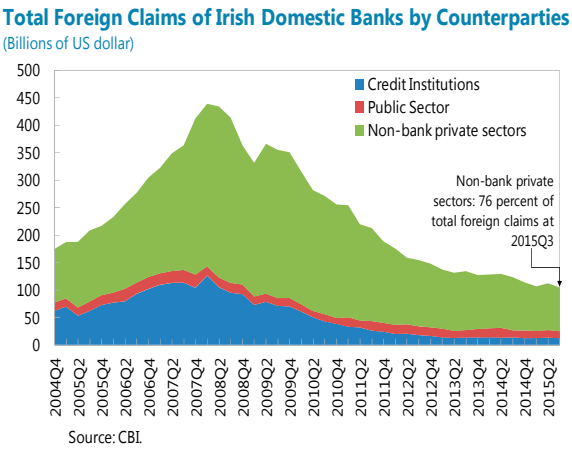


Table 8. Ireland: Balance and Share of Foreign Claims on Non-Residents

	2008Q1		2015Q3	
	Balance (US$ billion)	Share (Percent)	Balance (US$ billion)	Share (Percent)
France	20.5	4.6	5.0	4.7
Germany	21.8	4.9	0.9	0.9
Poland	17.7	4.0	0.4	0.3
Spain	16.3	3.7	2.8	2.7
United Kingdom	246.8	55.9	73.9	70.6
United States	39.5	9.0	6.1	5.8
Rest of the World	78.6	17.8	15.7	15.0
Total foreign claims	441.3	100.0	104.6	100.0

Sources: Central Bank of Ireland; and IMF staff calculation.

Box 1. BIS International Banking Statistics

The BIS collect two types of international banking statistics: the CBS and Locational Banking Statistics (LBS). These data are aggregated at the level of national banking systems and track developments in banks' foreign positions and cross-border financial linkages.

The LBS focus on all banking offices (both domestic- and foreign-controlled ones) resident in the reporting country and cover unconsolidated cross-border and local positions of these banks. These data are based on either residence or nationality of the reporting institution. For example, Irish resident banks include both Irish-owned banks and foreign-owned branches and subsidiaries resident in Ireland (Coates and others, 2015). These data corresponds to the compilation of national accounts, balance of payments, and external debt statistics.

The CBS focus on banks headquartered in the reporting country and cover banks' consolidated on-balance sheet claims and selected off-balance sheet exposures to counterparty countries and sectors. Positions are reported by head offices in their home country and include all branches and subsidiaries on a worldwide consolidated basis, net of inter-office accounts. This dataset is available on an immediate borrower basis (CBS-IBB) based on the country of the first counterparty exposure, and an ultimate risk basis (CBS-URB) based on the country where the final risk resides after taking into account risk transfers. Three different types of claims are included in the CBS: C, D, and E in the following text table. Total foreign claims are divided into international claims and local claims in local currency under the CBS-IBB, while they are categorized into cross-border claims and local claims under the CBS-URB. Because the local claims in foreign currency are minimal in Ireland, the size of cross-border claims under the CBS-URB is similar to that of international claims under the CBS-IBB. Appendix III explains what is included and excluded in these statistics.

Structure of BIS International Banking Statistics

Claims on residents of the reporting country		Claims on non-residents of the reporting country		
Cross-border claims booked by banking offices outside the reporting country (A)	Local claims booked by banking offices inside the reporting country (B)	Cross-border claims booked by banking offices outside the counterparty country (C)	Local claims booked by banking offices inside the counterparty country in foreign currency (D)	Local claims booked by banking offices inside the counterparty country in local currency (E)
Total domestic claims (A+B)		Total foreign claims (C+D+E)		
		Total international claims (C+D)		

Source: BIS.

The LBS are used to analyze capital flows between countries, while the CBS are used to measure the country risk exposures of internationally active banking groups. Because the note focuses on "risks" that banks transfer in and out of the Irish economy, rather than their role as a conduit, it uses the CBS, instead of the LBS. However, as highlighted in Coates and others (2015), even the CBS on the immediate borrower basis include exposures to the International Financial Services Centre, which focuses on international financial intermediation and plays a very limited role in the Irish financial system. Therefore, the risks can be overstated, which requires caution when interpreting the analysis.

Cross-border Network Analysis with the BIS Data

74. Understanding sources and transmission channels of financial contagion is important in identifying a build up of possible systemic risks and addressing them promptly. Even if supervisory data on banks' bilateral exposures are available, these data are only available nationally and unless both counterparties are located in the same country only one side of any transaction will be captured. For this reason, home supervisors around the world typically have much less information on credit or funding risk from "bilateral" exposures abroad than from domestic exposures. Host supervisors often do not have detailed balance sheet information of foreign branches. The lack of good data makes it difficult to conduct a similar type of solvency or liquidity stress tests as can be done for domestic exposures. Ireland is not an exception.[24] Cross-border bilateral liability exposure data are still incomplete, limiting the scope of quantitative analyses.

75. In the absence of individual bank-level data, this section uses country-level cross-border banking exposure data, particularly the BIS CBS-IBB, as opposed to supervisory data at the individual institution level.[25] It focuses on Irish resident banks' bilateral claims and liabilities vis-à-vis banks in 16 countries for which the CBS data are available from the BIS and the Central Bank of Ireland, and whose financial linkages with Ireland are relatively tight. The group of selected countries comprises Australia, Austria, Belgium, Canada, Finland, France, Germany, Italy, Japan, the Netherlands, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States, besides Ireland. The simulation results are based on information as of end-2014. A global banking system network is represented by the matrix of foreign claims for the 17 countries. As shown in Figure 15, bilateral exposures between Ireland and other countries are small relative to ones between countries where global banks are headquartered. Total regulatory capital data are taken from the IMF Financial Soundness Indicator statistics.[26]

76. This section of the note uses a network analysis tool from Espinosa-Vega and Solé (2011) to assess the importance of cross-border financial linkages, focusing on Ireland. This tool allows us to run simulations of a hypothetical adverse distress that a country's banking system can experience from direct cross-border exposures as well as a round of failures of other country's banking systems (Box 2). That is, the distress inflicts direct losses on domestic and foreign banks through interbank claims and claims on non-bank public and private sectors in a first round; next, the impact is magnified through the global banking network and propagated abroad through domino-like chain reactions.

