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FINANCIAL SECTOR ASSESSMENT PROGRAM

August 2017

TECHNICAL NOTE—RISK ANALYSIS

This Technical Note on Risk Analysis for Luxembourg was prepared by a staff team of the International Monetary Fund as background documentation for the periodic consultation with the member country. It is based on the information available at the time it was completed in July 2017.

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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 Luxembourg. 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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AIF	Alternative Investment Fund
AFS	Available For Sale
AuM	Assets under Management
BCL	Banque Centrale du Luxembourg
CAA	Commissariat aux Assurances
CCP	Central Clearing Counterparty
CDS	Credit Default Swap
CET1	Common Equity Tier1
CIMDO	Consistent Information Multivariate Density Optimization
CNAV	Constant Net Asset Value
COREP	Common Reporting Framework
CRD	Capital Requirements Directive
CRR	Capital Requirements Regulation
CRS	Comite du Risque Systemique
CSSF	Commission de Surveillance du Secteur Financier
EBA	European Banking Authority
ECB	European Central Bank
EDF	Expected Default Frequency
EL	Expected Losses
ELA	Emergency Liquidity Assistance
EM	Emerging Market
EU	European Union
EUR	Euro
FDI	Foreign Direct Investment
FE	Financial Entities
FINREP	Financial Reporting
FSGM	Flexible System of Global Models
FSSA	Financial System Stability Assessment
FX	Foreign Currency
GBP	British Pound Sterling
HFCS	Household Finance and Consumption Survey
HFT	Held For Trading
HQLA	High Quality Liquid Assets
HY	High Yield
IBB	Consolidated Banking Statistics on Immediate Borrower Basis
ICAAP	Internal Capital Adequacy Assessment Process
IMF	International Monetary Fund
LMT	Liquidity Management Tools
LSI	Less Significant Institution
NAV	Net Asset Value
NFC	Nonfinancial Corporations

NSFR	Net Stable Funding Ratio
OLS	Ordinary Least Squares
OTC	Over-the-Counter
O-SII	Other Systemically Important Institution
PIT	Point-in-time
PMD	Portfolio Multivariate Density
PoD	Probabilities of Distress
RAM	Risk Assessment Matrix
RCR	Redemption Coverage Ratio
RWA	Risk Weighted Assets
SA	Structural Approach
SI	Significant Institution
STA	Standardized Approach
STE	Short Term Exercise
STeM	Stress Test Matrix (for FSAP stress tests)
TN	Technical Note
TNA	Total Net Assets
TTC	Through-the-Cycle
U.K.	United Kingdom
URB	Consolidated Banking Statistics on Ultimate Risk Basis
U.S.	United States
USD	United States Dollar
UCITS	Undertakings for Collective Investments in Transferrable Securities
VAR	Vector AutoRegression
VIX	Chicago Board Options Exchange Volatility Index

EXECUTIVE SUMMARY[1]

Financial soundness indicators for Luxembourg's financial system, which plays a key role in the intermediation of financial capital, have remained relatively robust in recent years. Rising asset prices and inflows have seen the investment fund industry enjoy strong growth in assets under management, while exposure to liquid assets has remained steady. The banking sector, where a relatively large share of liquidity and revenues derive from private banking and fund management activities, has maintained high levels of profitability, capital, liquidity, and asset quality. The insurance industry, which is relatively less exposed to guaranteed products than regional peers, has adjusted well to the new regulatory regime, maintaining high profitability and capitalization levels.

Nevertheless, the defining structural characteristics of the financial system—size and interconnectedness—as well as elevated real estate valuations, give rise to potential vulnerabilities. First, as many Luxembourg foreign bank subsidiaries aggregate liquidity from investment fund and wealth management operations and 'upstream' it to their parents abroad, they may be exposed to maturity and currency transformation at the parent level—where exposures can be large (vis-à-vis subsidiaries capital) and oversight by the Luxembourg authorities may be limited where parents are not regulated under the Single Supervisory Mechanism. Second, should investment fund liquidity buffers struggle to accommodate large redemption shocks, asset fire sales and a drawdown of local bank deposits could occur (though operational deposits have been broadly stable in past stress periods). Finally, after a strong run up in prices and easing in lending standards, the real estate market, to which domestically-oriented banks are most exposed, poses the main home-grown vulnerability.

With these vulnerabilities in mind, the stress tests that form the basis of this Technical Note examined the resilience of the Luxembourgish financial system to solvency, liquidity, and contagion risks. They covered the three main sectors of the country's financial system, namely banks, insurance companies and investment funds. The banking sector stress tests included a top-down (TD) exercise based on macroeconomic scenarios and sensitivity analyses, conducted by the FSAP team, in cooperation with the European Central Bank (ECB). The tests based on macroeconomic scenarios assessed the impact of severe but plausible external and domestic shocks on the economy over a three-year horizon (2017-2019), based on data available through June 2016. The effects of these shocks on individual banks' profitability and capitalization were assessed using satellite models and methodologies developed by the IMF. To ensure the assessment was robust, international benchmarks taken from small open advanced economies with large financial systems that have experienced severe banking crises were applied to the credit risk parameter projections. In addition, sensitivity stress tests assessed vulnerabilities of the banking system to individual shocks. TD liquidity stress tests assessed the capacity of banks to withstand large withdrawals of funding, using a cash flow-based analysis and supervisory information, both on an aggregate basis and by

[1] Prepared by Ms. Jana Bricco, Messrs. Antoine Bouveret, Ziya Gorpe, and Cyril Pouvelle, all Monetary and Capital Markets Department of the IMF.

currencies. The contagion tests covered domestic interbank gross exposures (i.e. exposures without consideration of credit risk mitigation measures but with different assumptions about loss given default), interbank cross-liabilities, cross-exposures between domestic banks and insurers, cross-border interlinkages using supervisory data. Market data analysis was used to analyze connections between Luxembourg banks and investment funds, as well as to global banks.

With respect to the nonbank sector, the household, insurance and investment fund sectors were also subjected to stress tests, based on the same macro scenarios as for the banking sector wherever possible. Household balance sheets were stressed against a decline in income and home prices, and a rise in unemployment. The household stress test based on micro data was used to benchmark the credit loss projections in bank's mortgage holdings. Under the guidance of the Commissariat aux Assurances (CAA), insurance sector solvency stress tests followed a bottom-up approach using the adverse macroeconomic scenario to shock security holdings and fee income derived from unit linked products. Investment fund stress tests conducted by IMF staff included a solvency stress test for a sample of money market funds (MMFs), and a liquidity stress test for different types of UCITS bond funds (Emerging Market, High Yield, mixed funds and other bond funds), with redemption shocks calibrated on two scenarios: a historical approach based on the worst month for investor outflows specific to each individual fund, and a forward-looking approach based on the adverse macroeconomic scenario used in the bank stress tests. The sample of funds includes 191 funds, totaling €656 billion in total net assets. The MMF sample covered 75 percent of the sector, and the liquidity stress test covered 75 percent of High Yield and Emerging Market bond funds, 54 percent of mixed funds investing mainly in fixed income instruments and 32 percent of other bond funds in Luxembourg.

The banking sector and investment fund sector stress tests were integrated in a number of ways. These included (i) a common macro and financial scenario, (ii) the transmission of a fund redemption shock to bank deposits, (iii) market data-based analysis of spillovers and distress dependence, and (iv) network analysis of balance sheet exposures.

The design of the stress tests incorporated key external risks. These risks arise mostly from a renewed euro area recession, a surge in financial market volatility, and financial system outflows, which would affect the Luxembourgish economy through external demand, and investment fund flows. Moreover, an uplift in global financial market volatility could raise interest rates, credit spreads and funding costs.

Stress tests also incorporated key domestic risks which explain the high severity of the adverse scenario. First, domestic factors could amplify the effects of external shocks, such as a domestic confidence shock translating into a decline in consumption and investment, and a house price drop triggering adverse wealth effects. Moreover, this stress event could likely result in a sharp drop in government revenue, translating into a downgrade of the sovereign rating and an increase in sovereign risk premia.

Under the severe adverse scenario, the banking system at the aggregate level would remain very well-capitalized despite a meaningful decline in the system-wide capital ratio and higher vulnerabilities at some banks. This result derives largely from the significant capital buffers already established by Luxembourg banks, which act as an important shock absorber. The system wide Common Equity Tier 1 (CET1) ratio declines from 18.6 percent to 15.1 percent over the three-year period—a large though manageable decline—with domestically-oriented banks more severely impacted than the internationally-oriented. Key vulnerabilities in the banking system revealed in the adversely severe scenario include credit risk stemming from the corporate portfolio, and market losses in the bond portfolio, especially the foreign sovereign bond and non-sovereign portfolios without taking into account possible macro hedges. The capital of a number of banks making up less than 10 percent of the banking sector's assets would fall below the minimum regulatory Capital Adequacy ratio of 8 percent, although even then, recapitalization needs would be manageable, amounting to 0.8 percent of GDP. Based on the CET1 hurdle rate of 4.5 percent, the capital shortfall would be reduced to 0.1 percent of GDP.

As part of the assessment of banking sector vulnerabilities, household stress test results suggest that households' solvency would be significantly impacted by a drop in income and house prices, and a rise in the unemployment rate. However, the proportion of defaulted households would remain manageable. These findings could be interpreted as reflecting a relatively large financial wealth of Luxembourgish households.

Bank liquidity displays broad resilience, but would be weakened should wholesale funding dry up or funding stress emerge in foreign currencies. Limited data availability restricted parts of the liquidity stress tests to only eight banks leading to substantial gaps in IMF's liquidity analysis in Luxembourg. Under a more severe scenario than envisaged under the Basel III liquidity coverage ratio (LCR) metrics, liquidity stress tests reveal that a number of banks would be exposed to liquidity risks in the event of an extreme dry-up of unsecured wholesale funding including operational deposits by investment funds. Some banks also displayed exposures to their group entities, as their funding received in foreign currencies is channeled to their foreign parents. The reliance on securities to fund large short term gaps, as indicated in the cash-flow analysis, could become a point of vulnerability in times of distress when banks cannot necessarily sell large quantities of assets without facing reputational risk or even large haircuts.

Banks are found to be less vulnerable to direct contagions risks through bilateral exposures although most banks have considerable cross-border exposures. The contagion risk analysis reveals that the risks stemming from domestic interbank exposures, and from cross exposures between and among domestic banks and insurance companies, are very limited. By contrast, cross-border bank linkages are significant, a consequence of Luxembourg's role as a key hub for bank subsidiaries of foreign banking parent groups. Ongoing vigilance is required to ensure the risks of cross border spillovers from foreign parents to Luxembourg subsidiaries is minimized wherever possible. Market data-based analysis confirms that banks in Luxembourg are not strongly connected at the domestic level. This is in contrast to investment funds which appear to be closely connected to each other as well as to global banks.

Taken in aggregate, the assessment of banking sector vulnerabilities points to several areas where the authorities could prioritize supervisory attention going forward. Recent steps by the CSSF had the effect of increasing capital buffers to cover unexpected losses. The CSSF should continue to reinforce these steps with the regular conduct of stress tests based on severe shocks experienced in other small open economies with large financial systems. Moreover, the results point to the need to ensure that banks' Internal Ratings-Based models take into account losses in stressed environments and are sufficiently conservative. In this regard, the European authorities' plan to introduce regulatory floors for the risk-weights calculated by IRB banks should be commended and finalized shortly Liquidity monitoring should be strengthened by performing liquidity stress tests, requiring banks to extend the maturity of wholesale funding (CSSF & ECB), implement a foreign currency LCR at the group level (European Commission) and work together with the EBA to close liquidity reporting gaps and expand the harmonized EU bank reporting.

Insurance companies were found to be resilient in a scenario of increased market volatility and rise in interest rates despite the hit to the unit-linked business. High levels of starting capital, and key characteristics of the local industry, allow insurers to withstand a large market shock.

Liquidity risk in the UCITS investment fund and MMF industry is assessed by analyzing the capacity of individual funds in the sample to cope with severe but plausible redemption shocks. A historical approach quantifies the redemption shock on the basis of the worst realized monthly outflow, while a forward-looking simulation calibrates the shock based on macrofinancial variables from the adverse scenario as described in the banking sector stress tests. The redemption shock is then compared to fund liquidity as defined in two ways. The first (and most restrictive) measure includes only cash and short-term securities debt (with maturity of less than one year), following similar analysis by the European Systemic Risk Board in its quarterly risk dashboard (ESRB (2016)). The second measure of liquidity follows a high quality liquidity asset (HQLA) approach by attributing liquidity weights to each asset class depending on the rating, instrument type and issuer, following ESMA (2015).

Liquidity stress tests reveal that most fixed income funds would be resilient to severe redemption shocks, when liquidity buffers are measured by HQLA, with HY funds more vulnerable than others.[2] MMFs and most bond funds appear to have established sufficient liquid assets to meet severe redemption shocks under the HQLA approach (Table 9). In the forward-looking (macro scenario based) approach, mixed funds actually see inflows, while EM and other bond funds have sufficient liquid assets on hand to avoid selling less liquid assets or using liquidity management tools. Under the more restrictive measure of liquidity buffers (cash and short-term debt), MMFs and most mixed funds would be resilient while other funds would face a liquidity shortfall. More than half of HY funds are reported as having insufficient liquid assets under both scenarios and both measures of liquidity buffers, though self-assessments (by HY fund managers) via the newly introduced CSSF UCITS risk reporting point to a more benign assessment of possible liquidity mismatches. From a broader financial stability perspective, it should also be noted that

[2] This finding is consistent with recent IMF Global Financial Stability Reports and the 2016 Ireland FSAP Update.

UCITS HY funds account for only 5 percent of total net assets (TNA) of Luxembourg's investment fund industry.

Under the adverse scenario, some funds exposed to less liquid asset classes would face a liquidity shortfall, which could result in deposit outflows from banks. Most High Yield (HY) funds would face a liquidity shortfall, while EM and mixed funds would only have a shortfall under the more restrictive measure of liquidity buffers. The redemption shock could spread to banks through funds' deposit withdrawals, which would range between 20 and 25 percent of fund deposits in the sample.[3]

Solvency ('break the buck') stress tests for Constant Net Asset Value (CNAV) money market funds (MMFs) indicate that very large increases in interest rates and credit spreads would be needed for 'shadow' Net Asset Values (NAVs) to depart significantly from par value. This result owes to CNAV MMFs having established portfolios with low duration and limited exposures to risky assets. By way of illustration, a material (0.2 percent) deviation between the shadow NAV and par value would require a combined 170 basis point increase in risk free rates and a 70 basis point rise in credit spreads.

In aggregate, stress test analysis points to a case for further monitoring of investment fund liquidity risks and bank-fund interlinkages. Such an undertaking should include regular liquidity stress tests for funds exposed to less liquid asset classes such as HY and emerging market (EM) bond funds. The authorities are also advised to provide industry guidance regarding the modalities of liquidity stress tests (including coverage, stress test frequency, scenarios to be used, etc.) to ensure consistency and comparability across funds. Concentration risks should also be subject to heightened supervisory scrutiny given that a significant share of funds in the sample have very concentrated portfolios towards a few sovereign issuers. The CSSF and BCL are strongly encouraged to continue monitoring the potential risks arising from bank-fund interlinkages through the workstream established under the auspices of the Comité du Risque Systemique (CSR).

[3] Due to data gaps, deposit outflows are estimated assuming that 100 percent of funds deposits are with their depositary bank, while in practice funds' deposits are likely to be spread across several banks domiciled inside and outside Luxembourg.

Table 1. Luxembourg: Recommendations on Risk Analysis		
	Time[1]	**Responsibility**
Bank Risk Analysis		
Ensure banks' Internal Ratings-Based models take into account losses in severely stressed environments (see ¶ 49).	NT	ECB/CSSF
Consider the implementation of a regulatory LCR requirement in foreign currencies at the group level and step up monitoring of related FX liquidity risk (see ¶ 84)	MT	European Commission, ECB
The authorities should also work together with the EBA to close liquidity reporting gaps and expand the harmonized EU bank reporting. (see ¶ 84)	MT	CSSF/EBA
Extend maturity of wholesale funding, including deposits by parents (see ¶ 84).	NT	ECB/BCL/CSSF
Intensify bank liquidity supervision of foreign currency mismatches and perform liquidity stress tests based on cash flows at various maturities (see ¶ 84).	NT	ECB/CSSF
Conduct periodic reviews of bank eligibility in availing of large intragroup exemption waivers. (see ¶ 117)	NT	ECB/CSSF
Improve quality of metadata reporting on large exposures. (see ¶ 120)	NT	ECB
Close data gaps on funding sources by expanding the scope beyond the 10 largest counterparties. (see ¶ 118)	NT	ECB
Investment Fund Risk Analysis		
Provide industry guidance on liquidity stress tests for investment funds exposed to relatively less liquid asset classes, and develop internal liquidity stress testing capacity (¶69, ¶70, ¶87, ¶90, ¶94)	NT	CSSF
Commission a study on the effectiveness of investment fund liquidity management tools, to provide a basis for subsequent industry guidance (¶88, ¶91, ¶95)	NT	CSSF
Continue to assess risks related to bank-fund interlinkages, especially for depositary banks (¶91, ¶96)	NT	CSSF, BCL
Intensify monitoring of concentration risk, particularly in regard to single sovereign issuers (¶63, ¶67).	NT	CSSF

[1] I-Immediate" is within one year; "NT-near-term" is 1–3 years; "MT-medium-term" is 3–5 years.

INTRODUCTION

1. Financial soundness indicators for Luxembourg's financial system, which plays a key role in the intermediation of financial capital, have remained relatively robust in recent years. Rising asset prices and inflows have seen the investment fund industry enjoy strong growth in assets under management, while exposure to liquid assets has remained steady. The banking sector, where a relatively large share of liquidity and revenues derive from private banking and fund management activities, has maintained high levels of profitability, capital, liquidity, and asset quality. The insurance industry, which is relatively less exposed to guaranteed products than regional peers, has adjusted well to the new regulatory regime, maintaining high profitability and capitalization levels.

2. Nevertheless, the defining structural characteristics of the financial system—size and interconnectedness—as well as elevated real estate valuations, give rise to potential vulnerabilities. First, as many Luxembourg foreign bank subsidiaries aggregate liquidity from investment fund and wealth management operations and 'upstream' it to their parents abroad, they may be exposed to maturity and currency transformation at the parent level—where exposures can be large (vis-à-vis subsidiaries capital) and oversight by the Luxembourg authorities may be limited where parents are not regulated under the Single Supervisory Mechanism. Second, should investment fund liquidity buffers struggle to accommodate large redemption shocks, asset fire sales and a drawdown of local bank deposits could occur (though operational deposits have been broadly stable in past stress periods). Finally, after a strong run up in prices and easing in lending standards, the real estate market, to which domestically-oriented banks are most exposed, poses the main home-grown vulnerability.

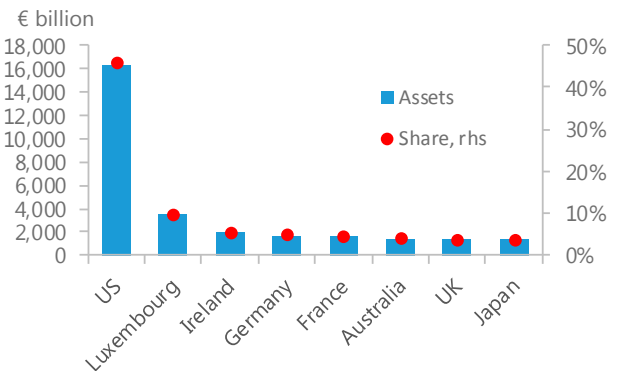
3. Luxembourg's banking sector is large, diverse, and displays a low level of concentration. The Herfindhal index of the banking system amounts to 5 percent, indicating a low level of concentration.[4]

4. Luxembourg is home to the world's second largest investment fund industry by assets under management (€3.6 trillion or 67 times GDP, Figure 1), which is diversified by asset class and geographical focus, and has experienced strong growth in recent years. Assets under management are divided roughly evenly across bond funds, equity funds and mixed funds. Real estate, hedge and other funds account for minor volumes (Figure 1). Luxembourg investment funds are distributed to over 70 countries (with particular appeal in Europe and Asia), a consequence of a well-established global brand and the majority of assets falling under the respected UCITS regime, which provides for a wide range of safeguards for investors such as diversification of assets and requirements on eligible assets.

[4] The index is built as the sum of the squares of banks' market shares. An increase in the index denotes higher concentration. A system with an index above 25 percent is considered to be highly concentrated.

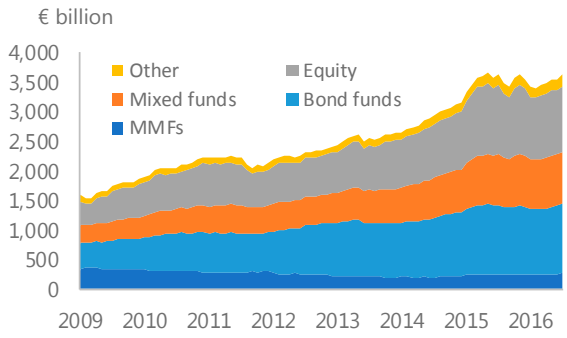
Figure 1. The Asset Management Industry

Worldwide Fund Industry



Sources: ICI, and IMF staff calculations.

Luxembourg: Investment Fund assets



Sources: BCL, and IMF staff calculations.

5. The investment fund industry in Luxembourg has been resilient to the Global Financial Crisis and the European sovereign crisis. In both cases, aggregate redemptions have remained limited thanks to the diversification of Luxembourg' s fund industry. While a few funds were forced to suspend redemptions during both the global financial and European sovereign debt crises, the investment fund industry was able to withstand major disruptions.

6. Nevertheless, the investment fund industry gives rise to three main vulnerabilities with implications for global financial market and domestic financial stability. First, funds that have (unhedged) concentrated exposures can be disproportionately affected by the distress of particular issuer and might find it difficult to liquidate their portfolios in a stress situation, especially if they own a large share of individual bonds (IMF (2014a), IMF (2014b)). In the case of common exposures, the distress of a fund can spillover to other funds through fire sales. Second, since most investment funds in Luxembourg offer daily liquidity to investors, they can be exposed to potential liquidity mismatches if they invest in asset classes with relatively lower liquidity than others, such as emerging market (EM) debt or HY bonds (IMF (2015a), IMF (2015b)). In a period of limited market depth and where liquidity management tools are ineffective, a large redemption shock could require funds to rapidly liquidate portfolios, resulting in a large price impact and price spirals ("fire sales") that make subsequent redemptions more likely. Third, funds can be exposed to the health of banks on both sides of the balance sheet: on the asset side, exposures arise from the purchase of bank debt securities and through bank deposits, in addition to derivatives transactions where banks serve as counterparties. On the liability side, while banks do not typically invest in funds' shares, investment funds do have the ability to put in place overdraft facilities and credit lines with banks but which may or may not be available in times of heightened stress.

7. The investment fund industry could pose a vulnerability to banks if liquidity buffers and portfolio adjustments proved inadequate in the face of an unexpectedly large redemption shock, possibly resulting in bank deposit withdrawals. In Luxembourg, this risk would apply predominately to international banks providing depositary services.

8. In general, the objective of the FSAP stress testing exercise is to assess the capacity of the financial system to withstand severe but plausible macroeconomic shocks. The tests are meant to explore potential weaknesses in the financial system and the channels through which adverse shocks might be 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.

9. FSAP stress tests may differ from stress tests conducted by other institutions, including those previously undertaken by the CSSF, the BCL, and the European Banking Authority (EBA). In relation to other stress tests, the FSAP team estimated different credit risk models, based on a different sample of banks, and with different assumptions relating to macro hedges and other parameters. Nevertheless, the FSAP team carried out the tests in close cooperation with the ECB, and was given access to a set of supervisory data in a physical secure data room at the ECB's premises, either on an aggregate or individual basis.

10. Although stress tests are useful to explore vulnerabilities in a financial system, results must be interpreted with caution. FSAP stress tests have a macrofinancial perspective aimed at assessing the resilience of the banking system as a whole to a set of macroeconomic and financial shocks. They differ from microprudential stress tests as their results are not supposed to lead to supervisory actions at the level of individual banks. Moreover, one caveat that should be borne in mind is that the FSAP credit loss estimates and solvency projections in the adverse scenario are subject to data and methodological limitations (no reflection of possible economic hedges, use of benchmarks taken from other countries due to a lack of relevant historical data, see paragraph 46 for further details). Choices must also be made regarding the severity of shocks. In adverse scenarios, the economy is typically affected by a combination of external and domestic shocks that (ex ante) have a very low probability of occurrence.[5] Hence, by construction, adverse scenarios should not be interpreted as macroeconomic "forecasts."

11. Consistency is sought across FSAPs in terms of stress test methodology. This said, the country-specific environment with regard to experiences with banking crises and other idiosyncrasies of the financial system precludes complete comparability between stress test results across FSAPs. Moreover, slight differences in methodologies may translate into different results for similar risk profiles.

12. The stress tests employed in this study examined the resilience of the banking system to solvency, liquidity, and contagion risks (Figure 2). The banking sector stress tests included a

[5] 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 long 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.

top-down (TD) exercise based on macroeconomic scenarios and sensitivity analyses, conducted by the FSAP team in cooperation with the ECB. The tests based on macroeconomic scenarios assessed the impact of severe but plausible external and domestic shocks on the economy over a three-year horizon (2017–2019), based on data available through June 2016. The effects of these shocks on individual banks' profitability and capitalization were assessed using satellite models based on international banking crisis experience and methodologies developed by the IMF. 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 domestic interbank gross exposures (i.e. exposures without consideration of credit risk mitigation measures but with different assumptions about loss given default), interbank cross-liabilities, cross-exposures between domestic banks and insurers, cross-border interlinkages with supervisory and market data.

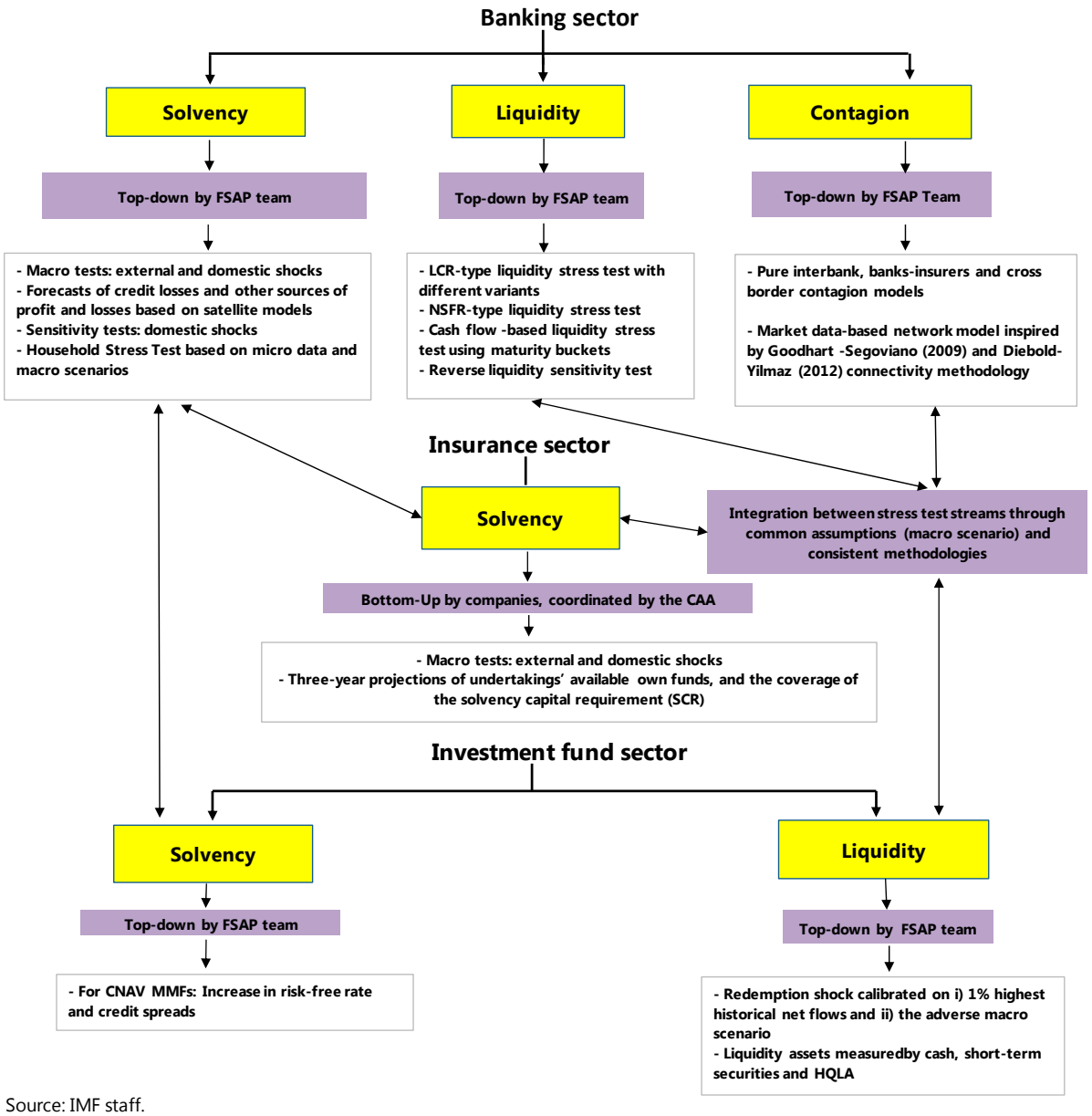
13. An additional household stress test was conducted to assess the vulnerabilities of Luxembourgish households to a significant drop in income, real estate prices and social transfers. The stress test used household data obtained from the Households Finance and Consumption Survey (HFCS) collected by the ECB.

14. The insurance and investment fund sectors were also subjected to stress tests incorporating information from the same macro scenarios as for the banking sector. The insurance sector was subjected to bottom-up solvency stress tests (coordinated by the CAA) based on financial market shocks from the macro-financial model. Insurers were adversely impacted by financial market shocks via reduced fee income from unit linked products due to a reduction in assets under management.

15. The investment fund stress test included both a solvency stress test for a sample of CNAV MMFs, and a liquidity stress test for five types of fixed income funds. Following the analysis reported in the recent Ireland FSAP (IMF (2016a)), the likelihood of a 'break the buck' scenario (where the shadow NAV, based on underlying market valuations, diverges significantly from par value) was assessed by subjecting portfolios to sharp increases in risk-free rates and credit spreads.

16. For investment fund liquidity stress tests, emphasis was placed on bond funds and MMFs due to their size and their susceptibility to liquidity mismatches. Bond funds account for 35 percent of the investment fund industry in Luxembourg (€1,170 billion as of July 2016 according to ECB data), followed by equity funds (33 percent) and mixed funds (26 percent), with the other funds (real estate, hedge funds etc.) accounting for around 6 percent. Unlike equity funds which typically invest in very liquid securities, bonds funds (and mixed funds investing primarily in fixed income instruments) can be exposed to liquidity mismatches due to divergences in the liquidity of liabilities vis-à-vis underlying assets.

Figure 2. Summary of FSAP Stress Tests



Source: IMF staff.

17. In terms of industry coverage, the TD stress test on the banking sector was based on sixteen banks. These included fifteen significant institutions (SIs), directly supervised by the ECB, and one less significant institution (LSI). They were deemed to be representative of the Luxembourgish banking system as they make up 73 percent of the banking sector's total assets (excluding the branches of foreign banks), 94 percent of residential mortgage loans and 68 percent of exposures to foreign banks. The liquidity stress tests covered 16 banks in the LCR analysis but due to data availability, stress tests based on the NSFR and cash-flow analysis covered only eight banks (45 percent of banking sector assets).

18. Coverage for the bottom-up solvency stress tests for the insurance industry included 10 life insurers (comprising 71 percent of technical provisions). In addition, the one dominant reinsurer, accounting for two thirds of sector assets, was also included.

19. The TD stress test conducted by the FSAP team for investment funds covered 191 funds, which were all UCITS except one fund. They were deemed to be representative of the bond fund and money market fund industry in Luxembourg as they account for 75 percent of the assets of High Yield (HY) funds, Emerging Market (EM) bond funds, MMFs; 54 percent of the assets of mixed funds investing primarily in fixed income instruments; and 32 percent of other bond funds.

20. 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

21. Solvency stress tests are aimed at assessing whether financial institutions have enough capital to withstand a range of economic and financial shocks. This section covers the solvency stress tests of the three sectors covered by the FSAP, namely banks, insurers and MMF/investment funds. The three stress tests are integrated through the design of a common macro scenario. Sensitivity tests also assessed the impact of individual shocks.

A. Solvency Stress Test of the Banking Sector

22. Solvency stress tests were aimed at assessing banks' robustness to various shocks to their capital, principally related to credit and market risks. Banking sector stress tests included a Top-Down exercise based on macroeconomic scenarios and sensitivity analyses.

23. Stress tests were based on the applicable international and national regulatory frameworks. They were conducted mainly with reference to the Basel III framework, in addition to the European Union and national frameworks, as defined by the Fourth Capital Requirements Directive (CRD IV), Regulation on Prudential Requirements, national law and CSSF regulation. The hurdle rates for the total capital adequacy, Tier 1 capital, and Common Equity Tier1 capital ratios were set according to the Basel III fully-loaded definitions of capital requirements (see Table 2 below). The leverage ratio requirement was also taken into account, with consideration for the fact that it will become binding from 2018 onwards.

24. The stress tests were based on minimum capital ratios under Pillar I. Individual requirements under Pillar II were not taken into account except for dividend distribution policy assumptions. Banks were allowed to deplete a capital conservation buffer of 2.5 percent in the adverse scenario. Most deferred tax assets and all goodwill were already fully deducted from Common Equity Tier 1 at the cutoff date of the FSAP (June 2016). Moreover, unrealized capital gains

were added to the initial capital base in anticipation of Basel III full implementation for consistency purposes.

Table 2. Luxembourg FSAP Stress Test Hurdle Ratios vs. Current Ratios				
Scenario	**Stress test hurdle rate (excluding capital conservation buffer)**	**Actual ratio before stress (excluding unrealized capital gains)**		
		16 banks	**Domestically-oriented**	**Internationally-oriented**
Total Capital ratio (total capital to RWAs, in percent)	8	19.4	20.8	18.6
Tier I Capital ratio (Tier 1 capital to RWAs, in percent)	6	18.7	20.4	17.8
Common Equity Tier I Capital ratio (CET1 capital to RWAs, in percent)	4.5	18.6	20.1	17.8
Leverage ratio (Tier 1 capital to total assets, in percent)	3	5.9	7.6	5.1

25. The effects of the shocks on individual bank profitability and capitalization were assessed using satellite models and methodologies developed by Fund staff.[6] In addition, sensitivity stress tests assessed vulnerabilities of the banking system to individual shocks. Sub-section 1 presents the main macrofinancial risks, the baseline and the macro scenarios that were applied for the conduct of the solvency stress test. Sub-section 2 describes the estimation of credit risks. Sub-section 3 sets out the analysis of market risks in the scenario analysis. Sub-section 4 provides the global results of the solvency stress tests based on scenario analysis. Sub-section 5 presents the results of the market risk sensitivity analysis. Sub-section 6 discusses the concentration risk analysis.

Macrofinancial Risks and Macroeconomic Scenarios

26. The Luxembourgish financial system 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):

[6] Satellite models link credit risk parameters (PDs) with various macrofinancial variables.

- *A sharp rise in global financial market risk premia and flight to safety:* while the domestic economy would feel the effects through lower investment fund and bank profitability, the impact could be somewhat limited if Luxembourg acts as a recipient of safe haven inflows;

- *Financial system outflows resulting from a larger than expected hit to bank and investment fund exposures, in an environment of prolonged negative interest rates and rising regulatory demands;*

- *Structurally weak (worse than currently projected) growth in key advanced and emerging economies, particularly the euro area.* Luxembourg would feel the effects through extensive trade and capital flow channels.

27. Domestic risks are concentrated in the real estate market. Domestically-oriented banks could be negatively affected by a shock to the domestic real estate market given currently high real estate prices and growing affordability issues. Exposures to the domestic real estate market make up 20 percent of domestically-oriented banks' total assets. Moreover, high loan-to-value ratio loans have accounted for a significant share of new mortgages.[7] However, where such loans are granted additional collateral is generally required.

28. At the current juncture the Luxembourgish banking sector appears in strong shape (Figure 3):

- *Profitability is relatively high.* Luxembourg banks' return on assets recently rose back to pre-crisis levels (0.8 percent at end-2015). Net interest margin compression has been less problematic in Luxembourg than elsewhere in Europe due to the banking industry's increasing reliance on fee and commission income derived from private banking and fund management activities.

- *Capitalization is comfortable.* Capital ratios and quality are high, with most banks already meeting fully-loaded Basel III capital requirements and Tier 1 capital representing 95 percent of total regulatory capital. No bank was found to have a capital shortfall by the 2014 ECB Comprehensive Assessment.

- *Asset quality is very high.* This is evidenced by a nonperforming loan ratio close to zero (1.2 percent as of June 2016 for the 16 banks composing our stress test sample).

[7] In November 2016, the European Systemic Risk Board issued a risk warning to Luxembourg highlighting risks related to the interaction between rising indebtedness and ability of households to repay their mortgage debt, and the price dynamics of residential real estate. In its warning, ESRB acknowledged that, on average, loan-to-value and debt-service-to-income ratios in Luxembourg are moderate in the stock of existing mortgages and may act as a mitigating factor against losses in the financial system should vulnerabilities crystallize.

- *The liquidity position is strong.* Despite large interbank transactions, banks appear to have established ample liquidity buffers, indicated by a loan-to-deposit ratio of 65 percent and a liquid assets-to-short-term liabilities ratio of 68 percent. Ample liquidity buffers are also reflected in the standard LCR metric, at 80 percent in 2017, which all 16 banks meet by a comfortable margin.

Figure 3. Bank Financial Soundness Indicators

Sources: BCL, CSSF, and IMF.

Notes: Luxembourg bank time series data in left panels are updated as of Q2 2016. Cross country comparisons in right panels are based on latest available data between Q4 2015 and Q2 2016. In the international comparisons, data displayed for Luxembourg banks include all banks (domestic and internationally oriented).

29. However, several features of the banking sector could make it vulnerable to shocks:

- *The risk density of Luxembourg banks' assets is relatively low, as risk-weighted assets amount to less than one third of overall assets in June 2016, and less than 30 percent at internationally-oriented banks.* This could reduce the loss-absorbing capacity of Luxembourg banks' capital in the event of a shock However, this low density seems to reflect more the large share of low-risk exposures than an underestimation of risks by banks' internal models:
    - two-thirds of Luxembourg banks' total credit exposures are treated under Basel II standardized approach. Therefore, low risk weights are a consequence of low-risk exposures such as exposures to the public sector -accounting for approximatively 16 percent of total assets (including the ones to the Luxembourg central bank)—and exposures to group entities, i.e. internationally operating banking groups—accounting for about one-third of total assets;
    - the RWA-to-total asset ratio is higher when excluding traded assets: the credit risk RWA to net loans ratio is equal to 48 percent. Based on the EBA Transparency Exercise, a breakdown by exposure class suggests that Luxembourg banks' median risk weights in the IRB portfolio are lower than for European banks for corporate and retail exposures but higher for mortgage exposures (Table 3);
    - banks' relatively low risk weights on mortgages resulting from their internal models play a minor role as mortgages under the IRB approach only make up for less than 5 percent of total assets.

Table 3. Median Risk Weights Across IRB Portfolios of Luxembourg and European Banks, June 2016
(in percent)

	Lux. banks	European banks
Corporate Exposures	47	51.8
Retail Exposures	24	27
Mortgage Exposures	17	15.5

Sources: EBA; and R. A. Turk "How Heterogeneous are Bank Risk Weights across Europe?", IMF Working Paper (forthcoming)

- *Asset quality, although at high levels currently, requires monitoring as rising household indebtedness, in the context of floating lending rates, could make households vulnerable to a spike in interest rates, an economic downturn or a reversal in real estate prices.* Moreover, while the share of nonperforming loans is currently negligible, the provisioning ratio is relatively low at 42

percent, which might reflect a large reliance of Luxembourg banks on collateral provided by borrowers, among other factors;

- *Contagion risks are potentially significant, notwithstanding the assumptions to the methodological approach employed.* The substantial financial and economic integration with the rest of the euro area implies considerable exposure through valuations of banks' foreign assets, as well as to potential withdrawals of foreign parent funding. Moreover, the nature of interconnectedness between Luxembourg banks and investment funds might constitute a transmission channel of external shocks to the domestic system should international investors redeem en-masse from the capital markets.

30. Stress tests are based on full-fledged macroeconomic scenarios. Given the risks and vulnerabilities described above, the stress test examined a baseline and an adverse macroeconomic scenario. Both scenarios stretch over a three-year horizon.[8] The first year of the shock would then be 2017 and the scenario would run until 2019, based on risks included in the Risk Assessment Matrix (Appendix Table 1).

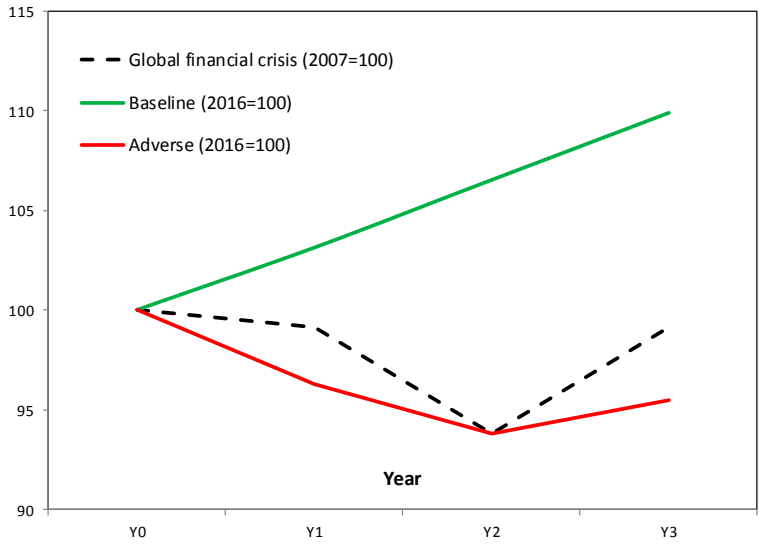
31. For the design of the macroeconomic scenarios, key domestic and euro area variables were calibrated over a 3-year horizon. These included real GDP growth, CPI inflation rate, unemployment rate, the three-month interbank rate, the nominal government bond rate, lending rates, the euro-dollar exchange rate, and real estate price growth. The two scenarios are the following (see Figure 4 and Table 3):

- The baseline scenario is based on the October 2016 World Economic Outlook projections;

- The adversely severe scenario features a V-shaped GDP profile, resulting in a "triple-dip" in the Luxembourg (and European) economy dating back to the global financial crisis (Figures 4 and 5). This outcome is driven by a combination of shocks based on the Risk Assessment Matrix; projections are based on the IMF Global Macro-Financial Model (GMF) for the external variables and on a Bayesian VAR developed for the domestic variables for the purpose of this FSAP (Annex III). The scenario includes a surge in financial market volatility, financial system outflows and a renewed euro area recession. Shocks would be transmitted to the economy and financial system through the following channels: external demand, investment fund flows, and the real estate market. Lower revenues from reduced cross-border financial activity would hit the fiscal balance, widening the credit spread against Germany and limiting fiscal space. The result would be a 1.5 percent per annum decline in GDP over 2017–2019, leading to a cumulative shock of 14.7 percentage points (equivalent to a 2 standard deviation shock, comparable to recent euro area FSAPs) with respect to the baseline scenario.

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

Figure 4. Scenario Severity from a Historic Perspective
(Real GDP in year Y_0=100)



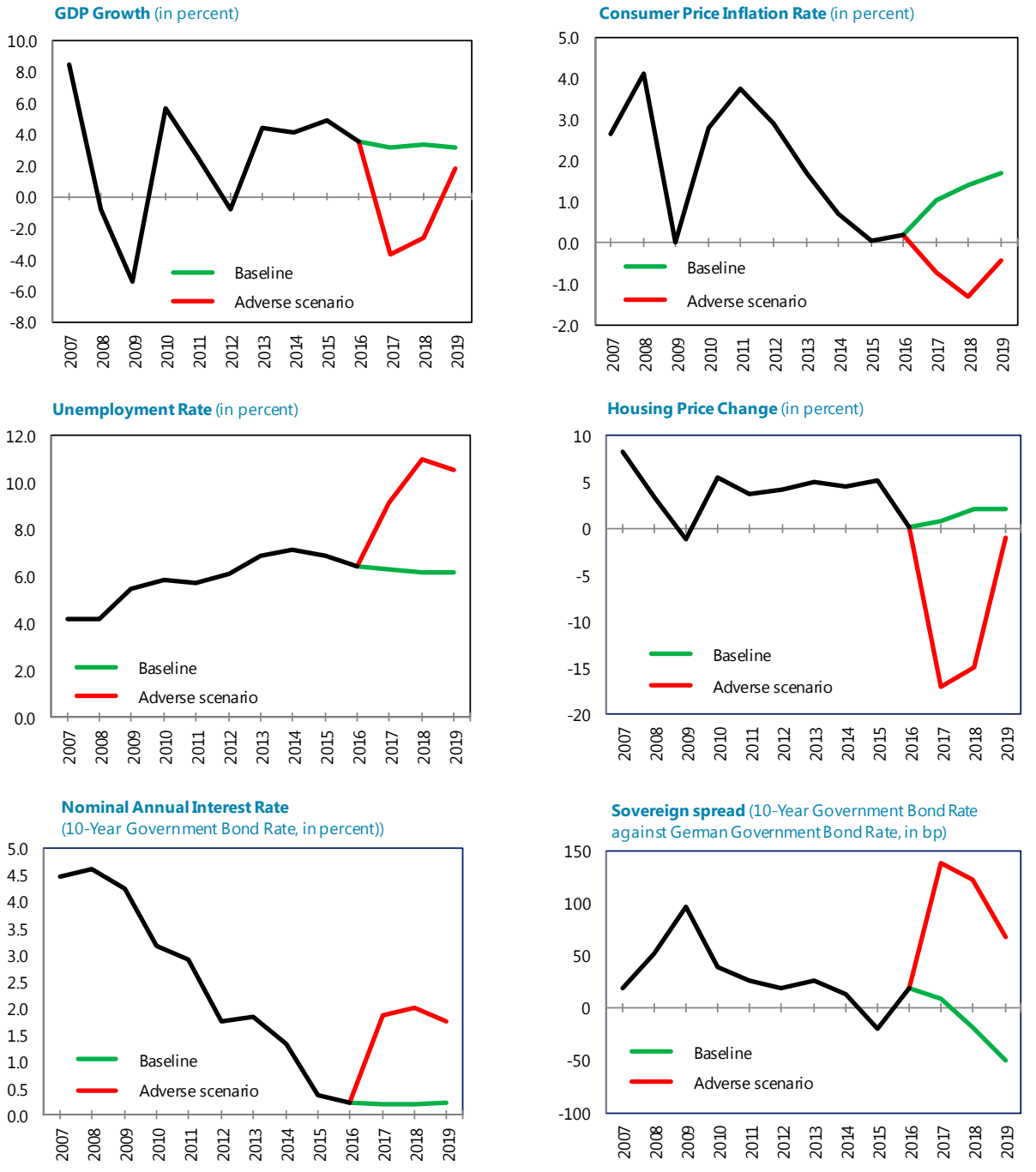
Credit Risks in the Scenario Analysis

Credit Risks in the Loan Book

32. Credit risk in the loan book constitutes a large risk factor for the banking system, along with the market risk in the securities portfolio. Total loans represent 58 percent of total banking sector assets. Mortgage loans comprise 4 percent of total assets but 19 percent of the assets of the five domestically-oriented banks. Debt securities (23 percent of total assets), most of which are marked-to-market, represent the second largest exposure. Loan book exposure extends to euro area corporates outside Luxembourg, especially neighboring countries Belgium, France, Germany and the Netherlands. Therefore, stress tests focused on how domestic, regional and global macrofinancial shocks affect euro area exposures. In terms of exposure class distribution, the largest exposures of the nine banks operating under the Basel II IRB approach are to other institutions (including parent banks), reflecting intragroup positions, followed by large corporates and central governments.

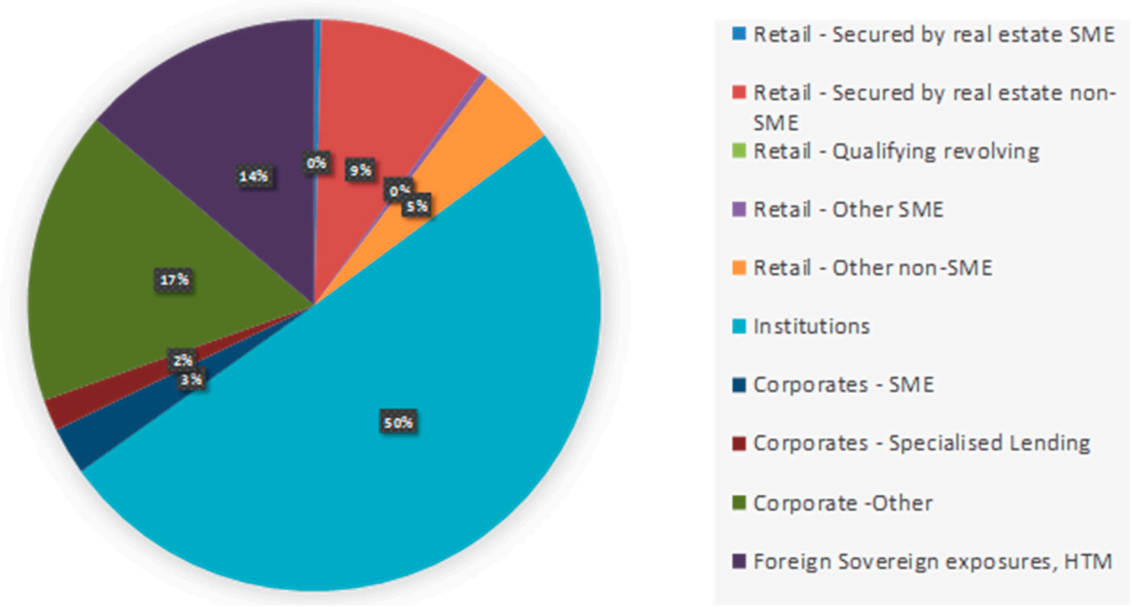
33. Expected losses in the adverse scenario are mostly driven by losses in the retail and corporate portfolios. The rise in PDs would be the sharpest in the corporate SME loan portfolio, climbing from 1.7 percent in June 2016 to 13 percent in 2018 in the adverse scenario. The larger losses in the corporate portfolio also reflect the largest initial exposures at default in this segment. The application of international benchmarks resulted in much more severe PD projections than those calculated by the national authorities based on purely Luxembourgish empirical data. Additionally, data limitations mean that no allowance was made for the credit guarantees that Luxembourg subsidiaries may receive from their foreign parents.

Figure 5. Macroeconomic Baseline and Stress Scenarios



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

Figure 6. Distribution of Banks' Exposures by Asset Class for IRB Banks

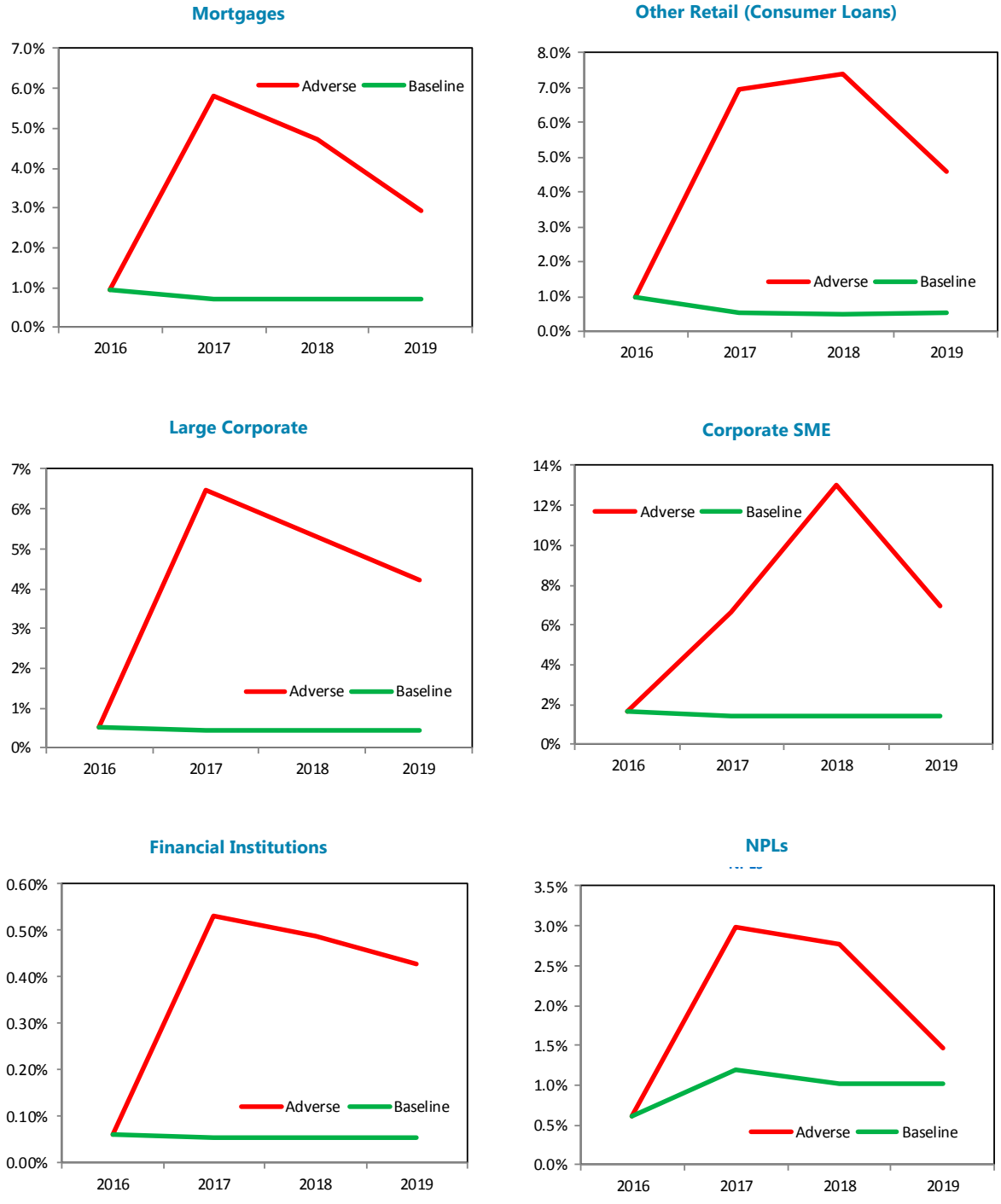


Source: IMF staff calculations.

34. The rise in PDs requires additional provisions that worsen bank profitability in the stress scenario. Credit losses over the three-year horizon in the loan book amount to €2.7 billion in the adverse scenario, equivalent to 0.6 percent of total banking system assets, as a result of the credit risk increase caused by the severe macroeconomic and financial conditions. By contrast, in the baseline scenario, the flow of new provisions is limited to €0.6 billion, equivalent to 0.1 percent of total banking system assets. These new provisions in the baseline scenario are more than offset by net income before losses (1.8 percent of total assets).