[24] The Central Bank of Ireland does have detailed loan-level data on U.K. exposures and has developed loan-loss forecasting models for the U.K. exposures.

[25] The results with the BIS CBS-URB data can be found in Appendix V.

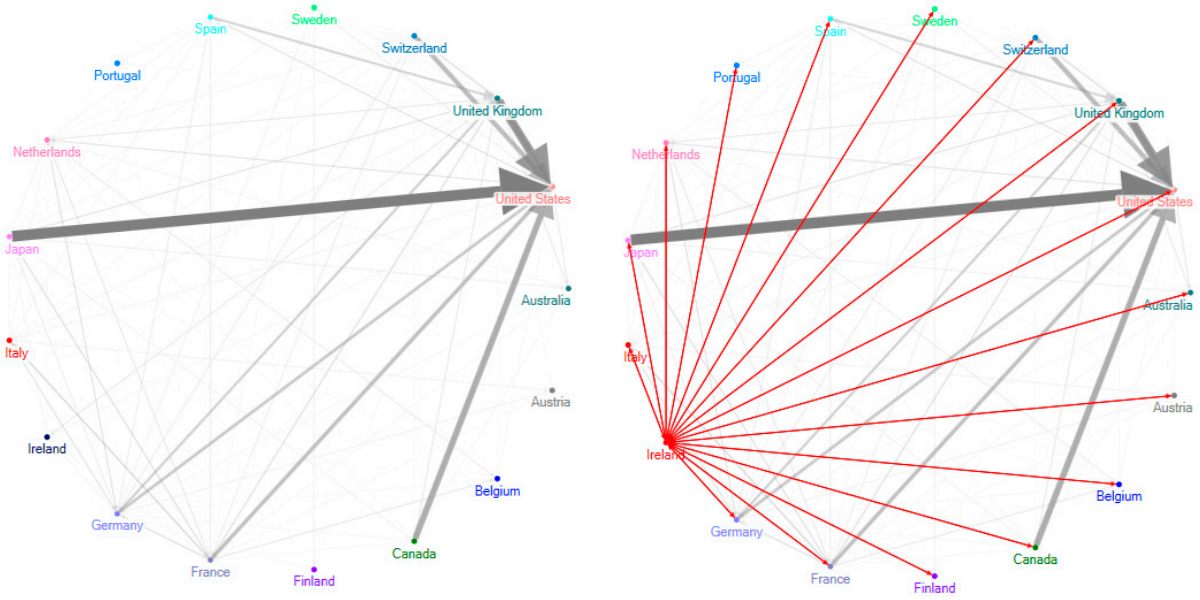
[26] Because the BIS CBS data in Ireland is compiled with the foreign claims of the three largest Irish banks (the BOI, AIB, and PTSB), their regulatory capital are cumulated. This note uses capital buffer figures as of end-2014. See Appendix IV for the size of capital buffers.

77. Two sets of simulations are undertaken under an assumption that new capital cannot be raised.

- **Simulation with a credit shock:** Failure of banking system "A" will incur capital impairment to a banking system "B" that has claims against "A." If system "B" does not have enough capital to absorb the losses, it also "fails" and subsequently causes domino effects; and

- **Simulation with a credit-funding shock:** The failure of system "A" can also lead to a liquidity squeeze for system "B" if it holds liability positions against the failed system. The event will force system "B" to find alternative sources of funding. However, when market liquidity is very tight, system "B" will not be able to fill the funding gap but will be forced to sell part of its liquid assets, possibly at fire-sale prices, thereby incurring trading losses. The compounding effects increase hazard probability of system "B."

Figure 15. Global Banking Network
(BIS Consolidated Banking Statistics at end-2014)



Sources: BIS; NodeXL; and IMF staff.

Box 2. Details of Simulation Method

This box summarizes the methodology explained in Espinosa-Vega and Solé (2011). For further detail, see Section II of the paper. A simple version of balance sheet identity for a banking system in a country i in a network of N countries can be simplified as equation (1),

$$(1) \quad a_i + \sum_{j=1}^{N-1} x_{ji} = k_i + b_i + d_i + \sum_{j=1}^{N-1} x_{ij}$$

where x_{ji} stands for country i foreign claims to country j; x_{ij} stands for country i foreign liabilities to country j; a_i, k_i, d_i, and b_i stand for other assets, total capital, deposits, and other short- and long-term borrowing of the banking system in country i, respectively.

Assume a banking crisis in country h causes the failure of the banking system and entails credit losses (λx_{hi}) in the banking system of country i. Then, the identity equation changes to:

$$(2) \quad a_i + \sum_{j\neq h}^{N-2} x_{ji} + (1-\lambda) * x_{hi} = (k_i - \lambda x_{hi}) + b_i + d_i + \sum_{j=1}^{N-1} x_{ij}$$

The banking system in country i fails as well if its capital cannot cover the losses ($k_i < \lambda x_{hi}$), which starts chain reactions to the banking systems in other countries. A parameter (loss given default ratio, λ) controls for severity of credit losses and capital impairment upon failure (i.e. 100 percent of the loss given default (LGD) ratio implies that all the claims vis-à-vis "A" are lost completely).

Assume the banking system of country i cannot fill a fraction of the funding from the failed system h ($\rho * x_{ih}$) and is forced to sell part of its assets at a discount rate δ. Then, the compound effects change the identity equation (2) to:

$$(3) \quad a_i + \sum_{j\neq h}^{N-2} x_{ji} + (1-\lambda)x_{hi} - (1+\delta)\rho x_{ih} = (k_i - \lambda x_{hi} - \delta\rho x_{ih}) + b_i + d_i + \sum_{j=1}^{N-1} x_{ij} - \rho x_{ih}$$

Let F_t be the set of failed banking systems through multiple rounds of contagion. A banking system fails the event if:

$k_i < \sum_{h\in F_t} \lambda x_{hi}$ for the simulation with credit shock and

$k_i < \sum_{h\in F_t} (\lambda x_{hi} + \delta\rho x_{ih})$ for the simulation with credit-funding shock.

For the failure of the banking system in country i, a simulation continues until there are no more failures of other banking systems. Each set of simulations runs 17 times, one per each country.

There are three parameters that need to be set: loss given default ratio (λ), loss of funding ratio (ρ), and the discount rate (δ). It is hard to estimate or calibrate these parameters based on the actual data, because there are 816 parameters in total (3*17*16). We simply set λ =1, ρ=0.5, and δ=0.5 as the baseline case, and show how the hazard rate changes as we use different parameter values in Appendix V.