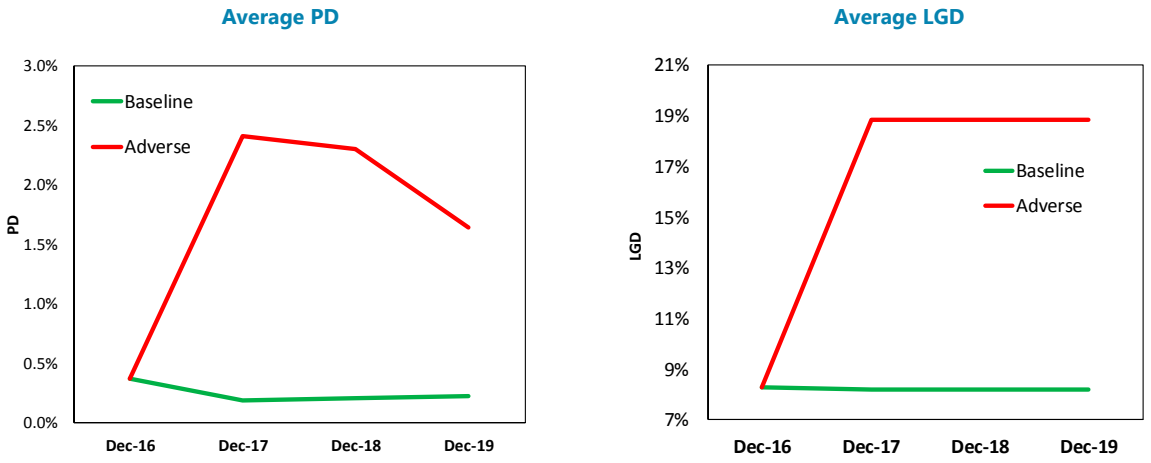
Figure 7. PD/NPLs Projections in the Baseline and Adverse Macroeconomic Scenarios

(IMF model)



Source: IMF staff calculations.

Figure 8. PD and LGD Projections in the Baseline and Adverse Macroeconomic Scenarios
(FSAP team model)



Sources: CSSF, ECB, and IMF staff calculations.

Market Risks in the Scenario Analysis

35. Stress tests also assessed the resilience of banks when facing different sources of market risk, making no allowance for macro hedges.[9] In addition to credit risk related losses, banks may experience losses due to changes in market variables (for instance, interest rates and exchange 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, exchange rate and equity risks were the three market risks included in the stress tests.

Interest Rate Risk

36. 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".[10] 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

[9] This is standard practice in FSAP stress tests to not take into account macro hedges unless detailed data to that effect are provided. (name and rating of the counterparty, terms and conditions of the agreement).

[10] Data was 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.

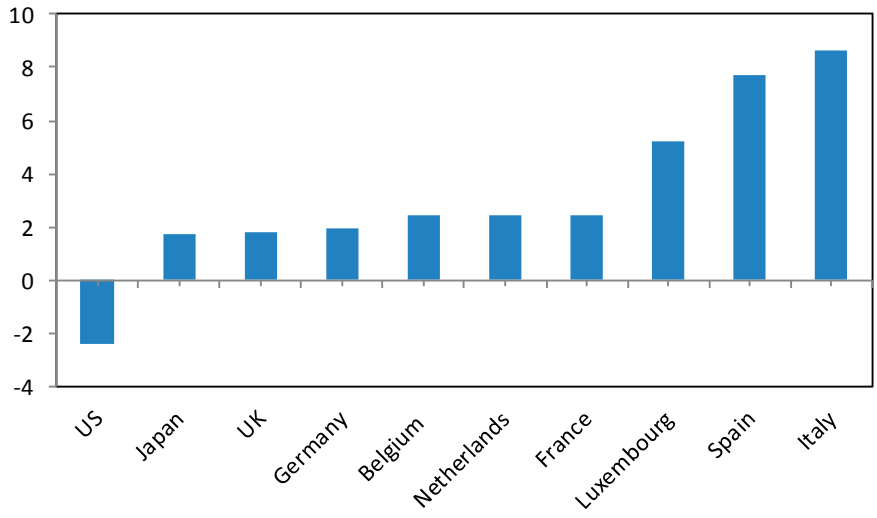
through credit risk and the effect on asset quality in the loan portfolio, were dealt with in the credit risk section.

37. In the adverse scenario, Luxembourgish banks lose a negligible amount of net interest despite the rise in the risk-free interest rate. Banks are usually exposed to a rise in interest rates because yield curves typically flatten in such an environment and they perform 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 the adverse macroeconomic scenario. The 4-year euro swap rate (chosen as the risk-free rate) is projected to increase by 0.3, 0.1, and 0.1 percentage points in 2017, 2018, and 2019, respectively, in the adverse scenario. Five banks in 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. At the aggregate level for the sixteen banks, the repricing gap in the balance sheet amounts to €16 million as of June 2016 for maturities below one year. In the adverse scenario, this repricing gap and the change in interest rates do not translate into a material effect on the CAR over the entire stress horizon.

38. Interest rate risk was also assessed through valuation effects on debt security holdings, principally government and corporate bonds. In the absence of data on the duration of banks' trading portfolios, the average maturity of the sovereign portfolio exposure by country was taken as a proxy for Luxembourgish banks based on the latest EBA Transparency exercise data. Exposures to general government debt, and the debt of financial corporations and corporates were taken from the European Financial Reporting (Finrep) template. Losses were calculated as the product of the size of the bond portfolio, its average maturity, and the change in the interest rate. An increase in interest rates translates into a valuation loss in the bond portfolio, and vice versa.

39. Potential valuation losses on foreign sovereign and corporate debt appear significant under the stress test. In the adverse scenario, losses due to a decline in the price of sovereign and corporate securities in the Available-for-Sale and Held-for-Trading portfolios amount to €2.5 billion, contributing by 1.4 percentage points to the decline in the CAR over the entire stress horizon. This result can be explained by: (i) the large size of the marked-to-market bond portfolio of Luxembourg banks, with an average AFS and HFT exposure of 12.5 percent of total assets and ratios at individual banks ranging between 0 and 41 percent, (ii) the significant increase in vulnerable government bond rates under the adverse scenario (up to 3 percentage points for the 10-year rate), resulting in large haircuts on bond prices (Figure 9). Moreover, economic hedges could not be taken into account for the other comprehensive income calculations (AFS portfolio) due to the absence of appropriate data. These factors are somewhat mitigated by a moderate average maturity of Luxembourgish banks' bond portfolio, averaging 4 years.

Figure 9. Haircuts on Sovereign Bonds in the Adverse Scenario
(in percent, 4-year duration)



Sources: Bloomberg, and IMF staff estimates.

Foreign Exchange Rate Risk

40. 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 two currencies: U.S. dollars and British pounds. 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.

41. 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 six of the sixteen banks. The net open FX position for the banking system amounts to €6 million as of June 2016, equivalent to 0.02 percent of Tier 1 capital.

42. Losses on banks' net foreign exchange positions are negligible in the adverse scenario. In this scenario, the euro is expected to rise against the U.S. dollar over the whole period, which results in a small loss of €0.4 million.

Results of the Solvency Stress Tests Based on Macro Scenarios

43. In the adverse stress scenario, credit losses and market valuation losses are the main channels through which risks materialize. 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 10.

44. Under the severe adverse scenario, the banking system would remain very well capitalized despite a material decline in the system-wide capital ratio and some weaker banks (Figure 10). High starting levels of system-wide capital allow most banks to absorb a large shock under the adverse scenario and retain substantial buffers, with domestically oriented banks impacted slightly more than internationally oriented banks given the dual (global and domestic) nature of the shocks. Key findings are as follows (Figure 11):

- Using fully-loaded Basel III regulatory requirements, the ratio of banks' Common Equity Tier 1 capital relative to their total risk-weighted assets (the aggregate CET1 ratio) would drop by 3.5 percentage points, from 18.6 percent as of June 2016, to 15.1 percent. Credit losses (-1.6 percentage points of RWAs), market losses in the bond portfolio (-1.4 percentage points of RWAs), and the change in risk-weighted assets (with an effect of –2.5 percentage points) would outweigh favorable factors, such as the widening interest margin and other effects (+2 percentage points). The capital of a number of banks making up less than 10 percent of the banking sector's assets would fall below the minimum regulatory Capital Adequacy ratio of 8 percent, although even then, recapitalization needs would be manageable, amounting to 0.8 percent of GDP. Based on the CET1 hurdle rate of 4.5 percent, the capital shortfall would be reduced to 0.1 percent of GDP. One more bank would need to use part of its capital conservation buffer but remains above the regulatory minimum. The higher vulnerability of these banks stems from three factors: lower profitability, a lower initial quality of the loan portfolio, and a relatively larger bond portfolio.

- The ratio of banks' Tier 1 capital relative to their total (not adjusted) assets (the leverage ratio) would decline from 5.9 to 5 percent. Six banks would see their ratios decline below the hurdle rate of 3 percent in 2019 (after which time it becomes binding), by an amount equivalent to 1.6 percent of GDP.

45. In the baseline scenario, every bank would stay above the regulatory CET1 minimum. It should be noted that capital shortfalls would be larger on the basis of bank-specific Pillar II requirements which are not publicly available.

46. One caveat that should be borne in mind is that the FSAP credit loss estimates and solvency projections in the adverse scenario are subject to data and methodological limitations. On the one hand, the top-down stress test did not take into account loan write-offs and cures due to data unavailability. Risk mitigants such as economic hedges and financial guarantees were not considered either, because of data issues and a lack of information about their enforceability during a crisis. Some assumptions were also made in terms of Loss Given Default and other supervisory parameters due to the lack of historic depth and of relevant crisis experience. At the same time, some items on the banks' balance sheets, such as the derivatives, were not subject to stress.

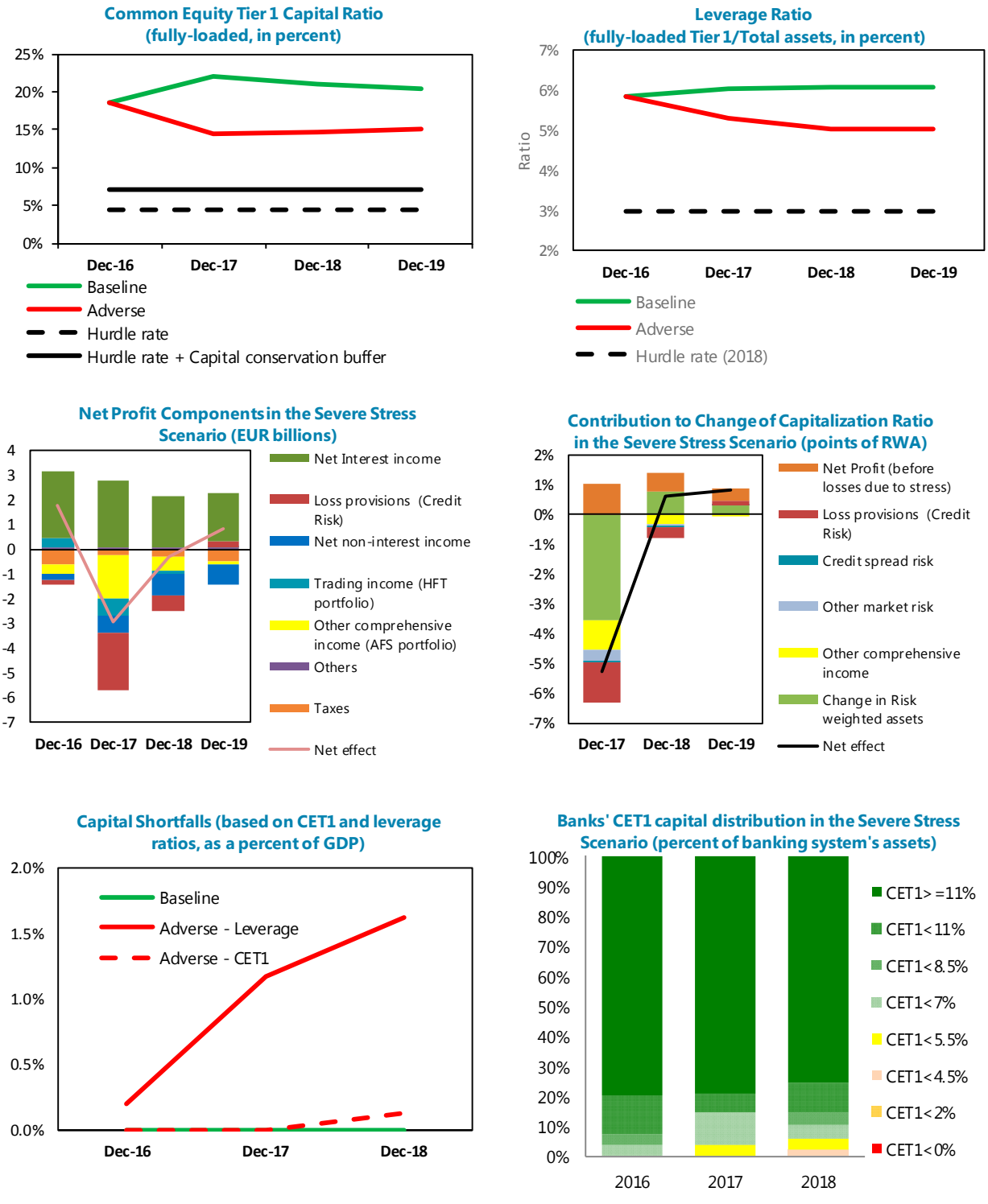
47. The Top-Down stress test results are more severe than the results based on banks' own estimates. The CSSF and the ECB provided the results of a sensitivity test conducted by Luxembourgish banks as part of the Short-Term Exercise in 2015 in the event of a 200 bp interest

rate shock affecting their whole balance sheets. Based on banks' own estimates, the aggregate CET1 ratio would fall by 5 percent in the event of such a shock after taking into account available macro/economic hedges, as compared to a decline of 9 percent under the IMF methodology. No bank would have a CET 1 ratio below the hurdle rate of 4.5 percent but three banks would need to use part of their capital conservation buffers and have a total CAR below the hurdle rate of 8 percent. The system-wide CET1 ratio would decline from 18.6 percent in June 2016 to 15.5 percent in 2019, as compared to 15.1 percent under the IMF methodology.

Policy Recommendations

48. These results point to the need to ensure that banks' Internal Ratings-Based models take into account losses in stressed environments and are sufficiently conservative. To avoid placing too high a weight on recent data in a benign environment, recent international experience could be taken into account to benchmark PDs and LGDs for retail portfolios in a stressed macroeconomic scenario. Supervisors should be in a position to effectively challenge banks if they find evidence of an aggressive use of modeling techniques to lower risk parameters. Finally, the European authorities' plan to introduce regulatory floors for the risk-weights calculated by IRB banks should be commended and finalized shortly.

Figure 10. Bank Solvency Stress Test Results



Sources: ECB, and IMF staff calculations.

Figure 11. Bank Solvency Stress Test Results: Breakdown Between Domestically-oriented and Internationally-oriented Banks

Market Risks Based on Sensitivity Analysis

49. In addition to stress scenario analysis, sensitivity stress tests assessed vulnerabilities of the banking system to key individual shocks. These included: a decline in the prices of domestic sovereign securities; an increase in interest rates that affects banks' net interest income; 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 decline in stock prices. Indirect effects of a nominal depreciation of the euro on credit quality were not assessed because the share of foreign currency

lending in total loans is very low in Luxembourg. 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 2016. In all the sensitivity tests, banks' risk-weighted assets are assumed to stay constant after the application of the shocks. The assumptions made for the sensitivity tests are usually harsher than the macro scenario projections (Table 4).

Table 4. Luxembourg: Comparison Between Macro Scenario Projections and Sensitivity Test Assumptions

	Severely adverse scenario	Sensitivity test
Lending rate shock	86 bps	500 bps
Domestic sovereign interest rate shock	177 bps	500 bps
Foreign exchange rate shock	-7.4 percent	+/- 30 percent
Equity price shock	-19 percent	-50 percent

Source: IMF staff calculations.

A Decline in the Prices of Domestic Sovereign Securities

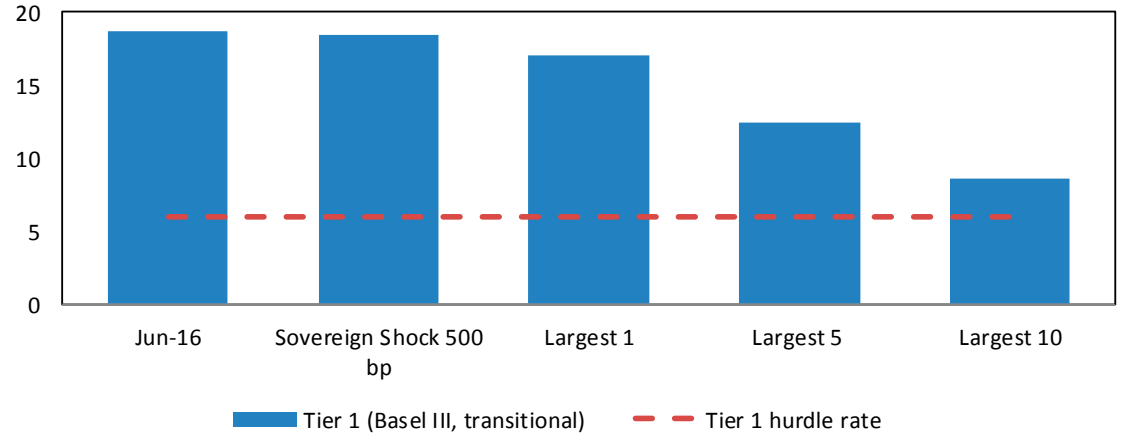
50. Sensitivity tests assessed the impact on the trading book from increases in the domestic sovereign interest rate. The tests assessed the sensitivity of banks' domestic sovereign bond AFS and HFT portfolios to a 500 basis points (bp) increase in interest rates. In the absence of data on the duration of banks' trading portfolios, the average maturity of the AFS and HFT portfolios of domestic sovereign exposures was taken as a proxy for Luxembourgish banks based on the 2016 EBA stress test data. Finrep exposures to the Luxembourgish general government were taken as a proxy for domestic sovereign exposures. Losses were then calculated as the product of the size of the bond portfolio, its average maturity, and the change in the interest rate.

51. The results show that Luxembourgish banks are little exposed to domestic sovereign bond risks. The impact of domestic sovereign bond portfolio losses would be very limited. Specifically, the CAR in the system would decline by 0.3 percentage points due to these losses taken in isolation (assuming that no other shocks trigger simultaneous losses for these banks). The comfortable initial capitalization of Luxembourgish banks would provide a large enough buffer to avoid undercapitalization as a result of this shock (Figure 12).

Figure 12. Sensitivity Analyses for Sovereign and Credit Concentration Risks

Sovereign Shock and Credit Concentration Tests

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



Sources: Corep, and IMF staff calculations.

Interest Rate Risk: Net Interest Income Effects

52. A sensitivity test based on a maturity ladder (gap) analysis suggests that the banking system would lose a moderate 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 bp 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 €0.8 million, with no impact on the aggregate Tier 1 capital ratio. It would not cause undercapitalization in any of the sixteen banks.

Foreign Exchange Rate Risk: Direct Effects on Banks with Net Open FX Positions

53. 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. The test indicates that a 30 percent appreciation of the euro nominal effective exchange rate would cause a loss of €1.8 million, with a very limited impact on the aggregate Tier 1 ratio. This shock, taken in isolation, would not cause undercapitalization in any of the sixteen banks. Conversely, a 30 percent depreciation of the euro nominal effective exchange rate would cause a gain of €1.8 million.

A Decline in Stock Prices

54. A decline in stock prices would have a manageable impact on banks' capitalization. Marked-to-market equity investments makes up a moderate share of banks' total assets, averaging 0.8 percent and ranging between 0 and 2.2 percent. Losses were calculated as the product of the banks' open position in stocks, and the change in the stock price index. The test indicates that a 50 percent decline in stock prices would cause a loss of €1.75 billion, translating into a 1.3 percentage point decline in the aggregate Tier 1 ratio. This shock, taken in isolation, would not cause undercapitalization in any of the sixteen banks.

Concentration Risk: Failure of a Number of Large Corporate Exposures

55. Name concentration risk (i.e. exposure to a single borrower) was tested by assessing the impact of the simultaneous default of the largest exposures. Supervisory data on the large bank exposures were used to perform this sensitivity analysis which included exposures to groups of non-financial interconnected clients, but excluded sovereign exposures and credit institutions (as these were addressed in the later section on interconnectedness and contagion risks). Luxembourgish banks' credit risk mitigation techniques are mostly comprised of financial collateral and third party financial guarantees. The test assessed the impact of the simultaneous 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 to assess the sensitivity of banks' solvency to a change in recovery rates, as done in other FSAPs.

56. Sensitivity tests show that some Luxembourgish banks would be vulnerable to the simultaneous default of their five largest exposures, after collateral received and other credit risk mitigation measures are taken into account. On average, the size of the single gross largest exposure reaches 22.4 percent of Tier 1 capital, whereas the size of the net largest exposure (without off-balance sheet contingent liabilities and after consideration of cash collateral and the application of other credit risk mitigation) is considerably smaller (8.8 percent). Under the European regulation regarding collateral valuation, the default of the net largest exposure of each of the sixteen banks would not cause any undercapitalization (Figure 11). The simultaneous default of the five net largest exposures would lead three banks to be undercapitalized with regard to the Tier 1 capital ratio of 6 percent, translating into a capital shortfall of 1.6 percent of GDP. The default of the ten net largest exposures would cause six banks to be undercapitalized in terms of Tier 1 capital, raising the capital shortfall to 8.9 percent of GDP.

57. A large drop in real estate collateral value would not lead to additional capital shortfalls. A haircut of 30 percent additional to the regulatory haircut already embedded in the national framework was applied to the valuation of the real estate collateral held by Luxembourgish banks against their large exposures, consistent with the adverse macro scenario. The number of undercapitalized banks following the default of the largest, five largest and ten largest exposures and the amount of capital shortfall would be the same as in the previous test. This reflects the fact

that banks do not hold most of their credit risk mitigation measures in the form of real estate against their large exposures.

58. Capital shortfalls would be much larger if exempted corporate exposures were reintegrated and if a zero recovery rate was assumed on credit risk mitigation measures. Exempted exposures refer to non-financial corporates benefitting from an explicit state guarantee. The number of undercapitalized banks following the default of the largest, five largest and ten largest exposures would increase to one, six and eight respectively. This would imply capital shortfalls of 1.2 percent, 11.6 percent and 24.4 percent of GDP respectively. The large differences with the previous tests reflect the fact that banks hold most of their credit risk mitigation measures in the form of financial collateral and third party financial guarantees. However, it is important to acknowledge that this sensitivity analysis is based on extremely severe assumptions as it would require the occurrence of a "double default" of the borrower and the financial guarantor for the credit loss risk to materialize for the bank. These stress test results assume no credit risk mitigant, and should be interpreted as such.

B. Household Stress Testing Methodology and Results

59. The household stress test was used to benchmark the banks' credit loss projections in the mortgage segment. Luxembourgish banks' internal models estimate low probabilities of default and loss given default in the housing loan segment. This can be attributed to banks' conservative lending practices, Luxembourgish households' payment culture, and the benign macroeconomic conditions of recent years. A household stress test based on micro data and household characteristics can thus provide a useful complementary assessment of solvency risk. To overcome the challenges associated with estimating credit risk satellite models in a data-constrained environment and to analyze non-linear effects of shocks related to households' financial condition, an additional stress test using micro data was performed.[11] The description of the methodology is provided in Appendix VI.

60. Household stress test results suggest that households' solvency would be significantly impacted by a drop in income and house prices, and a rise in the unemployment rate but the proportion of household in default would remain manageable. The stress test provides implicit probabilities of default in line with the projections made within the banking sector stress test framework and with the Central Bank of Luxembourg's own estimates. The same severely adverse macroeconomic scenario as that designed for the banking sector stress test was applied to the household sector, including a cumulative drop of 30 percent in house prices over three years, a 5 percentage point rise in the unemployment rate and an annual drop in wages and unemployment benefits by 5 percent. Such conditions would lead to a shock to implied households' PDs[12] from the current 2.5 percent (as estimated using micro data) to a peak of 6.4percent (reflecting a multiplier

[11] We used 2014 micro data on Luxembourgish households obtained from the Eurosystem Household Finance and Consumption Survey (HFCS) thanks to the collaboration of the ECB and the Central Bank of Luxembourg.

[12] These are not realized or true forward-looking PDs as those used for the banking sector solvency stress test. See Appendix V for details.

of 2.6). The current low share of defaulted households seems to reflect the following factors: (i) most households have repaid part of the principal on their mortgage since the time of acquisition; and (ii) many households have liquid assets which could be used in times of income shortages for debt service payments as more than 93 percent of indebted households have sufficient liquid assets to cover at least 12 months of income shortages (debt service payments and basic living costs larger than current income). It should be noted that the share of outstanding balance of mortgage debt for the 1st decile (households with highest PD) is equal to 4.1 percent of total outstanding balance of mortgage debt.

C. Solvency Analysis and Stress Test of the Investment Fund Sector

Scope

61. The analysis on investment funds focuses on a sample of UCITS funds accounting for a large share of the investment industry. The emphasis is put on UCITS funds as they account for 83 percent of AuM in Luxembourg (€2,847 billion as of March 2016), with Alternative Investment Funds playing a considerably smaller role (AuM of €445 billion).[13] The stress test sample of 191 funds which were all UCITS except one fund, amounting to €656 billion, covers 75 percent of the AuM of HY and EM bond funds in Luxembourg, 54 percent of mixed funds investing primarily in fixed income instruments, 32 percent of the large bond funds and 75 percent of the Money Market Fund industry in Luxembourg (Table 5).[14]

[13] Based on the AIFM reporting data as of 31 December 2015, within the Alternative Investment Fund (AIF) Within the AIF industry, hedge funds account for only 2 percent of AuM (€6 billion), as most AIFs in Luxembourg are either Fund of funds (33 percent of AuM) or other funds (e.g. fixed income or equity funds etc.). Real estate funds account for 9 percent of AuM of AIFs.

[14] According to ESMA's definitions, the money market fund universe is split between short-term MMFs (with a weighted average maturity of less than 60 days and a weighted average life of less than 120 days), that comprise CNAV MMFs and Variable Net Asset Value (VNAV) MMFs, and other floating NAVs MMFs (with a weighted average maturity of less than six months and a weighted average life of less than 12 months).

Table 5. Luxembourg: Investment Funds Coverage, 2016Q1
(in billions of euros, unless specified)

	Number of Funds	Total Net assets	TNA universe	Coverage (percent)
Bond funds				
EM	42	77	102	75.5%
HY	32	112	148	75.6%
Mixed funds	40	56	104	54.1%
Other bond funds	50	240	755	31.8%
Total bond and mixed funds	*164*	*485*	*1,108*	*43.8%*
MMFs				
Short Term CNAV	5	110	146	75.2%
Short Term VNAV	7	20	27	74.9%
Other MMFs	15	41	55	75.1%
Total MMFs	*27*	*171*	*228*	*75.1%*
Total	**191**	**656**	**1,336**	**49.1%**

Sources: BCL, CSSF, and IMF staff calculations.

Concentration Risk and Common Exposures of Investment Funds

Assessment

62. The portfolios of the sample of bond funds domiciled in Luxembourg are characterized by concentrated holdings in sovereign issuers. Under the UCITS Directive, funds can invest up to 5 percent in a single issuer, but this limit is waived for sovereigns.[15] Around half of Luxembourg's emerging market (EM) bond funds in the sample have exposures to single EM sovereign issuers in excess of 5 percent of TNA, with the exposure to a single sovereign issuer for a number of funds up to 30 percent of TNA (Figure 13).[16] EM bond funds tend to be more exposed to high yielding sovereign issuers and have significant common exposures (with holdings of Brazil, Mexico, Turkey and Indonesia amounting to more than 30 percent of TNA) which could lead to contagion effects.[17] A large part of bond and mixed funds (accounting for respectively 34 and

[15] The UCITS Directive allows investment in a single issuer beyond 5 percent (up to 10 percent) as long as these investments above 5 percent do not exceed 40 percent of TNA.

[16] The possibility of concentrated exposures of funds towards single sovereign issuers is disclosed to investors in the fund's prospectus.

[17] Some EM funds could have significant exposures to single EM issuers because they are replicating an EM bond index (such as JPMorgan EMBI). However, since the weights of Brazil, Indonesia, Mexico, and Turkey in the EMBI index (respectively 5, 8, 13, and 7 percent respectively) are different from the exposures reported in the figure, the replication effect can only partially account for the concentration of exposures for the funds in the sample.

46 percent of TNA in the sample) also have large exposures to individual sovereigns, though these sovereigns are typically developed country issuers with investment grade ratings (U.S., Germany, Italy, and France) and are thus less subject to market and liquidity risk concerns.[18]

63. By contrast, HY bond funds have limited concentration risk and low common exposures. Since HY bond funds invest primarily in corporate bonds, they are subject to the 5 percent exposures limit under UCITS and therefore have lower concentration risk, even though they are exposed to low-quality issuers.

64. MMFs also have limited concentration risk towards sovereigns. Among the sample of 27 MMFs, only 4 have exposures to individual sovereigns higher than 20 percent and they are all towards developed countries (U.S., Italy, and Spain).

Work Done by Authorities

65. The CSSF and the BCL do not currently monitor concentration risk and common exposures across funds on a regular or systematic basis. The CSSF and the BCL have access to monthly security-by-security data for all Luxembourg-domiciled funds but the data are either used for statistical purposes (BCL) or on an ad hoc basis (CSSF).

Recommendations

66. The CSSF should intensify its monitoring of concentration risk and common exposures within the fund industry. Through the recent introduction of the UCITS risk reporting template and further data gathering activities, the CSSF is well placed to improve its monitoring of such risks. This would allow the CSSF to identify funds that could be subject to increased supervisory scrutiny. The CSSF should also continue its efforts to obtain access to the ECB's Centralized Securities Database in order to fill possible data gaps. The CSSF should ensure that funds with high concentration risk, have a specific and adequate risk management process in place, including the tools to mitigate liquidity and market risks. Such tools could include having access to a set of Liquidity Management Tools that could be used in case of stress.

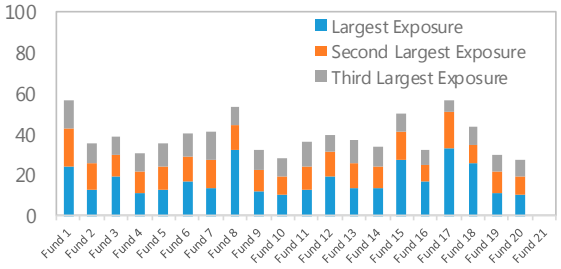
[18] Some of the mixed funds might invest up to 100% of their net assets in derivatives (such as Total Return Swap) in order to implement their investment policy, and, in order to cover their obligation arising from the use of derivatives, such funds may invest in money market instruments or liquid debt securities issued by a single sovereign issuer.

Figure 13. Concentration Risk and Common Exposures Among Investment Funds

Exposures to Sovereign Issuers, Except for HY Funds

EM Bond Funds: Concentration

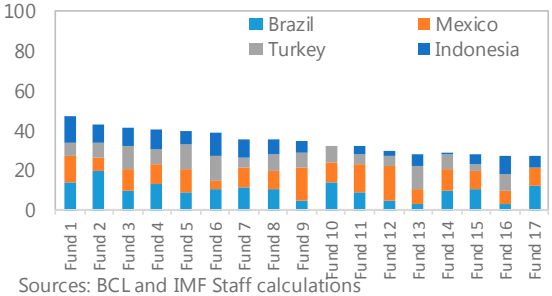
Portfolio Exposure to Single Issuers
(as a percent of total net assets)



Sources: BCL and IMF Staff calculations

EM Bond Funds: Common Exposures

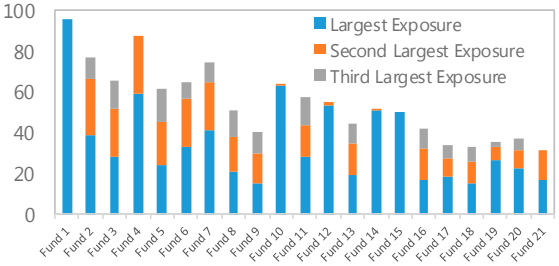
Portfolio Exposure to Common Issuers
(as a percent of total net assets)



Sources: BCL and IMF Staff calculations

Bond Funds: Concentration

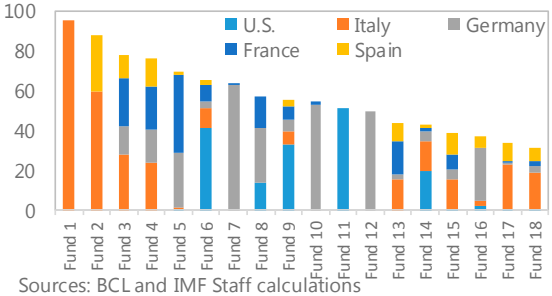
Portfolio Exposure to Single Issuers
(as a percent of total net assets)



Sources: BCL and IMF Staff calculations

Bond Funds: Common Exposures

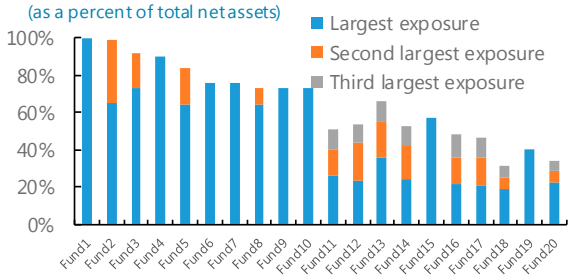
Portfolio Exposure to Common Issuers
(as a percent of total net assets)



Sources: BCL and IMF Staff calculations

Mixed Funds: Concentration

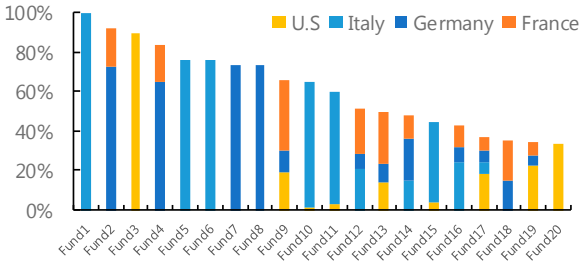
Portfolio Exposures to Single Issuers
(as a percent of total net assets)



Sources: BCL and IMF Staff calculations.

Mixed Funds: Common Exposures

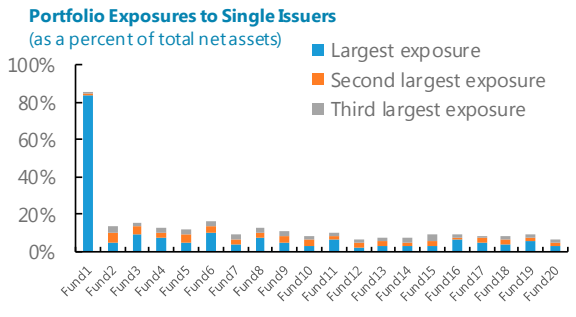
Portfolio Exposures to Common Issuers
(as a percent of total net assets)



Sources: BCL and IMF Staff calculations.

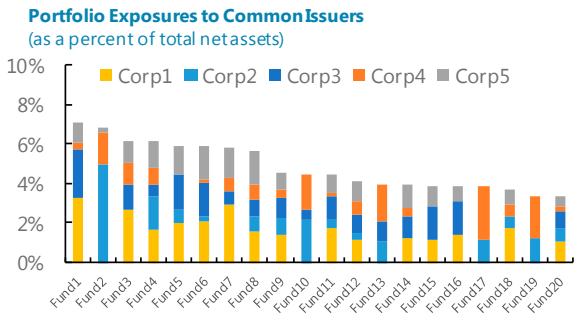
Figure 13. Concentration Risk and Common Exposures Among Investment Funds (concluded)

HY Funds: Concentration



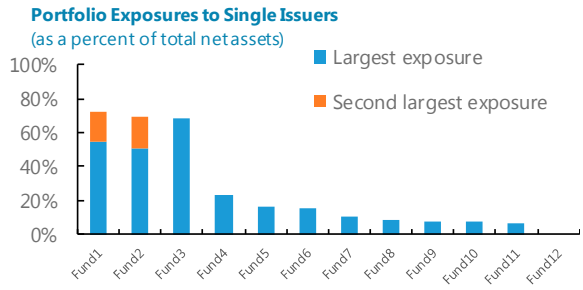
Sources: BCL and IMF Staff calculations.

HY Funds: Common Exposures



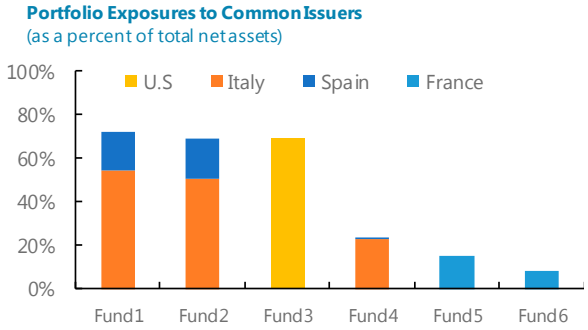
Sources: BCL and IMF Staff calculations.

MMFs: Concentration



Sources: BCL and IMF Staff calculations.
Only exposures higher than 5% of TNA are displayed.

MMFs: Common Exposures



Sources: BCL and IMF Staff calculations.

Solvency Stress Test for Money Market Funds[19]

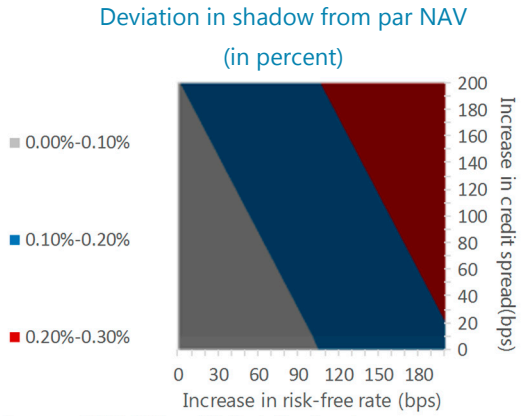
67. CNAV MMFs offer the ability to investors to redeem at par due to their use of amortized cost accounting. CNAV MMFs invest in a range of short-term fixed income instruments (principally commercial paper, certificates of deposits and bills) which are valued at amortized cost rather than based on mark-to market asset price valuations. Investors, such as corporate treasurers, use CNAVs for cash/treasury management purposes. However, investors might consider the 'redeemable at par' feature of CNAVs as substitutes for bank deposits, even though investors are exposed to market and liquidity risk, as witnessed during the Global Financial Crisis in the U.S. If the market value of CNAV portfolio were to decline substantially, and a large number of investors were to redeem shares simultaneously, the MMF might be unable to meet such requests. [20]

[19] Solvency risk refers to the risk that a CNAV might be unable to redeem at par value ('break the buck').

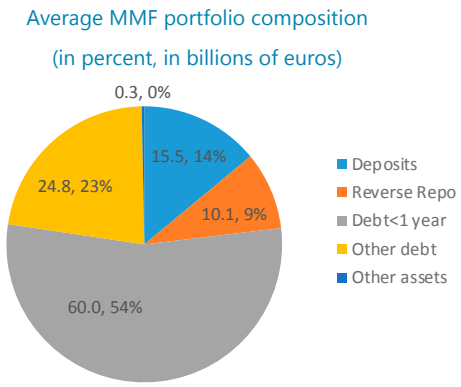
[20] During the GFC, one CNAV MMF 'broke the buck' in the U.S. as the shadow NAV of this MMF was more than 50 basis points lower than par value, leading to large redemptions across CNAVs. In Luxembourg, CNAVs experienced stress as well, but the largest deviation between the shadow NAV and the par value of the 10 largest CNAV MMFs remained below 20 basis points, with the exception of one MMF with a maximum deviation slightly above 20 basis

68. Stress tests based on sensitivity analysis show that a very large increase in risk free interest rates and credit spreads would be needed to 'break the buck' in Luxembourg's CNAV MMF industry. For instance, the combination of a 170 bps shock to risk free interest rates and an increase in credit spreads on non-sovereign holdings of 70 bps would be required for the shadow NAV to deviate substantially (by 0.2 percent or more) from par value (Figure 14, left panel).[21] Solvency risks are mitigated by CNAV MMFs establishing large cash buffers and holding high credit quality and short duration assets (Figure 14, right panel).[22] For the five CNAVs MMFs in the sample, deposits and reverse repo amount to almost one quarter of portfolio holdings and short-term debt instruments (mostly comprised of the highest short-term credit rating) account for more than half.

Figure 14. CNAV Money Market Fund Portfolios



Sources: CSSF, BCL and IMF staff estimates.



Sources: CSSF; BCL; and IMF staff calculations.

Notes: Data and results are aggregated as an asset-weighted average of the five largest CNAV MMFs. All individual funds produced qualitatively similar results as the asset-weighted average. The shadow NAV refers to the NAV if market fluctuations were reflected directly in the NAV. In the right chart, the split of debt securities is based on initial maturity and not residual maturity.

points, and no CNAVs suspended redemptions or used gates. After 2008, none of the 10 largest MMFs in Luxembourg experienced significant deviation (i.e. higher than 10 basis points) of its shadow NAV.

[21] There is no specific threshold for CNAVs under the UCITS Directive. However, the threshold of 0.2 percent is used in the guidelines of the industry association (Institutional Money Market Fund Association), in the transposition of the UCITS Directive under national law in Ireland (Regulation 88) and a similar threshold has been included in the European draft regulation on MMFs.

[22] The impact of interest rate and credit spread shocks on the market value of the portfolio is estimated using the duration of the portfolio for each CNAV in the sample (see Appendix VII for details).

Recommendations

69. The CSSF should, taking into account the requirements of the upcoming new-MMF Regulation, provide guidance on market risk-based stress tests for MMFs using amortized cost, and possibly for LVNAVs in the upcoming EU framework. In order to ensure comparability across funds, the CSSF should provide asset managers with broad guidance on how to perform solvency stress tests for CNAVs. Such guidance should cover the modalities of stress tests, including coverage, frequency and scenario design. The stress tests should cover current CNAVs, but also the new types of MMFs contemplated under the current EU proposal on MMF which would create Public Debt CNAV and Low-Volatility Net Asset Value MMFs. The authorities should also build internal capacity for performing stress tests, which could in time be used to develop stress tests for the broader investment fund industry.[23]

D. Solvency Stress Test of the Insurance Sector

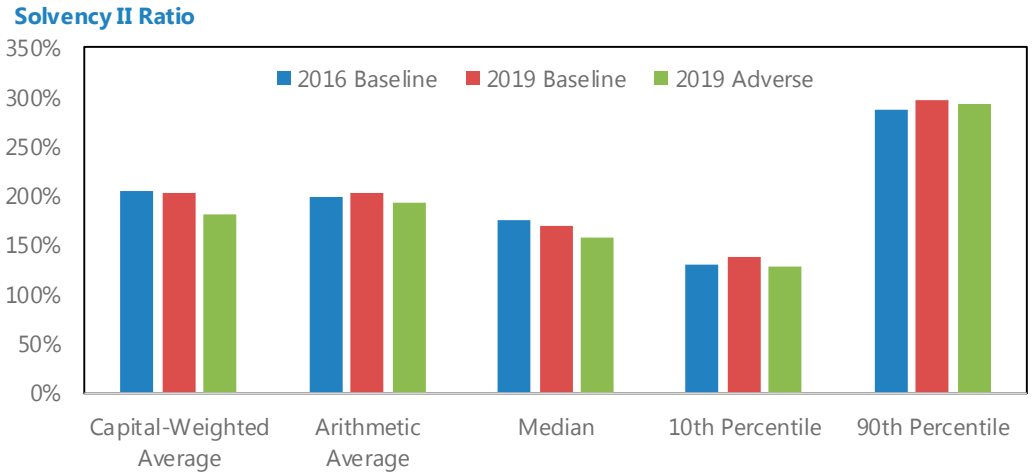
70. The insurance sector was subjected to bottom-up solvency stress tests (coordinated by the CAA, with limited IMF input) based on financial market shocks from the macrofinancial model. Coverage included 10 life insurers (71 percent of technical provisions) and the one dominant reinsurer (accounting for two thirds of sector assets).[24] The share of unit-linked products in the assets of the 10 life insurance companies comprising our sample was 77 percent. Although the FSAP scenario featured a "double hit" with an interest rate and an equity price shocks, as in the 2016 EIOPA stress test, specific features distinguished the FSAP stress test: (i) the size of the market shocks differed; (ii) companies' business plans were embedded in the stress test projections; and (iii) companies were allowed to recalculate their solvency capital requirement in the adverse scenario.

71. The Luxembourg insurance sector displays significant resilience in the adverse scenario despite an expected decline in Eligible Own Funds. As expected, companies with a larger share of unit-linked business were more severely hit than the others following the reduced fee income from unit-linked products due to a contraction in assets under management. The aggregate Eligible Own Funds decline by 27 percent in the third year of the scenario compared to the 2016 baseline. However, each of the 10 life insurers, plus the reinsurer, maintained a solvency II capital requirement well above the minimum requirement of 100 percent.

[23] A similar recommendation was made in the context of the Ireland FSAP (IMF (2016a)).

[24] Insurance sector stress tests do not include the non-life sector given the idiosyncratic nature of shocks to which this industry is most exposed. Non-life insurers comprise the smallest segment of the insurance industry.

Figure 15. Life Insurers' Bottom-up Stress Test Results



Source: CAA.

LIQUIDITY STRESS TESTS

72. Liquidity risk in the banking and investment fund industry was assessed by conducting a range of stress tests. TD liquidity stress tests assessed the capacity of banks to withstand large withdrawals of funding, by assuming various bank-run scenarios as well as differentiating flows by their maturities and currencies. Investment fund liquidity stress tests were performed by assessing the ability of investment funds to meet redemption shocks, calibrated on historical net flows and on the estimates derived from macroeconomic adverse scenario used for the banking sector stress tests.

A. Liquidity Stress Tests for the Banking Sector

73. Three types of liquidity stress tests were performed in order to arrive at a holistic assessment of bank liquidity risks. The first test was based on the national transposition of the Liquidity Coverage Ratio (LCR). The LCR measures bank's ability to meet its liquidity needs in a 30-day stress scenario by using a stock of unencumbered high-quality liquid assets (HQLA).[25] The implementation of the LCR follows a gradual approach. When the LCR came into effect in 2015, banks had to meet a ratio of 60 percent. The phase-in level in 2016 was 70 percent and will converge to 100 percent by January 2018. The second test was based on the Net Stable Funding Ratio (NSFR). While banks are not yet required to meet the NSFR-it is effective from January 2018 onward-it provides a useful complementary view of banks' funding profile in relation to the

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

composition of their assets and off-balance sheet activities at a one-year horizon.[26] The third liquidity test is a cash flow based analysis by maturity buckets. It allows for a more granular analysis of bank's liquidity buffers taking into account cash flows generated by different assets and liabilities with different maturities ranging from 7 days to more than a year.

74. Top-down liquidity stress tests were conducted jointly by the Luxembourg authorities and IMF staff. Results under the LCR analysis were based on supervisory information as of September 2016 covering all 16 banks in the sample while the NSFR and cash flow analysis had to rely on supervisory information drawn from the Short Term Exercise (STE) templates as of June 2016, covering only half the sample due to data availability.[27]

LCR-Based Stress Test

75. To assess the short-term resilience of banks to an abrupt withdrawal of funding, the LCR stress tests included scenarios that are more severe than those prescribed by the Basel III LCR (Table 6). The LCR liquidity stress tests covers three scenarios, including two scenarios tailored to stresses based on characteristics of liquidity practices of Luxembourg banks:

- *The standard LCR scenario applies the same parameters as set out by Basel III LCR 2013*. It is carried out at the aggregate currency level, i.e. combining the bank's positions in every currency.
- *The Luxembourg retail stress scenario aims to replicate a deposit run*. The key assumption raises run-off rates to 20 percent for stable and 30 percent for unstable retail and wholesale deposits.
- *A Luxembourg wholesale stress scenario*. This scenario is calibrated to link liquidity risk in the investment fund industry with stress in the interbank market by assuming a freeze of wholesale funding on the interbank market, the secured funding market via repo and covered bonds, and the commercial paper market; and sizable withdrawal rates by investment funds due to redemption shocks. Key assumptions include: (1) run-off rates of up to 100 percent for wholesale funding from other legal entity customers; (2) rates of 50 percent for operational deposits generated by clearing, custody, and investment fund activities; and (3) outflows by non-financial cooperates, central banks and multilateral development banks of up to 70 percent.

These three scenarios were carried out aggregating banks liquidity positions across every currency. To assess currency specific liquidity risk, IMF staff also applied a separate LCR stress tests based on major foreign currencies (EUR, USD, GBP) applying the same assumptions as under the standard LCR scenario.

76. Results based on the standard LCR show that Luxembourg banks have ample liquidity buffers (Table 7, Figures 16). Liquidity stress test results suggest that the aggregate LCR is equal to 109.4 percent in September 2016. Under this standard scenario four out of 16 banks do not pass

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

[27] Since the NSFR is not effective until 2018, banks don't have to specifically report it.

the 100 percent hurdle rate, which will be binding in 2018. However, the banks in the sample would still meet the prevailing 80 percent hurdle rate, the rate imposed by national regulators in 2017 according to the LCR phase-in agenda. Applying the future 100 percent hurdle rate, the shortfall would be equal to €3.5 billion or 0.8 percent of banks' assets.

77. In the case of a very large retail deposit outflow, the second scenario, retail banks would feel some pressure but continue to meet the 100 percent hurdle rate while private banks would fall below it. Under this adverse scenario, banks lose 20 to 30 percent of their retail and small business deposits, including sight and term deposits, in a month. Four out of 16 banks would fall below the hurdle rate of 100 percent but three would continue to meet the rate of 80 percent. This results reflects the strong liquidity position of the banking system which is able to withstand severe retail deposit outflows. It should be noted that the severity is stronger than what was experienced during the global financial crisis where peak outflow rates were equal to 8.6 percent for household deposits and 22.4 percent for non-financial corporate deposits. The results of this adverse liquidity stress test show that the aggregate LCR would fall to 107.6 percent, translating into a liquidity shortfall of €1.9 billion or 0.4 percent of banks' assets.

78. A scenario based on the contraction of unsecured wholesale funding, such as in the case of investment fund deposit withdrawals, would lead to liquidity pressures in seven banks. If banks faced 50 to 100 percent run-off rates on their unsecured wholesale funding, the aggregate LCR would fall to 96.3 percent, leaving seven banks below the 100 percent hurdle rate, with two below 80 percent (the threshold in 2017). Private banks and domestically oriented banks would be affected the most, with the LCR falling to 85 and 92 percent respectively. The total liquidity shortfall would amount to €7.2 billion or 1.6 percent of banks' assets. Given the stickiness of operational despots from investment funds, it should be noted this scenario is extreme, but was deemed worth conducting to analyze the relationship between banks and investments funds given the large positions the latter hold at the former.[28]

79. Separate LCR-liquidity stress tests carried out on foreign currency positions, which banks are not required to meet but were carried out for robustness reasons, revealed shortfalls at some banks. This test used the same assumptions as noted under the standard scenario but separated balance sheet items based on the following foreign currencies: U.S. dollar, euro, and British pound. Results show liquidity shortfalls ranging between €0.3 billion and €12.7 billion, i.e. 0.1 percent and 3.5 percent of banks' assets, with particular weaknesses in U.S. dollar positions. This result reflects Luxembourg's particular banking system structure, which is mostly comprised of foreign subsidiaries who rely on their foreign parent to manage foreign currency assets on their behalf, resulting in low LCR ratios.

[28] The next section on liquidity stress test in investment funds shows that drawdown of bank deposits by bond funds in an extreme macroeconomic scenario was estimated at €3–4 billion.

Table 6. Luxembourg: LCR-based Stress Test Assumptions on Run-off, Roll-off Rates, and Haircuts

(in percent)

C. Outflows of liquid assets (over 30 days)

	LCR	Outflow scenario 2	Outflow scenario 3
Retail Deposits			
Demand deposits			
Stable deposits	5%	**20%**	5%
Less stable retail deposits	10%	**30%**	10%
Term deposits, residual maturity > 30d	0%	0%	0%
Unsecured Wholesale Funding			
Demand and term deposits, residual maturity < 30d, small business			
Stable deposits	5%	**20%**	5%
Less stable deposits	10%	**30%**	10%
Operational deposits generated by clearing, custody, and cash manage	25%	25%	**50%**
Portion covered by deposit insurance	5%	5%	**50%**
Cooperative banks in an institutional network	25%	25%	25%
Nonfinancial corporates, sovereigns, central banks, multilat development banks, PSEs			
Fully covered by deposit insurance	20%	20%	**30%**
Not fully covered by deposit insurance	40%	40%	**70%**
Other legal entity customers	100%	100%	100%
Secured Funding			
Secured funding with a central bank, or backed by Level 1 assets	0%	0%	0%
Secured funding backed by Level 2A assets	15%	15%	15%
Secured funding backed by non-Level 1 or non-Level 2a asset, with domestic sovereign, multilat dev banks, or domestic PSEs as a counterparty	25%	25%	25%
Fundign backed by RMBS eligible for Level 2B	25%	25%	25%
Funding backed by other Level 2B assets	50%	50%	50%
Other secured funding transactions	100%	100%	100%
Additional Requirements			
Valuation changes on non-Level 1 posted collateral securing derivative	20%	20%	20%
Excess collateral held by bank related to derivate transactions that cou	100%	100%	100%
Liquidity needs related to collateral contractually due on derivatives tr	100%	100%	100%
Increased liquidity needs related to derivative transactions allowing co	100%	100%	100%
ABCP, SIVs, conduits, SPVs, or similar			
Liabilities from maturing	100%	100%	100%
Asset backed securities	100%	100%	100%
Undrawn but committed credit and liquidity facilities			
Retail and small business	5%	5%	5%
Nonfinancial corporates, sovereigns, central banks, multilat dev. banks, PSEs			
Credit facil	10%	10%	10%
Liquidity fa	30%	30%	30%
Supervised banks	40%	40%	40%
Other financial institutions			
Credit facil	40%	40%	40%
Liquidity fa	100%	100%	100%
Other legal entity customers, credit and liquidity facilities	100%	100%	100%
Other contingent funding liabilities			
Trade finance	5%	5%	5%
Customer short positions covered by customers' collateral	50%	50%	50%
Additional contractual outflows	100%	100%	100%
Net derivate cash outflows	100%	100%	100%
Any other contractual cash outflows (not listed above)	100%	100%	100%

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

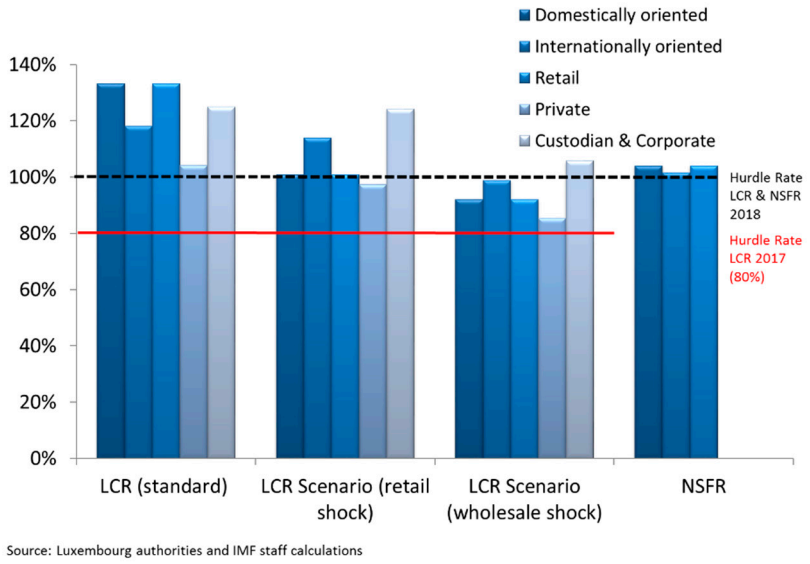
	LCR Stress Test Scenarios						NSFR Stress Test	Cash-Flow Stress Test	
	LCR Standard	LCR Retail	LCR Wholesale	LCR FX (USD)	LCR FX (EUR)	LCR FX (GBP)	NSFR	Outflows (before CC 2/)	Outflows (after CC 2/)
System-wide Liq. ratio (%)	109.4%	107.6%	96.3%	16.7%	161.8%	9.8%	101.1%	-	-
Liquidity shortfall 1/									
EUR billion	3.5	1.9	7.2	12.7	0.3	1.3	8.9	18.9	0.7
% GDP	6.4%	3.4%	13.1%	23.2%	0.6%	2.4%	16.2%	34.6%	1.3%
in % of banks' assets in sample	0.8%	0.4%	1.6%	3.5%	0.1%	0.4%	4.3%	9.2%	0.4%
No of banks falling short/out of sample	4 out of 16	4 out of 16	7 out of 16	11 out of 12	1 out of 8	4 out of 8	2 out of 8	6 out of 8	1 out of 8

Sources: Luxembourg authorities and IMF staff calculations

Note: 1/ Liquidity shortfall is the amount required so that the Liq. Ratio in each bank in the system be equal to or above 100 percent; the ratio effective as of January 2018.