78. The first simulation with the hypothetical failure of a banking system shows that, not surprisingly, Ireland is exposed to distress in the U.K. and U.S. banking systems (Table 9). It assumes banks in other countries can find alternative funding sources without resorting to fire sales of their assets, but are exposed to spillovers from a credit shock. As of end-2014, the hypothetical failure of the entire U.K. and the U.S. systems would, unsurprisingly, result in a total meltdown of the global banking system after three and five contagion rounds, respectively. Ireland would be directly hit by a U.K. banking failure due to the highly concentrated exposure across the Irish Sea. On the other hand, a failure in the U.S. would impact the Irish banking system in a second round due to contagion from the U.K.

79. Besides these two cases, the Irish banking system seems immune to hypothetical failures of other individual banking systems. Its index of vulnerability, measuring the average capital impairment due to the failure of all other banking systems, is only 17 percent. This is one of the lowest levels among the sample countries, as shown in Table 9. Excluding the events in the U.K. and the U.S., the index drops to 5 percent, the second lowest level after Australia, possibly reflecting Irish banks' deleveraging from other countries after the crisis.

80. A banking crisis in Ireland would not seem to cause any failure of other banking systems. It would deprive only 7 percent of total regulatory capital buffers in the global banking network, and would not generate any domino effect due to the small size of cross-border claims held in other banking systems relative to their capital buffers.

Table 9. Ireland: Simulation Results with Credit Shock

Country	Induced Failures	Contagion Rounds	Absolute Hazard 1/	Hazard Rate 2/	Index of Contagion 3/	Index of Vulnerability 4/
Australia	0	0	2	13	8	15
Austria	0	0	2	13	4	20
Belgium	0	0	2	13	8	23
Canada	0	0	2	13	7	17
Finland	1	1	0	0	6	14
France	0	0	2	13	21	31
Germany	1	1	2	13	36	24
Ireland	0	0	2	13	7	17
Italy	0	0	2	13	13	24
Japan	0	0	2	13	14	26
Netherlands	0	0	3	19	13	38
Portugal	0	0	2	13	2	22
Spain	0	0	2	13	9	19
Sweden	0	0	3	19	3	28
Switzerland	0	0	2	13	6	24
United Kingdom	15	5	1	6	100	14
United States	15	3	1	6	100	12

1/ Number of simulations in which that the banking system in each country fails.
2/ Percentage of failures out of 17 rounds of the simulation.
3/ Percentage of total capital impairment in other banking systems due to the failure of the banking system in each country.
4/ Average of capital impairment of the banking system in each country due to the failure of all other banking systems.

81. When credit and funding shocks are considered jointly, the hypothetical failure of the German and French banking systems becomes another source of negative spillovers towards Ireland. As indicated in Box 2, we assume a 50 percent haircut in fire sales of assets and a 50 percent rollover ratio of cross-border funding. The impact of a liquidity squeeze increases the systemic role played by Germany as well as the U.K. and the U.S. For Germany, the numbers of affected countries increase from one to sixteen (Table 10). Ireland would be affected after three rounds of contagion through the Netherlands in the first round, and Belgium, Italy, and Sweden in the second round. Even if banks headquartered in Belgium reduced their exposures to Ireland, they are still important lenders to Ireland, as shown in a text figure of the previous section. A failure of the French banking system would not induce a failure of the Irish banking system, but would deprive it of 90 percent of its capital buffers as the shock spills over to Belgium and the Netherlands.

82. Even under the compounding effects, the Irish banking system would not play a systemically important role in the global banking network. Table 10 shows that the index of contagion, measuring the credit losses to other banking systems that an Irish banking system failure can cause, stays below 10 percent, and would not be associated with any failures.

Table 10. Ireland: Simulation Results with Credit and Funding Shocks

Country	Induced Failures	Contagion Rounds	Absolute Hazard 1/	Hazard Rate 2/	Index of Contagion 3/	Index of Vulnerability 4/
Australia	0	0	3	19	10	24
Austria	0	0	3	19	5	27
Belgium	0	0	4	25	9	35
Canada	0	0	3	19	12	24
Finland	1	1	4	25	7	31
France	2	2	3	19	50	36
Germany	16	6	2	13	100	29
Ireland	0	0	3	19	8	33
Italy	0	0	3	19	15	29
Japan	0	0	3	19	24	32
Netherlands	0	0	4	25	18	43
Portugal	0	0	3	19	3	32
Spain	0	0	3	19	13	26
Sweden	1	1	4	25	6	31
Switzerland	0	0	3	19	12	30
United Kingdom	16	3	2	13	100	23
United States	16	3	2	13	100	22

1/ Number of simulations in which that the banking system in each country fails.
2/ Percentage of failures out of 17 rounds of the simulation.
3/ Percentage of total capital impairment in other banking systems due to the failure of the banking system in each country.
4/ Average of capital impairment of the banking system in each country due to the failure of all other banking systems.

Cross-Border Network Analysis with Market Price Data[27]

83. The network analysis with market price data corroborates the finding that Irish financial institutions are mostly on the receiving end of spillovers. Evidence based on a variance decomposition of weekly equity returns suggests that Irish financial institutions are significantly affected by the performance of banks in the U.K. and France, as well as the financial systems in Spain and Italy, within a representative network of systemically-important financial systems in the world (see Appendix VI for a technical description of the methodology and network). The individual contributions of these four sectors to the Irish financial system total inward spillovers exceed 5 percent, their combined contribution reaching 28½ percent. Moreover, within this network, the amount in percent of the Irish financial system's inward spillovers is higher than its amount of outward spillovers, with a net inward connectedness equal to 7.7 percent, meaning this entity is a net recipient of spillovers (Figure 16).

[27] This analysis was made possible by the excellent research support and econometric software coding work performed by Mr. Ben Huston (MCM).

84. These results likely reflect balance sheet and off-balance sheet as well as common exposures. While the significant impact of U.K. banks can be easily explained by the presence of a large subsidiary of a U.K. bank in Ireland, the presence of a large subsidiary of an Irish bank in the U.K., and funding interlinkages between the two financial systems, the large effect of French banks is more surprising. However, French banks are the entities that send the most outward spillovers in this network, not only to Ireland. This may reflect French banks' worldwide systemic importance associated with their size and interconnectedness. Direct and indirect common exposures to the non-financial sector, in particular to the U.K. real estate market, or linked to exports to and FDI inflows from continental Europe in the industry sector, might play a role as well.