2/ CC=Counterbalancing capacity

Figure 16. Liquidity-based Stress Test Results by Business Model



Source: Luxembourg authorities and IMF staff calculations

Sources: CSSF, BCL, and IMF staff calculations.

NSFR-Based Stress Test

80. The results based on the NSFR approach, which is binding in January 2018, do not suggest excessive maturity transformations at the aggregate level. Under the NSFR methodology, available stable funding for eight banks amounts to €165 billion in June 2016 and the required stable funding to €160 billion, resulting in an aggregate NSFR of 101.1 percent, slightly above the minimum requirement of 100 percent. Although most banks already meet the hurdle rate by a wide margin, albeit significant variations across business models, two banks fall short resulting in a shortfall larger than under the LCR wholesale shock scenario. Although the NSFR is more

difficult for the banks to implement due to the long-term nature of underlying funding sources, the authorities are confident that these two bank are likely to be fully compliant with NSFR by January 2018.

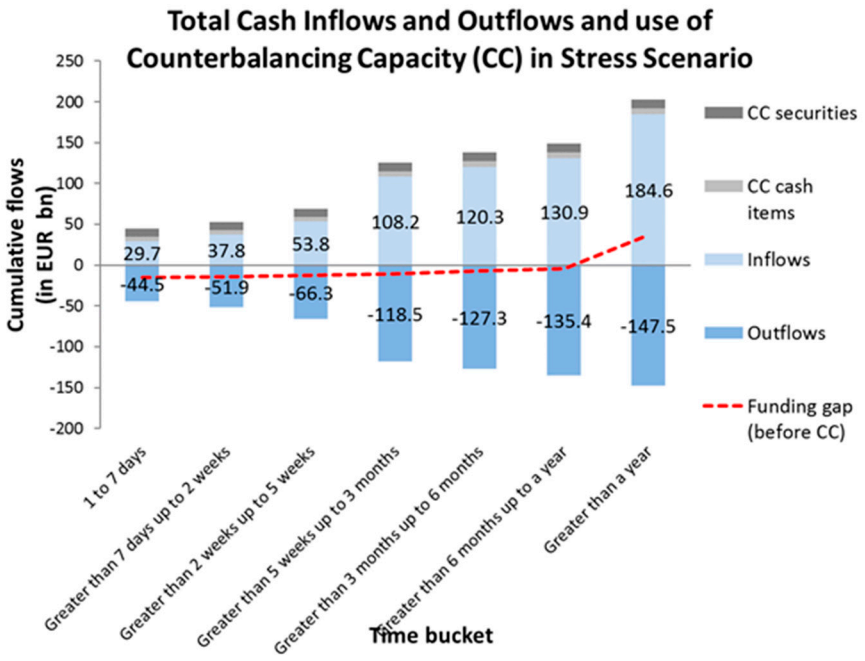
Outflow Analysis Stress Test

81. The outflow analysis was based on six maturity buckets aimed at capturing the comprehensive time structure of banks' cash in- and outflows. The maturity ladder was composed of the following seven buckets: 1 to 7 days, 8 days to 2 weeks, greater than 2 weeks up to 4 weeks, greater than 4 weeks up to 3 months, greater than 3 months up to 6 months, greater than 6 months up to a year and more than a year. These tests assessed banks' resilience to severe 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) banks' liquidity needs derived from outflows, (ii) available standby liquidity from inflows, and (iii) buffers available to counterbalance liquidity gaps (Table 8). For each bucket, the amount of net outflows was compared to the amount of liquid assets available for sale to counterbalance funding gaps in the so called "counterbalancing capacity", with liquid assets subject to 20 percent haircuts.

82. The results of the outflow analysis suggest that most banks are resilient to substantial funding gaps over the short term by selling liquid assets. All banks except one would be able to meet substantial funding gaps in 1 to 7 days by selling liquid assets equal to 9.2 percent of bank's total assets (Table 7 and Figure 17). This result supports the assessment of a strong liquidity position among Luxembourg banks. However, the reliance on securities to fund short term gaps could become a point of vulnerability in times of distress when banks cannot necessarily sell large quantities of assets at the same time without suffering losses if market prices are below par. Another limitation is the lack of data availability which restricts this analysis to only eight banks, leading to substantial gaps in the liquidity analysis in Luxembourg as the largest bank is excluded from the sample. Data for this analysis relies on information obtained through the Short Term Exercise (STE) as carried out by the ECB, which covers only eight banks in Luxembourg.

83. The liquidity stress test results confirm the strong liquidity buffers present in Luxembourg but also hint at banks' exposures to short-term liquidity risks stemming from their reliance on funding from other financial institutions, as well as foreign currency funding by parent groups. The LCR and cash flow analysis point to substantial short term positions in intragroup funding as well as reliance of foreign currency (FX) management by parent groups. To address these vulnerabilities, the authorities should require banks to lengthen the maturity of unsecured wholesale funding beyond a seven-day window, including by parents. Also, authorities could improve their liquidity monitoring by performing liquidity stress tests using the structure of cash flows at various maturities and FX. Since it is difficult for the Luxembourg authorities to verify the LCR in FX at the group level on a frequent basis, the ECB should give consideration to the implementation of a binding FX LCR framework at the group level. Furthermore, the coverage of banks reporting on liquidity should be extended to more banks. Thus the authorities should work together with the EBA to close liquidity reporting gaps and expand the harmonized EU bank reporting.

Figure 17. Outflow Analysis-based Stress Test Results



Source: Luxembourg authorities, and IMF staff calculations.

Table 8. Luxembourg: Outflow Analysis Stress Test Assumptions on Run-off, Roll-off Rates, and Haircuts

(in percent)

	1	2	3	4	5	6	7
	1 to 7 days	**Greater than 7 days up to 2 weeks**	**Greater than 2 weeks up to 4 weeks**	**Greater than 4 weeks up to 3 months**	**Greater than 3 months up to 6 months**	**Greater than 6 months up to a year**	**Greater than a year**
Run-off rates on potential outlfows							
Retail funding: sight deposits							
Stable	2%	4%	4%	4%	0%	0%	0%
Unstable	8%	6%	6%	3%	0%	0%	0%
Retail funding: term deposits	5%	5%	5%	15%	10%	10%	10%
Other deposits	10%	10%	10%	10%	10%	10%	10%
Secured wholesale funding from other financial institutions	20%	20%	20%	20%	20%	20%	20%
Unsecured wholesale funding from other financial institutions	60%	60%	60%	60%	60%	60%	60%
Outflows from derivatives	100%	100%	100%	100%	100%	100%	100%
Other obligations	50%	50%	50%	50%	50%	50%	50%
Roll-off rates on cash inflows							
Securities in trading book	100%	100%	100%	100%	100%	100%	100%
Securities available for sale	100%	100%	100%	100%	100%	100%	100%
Securities held to maturity	100%	100%	100%	100%	100%	100%	100%
Inflows from derivatives	100%	100%	100%	100%	100%	100%	100%
Loans maturing	60%	60%	60%	60%	60%	60%	60%
Other	80%	80%	80%	80%	80%	80%	80%
Haircuts on liqudity assets							
Cash items	0.0%						
Securities in trading book	20.0%						
Securities available for sale	20.0%						
Securities held to maturity	20.0%						

B. Liquidity Risks in the Investment Fund Industry

84. Stress test results show that most fixed income funds are resilient to adverse redemption shocks, though HY bond funds appear more vulnerable. The results are consistent across the different scenarios and measures of liquidity used, though fund managers self-assessments, based on new UCITS risks reporting to the CSSF, point to more benign liquidity risks among HY bond funds.

Methodology

85. The liquidity stress test assesses the ability of investment funds to withstand a severe redemption shock with minimal disruption. The analysis compared liquid assets to net outflows under two approaches: (i) an historical approach where the redemption shock is equal to the worst monthly outflow experienced by each fund; and (ii) a forward-looking approach that incorporates the adverse macroeconomic scenario to calibrate fund flows (Box 1). The redemption shocks are

then compared to two measures of liquid assets (Box 2). The outcome of the liquidity stress test for each fund is based on the Redemption Coverage Ratio (RCR), which relates liquid assets to net flows.

Box 1. Estimation of the Redemption Shock in the Liquidity Stress Test for Investment Funds

Under the historical approach, the redemption shock is calibrated using the 1 percent highest monthly net flows observed over 2007–2016 for each individual fund.[1] Therefore, each fund faces a different redemption shock. Given that the actual redemption shocks occurred at different periods in time, the results cannot be aggregated.

Under the forward-looking approach, an econometric model relates net flows at the strategy level (EM, HY, mixed and other bond funds) to macrofinancial variables.[2] The redemption shock is calibrated by using the values of the macrofinancial variables in the adverse scenario (see Annex VIII for further details) and within the same fund strategy, each fund in the sample is subject to the same shock. Results can be aggregated as all funds in the sample are exposed to the same shock at the same time.

Table 9 shows that under the historical approach, redemption shocks are more severe at around 18 percent of TNA on average, in line with recent FSAPs and common industry practice.[3] Under the forward-looking approach, shocks are milder.

Luxembourg: Redemption Shocks in the Investment Fund Liquidity Stress Test

(percent of total net assets)

	Historical approach	Macro model
	Net flows (average)	Net flows
Bond funds		
EM	18%	9%
HY	19%	11%
Mixed funds	9%	*
Other bond funds	18%	6%
MMFs		
Short Term CNAV	19%	**
Short Term VNAV	23%	**
Other MMFs	18%	**

Sources: BCL; CSSF; and IMF Staff calculations
*Under the adverse scenario, mixed funds would experience net inflows of 11%
**The model is not significant

[1] The 2015 U.S. FSAP and the 2016 Sweden FSAP used a similar threshold of 1 percent for net flows ((IMF (2015c), IMF (2016b)).

[2] MMFs were excluded from the forward looking approach as regression analysis did not establish significant relationship between net flows and macrofinancial variables.

[3] For example, the daily redemption shocks used in the Ireland FSAP reached up to 20 percent of TNA (IMF (2016a)).

Box 2. Measures of Liquidity Assets for Investment Funds and Redemption Coverage Ratio

Liquid assets are measured by (i) cash and short-term debt securities (with a residual maturity of less than one year), following ESRB (2016) and (ii) a high quality liquid asset (HQLA) approach following ESMA (2015), where liquidity weights applied to each security holding are a function of credit rating, instrument type and issuer, as shown in Table 9.[1]

Luxembourg: Liquidity weights by instrument

	Cash	Sovereign bonds	Corporate bonds	Securitization	Equities
AAA to AA-	100%	100%	85%	85%	50%
A+ to A-		85%	50%	50%	
BBB+ to BBB-		50%	50%	0%	
Below BBB-		0%	0%	0%	

Sources: Credit Quality Step; and IMF Staff calculations

For each fund, stress test results are based on the RCR:

$$\text{RCR} = \frac{\text{Liquid assets}}{\text{Net outflows}}$$

If the RCR is below 1, the fund is assumed not to have sufficient liquid assets to cope with redemptions, and thus would either need to sell less liquid (non-HQLA) assets (with possible fire sale risk) and/or use Liquidity Management Tools (LMT) such as redemptions gates, or temporary suspension of redemptions.

[1] Non-investment grade corporate bonds are given a weight of zero, resulting in relatively low HQLA assets for HY funds. The HQLA measure does not take into account the possibility of funds to liquidate non-investment grade bonds to meet redemptions.

Results

Historical Approach

86. Overall, the analysis shows that the MMF sector and most bond funds would be resilient to large redemption shocks, though HY bond funds appear more vulnerable. For MMFs, liquidity buffers measured by short-term debt securities and cash would cover the simulated redemption shocks (Table 10). For mixed, EM and other bond funds, short-term assets might not be enough to cover the redemption shocks, but under the HQLA approach only a few funds would have an RCR below one, thanks to their exposures to sovereigns. HY funds would have lower RCR using both measures of liquidity. Therefore, under stress HY funds would need to sell less liquid assets, possibly at a significant discount and/or use LMTs or have recourse to temporary borrowing from banks. However, fund manager self-assessments for the same sample of funds, based on new

UCITS risk reporting to the CSSF, point in contrast to ample liquidity buffers based on the (low) number of days it would take them to sell their portfolio (Figure 18).[29]

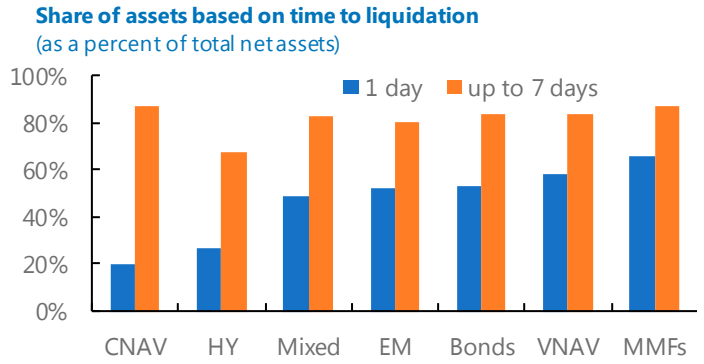
Table 9. Luxembourg: Liquidity Stress Test Results for the Historical Approach

	Historical approach		
	Average redemption shock (% TNA)	Cash and ST debt	HQLA
Short Term CNAV	19%	0%	^
Short Term VNAV	23%	0%	^
Other MMFs	18%	0%	^
EM	18%	71%	2%
HY	19%	78%	75%
Mixed funds	9%	28%	5%
Other bond funds	18%	52%	8%

Sources: BCL, CSSF, and IMF staff calculations.

Note: Figures in white panels depict the size of the redemption shock for each fund type (as a share of total net assets, TNA). Figures in gray panels depict the percentage of funds in the sample who would be unable to cover a redemption shock under two different metrics for liquidity (cash and short-term debt; and HQLA).

Figure 18. Liquidity of Funds in the Sample Based on Asset Manager's Reporting to the CSSF



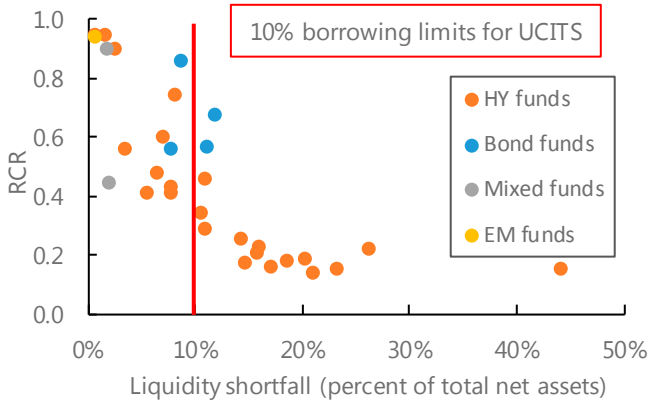
Sources: CSSF, and IMF staff calculations.

87. Under the historical approach, the estimated liquidity shortfall for some funds would be above the borrowing limit under UCITS. The liquidity shortfall amounts to the difference

[29] The data refer to March 2016 and is based on the half-yearly CSSF UCITS Risk report. The report has been recently launched and therefore data quality issues might impact the interpretation of the data. For example, CNAVs reported less liquid assets (up to one day) than HY funds, which is due to different interpretations by the asset managers., particularly by one CNAV where there was a misinterpretation on final maturity and time to liquidate, but where the fund was very liquid. Data reported in Figure 18 refer to liquidity under normal conditions. The UCITS Risk report also requests data on liquidity under stress but the reporting was optional for the first report and due to low coverage of respondents, liquidity measures under stress are not reported here.

between the redemption shock and liquid assets (HQLA measure) expressed in percent of TNA. For some HY funds and a few bond funds, the shortfall would be above 10 percent of total net assets (Figure 19), the maximum (temporary) borrowing limit under the UCITS Directive.

Figure 19. Liquidity Shortfall and RCR for Selected Investment Funds



Sources: CSSF, BCL, and IMF staff calculations.

88. Most funds with an estimated liquidity shortfall have access to a range of liquidity management tools (LMTs). LMTs are used by investment fund managers to navigate periods of unusually large investor redemptions, and can differ widely across jurisdictions and fund types. In Luxembourg, a wide range of LMTs are allowed for UCITS.

Forward-Looking Approach

89. Overall, results of the liquidity stress test are milder under the macroeconomic scenario, yet most HY funds would need to liquidate less liquid security holdings in order to cope with redemptions (Table 11) or use LMTs. All bond funds except HY funds would have enough HQLA to cover the redemption shock. Around 70 percent of HY funds would experience liquidity shortfalls, a slightly lower share than in the historical approach. When liquidity is measured by short-term assets, a significant share of EM and other bond funds would have an RCR below one, though the proportion would be lower than under the historical approach.

Table 10. Luxembourg: Liquidity Stress Test Results for the Forward-looking Approach

	Forward-looking approach		
	Average redemption shock (% TNA)	Cash and ST debt	HQLA
Short Term CNAV	*		
Short Term VNAV	*		
Other MMFs	*		
EM	9%	50%	0%
HY	11%	66%	69%
Mixed funds	**	**	**
Other bond funds	6%	30%	0%

Sources: BCL, CSSF, and IMF staff calculations.
Note: Figures in white panels depict the size of the redemption shock for each fund type (as a share of total assets, TNA). Figures in gray panels depict the percentage of funds in the sample who would be unable to cover a redemption shock under two different metrics for liquidity (cash and short-term debt; and HQLA).
* The model is not significant for those funds.
** Under the adverse scenario, mixed funds would experience net inflows.

90. Stress test results indicate that in the absence of adequate liquid securities and effective liquidity management tools, investment funds might need to draw down on bank deposits. Modeling results suggest deposit outflows could amount to around 25 percent of total cash deposits of investment funds in the sample (equivalent to around €5.2 billion),[30] or close to 20 percent (€4.9 billion) when incorporating projected inflows into mixed funds. The latter result is an empirical regularity captured by the redemption forecast model, and reflects the diversity in investment fund offerings in Luxembourg in which outflows from some funds frequently occur while other funds see inflows.

Work Done by the Authorities

91. The CSSF monitors fund liquidity risk to ensure compliance with UCITS regulations, but does not require regular liquidity stress test for funds. Under UCITS, liquidity stress tests are required "where appropriate" and the CSSF Regulation transposing the UCITS Directive does not provide guidance on liquidity stress tests. Nevertheless, the ongoing supervision of UCITS funds includes the requirement for a risk management process, including liquidity risk management and stress testing. In the context of the authorization process and supervision of UCITS funds, the CSSF has asked, in certain cases, Management Companies to provide further data and to improve their liquidity stress tests policies. On a practical note, even though Management Companies are not

[30] Due to data gaps, deposit outflows are estimated assuming that 100 percent of funds deposits are with their depositary bank, while in practice funds' deposits are likely to be spread across several banks domiciled inside and outside Luxembourg.

always required to perform liquidity stress tests, based on studies performed by the CSSF, many Management Companies perform these tests on a regular and systematic basis.

92. The CSSF has set up a range of reporting requirements for funds to assess risks. The half-yearly UCITS Risk Reporting, which requests a wide range of data, including an assessment of the liquidity of the portfolio of a major sample of the UCITS fund industry, has recently been launched. In particular, fund managers are asked to report the liquidity of their portfolio by buckets under normal and stress periods. This report provides a wealth of information to the CSSF, especially when frequent reports will be filled by fund managers (the second UCITS risk report has been in December 2016). The CSSF also asks for quarterly reporting for UCITS using leverage, and has used ad hoc data collection to analyze risks linked to securities financing transactions.

Recommendations

93. The CSSF should provide industry guidance on liquidity stress tests for funds most exposed to less liquid asset classes. The CSSF should require such funds to perform liquidity stress tests on a regular basis, ideally using a scenario provided by the Authorities to ensure comparability across funds. The CSSF should review and challenge such liquidity stress tests, which will require building internal capacity.[31]

94. The CSSF should ensure that funds exposed to potential liquidity mismatches have adequate LMTs in place, and assess their effectiveness. For funds that could have significant liquidity shortfalls under stress, an adequate set of LMTs should be in place. Most funds in Luxembourg have access to a wide range of LMTs (suspension of redemption, redemption gates, swing pricing), however no systematic analysis on their effectiveness during stress periods has been conducted. Therefore, the CSSF should, in line with international developments, commission a study on the effectiveness of LMTs, which could provide the basis for subsequent industry guidance.

95. The CSSF and the BCL should continue to analyze possible risks arising from bank-fund interlinkages. Funds' deposits, especially with depositary banks could be a channel of transmission of stress in the fund sector to the banking system. The CSSF and the BCL should continue the work on interlinkages that was started under the auspices of the CRS. Data gaps should be closed, by collecting data on individual funds' exposures to banks in Luxembourg to assess depositary banks' vulnerabilities to stress in the fund industry.

[31] This recommendation is in line with recent proposals by the Financial Stability Board, and was also featured in the Ireland FSAP (IMF (2016a)).

INTERCONNECTEDNESS ANALYSIS AND CONTAGION RISKS

96. To assess systemic risks, analysis needs to extend beyond an assessment of individual financial institutions by investigating whether interlinkages have systemic implications. Systemic interconnections within and across sectors can arise through direct (e.g., lending) and/or indirect (e.g., exposure to common risk factors) linkages. These linkages can lead to contagion, when shocks not only spread through the financial system, but are amplified through these connections in times of crisis.[32]

97. Network analysis can be used to uncover potential systemic interlinkages not only within a domestic financial system but also in a cross-border setting. Three standard approaches that are suitable for this assessment are: (1) Espinosa-Vega and Sole (2010), (2) Segoviano and Goodhart (2009) and (3) Diebold and Yilmaz (2014). These commonly-used methodologies aim to quantify the strength and direction of spillovers within a network. The first methodology uses supervisory data while the other two rely mainly on market data. The application of these methods allowed carrying out a comprehensive assessment of domestic, cross-sector, and cross-border relationships, making use of the available data. It should be pointed out, however, that the market based network analysis was only covered four banks due to data availability, thus general conclusions from this analysis cannot be drawn. This is in contrast to investment funds, where coverage was extensive, with 75 percent of the total net assets for HY, EM bond funds, VNAVs, and MMFs, 54 percent for mixed funds, and 32 percent for bond funds.[33]

A. Domestic Interconnectedness Analysis

98. Contagion risks arising due to the domestic interlinkages were assessed using a network model of contagion based on Espinosa-Vega and Solé (2010), Segoviano and Goodhart (2009), and Diebold and Yilmaz (2014). The domestic assessment focused on interbank, bank-insurer and bank-fund networks separately, where the three methodologies complemented each other based on data requirements. The analysis reveals that contagion risks stemming from domestic interbank exposures as well as bank-insurer exposures are very limited. Network analysis based on market data confirms this result by showing limited interconnections between banks. The bank-fund network, based on market data, shows strong connections between some investment funds and banks as well as amongst investment funds. The next three sub-sections presents these results in more detail.

[32] Interdependence is defined as the relationship that exists between asset classes (sectors) on average over the sample period. Contagion is defined as a change in the transmission mechanism between asset classes (sectors) in crisis times (see Beirne and Gieck, 2014).

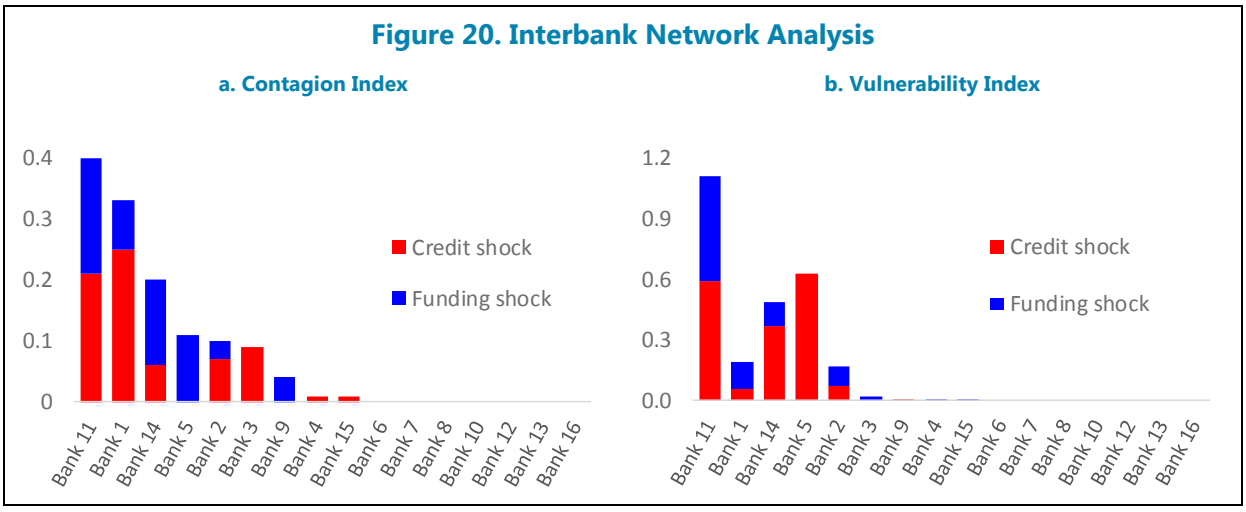
[33] The discussions on methodologies as well as data sources are featured in Boxes 3–5.

Interbank Network Analysis

99. In Luxembourg, domestic interbank positions are found to be small, especially compared to banks' capitalization. For each of the sixteen banks in the sample, the total gross exposures to the other fifteen banks are smaller than its regulatory capital.[34] Therefore, no single failure of a domestic bank would trigger the failure of another bank, and thus no "cascade effect" would take place in this representative sample. Moreover, aggregate indices of contagion and vulnerability also appear low. The entity with the highest contagion index causes losses of less than 0.4 percent of counterparties' capital (Figure 20a), with the entity most adversely impacted incurring losses of less than 1.5 percent of its capital (Figure 20b). A visual representation (Figure 20c) of this interbank network further illustrates the low level of domestic interconnectedness in the banking sector. Only a few banks stand out as having relatively stronger linkages to multiple other banks while the rest of the network map appears sparsely connected. Market data based network analysis confirms this result by showing limited interconnections between domestic banks as indicated by the dark blue lines, except for two banks (Figure 20d).