85. A historic comparison shows that cross-border linkages were higher before the global financial crisis for the Irish financial system. Taking the March 2008 Bear Sterns failure as the starting date of the financial crisis, the spillover index, defined as the total amount of forecast error variance attributable to spillovers, remained broadly similar in the pre- and post-crisis periods, at above 70 percent. However, the share of the Irish financial system's spillovers to itself increased by 2.7 percentage points to 32 percent of total spillovers. The sectors which saw their contribution fall most were the French insurers, the MSCI world real estate index and the Greek banks, reflecting the post-crisis fragmentation of real estate markets, the decline in banks' exposures to commercial real estate markets and the specific situation of Greek banks following the prolonged crisis. Foreign banks sold their subsidiaries and reduced their interbank exposures to Greek banks, thereby reducing the international financial linkages.

Figure 16. Ireland: Global Connectedness of the Irish Financial System

(January 1, 2000 – February, 4, 2016)

Sources: Bloomberg, and IMF staff calculations.

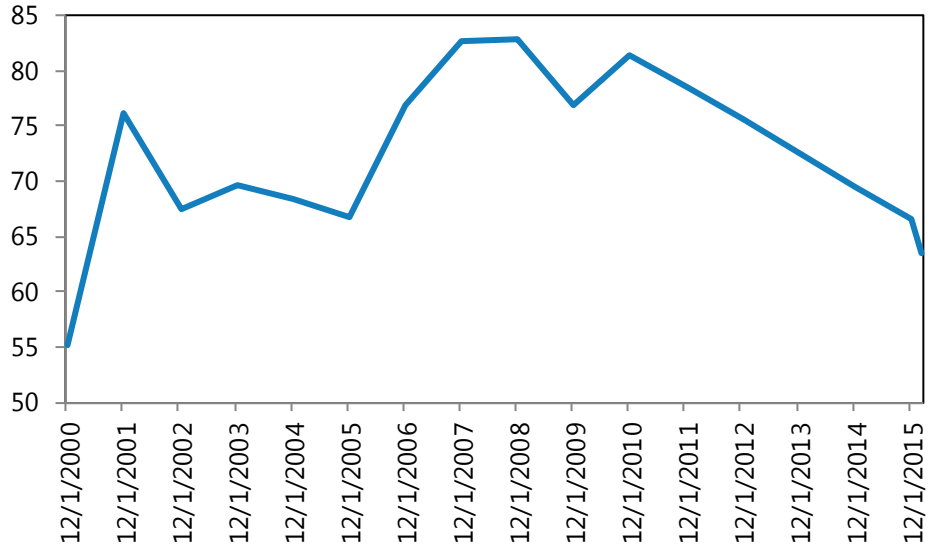
Note: The chart shows a variance decomposition network for the weekly equity return indexes for each sector, by country. The arrows signify and figures show the percentage of the variance of the 10-day ahead forecast error that is explained by the node where the arrow starts. The number of arrows originating in one node measures that industry's spillover potential. The number of arrows ending in a node measures that industry's vulnerability.

86. Some limitations of the methodology need to be borne in mind. First, the informational content of post-crisis market data of some of the Irish banks is low due to the large government share in the capital of a number of banks and the impact of government guarantees. The ISEQ financials index was used as it represented the best available data. However, it should be noted that this index has its own limitations—primarily that it is dominated by one large bank which makes up the majority (90 percent) of the index market capitalization—and thus this index is not diversified. The other constituents of the index are mainly banks and no real estate companies are included.

Second, the choice of a generalized forecast-error variance decomposition as opposed to a more structural approach does not allow for inferring causality with certainty. In particular, running a Granger-causality test does not enable ruling out the effect of common exposures completely. However, this methodology is meant to complement the analysis based on supervisory or balance sheet data. The convergence between the results of the two sets of analysis is a reassuring factor.

Figure 17. Ireland: Spillover index of the Irish financial system since 2000

(total amount in percent of forecast error variance attributable to spillovers, one-year rolling window)



Sources: Bloomberg, and IMF staff calculations.

Summary

87. Given the deleveraging in recent years, cross-border bank linkages appear to be less of a concern compared with the pre-crisis period. Both foreign banks' exposures to Ireland and Irish domestic banks' claims to non-residents have reduced dramatically. The BIS Consolidated Banking Statistics show that through direct cross-border credit and funding exposures, Ireland is exposed to financial distress in the four largest banking systems, namely those in the U.K., the U.S., Germany, and France. A network analysis suggests that the Irish banking system would be directly affected by distress in the U.K. banking system due to the highly concentrated exposures. Distress in the U.S., German, and French banking systems would generate domino effects through the U.K., Belgian, and Dutch banking systems. Meanwhile, a banking crisis in Ireland is not expected to cause failures in any other banking system. Market-data based interconnectedness analysis suggests spillovers from U.K. and French banks, as well as Spanish and Italian financial systems, towards the Irish financial system. However, Ireland's exposure to international spillovers has declined significantly since the onset of the financial crisis.

88. The tight linkages with the U.K. financial system warrant ongoing attention. Irish domestic banks have large exposures to the U.K. relative to the size of their balance sheets, and thus a severe distress in the U.K. financial system would inflict large losses on Irish banks.[28] In this vein, the Central Bank of Ireland's close monitoring of U.K. exposures of Irish banks is welcome, including the development of loan-loss forecasting models for stress-testing purposes. The efforts that the Central Bank of Ireland and its staff have made in developing a loan-loss forecasting model for U.K. mortgage exposures, corporate loans, and other consumer loans for the three largest domestic banks are also welcome.

CONCLUSION

89. Stress tests assessed the stability of the banking sector in Ireland. Top-down stress tests performed by the FSAP team and Central Bank of Ireland staff, and supported by the ECB on selected issues, assessed the solvency and liquidity positions of a sizeable composition of the banking system. These stress tests were complemented by bottom-up stress tests, carried out by five banks operating in the country, using their own internal methodology and guidelines received from Central Bank of Ireland.