100. Financial distress in Luxembourg banks has decreased since the European debt crisis (Figure 21). The JPoD, based on Segoviano and Goodhart (2006), indicates the joint probability of all banks in the sample being in distress, shows how risks evolve through time. Figure 21 shows risks to have declined since the European debt crisis. For robustness, the total connectedness indicator by Diebold-Yilmaz was also estimated. This indicator shows how connected the system of financial entities is over time. The higher the indicator, the stronger is the transmission of shocks from one entity to another (i.e. the higher the indicator, the higher is the forecast error variance of entities due to shocks emanating from other entities in the sample). This indicator suggests that connectivity has declined in 2016.

Figure 20. Interbank Network Analysis



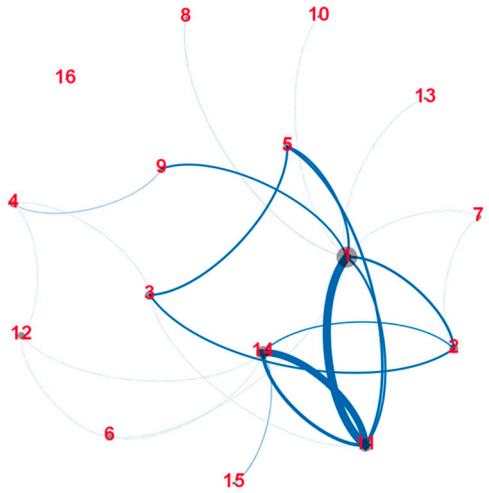
[34] In a system with 16 banks, the interbank exposure matrix is a square matrix of size 16x16.

Figure 20. Interbank Network Analysis (concluded)

Source: IMF staff.
Note: The index of contagion represents the average loss experienced by each entity (expressed as a percentage of their Tier 1 capital) due to the triggered failure of one entity. For example, the failure of Bank 11 results in the average loss to other entities of around 0.4 percent of capital.

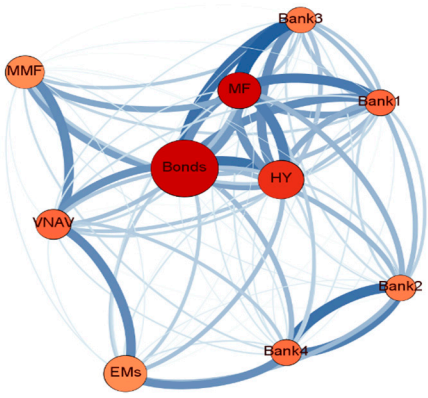
Source: IMF staff.
Notes: The vulnerability index represents the average loss experienced by each entity (expressed as a percentage of its Tier 1 capital) across individually triggered failures of all other entities. For example, Bank 11 suffers an average hit to capital of 1.2 percent across individually triggered failures of all other entities (i.e. 15 independent failures).

c. Domestic Interbank Network Graph based on Balance Sheet Data



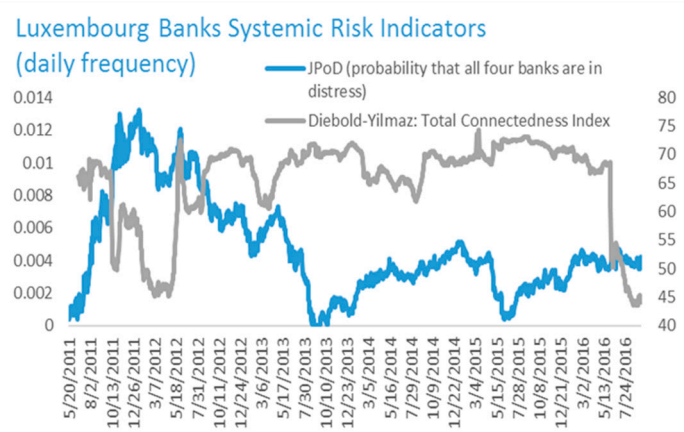
Node size is proportional to bank's total assets; edge thickness is proportional to exposure in percent of bank's tier 1 capital.

d. Domestic Bank-Fund Network Graph based on Market Data (2011-2016)



1/ Edge thickness and darkness shows the strength of the pairwise relationship, depicted as the 12-month forecast variance of entity *i* due to shocks from entity *j*. The underlying error-variance decomposition matrix was calculated using probability of distress data (PoD). PoDs for Luxembourg banks were derived using bond spreads, and for investment funds, derived from marked-to-market return data. Node size indicates total asset size; color of nodes indicates "total connectedness to others" with dark red indicating connections with other entities in the sample. Node location is derived using ForceAtlas2 algorithm in which nodes repel each other, but strength of edges (i.e. connections) is attracting the nodes to each other.

Figure 21. Risk Indicators



Sources: Datastream, Bloomberg, and IMF staff calculations.

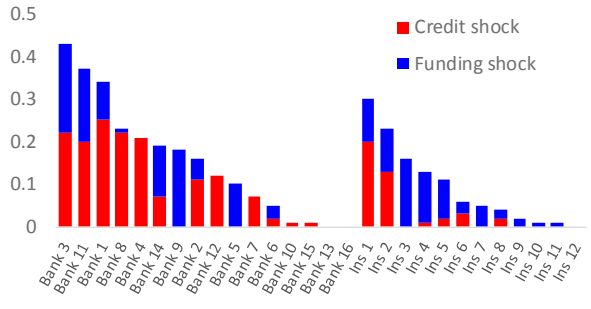
Bank-Insurer Network Analysis

101. A contagion stress test was carried out based on supervisory data on interlinkages between Luxembourgish banks and insurers. In order to assess the degree of vulnerability of the largest Luxembourgish financial institutions stemming from the interconnectedness within the financial system, the analysis was complemented by the computation of a matrix of bilateral domestic gross exposures between the 16 banks and the 12 largest Luxembourgish insurers, including data on capital cross-participation, bonds, credit and deposits.

102. The analysis reveals limited potential for spillovers within and across the domestic banking and insurance sectors. There is little evidence to suggest that the failure of any bank or insurer would result in the failure of another institution. Aggregate indices of contagion and vulnerability also appear low. The entity with the highest contagion index causes losses of less than 0.5 percent of counterparties' capital (Figure 22a), with the entity with the highest vulnerability index incurring losses of less than 2.5 percent of its capital (Figure 22b). As expected, banks tend to have higher indices of contagion, whereas, insurers tend to have higher indices of vulnerability. It is noteworthy to point out that all bank exposures to insurers are through their debt security holdings and vast majority of insurer exposures to banks are in the form of deposits. There are no direct cross exposures amongst the insurers.

Figure 22. Indices of Contagion and Vulnerability: Bank-Insurer Network

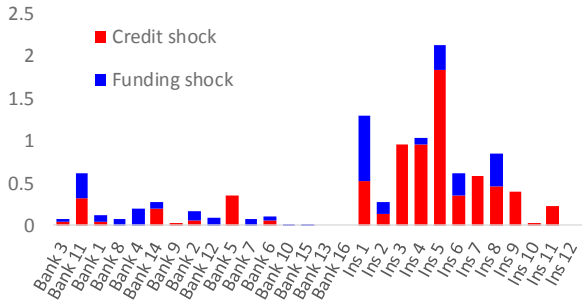
a. Contagion Index



Source: IMF staff.

Note: The index of contagion represents the average loss experienced by each entity (expressed as a percentage of their Tier 1 capital) due to the triggered failure of one entity. For example, the failure of Bank 3 results in the average loss to other entities of around 0.4 percent of capital.

b. Vulnerability Index



Source: IMF staff.

Notes: The vulnerability index represents the average loss experienced by each entity (expressed as a percentage of its Tier 1 capital) across individually triggered failures of all other entities. For example, Insurer 5 suffers an average hit to capital of 2.2 percent across individually triggered failures of all other entities (i.e. 27 independent failures).

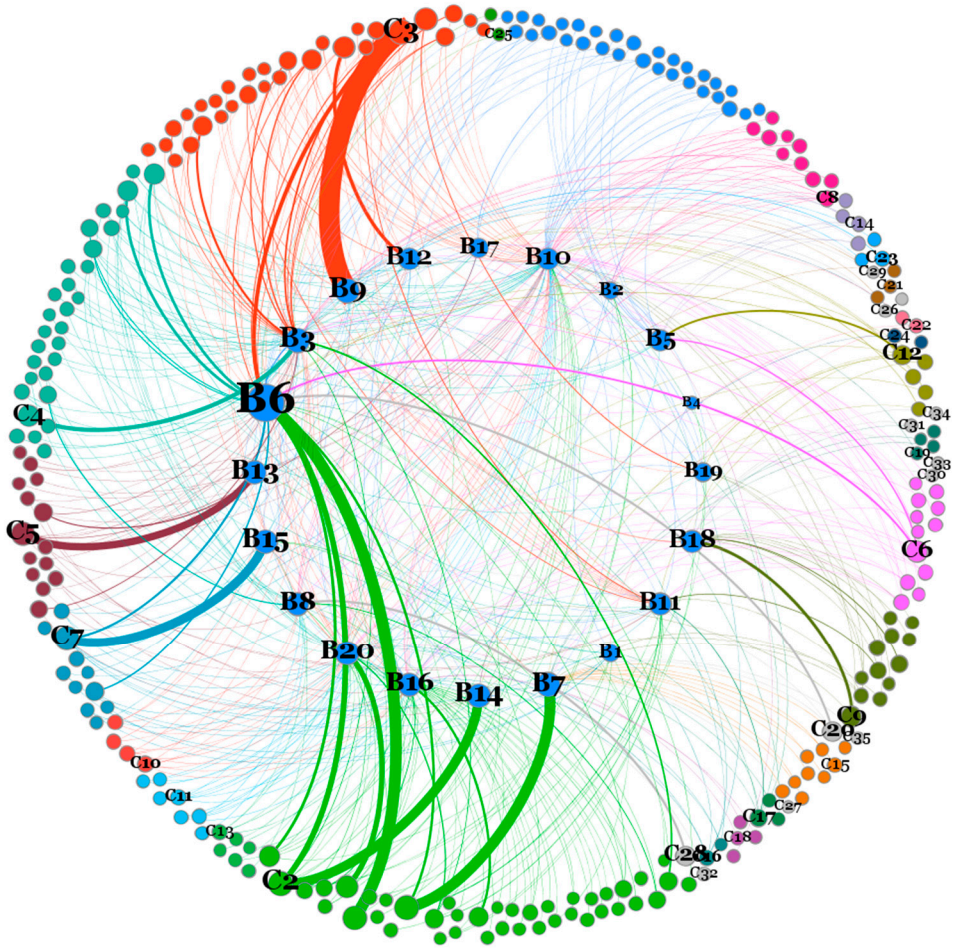
Domestic Interfund and Bank-Fund Network Analysis

103. Using market data, network analysis shows strong connections between some investment funds as well as with two banks. Bond, mixed and HY investment funds are closely related to each other according to the network methodology employed by Diebold and Yilmaz (2014), as indicated by the dark blue lines (i.e. edges) which reflect the strength of the pairwise connections (Figure 20d). The proximity between the nodes (i.e. bubbles) representing these funds also indicates their strong connectivity to each other. The outside location of MMF, EM and VNAV funds as well as the green color of their nodes, which reflects their average connectivity to the whole network, suggest that they are not strongly connected to other entities. The center location of the bond node and its red color suggest that it is the most interconnected entity. With regards to bank-fund relations, as shown by the dark blue edges, two banks (Bank 3 and 1) appear to be closely related to bond and mixed funds but are relatively independent from other entities in the network as reflected by their outside location.

B. Cross-border Contagion Risks

104. Unsurprisingly, cross-border balance sheet analysis reveals strong linkages with euro area members and countries with deep financial sectors. Cross-border exposures between the subsidiaries and their foreign parents in the euro area are particularly strong. There are also significant exposures outside the euro zone, particularly with the UK, the US and Switzerland. The network chart (see Figure 23) reveals the importance of Luxembourg banks in a global network, and provides a visual clue as to the high-level interconnectedness of Luxembourg banks (in the inner core) with foreign banks (on the outer circle), in particular their foreign parents.

Figure 23. Cross-border Banking Network



Note: Luxembourg banks are in the inner circle with their counterparties on the outer circle designated by different colors based on country. The sizes of the nodes are proportional to the number of connections for a given entity and the line thickness indicates degree of exposure in relation to capital.

Cross-Border Macro-Exposure Analysis of Banks

105. Germany is the largest recipient of Luxembourg-domiciled banks' assets as well as the largest source of funding to Luxembourg banks (see Figure 24a). More than half of Germany's shares are associated with corporate finance activities. France, the UK and the US, the next three largest recipients, account for one-third of total foreign assets while they provide a combined funding of only less than half of that of Luxembourg banks. A significant share of these countries are associated with custodian banking activities, while, in the case of France, private banking and domestically-oriented activities also play an important role. Switzerland has almost an even status between being a recipient and a funding source, where mostly private banking activities make up its

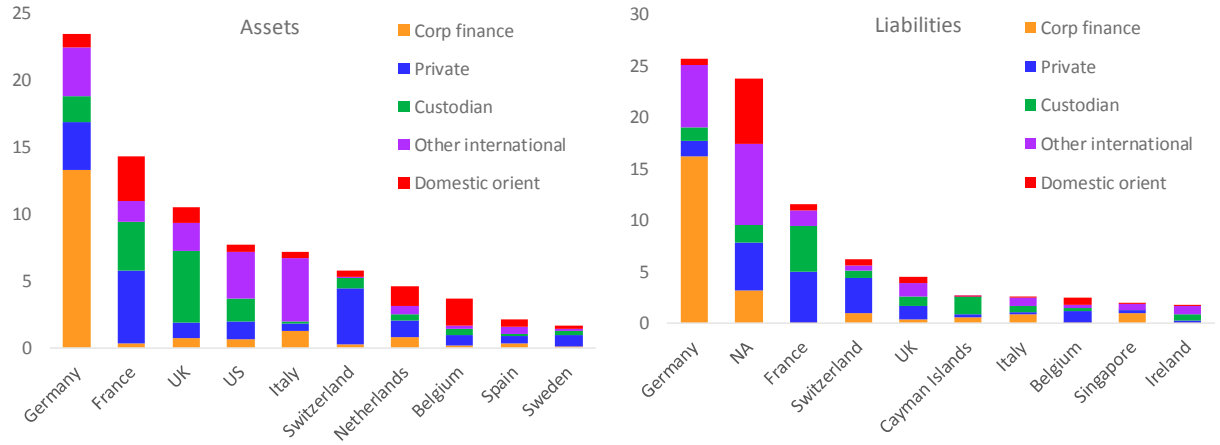
share. Apart from other European countries, Cayman Islands and Singapore take their place in the top 10 list, where both are important sources of funding.

106. On the asset side, claims in the forms of loans to affiliated entities make up the largest share of cross-border exposures (Figure 24b). On the liabilities side, debt in the form of overnight deposits, deposits with agreed maturity, deposits redeemable on notice and repos and short sale securities make almost three quarters of the foreign sources of funding. More than half of this debt (equivalent to about 40 percent of total foreign liabilities) is owed to affiliated entities.

Figure 24. Banks' Cross-border Exposures

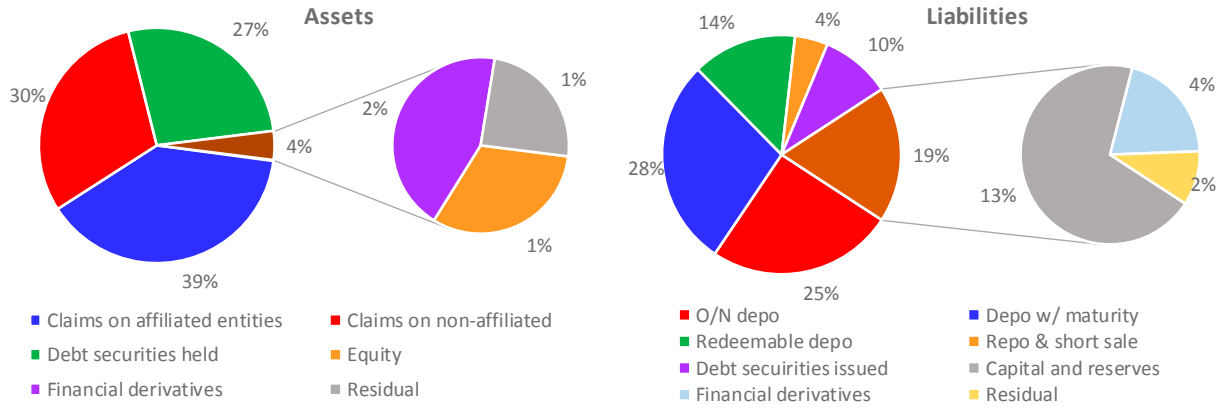
a. Foreign Assets and Liabilities Exposures by Country and Activity

(in percent of total foreign assets and liabilities; as of 2016Q2)



b. Foreign Assets and Liabilities Exposures by Transaction Type

(in percent of total foreign assets and liabilities; as of 2016Q2)



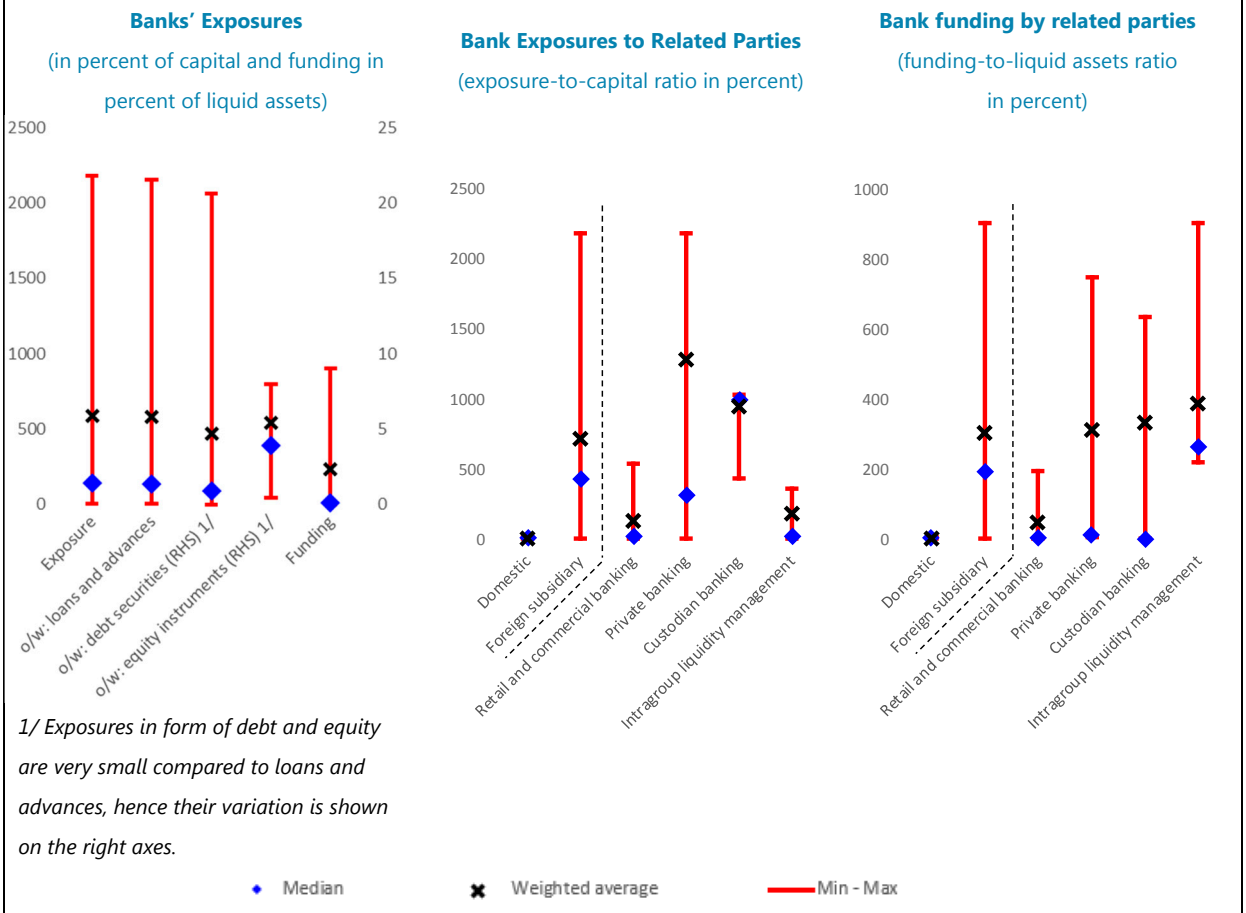
Sources: BCL.

Note. The coverage for this analysis include all banks, excluding foreign branches, in Luxembourg.

Cross-Border Bank and Fund Network Analysis

107. Balance sheet analysis of cross-border intragroup interconnectedness confirm that Luxembourg entities are highly exposed to their foreign parent groups (Figure 25). This is almost entirely in the form of loans and advances, with a weighted average exposure across banks of almost 6 times the subsidiary's capital compared to a maximum of 25 percent without the waiver. In terms of funding links, the weighted average exposure from parents is around 2.5 times liquid assets of the subsidiary. Custodian banks stand out with uniformly higher exposures to intragroup entities (the result of upstreaming deposits), while banks focused on intragroup liquidity management have by nature a uniformly higher share of intragroup funding.

Figure 25. Intragroup Exposures: Balance Sheet Metrics[2/]



1/ Exposures in form of debt and equity are very small compared to loans and advances, hence their variation is shown on the right axes.

Note: Retail and commercial banks are domestically-oriented while private, custodian (includes corporate finance banks), and intragroup liquidity management (includes covered bond banks) are internationally-oriented.

2/ This analysis relies on FINREP Related Parties template reported at the highest level of consolidation for each bank in the 16-bank sample.

108. The Espinosa-Vega and Sole (2000) model forms the main analytical basis for the assessment of intragroup bank exposures using supervisory data. The primary and most populated data source for this analysis is the COREP large exposure template which shows the

breakdown each bank's assets by counterparty.[35] On the liabilities side, this data was complemented by the limited information available through COREP template on Concentration of Funding by Counterparty (see Box 3).

Box 3. Implementation of Espinosa-Vega and Sole (2010) Network Model

- Contagion risk assessment relied on this methodology for the analysis of supervisory data on banks' large exposures and funding sources provided in a secure room at the ECB.

- For the domestic analysis, the initial data collection focused on the main 16-bank sample with the additional data on 12 insurance companies provided by CAA.

- For the cross-border analysis, the 16-bank sample was slightly expanded to incorporate three additional custodian banks and Clearstream Bank, Luxembourg. The large exposure data was complemented with the 10 largest counterparties who provide funding. The scope of the network is contained to the counterparties classified as credit institutions both in Luxembourg and abroad. Furthermore, in order to have a stronger understanding of intra-group exposures, all the single counterparty level data was aggregated to the level bank holding groups to the extent possible but excluding exposures to nonbanking clients within each group. The exposures vis-à-vis clients amounting to less than 100,000 euros were filtered out. After the aggregation and filtering, the final network dataset comprised: (i) the 20 Luxembourgish reporting banks; (ii) 8 additional smaller banks in Luxembourg (not part of the sample); (iii) 26 parent holding groups of the Luxemborguish banks; (iv) 104 other banks.

- Given limited resources to analyze underlying collateral for each counterparty, the data used focused on gross original exposures. Consequently, exposures included all off-balance contingent liabilities. At the same time all credit risk mitigation measures and all collateral, like cash deposits, financial assets or guarantees received were not taken into account leading to an overestimation of linkages and vulnerabilities. . At the same time, the exercise tested a wide range of loss-given-default ratios as a sensitivity check (see Box 4).

- The two main supervisory data sources are:

    1. COREP large exposure template shows the breakdown of each bank's assets by counterparty. A large exposure is defined as an exposure that is 10 percent or more of a bank's eligible capital base vis-à-vis a single borrower or a group of connected clients. For qualifying exposures vis-à-vis a group of connected clients, all exposures vis-à-vis each client in the group must be reported regardless of the 10 percent threshold. For the network analysis, a comprehensive dataset was built by combining the data reported by each bank in the sample. Due to the dataset size as well as the imperfect nature of the reported metadata, the biggest task involved reconciling all the counterparty level data into a standard form where the counterparties as reported by different banks could be matched and further filtering can be performed.

    2. COREP template on Concentration of Funding by Counterparty (C 67.00). In accordance with the CRR, banks collect and report the top ten largest counterparties either as a single creditor or a group of connected clients from which funding obtained exceeds a threshold of 1 percent of total liabilities. Completing the funding dataset was relatively less complex task as the data reported on the top ten largest counterparties by its nature is limited to a small number of counterparties and metadata reporting is of higher quality.

[35] See Capital Requirements Regulation (CRR) 575/2013 for details of the large exposures reporting.

109. The contagion risks arising due to the cross-border interlinkages were assessed using similar assumptions as the domestic network analysis with one exception. Rather than making one general parametric assumption, multiple simulations were tested by varying loss-given-default parameter (?) in the range between 5 and 100 percent as a sensitivity check (Box 4).

Box 4. Technical Summary of Espinosa-Vega and Sole (2010) Network Model

Essentially, the model looks at the domino effects of triggering the failure of an institution transmitted to the other banks in the network as credit and funding shocks. The data on interbank exposure and Tier 1 capital can be obtained from COREP templates.

To analyze the effects of a credit shock, the exercise simulates the individual default of each bank (with probability of default=1), for a given loss-given-default parameter (λ), where the counterparties' capitals absorb the losses on impact. Then, bank i is said to fail if its capital is insufficient to fully cover its losses due to bank h defaulting:

- that is if $k_i - \lambda x_{hi} < 0$, where x_{hi} stands for bank i loans to bank h and k_i stands for i's capital.

As for the funding shock, in this stylized exercise, it is assumed that banks are unable to replace all the funding previously granted by the defaulted bank, which, in turn, triggers a fire sale of assets. In this setup, bank i is able to replace only a fraction (1-ρ) of the lost funding from bank h, and its assets trade at a discount, so that bank i is forced to sell assets worth (1+δ) ρxih in book value terms, where xih stands for bank i borrowing from bank h. The funding shortfall induced loss, δρxih is absorbed by bank i's capital. Then, bank i is said to fail if its capital is insufficient to fully cover its loses plus the funding shortfall induced loss due to bank h defaulting:

- that is if $k_i - (\lambda x_{hi} + \delta\rho x_{ih}) < 0$.

In the subsequent rounds, if there are multiple failures, the losses need to be summed over.

In terms of results, this exercise generates four main outputs for each bank:

a) Induced failures: the number of following failures if bank i fails first.
b) Vulnerability level: sums the number of bank i's failures due to other banks failing
c) Index of contagion: averages the percentage of loss of other banks due to the failure of bank i:

$$\textit{Index of Contagion of Bank } i = 100 * \sum_{j \neq i} L_{ji}/K_j$$

where K_j is bank j's capital and L_{ji} is the loss to bank j due to the default of bank i.

d) Index of vulnerability: averages the percentage of loss of bank i due to the failure of all other banks.

$$\textit{Index of Vulnerability of Bank } i = 100 * \sum_{j \neq i} L_{ij}/K_i.$$

where K_i is bank i's capital and L_{ij} is the loss to bank i due to the default of bank j.

The baseline parameters used in this exercise are as follows: λ=0.4, ρ=0.35, δ=1, which means that loss-given-default is 40 percent, the fraction of funding lost is equal to 35 percent with a 50 percent discount rate on the assets that a bank may be forced to sell. This means if the initial funding is equal to EUR 1 billion, then the bank would lose EUR 350 million in capital. This can be described as a high-distress scenario to check the robustness of the banking system from the perspective of contagion risk. Since it is hard to estimate or calibrate these parameters based on actual data, a wide range of loss-given-default parameters (λ={0.05, 0.1, 0.2, 0.4, 0.6, 0.8, 1} were tested as a sensitivity check on the baseline simulation.