90. The quantitative analysis included macroeconomic scenario-based stress tests, complemented by sensitivity analysis. Scenario-based stress tests used three full-fledged macroeconomic scenarios (one baseline and two adverse scenarios) to assess the solvency of the banking system. These stress tests included comprehensive risk coverage, analyzing risk factors such as: credit risk in the loan book, market risk effects on interest income and valuation effects on the debt instrument holdings, and exchange rate related risks, among others. The risk analysis also included sensitivity tests to assess potential concentration risks, and an assessment of domestic interbank contagion risks and cross-border interconnectedness. Finally, liquidity stress tests were carried out to assess the overall liquidity positions of the banks and liquidity positions in pound sterling.

91. The main results of the stress tests are the following:

- **There are several sources of vulnerabilities in the system in terms of solvency but these have declined markedly since the onset of the financial crisis and they remain manageable at the macro level.** In the severe stress scenario on a fully-loaded Basel III basis, two banks become undercapitalized with regard to the total CAR and Tier 1 capital ratio hurdle rates of 8 percent and 6 percent, respectively; three banks would have a leverage ratio below the hurdle rate of 3 percent in 2018, and four banks would not meet the Common Equity Tier 1 (CET 1) level of 7 percent, representing the combined minimum CET1 ratio and the capital conservation buffer level. The results would be similar under the transitional arrangements, with a reduced capital shortfall. The higher vulnerability of the two banks mentioned above stem from different

[28] Central Bank of Ireland (2015) notes that the impact of a disorderly Brexit could have a significant negative impact on Irish banks, insurance firms and non-bank financial intermediaries, in particular regarding business models and profitability.

factors, including lower initial capitalization, asset quality and profitability, higher exposure to funding risks, and sensitivity to Basel III capital adjustments.

- **Funding and credit risks are the two main vulnerabilities.** Funding costs are found to increase sharply under the adverse scenario. Moreover, loan quality is found to be very sensitive to changes in the unemployment rate and to GDP growth and, to a lesser extent, to real interest rates. In the severe stress scenario, bank loan loss provisions would rise in parallel with higher PD and LGD, with negative effects on profitability. Sensitivity tests confirm the predominance of credit risks, the exposure to sovereign and real estate market risks, and also indicate that these risks are exacerbated in one bank by the high concentration of loan portfolios, with the failure of the five largest exposures causing undercapitalization of this bank.

- **The global liquidity stress tests reveal that some banks in the system would be exposed to liquidity risks in the event of large deposit withdrawals, under a more severe scenario than the Basel III LCR metrics, or of a dry-up of unsecured wholesale funding**. In addition, some banks display material exposure to funding risks in pound sterling.

- **By contrast, banks are found to be less vulnerable to direct contagion risks through bilateral exposures or to cross-border contagion risks.** The contagion risk analysis reveals that the risks stemming from interbank exposures between the three largest domestic banks are very limited. Both foreign banks' exposures to Ireland and Irish domestic banks' claims on non-residents have reduced dramatically since the financial crisis. Even though the Irish financial system receives a lot of spillovers from U.K. and French banks, as well as the Italian and Spanish financial systems, the level of interconnectedness has decreased significantly since the onset of the crisis.

92. In conclusion, the Irish banking system appears to be more resilient than some years ago but remains exposed to large vulnerabilities. On the basis of the supervisory data used, two banks seem to be weaker than the other three systemically-important ones due to their lower asset quality and their exposure to solvency risks, as well as liquidity risks for one of them, while another bank is significantly exposed to sovereign risk. The two weaker banks are not highly interconnected with the other banks within the system, suggesting that any potential losses are likely to have limited direct spillovers to the rest of the banking system. However, indirect contagion risks (through for example reputational risks), not assessed in the stress tests, might entail significant risks to the system's stability.

93. The authorities need to work closely with other European countries and agencies on closing data gaps on cross-border bilateral financial exposures. Currently, data on individual Irish banks' cross-border asset positions vis-à-vis counterparties are available to the Central Bank of Ireland, but information on their foreign bilateral liability positions is still incomplete. As Hallissey (2016) points out, future data collection enhancements will help the monitoring of systemic risk related to cross-border linkages within the global financial system.

Appendix I. Ireland: Risk Assessment Matrix

Source of Risks	Overall Level of Concern	
	Relative Likelihood	**Expected Impact**
I. Structurally weak growth in key advanced and emerging economies.	High The Fund's recent World Economic Market Developments report noted widespread downside risk for advanced economies. The Euro Area remains subject to low trend growth and vulnerable to economic and political shocks.	Medium Ireland's economy is extremely open. Exports were equivalent to 110 percent of GDP in 2015, with the EA taking 35 percent of the total. The export growth impact would be significant but moderated if U.S. and U.K. markets remained robust. However protracted EA weakness could undermine domestic confidence, investment, and direct investment inflows. Weakness in other advanced economies could reduce investment in the multinationals sector.
	Medium The Fund's recent World Economic Market Developments report noted downside risk for emerging economies. Markets have remained volatile.	Low Ireland's direct trade exposure to emerging markets is limited, but the country might be affected by a contraction of world demand and trade, a reversal in investor sentiment, and flight-to-safety flows.
II. Sharp asset price decline and decompression of interest rate spreads as investors reassess underlying risks and move to safe-haven assets.	Medium Market developments suggest any spread widening is most likely contained by the ECB's OMT and QE	Medium Ireland's high level of private and public debt makes it susceptible to financial contagion. To the extent spreads widen, the impact on deficits and debt is limited by low financing needs, and substantial cash buffers. The impact on growth could be significant, especially if there was also a reversal of inflows into CRE.
III. Higher-than-expected fallout from the UK referendum result on EU membership.	Medium The UK referendum on 23 June 2016 resulted in a majority for the UK leaving the EU. The initial impact on financial markets was negative, with the pound Sterling depreciating sharply, highest-rated long-term bond yields declining further, and an uptick in spreads. The vote to leave the EU is expected to lead to a period of heightened uncertainty regarding cross-border trade, financial, and migration relationships between the UK and EU, and therefore, slower overall growth. These effects could be larger than projected in the (revised) baseline,	High A sharper-than-expected slowdown in the UK and the rest of Europe, persistent investor uncertainty, and prolonged high financial market volatility would adversely affect the Irish economy. An increase in trade barriers and persistent depreciation of the pound Sterling would reduce exports to the UK. Irish banks' profitability would decline, given their direct and indirect exposures, and asset quality may deteriorate in Ireland and the UK. Moderate/Low Some of these effects may be mitigated by possible relocation of firms that service the EU from the U.K. to Ireland, resulting also in an increase of FDI inflows over the medium term.