110. The banks that are in the sample provide a reasonable representation of the Luxembourgish banking system for the intragroup analysis. Their combined sum of large exposures amount to 362 billion euros, which compares to around 521 euros in total assets of the same banks. On the liabilities side, they receive a combined funding of 220 billion euros from their respective 10 largest counterparties, of which 162 billion euros are associated with credit institutions. Most of this bank-to-bank funding is related to intra-group entities with about 140 billion, followed by a distant 16 billion in unsecured wholesale funding from financial counterparties (compared to a combined 484 billion euros in total liabilities).

111. An unexpected increase in the defaulted share of cross-border claims through the failure of a parent group poses a threat to subsidiaries' capital position under the model. Based on data on gross original exposures before credit risk mitigation and under standard model assumptions, the most prominent pattern (see Figure 26a) emerging from this analysis is in line with large intra-group exposures.[36] Because these exposures are significantly large in relation to these banks' capital, six banks suffer losses in excess of their capital even with a low loss-given-default assumption of 5 percent. Seven additional banks face similar distress under higher but reasonable losses (loss-given-default range of up to 40 percent). Contagion may also derive from a non-parent foreign bank, one custodian bank (L3) particularly stands out as being strongly connected to a number foreign banks.

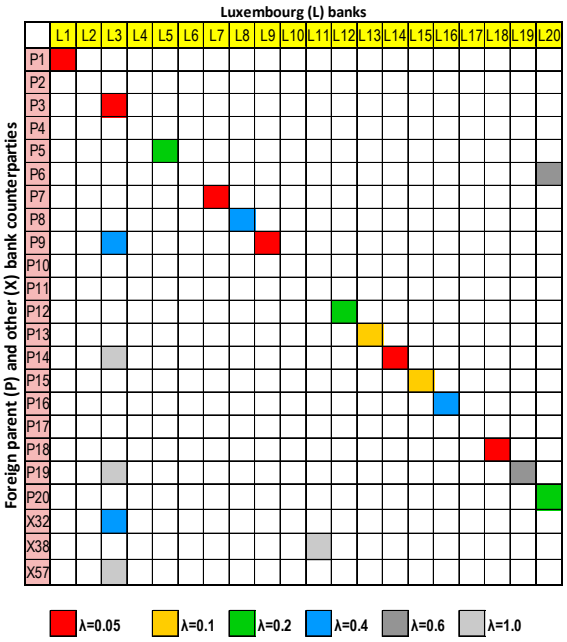
112. The right panels in Figure 26 illustrate the degree of vulnerability in the system and the degree of contagion to the system. Particularly, two banks average above 25 percent losses to their capital across independently triggered failures of all parents. On the flip side, the sources of contagion amongst the parents are highly concentrated on a couple of institutions, both causing losses to a few counterparties. The losses on these few counterparties represent more than 100 percent of their capital. The analysis further reveals the breakdown of vulnerability or contagion assessment by credit shock (using gross exposures and an LGD of 40 percent) and funding shocks (assuming that a given lost funding leads to a capital reductions of 35 percent) for each entity. It reveals that, for example, two-thirds of L3's losses can be attributed to credit shock. On the other hand, P14 induces losses to Luxembourg banks through credit and funding channels almost by equal amounts.

[36] These assumptions are as follows: loss-given default: 0.4; funding shortfall: 0.35; discount rate for asset firesale: 0.5. However, a wide range of loss-given-default parameters (λ={0.05, 0.1, 0.2, 0.4, 0.6, 0.8, 1} were tested as a sensitivity check on the baseline simulation. See Boxes 3 and 4 for details.

Figure 26. Cross-border Exposures: Network Analysis

a. Cross-border Vulnerability Matrix

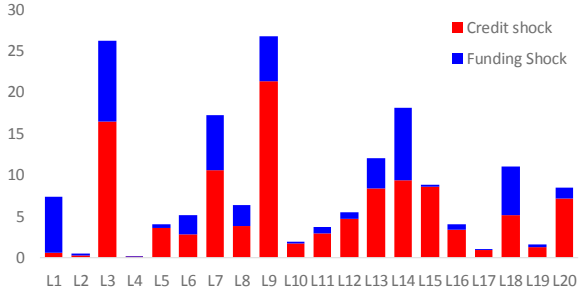
(Luxembourg subsidiaries' failures induced by foreign banks)



Note: Luxembourg banks are listed in the columns and their respective parents (P) and non-parent foreign banks (X) in the rows. Colors refer to the lowest λ at which failure occurs. Other parameters are set to ρ=35 percent (i.e. 35 percent loss given funding lost). Calculations based on gross exposure, i.e. including off-balance sheet contingent liabilities and excluding cash and other collateral received and without other credit risk mitigation measures.

b. Vulnerability Index

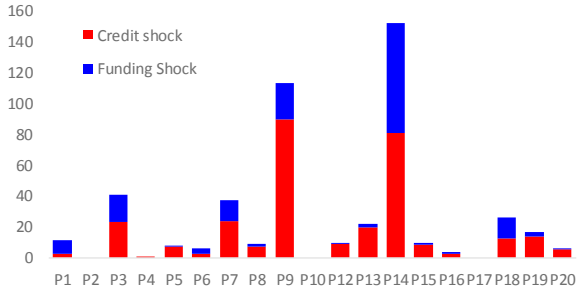
(average loss in percentage of capital)



Note: For example, Bank 3 suffers an average hit to capital of around 25 percent across individually triggered failures of all parent entities. Parameters used: Λ=40 percent (loss given default); ρ=35 percent (i.e. 35 percent loss given funding lost). Calculations based on gross exposure, i.e. including off-balance sheet contingent liabilities and excluding cash and other collateral received and without other credit risk mitigation measures.

c. Contagion Index

(average induced loss on others)

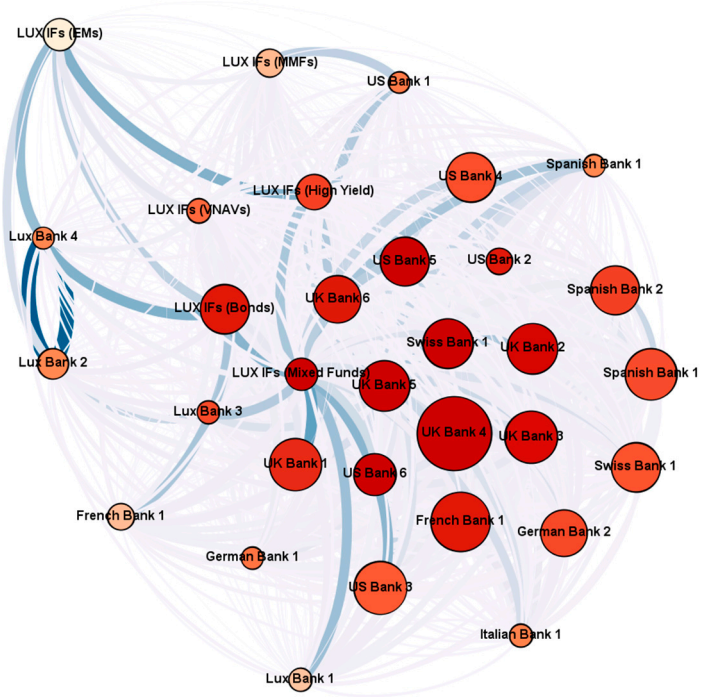


Note: For example, the failure of Parent of Bank 9 results in the average losses to the other 16 entities of above 100 percent of their capital. Parameters used: Λ=40 percent (loss given default); ρ=35 percent (i.e. 35 percent loss given funding lost). Calculations based on gross exposure, i.e. including off-balance sheet contingent liabilities and excluding cash and other collateral received and without other credit risk mitigation measures.

113. Market-based network analysis suggests strong interconnectivity across Luxembourg investment funds and global banks. This is particularly so for mixed, bond and HY funds, where market data shows strong connections to non-domestically located US and UK banks as indicated by the dark blue connections (Figure 27). Their central location in the network and color (red/orange) also indicated that these funds are strongly interconnected and central to this network

of entities. Luxembourg EM and MMF funds, on the contrary, appear to be relatively independent form the network as indicated by their outside location. Since this network was estimated over 2011–April 2016, relying on return data to include investment funds, the outside location of EM funds likely reflects their better return performance during the sovereign debt crisis.

Figure 27. Global Network Based on Market Data (2011–2016) 1/



Source: Datastream and Bloomberg for bank data and Luxemburg authorities for investment fund data.
1/ Edge thickness shows the strength of the pairwise relationship between entities i.e. the 12-month forecast error variance of entity *i* due to shocks from entity *j*. Underlying error-variance decomposition matrix was calculated using probability of distress data (PoD). PoDs for Luxembourg banks were derived using bond spreads. For investment funds, PoDs were derived using returns based on marked-to-market assets data. Credit default swap spreads were used to derive PoDs for global banks. Node size indicates total asset size color of nodes indicates "total connectedness to other entities" which is equal to the sum of the pairwise connections to all other institutions in the sample; increased intensity of red reflects higher degree of connectivity to others entities. Node location is derived using ForceAtlas2 algorithm in which nodes (size) repel each other, but strength of edges (connection) is attracting the nodes to each other.
2/ There are four Luxembourg banks in the sample, indicated as LUX Bank 1 to 4.

Box 5. Technical Summary of Market Based Models

The methodology based on Segoviano and Goodhart (2009) and Diebold and Yilmaz (2014) allows for a broader assessment of systemic risk and interconnections between banks and nonbanks using market data:

- In **Segoviano and Goodhart's (2009)** framework the financial system is conceptualized as a portfolio of financial entities (FEs) spanning different sectors. A structural approach (SA) for modeling portfolio risk[1] is used to derive probabilities of distress (PoD) for each entity.[2] Making use of the Consistent Information Multivariate Density Optimization (CIMDO) methodology and taking the individual estimated PoDs as inputs, a portfolio multivariate density (PMD) describing the joint likelihood of distress of all FEs in the system can be recovered. The PMD and simulated systemic loss distribution allow for the computation of several informative measures of systemic risk and interconnectedness.

- The methodology based on **Diebold and Yilmaz (2014)** starts out by first estimating a Vector Autoregression (VAR) model with market data. The interconnectedness measure is then derived from the Generalized Variance Decomposition (Pesaran and Shin, 1998) of the underlying VAR. This approach derives a set of pair-wise directional connectedness measure between FEs, based on the Generalized Variance Decompositions which can be used to visualize a network.

The application of both methods is limited in Luxembourg as most of the 16 banks in the sample don't list equities due to their status as subsidiaries. In Luxembourg, four banks with bond yield information were identified for the network analysis (Figure 29, left panel). From their bond yield information, bond spreads using the euro area risk free rate were derived. If available, Credit Default Swap (CDS) data was preferred over bond spread information for the derivation of PoDs. However, a comparison of bond spread movements with CDS data for the parent banks of the subsidiaries (Figure 29, right panel) shows that spreads tend to move closely with CDS, confirming their suitability as second best approximation for this analysis.

In order to integrate investment funds into the systemic risk analysis, a new approach was applied. Including investment funds into the systemic risk analysis is not straightforward as investment funds are not subject to solvency risks per se since losses are fully borne by asset owners, not the institutions themselves. Thus, for investment funds Probabilities of Distress were derived by linking investment funds' returns to their potential outflows (i.e. redemption risk). The idea is that whenever investment funds experience strong outflows (exceeding their cash holdings) they are likely to sell their assets to meet these redemption demands, putting them as well as others in a position of distress because then cash holdings are not enough to cover outflows. If investment funds are forced to sell their assets this could have a market impact, thereby indirectly affecting other institutions holding the same assets, and potentially leading to systemic risk through fire sales.

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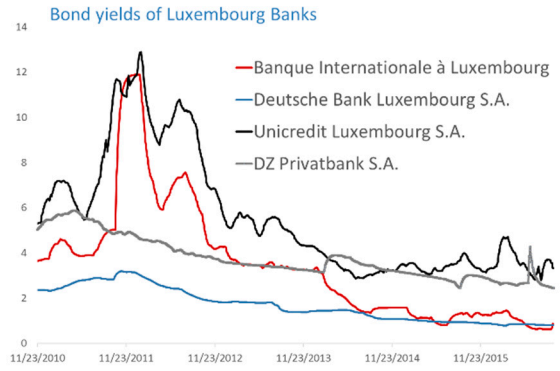
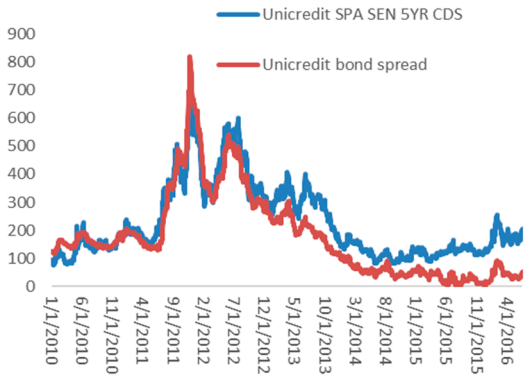
[1] The SA is normally used to measure credit risk in portfolios of loans. In contrast, in this exercise the SA is used to measure risk in a portfolio of FEs across sectors. Widely known applications of the structural approach include the Credit Metrics framework (Gupton et al., 1997) and the KMV framework (Crosbie et al., 1998).

[2] Under the SA, a change in the value of a borrower's assets is related to the change in its credit risk quality. The basic premise of the SA is that a borrowing entity's underlying asset value evolves stochastically over time and distress is triggered by a drop in the firm's asset value below a threshold value (distress/default region), the latter being modeled as a function of the FE's financial structure. Thus, it follows that the likelihood of the entity's asset value falling below the distress threshold is represented by the PoD of the entity.

Box 5. Technical Summary of Market Based Models (continued)

Banks' Bond Yield Information and a Comparison of CDS and Bond Spreads of Parent Companies





Sources: Thomson Reuters Datastream, Bloomberg, and IMF staff calculations.

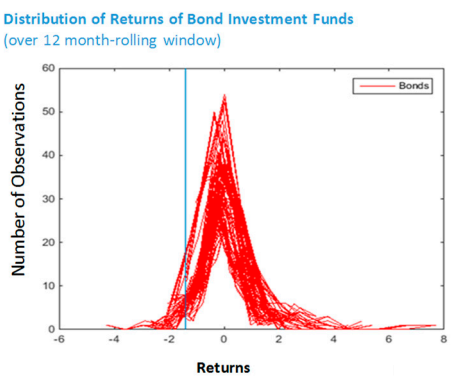
Balance sheet information provided by the authorities enabled the implementation of the new approach where PoDs are derived by connecting redemption risk to investment funds return performance. The Luxembourg authorities provided fund by fund data for different classes of investment funds such as bonds, emerging markets (EM), high yields (HY), mixed funds (MF), variable net asset value (VNAV), constant net asset value (CNAV) and money market funds (MMF).[1] To derive the PoDs for investment funds, returns were estimated using monthly mark-to-market asset data (i.e. total net assets; TNA). TNA's were adjusted by monthly redemptions and subscriptions to receive the "pure" market return caused only by changes in prices. Over a 12-month rolling window, the number of times returns fell under a specific threshold were summed-up and divided by the number of observations to get the probability of distress (see Figure 30, left panel). Since there is no guidance on which threshold to use, PoDs were derived using several thresholds, starting with the mean of the distribution of overall returns (not the rolling window). PoDs were most sensible when using the 5th percentile of the overall distribution of returns as a threshold which is also comparable to the percentile threshold used in Basel III regulation. For VNAVs, however, this threshold was deemed too low (likely due to the low number of funds in this sample; only seven). Thus, the 8th percentile of the overall distribution, was used for this type of funds. The PoDs derived from this approach appear reasonable; reflecting the increased risk during the global financial crisis and European debt crisis properly (Figure 30, right panel).

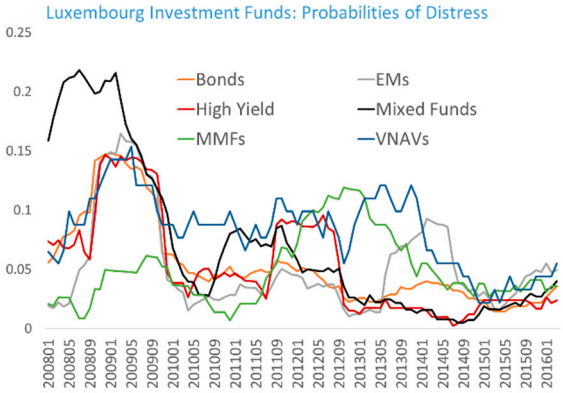
PoDs of banks and investment funds were combined to analyze possible interlinkages. Since PoDs are exogenous to Segoviano's model, they can be derived from different sources allowing the inclusion of PoDs derived from bond spreads (see Hull et al. 2005) using the risk-free rate, divided by 0.6 to get the risk-neutral rate (for banks), credit default spreads for global banks and balance sheet information (for investment funds).

[1] CNAVs could not be included into the exercise as the number of data points was too low.

Box 5. Technical Summary of Market Based Models (concluded)

Derivation of Probability of Distress for Investment Funds





Source: Luxembourg authorities and IMF staff calculations

CONCLUSION

114. An assessment of the capacity of the financial system to withstand severe but plausible shocks suggests a good deal of resilience at the aggregate level, despite higher vulnerabilities at some banks. High starting levels of system-wide capital allow most banks to absorb a large shock under the adverse scenario and retain substantial buffers. Bank liquidity displays broad resilience, but would be weakened should wholesale funding dry up. Solvency stress tests for insurers conducted by the authorities indicate that high starting levels of capital allow life insurers to absorb large market shocks while maintaining adequate capital buffers. Liquidity and solvency risk for money market funds appears muted, while liquidity and concentration risk suggests continued monitoring in the case of select bond funds is appropriate. Luxembourg banks are not interconnected at the domestic level, but quantitative analysis confirms significant intra-group exposures at the cross-border level, pointing to the need for ongoing vigilance. Network analysis also reveals interconnectivity between investment funds and domestic and global banks.

115. A number of recommendations follow. Liquidity monitoring should be strengthened by performing liquidity stress tests, extend the maturity of wholesale funding, implement the FX LCR at the group level and work together with the EBA to close liquidity reporting gaps and expand the harmonized EU bank reporting.

116. A number of recommendations follow from the analysis of investment fund vulnerabilities. These include: providing industry guidance on liquidity stress tests for funds investing in less liquid asset classes (including on frequency and possibly the use of a common

scenario/approach to ensure comparability across funds); enhanced monitoring of concentration risk; an assessment of the effectiveness of liquidity management tools; and further analysis on the vulnerabilities posed by interlinkages between investment funds and banks.

117. A few recommendations follow from the analysis of contagion risks. The ECB needs to work closely with other European countries and agencies on closing data gaps on cross-border bilateral exposures. Currently, data on bank-level cross-border asset positions vis-à-vis counterparties are available to the authorities. But, the information on bilateral cross-border liability positions is still limited to the ten largest funding sources. Furthermore, the maturity information on large exposures is limited for short-term exposures. Future data collection enhancements will help the monitoring of systemic risk related to cross-border and cross-sectoral linkages.

Appendix I. Luxembourg: Risk Assessment Matrix

Source of risks	Relative likelihood and transmission channels	Impact if realized
Sharp rise in financial market risk premia and renewed Euro area recession.	**Medium** Cross-border financial intermediation would contract abruptly, increasing the risk that liquidity 'upstreamed' from Luxembourg bank subsidiaries to parents abroad could be trapped. An unexpectedly large and synchronized redemption shock experienced by investment funds could result in asset fire sales in international markets and a drawdown of local bank deposits. A shock to international financial markets could also result in operational stresses at Clearstream (CBL), leave international financial market participants unable to access or trade some or all of the securities held in CBL.	**High** The internationally-oriented financial industry could encounter liquidity stress and experience a substantial hit to profitability should the shock be sustained, thus leading to reduced employment, economic activity and fiscal revenues in Luxembourg.
Protracted uncertainty associated with political fragmentation in advanced economies, including uncertainty associated with post-Brexit arrangements, and the rising threat of protectionism and economic isolationism in Europe and the United States.	**Medium** Protectionism and economic isolationism would detrimentally impact the trade and financial flows that contribute to the openness of the Luxembourg economy. The new Brexit arrangements could lessen London's appeal as a financial center, as UK-based banks and investment funds could lose their "passporting" rights to the rest of the EU. Luxembourg's investment funds have large exposures to US capital markets.	**Medium** A negative outcome from upcoming elections would have substantial effects on financial flows and economic confidence. Luxembourg's small open economy and internationally-oriented financial system mean that it will be adversely impacted by any interruption to the free movement of capital and services. However, the departure of the UK from the EU may also result in some financial activity relocating to Luxembourg.

Downturn in Luxembourg's residential housing market following a substantial earlier increase in valuations, easing in mortgage lending standards and increase in household indebtedness.	**Medium** Domestically-oriented banks are the principal mortgage originators in Luxembourg and thus would be most exposed to an increase in non-performing mortgages and possible hit to bank capital. Household net worth would also decline, impacting consumption.	**Medium** A hit to profitability and possibly capital at domestically-oriented banks could trigger a tightening in domestic lending conditions. A capital shortfall in a domestically-oriented bank in which the state holds a key ownership stake could see the realization of a contingent liability for the government. Negative wealth effects in the household sector could result in a second-round impact on the economy.
Structural outflows from the financial system initiated by an adverse hit to bank and investment fund operating conditions. Institutions struggle to adapt to rising regulatory demands (including changes to international taxation rules and standards for cross border activities) and innovative technologies (including Fintech).	**Medium** A prolonged period of problematic operating business conditions for Luxembourg's banks and investment funds could result in a shrinkage in financial system assets. A large share of fiscal revenues also depends on cross border operations.	**High** One quarter of Luxembourg's GDP is directly generated by the financial sector, with additional contributions from ancillary professions (law, technology, etc.). An important component of the tax base could also be eroded.

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. Luxembourg: Stress Test Matrix (STEM) for the Banking Sector: Solvency, Liquidity, and Contagion Risks

Domain		Assumptions
		Top-down by FSAP Team
Banking Sector: Solvency Risk		
1. Institutional Perimeter	Institutions included	• 16 banks
	Market share	• 73 percent of the banking sector's assets • 94 percent of residential mortgage loans • 68 percent of exposures to foreign banks
	Data and baseline date	• Publically-available and supervisory data • Baseline date: June 2016 • Bank consolidated level data for banks having their headquarters in Luxembourg and sub-consolidated level data for the subsidiaries of foreign banks • Market-data
2. Channels of Risk Propagation	Methodology	• Satellite models developed by the FSAP team • Balance sheet-based approach • Market data-based approaches
	Satellite models for macro-financial linkages	• 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 projected based on assumptions on investment funds' business volume and redemptions
	Stress test horizon	• 3-years (2017–2019)
3. Tail shocks	Scenario analysis	• The TD exercise was based on a baseline macroeconomic scenario and an adverse scenario, assessing the impact on the entire portfolio including the loans and the trading book. • The TD analysis covered three main sources of risk: domestic real estate, exposures to parent companies and investment funds and sovereign risks. • Variables in the scenarios included domestic macrofinancial variables (e.g., GDP, inflation, unemployment, growth in investment fund assets), and GDP for key trading partners, interest rates, exchange rates and real estate prices. • In the adverse scenario, the GDP growth rate declines to -3.7, -2.6 and +1.8 percent, in 2017, 2018 and 2019 respectively. • The output gap would be similar to the one experienced during the last financial crisis. A set of market shocks, including large and sudden changes in interest rates and exchange rates, is calibrated to magnitudes close to those observed in 2008/2009.

Domain		Assumptions
		Top-down by FSAP Team
	Sensitivity analysis	• Sensitivity analyses was conducted in the TD exercises, evaluating *domestic* shocks. • In particular, the analysis evaluated households' balance sheet sensitivity to macroeconomic shocks, including increases in borrowing costs, declines in income and in residential house prices, rising unemployment rates, and a combination of these shocks. Direct effects of interest rate shocks; direct effects of exchange rate shocks; a decline in the prices of sovereign bonds; and failure of the largest to 10 largest corporate exposures were estimated as well.
4.Risks and Buffers	Risks/ factors assessed	• Credit risk on the banking book and trading book; • Market risk and bond losses: direct effects of interest rate shocks; direct effects of exchange rate shocks; shocks to sovereign bond yields.
	Behavioral adjustments	• 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	• Through the cycle and 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 Authorities and FSAP team jointly
1. Institutional Perimeter	Institutions included	• 16 banks for the LCR analysis and eight for the NSFR and cash-flow analysis
	Market share	• 45 to 73 percent of banking sector's assets
	Data and baseline date	• Latest data: September 2016 for LCR and June 2016 • for NSFR and cash flow analysis • Source: supervisory data • Scope of consolidation: perimeter of individual banks
2. Channels of Risk Propagation	Methodology	• Basel III-LCR and NSFR type proxies • Cash-flow based liquidity stress test using maturity buckets by banks • Liquidity test in foreign currencies
3. Risks and Buffers	Risks	• Funding liquidity (liquidity outflows) • Market liquidity (price shocks)

Domain		Assumptions
		Top-down by FSAP Team
	Buffers	• Counterbalancing capacity • Central bank facilities
4. Tail shocks	Size of the shock	• Run-off rates calculated following historical events, or IMF expert judgment and LCR/NSFR rates • Bank run and dry up of wholesale funding markets, taking into account haircuts to liquid assets
5. Regulatory and Market-Based Standards and Parameters	Regulatory standards	• Basel III standards (revision as of January 2013). See Committee on Banking Supervision (2013), "Basel III: The Liquidity Coverage Ratio and liquidity monitoring tools," Basel, January 2013 • European Commission Delegated Act
6. Reporting Format for Results	Output presentation	• 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	• 16 banks • 12 insurance companies • 5 investment fund groups covering 75 percent of the total net assets for HY, EM bond funds, VNAVs and MMFs; 54 percent for mixed funds; 32 percent for bond funds
	Market share	• 73 percent of total banking system assets
	Data and baseline date	• Latest data: June 2016 • Source: supervisory and market data • Scope of consolidation: perimeter of individual institutions or sectoral indexes • Possible use of indexes
2. Channels of Risk Propagation	Methodology	• Balance sheet and off balance sheet based financial metrics • Network interbank model by Espinosa-Vega and Solé (2010) • Diebold-Yilmaz variance decomposition connectedness methodology • CIMDO/SyRIN approach (Goodhart and Segoviano, 2009)
3. Tail shocks	Size of the shock	• Pure contagion: default of institutions • Spillover index and transmission
4. Reporting Format for Results	Output presentation	• Number of undercapitalized and failed institutions, and their shares of assets in the system • Evolution and direction of spillovers within the network
Investment Funds: Liquidity Risk		
Domain		Top-Down by FSAP team
1. Institutional Perimeter	Institutions included	• 191 investment funds: 42 EM bond funds; 32 HY bond funds; 40 mixed funds (investing at least 70 percent of their assets into fixed income instruments); 50 largest bond funds; 5 CNAVs short term MMFs (3 of which are in USD, 1 in EUR, 1 in GBP); 7 VNAV short term MMFs, 15 MMFs

Domain		Assumptions
		Top-down by FSAP Team
	Market share	• 75 percent of the total net assets for HY, EM bond funds, CNAVs, VNAVs, and MMFs • 54 percent for mixed funds • 32 percent for bond funds
	Data and baseline date	• Latest data: March 2016 • Source: supervisory data
2. Channels of Risk Propagation	Methodology	• Liquidity measures by i) cash and short-term debt securities (residual maturity less than one year) and ii) cash and high quality liquid assets
3. Risks and Buffers	Risks	• Funding liquidity (liquidity outflows) and inability to sell assets to cope with redemptions
	Buffers	• Liquidity buffers • Credit facilities and Liquidity Management Tools
4. Tail shocks	Size of the shock	• Monthly Redemption shock equal to the 1th percentile of historical net flows observed over 2007–2016 • Redemption shock estimated from an econometric model relating funds flows to macrofinancial variables (including the ones used in the bank macroeconomic scenario)
5. Regulatory and Market-Based Standards and Parameters	Regulatory standards	• European Commission Directive 2010/43/EU Article 45(3): • "*Where appropriate, management companies shall conduct stress tests which enable the assessment of the liquidity risk of the UCITS under exceptional circumstances*"
6. Reporting Format for Results	Output presentation	• Redemption coverage ratio by investment fund and liquidity shortfall • Number of funds and share of funds that cannot meet their obligations
Investment Funds: Solvency Risk		
Domain		Top-Down by FSAP team
1. Institutional Perimeter	Institutions included	• 5 CNAVs short term MMFs
	Market share	• 75 percent of the total net assets for short term CNAVs MMFs
	Data and baseline date	• Latest data: March 2016 • Source: supervisory data
2. Channels of Risk Propagation	Methodology	• Increase in risk free rates and credit spreads that would result in deviations between shadow Net Asset Value (NAV) and Constant Net Asset Value
3. Risks and Buffers	Risks	• Inability to maintain Constant NAV
	Buffers	• Liquidity buffers • High credit quality and short duration assets

Domain		Assumptions
		Top-down by FSAP Team
4. Tail shocks	Size of the shock	• Sensitivity analysis with shocks to risk free rates and credit spreads ranging from 10 to 200 basis points.
5. Regulatory and Market-Based Standards and Parameters	Regulatory standards	• According to the IMMFA Code of Practice, drat MMF Regulation and the Ireland FSAP analysis, escalation procedures should exist for deviation between the published price and the shadow NAV above 20 basis points.
6. Reporting Format for Results	Output presentation	• Deviations between constant NAV and shadow NAV • Number of funds and share of funds that can still meet their obligations
Insurance Sector: Solvency Risk		
Domain		Bottom-up by Authorities (CAA)
		• Bottom-up by companies under the guidance and supervision of the Luxembourg authorities
1. Institutional Perimeter	Institutions included	• 10 life insurance companies and one re-insurer
	Market share	• 71.5 percent of the Luxembourg insurance market in terms of gross life technical provisions
	Data and baseline date	• Supervisory data • Baseline date: June 2016
2. Channels of Risk Propagation	Methodology	• Analysis was based on Solvency II requirements using the infrastructure developed by the Luxembourg Commission aux Assurances and/or the EIOPA
	Stress test horizon	• 2017–2019
3. Tail shocks	Scenario analysis	• Macro scenarios included a baseline and an adverse scenario in line with the banking sector stress test
4.Risks and Buffers	Risks/ factors assessed	• Credit risk and market risk
5. Reporting Format for Results	Output presentation	• Three-year projections of undertakings' available own funds • The coverage of the solvency capital requirement (SCR) • Capital adequacy ratios with and without the "long-term guarantee package"

Appendix III. Technical Details on the Stress Test Adverse Scenario Calibration[1]

The stress scenario provides the rationale for the econometric analysis. Luxembourg, as a small open economy within the EU, is best modeled on the basis of a two-country framework with domestic (endogenous) and external (exogenous) variables. In addition, a few domestic variables (interest rates, investment fund flows) that serve to transmit shocks to the economy are treated as exogenous in the model. The scope of the Global Macro-Financial Model (GMF) was relevant in determining which variables should enter the model as exogenous and which variables need to be estimated by the FSAP team. The details of the econometric analysis are outlined below.