	especially if the process is volatile, looks likely to result in a large increase in barriers, or has significant political repercussions.	
IV. Financial imbalances from protracted period of low interest rates.	Medium Current Fund and market forecasts suggest that European interest rates may remain low for a prolonged period.	Low-Medium The international search for yield appears to be a significant factor driving Irish CRE markets. Further strong inflows into CRE could eventually generate over-building and risks of future slump in prices. A residential real estate (RRE) price bubble or a consumer lending boom could emerge. Low interest rates may, in due course, lead to over-investment. The high concentration of the Irish banking sector increases the likelihood that banks will follow similar strategies, making the sector as a whole less robust. Low domestic credit growth limits risks at present. Currently, the lack of construction since the crisis has led to a significant lack of CRE in downtown Dublin, and new RRE more widely. Irish insurance companies offer mainly unit-linked savings products and are therefore not directly affected by low interest rates.
V. Persistently lower energy prices, triggered by supply factors.	High Current Fund and market forecasts suggest that energy prices may remain low for a prolonged period. Political turmoil in the Middle East could lead to a sudden rebound in prices.	Low Lower oil prices could further reduce inflation and inflation expectations. Low inflation could lead to high savings and lower investment, given the slower decline in private debt burdens. Conversely, an increase in commodity and energy prices due to oil supply disruptions and geopolitical tensions in the Middle East would dent households' purchasing power, reduce firms' profitability and dampen the economic recovery. Lasting low energy prices would reduce production costs and increase real incomes.
VI. Domestic reform fatigue coupled with increased political fragmentation.	Medium Calls to reap soon the fruits of the recovery have become common.	Medium Public pressure to reverse some recent prudential measures and encourage credit-based expansion may increase the economy's vulnerabilities to adverse shocks.

Note: The RAM shows events that could materially alter the baseline path (the scenario most likely to materialize in the view of IMF staff). It reflects current staff views on the sources of risk surrounding the baseline, their relative likelihood, and the overall level of concern.

Appendix II. Ireland: Stress Test Matrix (STeM) for the Banking Sector: Solvency, Liquidity, and Contagion Risks

Domain		Assumptions		
		Bottom-up by banks	Top-down by Central Bank of Ireland	Top-down by FSAP Team
Banking Sector: Solvency Risk				
1. Institutional Perimeter	Institutions included	• 5 banks	• 11 banks	• 5 banks
	Market share	• 61 percent of the banking sector's assets	• 85 percent of the banking sector's assets	• 61 percent of the banking sector's assets
	Data and baseline date	• Bank proprietary data • Baseline date: end-June 2015 • Bank consolidated level data for banks having their headquarters in Ireland and sub-consolidated level data for the subsidiaries of foreign banks	• Supervisory data • Baseline date: end-June 2015 • Bank consolidated level data for banks having their headquarters in Ireland and sub-consolidated level data for the subsidiaries of foreign banks	• Publically-available and supervisory data • Baseline date: end-June 2015 • Bank consolidated level data for banks having their headquarters in Ireland and sub-consolidated level data for the subsidiaries of foreign banks • Market-data
2. Channels of Risk Propagation	Methodology	• Guidelines issued by the Central Bank of Ireland and FSAP team and banks' internal stress testing methodology	• Satellite models developed by the Central Bank of Ireland and the ECB	• Satellite models developed by the FSAP team • Balance sheet-based approach • Market data-based approaches

Domain		Assumptions		
		Bottom-up by banks	Top-down by Central Bank of Ireland	Top-down by FSAP Team
	Satellite models for macro-financial linkages	• Models for credit losses, pre-impairment income, credit growth, pensions, valuation models for marketable securities; expert judgment	• Methodology to calculate losses on AFS sovereign risk • Model to calculate idiosyncratic funding shock • Methodology to assess income projections, including accrued income on NPL loans • Methodology to assess pension risk • RWA forecast model	• Models for credit losses, pre-impairment income, credit growth; expert judgment • Models to integrate solvency-funding interactions • Methodology to calculate sovereign risk • Methodology to calculate losses from bonds and money market instruments (sovereign and other issuers). Haircuts are calculated based on a modified duration approach • Net fee income and commission income, and operating expenses, projected based on nominal GDP growth • No accrued income on NPL loans.
	Stress test horizon	• 3-years (2016/2018)		
3. Tail shocks	Scenario analysis	• Scenario-based tests, which assess the impacts on the entire portfolio including the loans and, if applicable, the trading book, were conducted in the TD exercise • Variables in the scenarios include domestic macro-financial variables (e.g., GDP, inflation), and GDP for key trading partners, interest rates, and real estate prices • In the Ireland-specific adverse scenario, the GDP growth rate declines to 1.1, 0.3 and 0.1 percent, in 2016, 2017 and 2018 respectively • A set of market shocks, including large and sudden changes in interest rates, is calibrated to magnitudes close to those observed in 2008/2009		
	Sensitivity analysis	• Sensitivity analyses will be conducted in the BU and TD exercises • They evaluate *domestic* shocks: direct effects of interest rate shocks; interest rate shock on credit quality; credit quality effect of unemployment rate; direct and indirect effects of exchange rate shocks; a decline in the prices of sovereign bonds and real estate; and failure of the largest to 10 largest corporate exposures		
4.Risks and Buffers	Risks/ factors assessed	• Credit risk on the banking book and trading book; • Market risk and bond losses: direct effects of	• Credit losses • Losses from bonds and money market instruments (sovereign and other issuers) in the banking and trading books. • Funding costs	

Domain		Assumptions		
		Bottom-up by banks	Top-down by Central Bank of Ireland	Top-down by FSAP Team
		interest rate shocks; direct effects of exchange rate shocks; shocks to sovereign bond yields.	• Market risk, including foreign exchange risk	
	Behavioral adjustments	• Dynamic balance sheet assumption.	• Dynamic balance sheet assumption. • No dividends are paid out.	• Balance sheet grows with nominal GDP. • Dividends are paid out by banks that remain adequately capitalized throughout the stress.
5. Regulatory and Market-Based Standards and Parameters	Calibration of risk parameters	• Point in time risk parameters for credit risk parameters or proxies	• Point in time risk parameters for credit risk parameters or proxies	• Point-in-time for credit risk parameters or proxies
	Regulatory/ accounting and market-based standards	• National regulation • Basel II IRB approach + Basel III		
6. Reporting Format for Results	Output presentation	• System-wide capital shortfall • Number of banks and percentage of banking assets in the system that fall below certain ratios.		
Banking Sector: Liquidity Risk				
			Top-down by Central Bank of Ireland and FSAP team jointly	
1. Institutional Perimeter	Institutions included	n.a.	• 5 largest banks in the system	
	Market share	n.a.	• 61 percent of banking sector's assets	
	Data and baseline date	n.a.	• Latest data: June 2015. • Source: supervisory data • Scope of consolidation: perimeter of individual banks	
2. Channels of Risk Propagation	Methodology	n.a.	• NSFR and LCR type proxies, • Cash-flow based liquidity stress test using maturity buckets by banks	
3. Risks and Buffers	Risks	n.a.	• Funding liquidity (liquidity outflows) • Market liquidity (price shocks)	
	Buffers	n.a.	• Counterbalancing capacity • Central bank facilities	
4. Tail shocks	Size of the shock	n.a.	• Run-off rates calculated following historical events and LCR/NSFR rates • Bank run and dry up of wholesale funding markets, taking into account haircuts to liquid assets	

Domain		Assumptions		
		Bottom-up by banks	Top-down by Central Bank of Ireland	Top-down by FSAP Team
5. Regulatory and Market-Based Standards and Parameters	Regulatory standards	n.a.	• European Commission Delegated Regulation (EU) 2015/61; and Basel Committee on Banking Supervision (2014), "Basel III: The Net Stable funding ratio" Basel, October.	
6. Reporting Format for Results	Output presentation	n.a.	• Liquidity gap by bank, and aggregated • Survival period in days by bank, number of banks that can still meet their obligations	
Banking Sector: Contagion Risk				
1. Institutional Perimeter	Institutions included	n.a.		• 3 banks • Financial sub-index of ISEQ index
	Market share	n.a.		• 50 percent of total banking system assets
	Data and baseline date	n.a.		• Latest data: June and December 2015. • Source: supervisory and market data • Scope of consolidation: perimeter of individual banks
2. Channels of Risk Propagation	Methodology	n.a.		• Network interbank model by Espinosa-Vega and Solé (2010) • Diebold-Yilmaz variance decomposition connectedness methodology • Data-driven correlation networks
3. Tail shocks	Size of the shock	n.a.		• Pure contagion: default of institutions • Spillover index and transmission
4. Reporting Format for Results	Output presentation	n.a.		• Number of undercapitalized and failed institutions, and their shares of assets in the system • Evolution and direction of spillovers within the network

Appendix III. Key Characteristics of the BIS International Banking Statistics

	Included	Excluded	Notes
Locational Banking Statistics	• Cross-border transaction within a financial group. • On-balance sheet items for both claims and liabilities. • On an immediate counterparty basis • By sector (bank vs. non-banks). • 44 reporting countries.	• Off-balance sheet items • Disregard risk transfers	• Bilateral data are confidential, need to request to BIS.
Consolidated Banking Statistics	• Cross-border claims only • Key off-balance items (guarantees extended, credit commitments and derivatives) • Immediate risk basis (e.g., BOI's lending to Santander U.K. will appear as Irish claims to U.K.), 31 reporting countries. • Ultimate risk basis (e.g., the above claims will appear as Irish claims to Spain), net of risk mitigants (guarantees and collateral), 26 reporting countries. • By counterparty sector (bank, official sector, non-bank financial institutions, non-bank private sector)	• Cross-border transactions within a financial group • Domestic claims in the reporting country (BOI's lending in Ireland) • Data by sector on immediate risk basis • Off-balance sheet items excluding guarantees, credit commitments and derivatives	• Bilateral data are publicly available.

Sources: IMF staff, based on documents published by the BIS.

Appendix IV. Size of Capital Buffers in the Sample Countries (As of end-2014)

	Millions of US dollars	Millions of Local Currency
Australia	174,227	213,167
Austria	74,864	61,868
Belgium	74,449	61,525
Canada	192,713	223,566
Finland	24,034	19,862
France	459,416	379,662
Germany	532,663	440,193
Greece	23,448	19,377
Ireland	27,080	22,379
Italy	224,804	185,778
Japan	366,799	43,961,000
Netherlands	156,405	129,253
Portugal	37,093	30,653
Spain	268,273	221,701
Sweden	82,765	647,594
Switzerland	217,808	216,370
United Kingdom	861,848	553,220
United States	1,559,796	1,559,796

Source: IMF Financial Soundness Indicators; Central Bank of Ireland; Haver Analytics; and IMF staff calculation.

Appendix V. Simulation Results with the BIS CBS on Ultimate Risk Basis or Different Parameters

Credit and Funding Shock Results with the BIS CBS on **Ultimate Risk Basis**
(λ=1.0, ρ=0.5, and δ=0.5)

Country	Induced Failures	Contagion Rounds	Absolute Hazard 1/	Hazard Rate 2/	Index of Contagion 3/	Index of Vulnerability 4/
Australia	0	0	3	19	9	23
Austria	0	0	3	19	5	26
Belgium	0	0	3	19	7	32
Canada	0	0	3	19	12	24
Finland	1	1	4	25	7	29
France	0	0	3	19	32	36
Germany	16	6	2	13	100	26
Ireland	0	0	3	19	7	31
Italy	0	0	3	19	16	28
Japan	0	0	3	19	25	30
Netherlands	0	0	3	19	15	37
Portugal	0	0	3	19	3	30
Spain	0	0	3	19	13	25
Sweden	1	1	4	25	6	29
Switzerland	0	0	3	19	12	25
United Kingdom	16	4	2	13	100	22
United States	16	3	2	13	100	21

1/ Number of simulations in which that the banking system in each country fails.
2/ Percentage of failures out of 18 rounds of the simulation.
3/ Percentage of total capital impairment in other banking systems due to the failure of the banking system in each country.
4/ Average of capital impairment of the banking system in each country due to the failure of all other banking systems.

Credit and Funding Shock with the BIS CBS on Immediate Risk Basis
(**λ=0.5**, ρ=0.5, and δ=0.5)

Country	Induced Failures	Contagion Rounds	Absolute Hazard 1/	Hazard Rate 2/	Index of Contagion 3/	Index of Vulnerability 4/
Australia	0	0	4	25	11	31
Austria	0	0	4	25	5	34
Belgium	0	0	5	31	10	37
Canada	0	0	4	25	17	30
Finland	1	1	5	31	9	37
France	16	5	3	19	100	40
Germany	16	4	3	19	100	33
Ireland	0	0	4	25	8	42
Italy	0	0	4	25	18	33
Japan	0	0	4	25	35	34
Netherlands	1	1	4	25	29	46
Portugal	0	0	5	31	3	36
Spain	1	1	4	25	19	31
Sweden	1	1	5	31	8	36
Switzerland	0	0	4	25	18	32
United Kingdom	16	3	3	19	100	29
United States	16	2	3	19	100	29

1/ Number of simulations in which that the banking system in each country fails.
2/ Percentage of failures out of 17 rounds of the simulation.
3/ Percentage of total capital impairment in other banking systems due to the failure of the banking system in each country.
4/ Average of capital impairment of the banking system in each country due to the failure of all other banking systems.

Credit and Funding Shock with the BIS CBS on Immediate Risk Basis
(λ=1.0, **ρ=1.0**, and δ=0.5)

Country	Induced Failures	Contagion Rounds	Absolute Hazard 1/	Hazard Rate 2/	Index of Contagion 3/	Index of Vulnerability 4/
Australia	0	0	1	6	7	19
Austria	0	0	1	6	3	22
Belgium	0	0	4	25	5	31
Canada	0	0	1	6	14	16
Finland	0	0	2	13	2	28
France	3	2	1	6	50	27
Germany	3	2	1	6	51	23
Ireland	0	0	4	25	5	41
Italy	0	0	1	6	11	24
Japan	0	0	1	6	28	20
Netherlands	1	1	3	19	19	36
Portugal	0	0	2	13	2	23
Spain	1	1	1	6	14	21
Sweden	1	1	1	6	5	24
Switzerland	0	0	1	6	15	22
United Kingdom	1	1	1	6	51	20
United States	16	4	0	0	100	16

1/ Number of simulations in which that the banking system in each country fails.
2/ Percentage of failures out of 17 rounds of the simulation.
3/ Percentage of total capital impairment in other banking systems due to the failure of the banking system in each country.
4/ Average of capital impairment of the banking system in each country due to the failure of all other banking systems.

Credit and Funding Shock with the BIS CBS on Immediate Risk Basis
(λ=0.5, ρ=0.5, and **δ=1.0**)

Country	Induced Failures	Contagion Rounds	Absolute Hazard 1/	Hazard Rate 2/	Index of Contagion 3/	Index of Vulnerability 4/
Australia	0	0	4	25	11	31
Austria	0	0	4	25	5	34
Belgium	0	0	5	31	10	37
Canada	0	0	4	25	17	30
Finland	1	1	5	31	9	37
France	16	5	3	19	100	40
Germany	16	4	3	19	100	33
Ireland	0	0	4	25	8	42
Italy	0	0	4	25	18	33
Japan	0	0	4	25	35	34
Netherlands	1	1	4	25	29	46
Portugal	0	0	5	31	3	36
Spain	1	1	4	25	19	31
Sweden	1	1	5	31	8	36
Switzerland	0	0	4	25	18	32
United Kingdom	16	3	3	19	100	29
United States	16	2	3	19	100	29

1/ Number of simulations in which that the banking system in each country fails.
2/ Percentage of failures out of 17 rounds of the simulation.
3/ Percentage of total capital impairment in other banking systems due to the failure of the banking system in each country.
4/ Average of capital impairment of the banking system in each country due to the failure of all other banking systems.

Appendix VI. Market Data-based Interconnectedness Analysis: Technical Details

Methodology

The methodology used to measure spillovers draws from Diebold and Yilmaz (2014) for market data analyses. The measurement of spillovers using market data starts with estimating a Vector Auto Regression (VAR) based on a specification as follows:

$$A(L)Y_t = \varepsilon_t$$

$D^H = \left[d_{i,j}^H\right]$ is the H-step ahead variance decomposition matrix.

with *Y* being a vector of weekly equity returns, *A(L)* a lag polynomial with order chosen by the Bayesian Information Criterion (BIC), and ε_t an error term.

The VAR model above is used to build a generalized forecast-error variance decomposition to identify uncorrelated structural shocks to returns. To that end, Pesaran and Shin's (1998) methodology is used. The spillover measures consist of the percent contribution of entity A to the H-step ahead forecast error variance of entity B, where the entities can be banks, sectors or countries. The advantage of this approach relative to the more standard Cholesky ordering or a more structural approach is that it does not require the modeler to explicitly choose the ordering of the variables.[1]

Since variance decompositions do not fully control for common exposures, this approach was complemented with a Granger-causality test using the same VAR model. To that end, a Wald test is performed on each entity, with the null hypothesis being that lagged returns of entity A do not help to explain the returns of entity B in a statistical sense. If the null hypothesis is rejected at the five percent significance level, then a direct connection exists from A to B, beyond what can be explained by common exposures.

Data

Analyses were conducted at the sectoral level. The network is meant to capture linkages between financial systems. Two worldwide indexes compose the network: the world real estate MSCI index and the global hedge fund index taken as global factors. Countries covered are: Ireland, China, France, Germany, Greece, Italy, the Netherlands, Portugal, Spain, the U.K and the U.S. The number of indices varies from country to country. For China, France, Greece, the U.K and the U.S, sectoral indices were available for banking, insurance and real estate sectors. For the other countries, including Ireland, a stock price index for the financial system as a whole was chosen. For Ireland, this choice allowed us to circumvent the problem of entities' representativeness as most Irish banks are currently state-owned and only a small part of their capital is publically-traded. The ISEQ financial

[1] Although in some cases market size may be a natural order, experiments based on trying different ordering showed that results were moderately sensitive to the choice of ordering.

index was deemed to be the most representative and diversified of the available indexes and to face the least data gaps. However, this index is dominated by one institution which comprises over 90 percent of the market capitalization, and so is not diversified.

Data for equity returns comes from Bloomberg and spans from January 1, 2000 to February 4, 2016 at the daily frequency. Forecast error variance was calculated on a 10 days ahead basis.

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