A3.1. VARIABLES

Endogenous Variables (All Domestic Luxembourg)

i. Real GDP (GDPLUX)
ii. Consumer price index (CPILUX)
iii. Unemployment rate (UNRLUX)
iv. Real house price index (RHPILUX)

Exogenous Variables (External and Domestic)

i. Real euro-area GDP (GDPEA)
ii. Euribor (3-month) rate (EURIBOR)
iii. VIX index (VIX)
iv. Luxembourg long-term (10-yr) interest rate (LTRLUX)
v. Luxembourg investment funds' total assets (IFALUX)

[1] Ongoing data verification will determine the details of the stress testing.

Table A3.1. Luxembourg: Description of Variables

	Variable	Historical	Baseline	Adverse	Transformation	Conversion
Endogenous	GDPLUX	WEO	WEO	BVAR	Log-difference	Sum
	CPILUX	WEO	WEO	BVAR	Log-difference	Average
	UNRLUX	WEO	WEO	BVAR + adjustment	Difference	Average
	RHPILUX	BCL	ARIMA	BVAR + adjustment	Log-difference	Average
Exogenous	GDPEA	WEO	WEO	GMF	Log-difference	Sum
	EURIBOR	WEO	WEO	GMF	Difference	Average
	VIX	Haver	ARIMA	Max historical shock + ARIMA	Log-difference	Average
	LTRLUX	WEO	WEO	GMF	Difference	Average
	IFALUX	BCL	ARIMA	Max historical shock + ARIMA	Log-difference	Last

- The historical figures and baseline projections reflect the published October 2016 WEO.

A3.2. TIMEFRAME

a) Frequency: Quarterly

Quarterly frequency was chosen to calibrate the macro scenario to ensure a sufficient number of observations.

b) Estimation Period: 1996Q1-2016Q2

The estimation period is constrained by the availability of historical data, particularly, the availability of the series with the shortest historical coverage: the total assets of the investment fund industry, which is available from 1995 onwards. Since all variables enter the model as year-on-year differences, the estimation period starts with 1996Q1 and ends with 2016Q2, the quarter for which the latest actual data was available.

c) Timing of Shocks: 2017Q1 Onwards

The timing of the shocks is determined by the assumptions underlying the GMF simulation results. GMF's exogenous variables are hit with shocks during 2017Q1–2018Q4, which causes the endogenous variables in that model to peak between 2017Q4 and 2018Q4. In the Luxembourg-specific macro model, the largest shocks are front-loaded in the first year of the stress horizon and then gradually phased out.

d) Forecast Period: 2017Q1–2019Q4

The forecast period matches the stress scenario period. Dynamic forecasting is used to generate adverse scenario projections. The forecast calculations beginning at 2017Q1 take as inputs contemporaneous and lagged values of exogenous variables and lagged values of endogenous variables. At 2017Q2, the calculation uses model-generated 2017Q1 values of endogenous variables

and prior lags. The calculation incorporates more and more model-generated values of endogenous variables with every new quarter in the horizon.

A3.3. SCENARIOS

a) Baseline Scenario

The baseline scenario has two main purposes in this exercise: (i) to serve as a shock-free comparator to the adverse scenario from which the deviations are calculated for the endogenous variables; and (ii) to serve as a base to build on periodic shocks for the exogenous variables. Hence, it is important to have a methodological approach to estimating baseline projections.

In this context, the published WEO projections are the primary data source for the baseline scenario. When WEO projections are available only at annual frequency, quarterly series were interpolated. For variables outside the WEO coverage, Automatic ARIMA Forecasting was used to generate their projections.[2]

b) Adverse Scenario

Two models were used for the adverse scenario with further adjustments on a few variables for conservatism.
Global Macro-Financial Model (GMF)

The GMF is a structural macro-econometric model of the world economy, disaggregated into forty national economies, as documented in Vitek (2015).[3] It was developed by an IMF team and builds on the IMF G-RAM. Its projections were driven by the following factors: a rise in risk aversion affecting the European vulnerable/large spread countries, adverse investment sentiment, and a sharp slowdown in emerging market economies. This model was used within the context of the Luxembourg FSAP for the external assumptions and the projections related to countries other than Luxembourg. Luxembourg is not included in the list of forty economies embedded in the model, which is one of the reasons the FSAP team had to develop a macro model to forecast Luxembourg variables in an adverse scenario.

Luxembourg Macro Model with further adjustments

The FSAP team developed a model for the projections of Luxembourg domestic variables and applied expert judgement. The design of the model took into account Luxembourg's status as a small open economy, the strong links between the banking sector and the investment fund industry, and specific risks stemming from the real estate market in particular. To that end, the FSAP team

[2] EViews' Automatic ARIMA Forecasting allows the user to efficiently and objectively determine an appropriate ARIMA specification and use it to forecast the series into the future. This method selects the best transformation, level of differencing and the order of the ARMA terms based on information criteria.

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

estimated a Bayesian VAR (with Minnesota prior) with quarterly data on year-on-year differences since 1996. The model can be written in the general form:

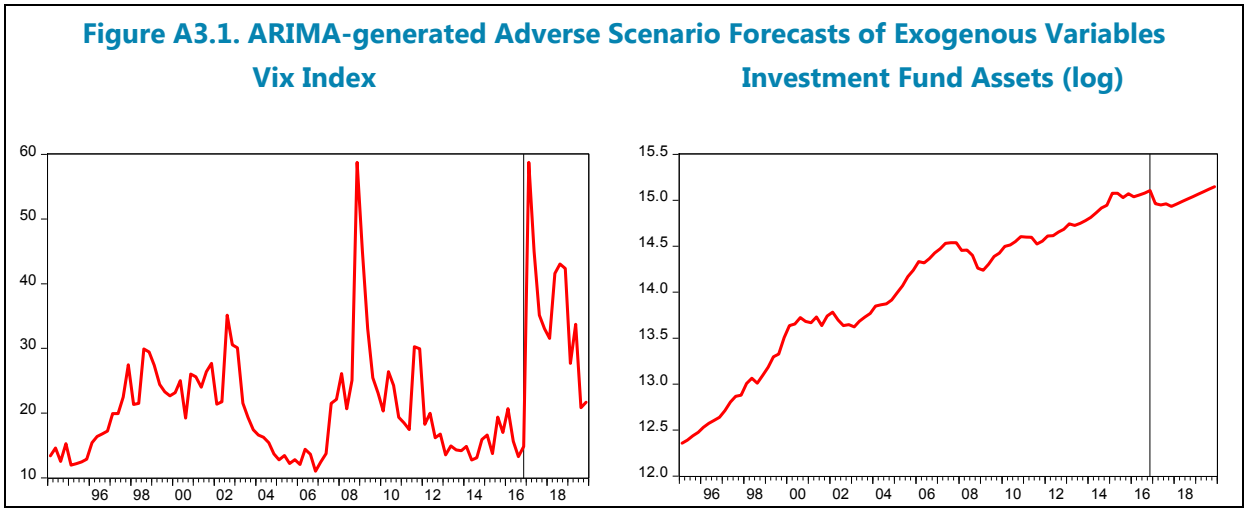
$$Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + B_3 Y_{t-3} + B_4 X_t + B_5 X_{t-1} + B_6 X_{t-2} + B_7 X_{t-3} + u_t$$

where,

$$Y_t = \begin{bmatrix} \Delta_{yoy} \ln(GDPLUX_t) \\ \Delta_{yoy} \ln(CPILUX_t) \\ \Delta_{yoy} (UNRLUX_t) \\ \Delta_{yoy} \ln(RHPILUX_t) \end{bmatrix} \quad \text{and} \quad X_t = \begin{bmatrix} \Delta_{yoy} \ln(GDPEA_t) \\ \Delta_{yoy} EURIBOR_t \\ \Delta_{yoy} \ln(VIX_t) \\ \Delta_{yoy} LTRLUX_t \\ \Delta_{yoy} \ln(IFALUX_t) \end{bmatrix}$$

As shown above, the exogenous variables enter the model contemporaneously and with three lags along with three lags of the endogenous variables. Once the coefficients are estimated based on historical data, they can be used to dynamically forecast future values of the endogenous variables, where the only additional input needed is the contemporaneous values of exogenous variables at each quarter. These inputs are taken from the GMF model for the following variables: euro area GDP growth, Euribor and the Luxembourg long-term interest rate. The shock to Luxembourg interest rates has been aligned with those of the vulnerable (euro area periphery) countries in the GMF model as an extreme sovereign stress was assumed. The projections of the investment funds' asset growth were done exogenously. For this variable, the worst historical quarterly decline was applied on the first quarter of the stress period, with the remaining period forecasted with an ARIMA model. The resulting pattern was a cumulative drop of 15 percent over the first year followed by a gradual normalization during the last two years of the projection period. Likewise, the projection of the VIX index was estimated by applying the 4 highest quarterly values of the index over the first four quarters of the stress period, with the remaining period forecasted with an ARIMA model. This resulted in almost full reversal to pre-stress levels of VIX by the end of the projection period.

Figure A3.1. ARIMA-generated Adverse Scenario Forecasts of Exogenous Variables



The outcome of the models comprises deviations from the baseline and the projections for adverse growth/variables in the stress scenario. The projected path of the Luxembourg GDP growth was found to be adequately severe with an average real GDP growth of -1.5 percent per annum over 2016–2018 (-3.7 percent in the first year, -2.6 percent in the second, and +1.8 percent in the third year). The cumulative decline of GDP relative to the baseline over three years would be about 14.7 percentage points, equivalent to a 2 standard deviation shock in terms of Luxembourg 3-year GDP growth taking the 1980–2015 period as the benchmark for GDP growth. The output gap would be similar to the one experienced during the last financial crisis.

The FSAP team made some further adjustments for conservatism. In particular, the unemployment rate was assumed to start rising sharply and to peak at 11 percent of the labor force during the second year of the scenario. This corresponds to a 2 standard deviation shock to the annual change in the unemployment rate in Luxembourg, taking the 1980-2015 period as a benchmark, with an additional assumption of a 10 percent decline in the employment in the financial sector and support services. Moreover, this is consistent with the weight of the financial sector and associated services in the Luxembourg economy, which make up 25 percent of the country's value added and more than 10 percent of (direct) total employment.

House prices were assumed to decline by 30 percent in cumulative terms over the 3-year stress horizon, a decline bringing house prices back to their 2008 level. Such a drop would be in line with international experience, especially the experience of financial centers (Hong Kong, Singapore),[4] and is comparable to assumptions made in recent European country FSAPs. The 3-year projections were mainly based on demand factors and a shift in price expectations as supply factors (demographic growth, supply constraints) were deemed to have long-term effects only. Moreover, developing a comprehensive model to estimate a long-term relationship in the Luxembourg real estate market (such as a vector error correction mechanism) exceeded the scope of this exercise.

A3.4. ROBUSTNESS CHECKS

In the process of determining the best specification for Luxembourg, many iterations of the macro model were tested. These include a number of additional variables as well as different parametric assumptions.

- **Additional variables:** Based on an assessment of small open economies, particularly in the European context, the variables listed below were added on an individual basis or in combination: commodity prices (energy, non-energy and a joint index); EU-wide consumer price index; Luxembourg credit to non-financial corporates; exchange rates (bilateral, nominal and real effective); and real wages in Luxembourg. These estimations were not pursued further as they either lead to erratic forecast patterns or were counterintuitive to accepted economic notions.

[4] A comparison with other financial centers shows that the largest peak-to-trough declines in Hong Kong and Singapore real estate over the past two decades were -65 percent and -55 percent respectively in nominal terms during the late-1990s Asian crisis, and -20 percent and -25 percent respectively during the 2008/2009 global financial crisis. Ireland experienced a 50 percent decline in residential property prices between 2007 and 2013.

- **Finally, corporate credit spreads were projected based on the global financial crisis experience.** To that end, a synthetic corporate cash bond spread series was constructed based on actual realized outcomes, as per the following:
    - Country weights adhered to the asset share used elsewhere in the stress testing exercise, resulting in a weighting of EUR spreads of 83.5%, and hence 16.5% for US corporate spreads;
    - A 95% weight was assumed for Investment Grade corporate spreads, and 5% for high yield, in line with the average share of unrated bonds in Luxembourg banks' corporate bond portfolio;
    - All spread data were based on the cash bond spread data compiled by Merrill Lynch/Bank of America;
    - The reference period spanned from the start of the financial crisis, i.e. end-Q2 2007 until the peak of the crisis in Q4-08. The single largest annual spread shock with this method (year 1) reaches 119 bps.

This approach ensured consistency with:

- the underlying macroeconomic scenario, characterized by two years of recession in the euro area, followed by a partial recovery in the third year;
- the actual corporate bond spread developments in Europe (and the US) experienced over the Q2-2007 to Q2-2010 period.

Appendix IV. Methodological Assumptions for Banks' Balance Sheet and Profit Projections

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.[1] 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 and exposures at default (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.* For the nine banks in our sample operating under the Basel II Internal Rating-Based approach, risk weights were projected using the corresponding Basel II formula for credit risk whereby the capital requirement ratio depends on the value of probability of default (PD), loss given default (LGD) and asset correlation. This means that risk weights should typically rise in a stress scenario. For the remaining seven banks operating under the Basel II standardized approach, RWAs were projected based on the new defaulted loan projections and reduced in proportion to the new provisions, after the application of provisioning rate assumptions.[2] Indeed, past due loans are projected to increase under the adverse scenario. The Basel II framework under the standardized approach provides that past due loans must be risk-weighted with a risk-weight comprised between 100 and 150 percent for the unsecured portion of the loan, i.e. net of specific provisions. In line with the Basel II framework, exposures are risk-weighted net of specific provisions.

- *Evolution of profits.* Most non-interest profit items and lines were projected to grow in line with nominal GDP. The projections of net fee and commission income took into account projections of investment funds' asset growth embedded in the macro scenario for banks having businesses with investment funds. Operational and administrative expenses were assumed to grow in line with nominal GDP growth with a floor set at zero, with consideration to nominal wage downward rigidity and to rising regulatory costs which are independent of the economic situation. It was further assumed that income from extraordinary items did not recur again

[1] Due to the quasi-dynamic adjustments, banks' balance sheets in the stress test model can shrink if credit growth is negative. However, the limit of deleveraging is aligned with the negative nominal GDP growth rate.

[2] For the residential mortgage segment, real provisioning rates as observed in 2016 were taken as the working assumption for the projection period. For the other loan segments, provisioning rates were projected so as to obtain a system-wide average provisioning rate (including the mortgage segment) of 50 percent, deemed to be conservative enough and consistent with the system average.

during the 2017–2019 period in the baseline and the adverse scenarios. Moreover, non-performing loans were assumed to not provide any accrued income.

- *Banks' funding costs* were assumed to evolve in line with the changes in the stressed Euribor rate.[3] Lending rates (approximated by the ratio of banks' interest income to net loans) were projected based on an econometric OLS panel model with fixed effects estimating the annual change in Luxembourgish banks' average interest income to net loans ratio, with annual data over 1990–2015. Explanatory variables were the annual change in the 3-month money market interest rate, and the annual change in the amount of total funding in percent, lagged by one period to avoid endogeneity issue (Table 12). This model allowed us to capture the relationship between banks' funding availability, banks' funding costs, lending rates and solvency. For banks with a traditional business model, when funding evaporates, funding costs rise, and banks may be inclined to pass on this increase to their customers to maintain their interest margin and solvency. However, the market structure and the degree of competition in the system might not allow them to pass on the increase fully.

The projection of total funding in the adverse scenario was aligned with the parameter set for the liquidity stress test. This made it possible to integrate the liquidity stress test parameters and the solvency stress test results. The change in the interbank rate was found to be the variable with the most significant effect on the average effective interest rate that Luxembourgish banks set on their loans to their borrowers. The change in lending rates was then applied to banks' loans.

[3] For the subsidiaries of foreign banks, the funding cost projections linked to intragroup funding were based on the Euribor rate projected for the home country.

Table A4.1. Luxembourg: Results from the Estimation of Banks' Lending Rates
(Dependent variable: annual change in the ratio of banks' interest income to net loans, panel fixed-effects OLS model)[1/]

annual change in Euribor rate	0.5893***
	(218.64)
annual change in total funding (in percent)	-0.0014***
	(-4.93)
Constant	-0.0116**
	(-2.17)
R-square	0.93
# of observations	255

Source: IMF staff calculations.

t-statistics in parentheses.

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

Note: the value of the coefficient of the constant is the average of the individual fixed effects.

[1]/ In general terms, obtaining a robust estimate for funding costs would require much longer time series and more observations. Therefore, the results of the satellite models should be interpreted with appropriate care.

- *Distribution of dividends*. Banks were assumed to distribute their after-tax profits according to the following rules:

  i) Banks with a total Capital Adequacy ratio below the Pillar II requirements[4] in any year of a given scenario were not allowed to distribute dividends;

  ii) Banks that pass Pillar II requirements distribute their dividends at a rate of 50 percent.

[4] The Pillar II requirements cannot be displayed as this is not public information for every bank.

Appendix V. Satellite Models for Credit Risk—Technical Details

Solvency Stress Testing Methodology

The estimation of credit losses in a stress environment is a challenging exercise in the case of the Luxembourg banking system. Typically, the transmission of macroeconomic shocks to probabilities of default and loan loss provisions of individual banks are assessed by estimating specific satellite models of credit risks. A challenge to estimate credit risk parameters in the Luxembourg banking system resulted from the short length of the times series, and the lack of relevant crisis experience in the country as the latter did not suffer a severe banking crisis in recent decades, despite a severe recession in 2009. Time series coming from supervisory databases started in 2009 only for IRB banks, with a structural time break upon the SSM establishment in November 2014. Therefore, the effect of adverse macroeconomic and financial developments on credit risk parameters could not be captured well enough via statistical models based on Luxembourg data.

These shortcomings led the FSAP team to apply international benchmarks for the projections of credit losses. The use of global rules of thumb taken from Hardy and Schmieder (2013) and the experience of other advanced countries having experienced severe banking crises such as Ireland in 2008-2013, provide a valuable additional metric in cases – such as Luxembourg- which have experienced an extended period of benign financial conditions and low credit risk. The shocks are calibrated based on estimates of credit loss sensitivities under extreme severity. We used Luxembourg banks' supervisory Through-The-Cycle PDs excluding defaulted exposures for eight broad exposure classes as the starting point of our projections, applying correction factors to approximate Point-in-Time PDs for the expected losses calculations. For exposures to foreign sovereigns, institutions, corporate and commercial real estate exposures, we used the Expected Default Frequencies dataset provided by Moody's/CreditEdge on a sample of 12 advanced countries, starting in 2005. For the mortgage segment, we used historic PDs for countries where they are available from banks' annual reports. For exposures under the Basel II standardized approach, CRR standard risk weights were used for the migration of loans; and NPL data was used to construct a simple satellite model. Finally, own sovereign exposures were stressed for banks choosing the advanced approach by migrating exposures by three notches in the adverse scenario and applying corresponding long-term PDs and LGDs from Moody's report.[1]

Expected losses were calculated separately depending on the exposure classes. For portfolios under the IRB approach, expected losses related to credit risk were calculated as the product of the proxies for PIT PDs, loss given default (LGD) and exposure at default (EAD). For portfolios under the standardized approach (except sovereigns), flows of NPLs were multiplied by the bank's effective provisioning ratio in the mortgage segment or an average provisioning ratio of 50 percent. The FSAP team estimated panel data models to project PDs, while LGD projections were based on house price projections and bank-by-bank loan-to-value distribution.

[1] See Moody's (2015), Sovereign Default and Recovery Rates, 1983-2014.

Data access on individual institutions was restricted to a physical data room. For the estimation of the credit risk satellite models and the conduct of the solvency stress test, supervisory data was available at the individual bank level, on solo, consolidated and sub-consolidated bases, in a physical data room only (Table 13). Finally, publically-available data was used, including from commercial providers, data from the EBA Transparency exercise as well as banks' annual reports.

Table A5.1. Luxembourg: Summary of FSAP 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.

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.

Probabilities of Default (PDs) for credit risk estimation were projected for eight asset classes through a panel-based approach. Starting point PDs obtained from supervisory authorities (both CSSF and ECB) were Through-the-Cycle PDs excluding defaulted exposures. Ideally, TTC PDs without defaulted exposures are required for RWAs calculation and one-year PIT PDs without defaulted exposures are typically used for expected losses' calculation. That is why conversion factors close to 1.5 were applied to the starting point TTC PDs to approximate Point-in-Time PDs for expected losses projections. Moreover, TTC PDs used for the RWA calculation were smoothed in our model by applying a cyclical parameter of 0.5 to the annual change in our projected PiT PDs.

The historic TTC PD time series provided by the CSSF were not appropriate for a credit satellite model estimation because TTC PDs are by definition not very sensitive to economic variables and due to the short length of the time series. Therefore, the satellite models for PiT PDs as dependent variables were constructed as follows based on a sample of foreign advanced countries having experienced a banking crisis, such as the 2008-2013 Irish crisis:

i) 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:

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

ii) To estimate impact of shocks of macrofinancial variables on PDs, the logit-transformed PDs were modeled as a linear function of different exogenous macroeconomic and financial factors (regressors). Therefore, the estimated model for a typical Luxembourgish exposure class can be expressed as:

$$Y_{i,t} = \delta Y_{i,t-1} + \alpha + \beta X_{t-s} + \varepsilon_{i,t} \qquad for\ t = 1, \cdots, T \quad and \quad i = 1, \cdots, N \qquad (2)$$

where $Y_{i,t}$ is the logit transform of the PD for asset class i at time t, X_t is a vector of macroeconomic and financial variables; $Y_{i,t-1}$ is the lagged dependent variable; $\varepsilon_{i,t}$ is an independent and identically distributed error-term, and α, and vector β, δ are parameters to be estimated.

iii) The determinants of PDs included:

- for the retail household mortgage loans: the contemporaneous year-on-year Luxembourg real GDP growth (in log) and the real interest rate that Luxembourgish banks set on their loans to their borrowers (lending rate) lagged by one quarter. The GDP growth rate was expected to have a negative effect on PDs because it is associated with higher income, which increases households' debt repayment capacity. The lending rate was expected to have a positive effect on PDs as an increase in the lending rate swiftly translates into a larger debt service burden in Luxembourg due to the predominance of floating lending rates;

- for other retail (consumer) loans: the year-on-year euro area real GDP growth (in log) lagged by one period, and the lending rate on consumer loans lagged by one quarter. To correct for serial autocorrelation of residuals, the lagged dependent variable (PD of the previous quarter) was included;

- For retail SME loans secured by immovable property: the year-on-year euro area real GDP growth (in log), the real lending rate on corporate loans, the year-on-year change in commercial real estate prices and the euro-dollar exchange rate;

- For unsecured retail SME loans: the year-on-year euro area real GDP growth (in log) lagged by two quarters, the real lending rate on corporate loans, and the dependent variable lagged by one quarter;

- for corporate SME loans: the year-on-year euro area real GDP growth (in log) lagged by one period, the lending rate on corporate loans lagged by one quarter, and the dependent variable lagged by one quarter;

- for non-financial corporate loans: the year-on-year euro area real GDP growth (in log) lagged by one period, as Luxembourg banks mostly lend to corporates in euro area countries outside

Luxembourg, the real lending rate on corporate loans lagged by six quarters, and the euro-dollar exchange rate;

- for specialized lending corporate loans: the year-on-year change in the lending rate on corporate loans lagged by three quarters, and the dependent variable lagged by one quarter;
- for loans to financial institutions: the year-on-year euro area real GDP growth (in log) lagged by one period, the real Euribor rate lagged by two quarters, and the euro-dollar exchange rate;
- for sovereign exposures: the dependent variable was the year-on-year change in the Moody's/CreditEdge Expected Default Frequency, and the explanatory variables were the year-on-year change in the sovereign rate lagged by one period to avoid endogeneity issues, and the lagged dependent variable;[2]
- for exposures under Basel II STA approach: the dependent variable was the logit transform of the non-performing loans ratio; the explanatory variables were the contemporaneous Luxembourg real GDP growth, and the lagged dependent variable;

iv) Finally, the PDs/NPLs 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:

$$PD_{type,t}^{stress} = \frac{1}{1+\exp\{-(\alpha+\beta X_{t-s})\}} * 100 \qquad (3)$$

Projections of (point-in-time) probabilities of default are based on quarterly data over the period 2005Q1-2016Q2, applying international benchmarks taken from advanced countries having experienced a banking crisis such as Ireland. To minimize model error risks, PD/NPLs and LGD projections from the IMF were compared with ECB benchmarks. Models differ as to their design and explanatory variables used. The ECB satellite models used for projecting the PiT PDs and LGD at the individual country and portfolio level rely on a Bayesian Model Averaging (BMA) technique. The BMA approach operates with a pool of equations per dependent variable to which weights are assigned that reflect their relative performance to then result in a so-called 'posterior model' equation. The dependent variable in these equations is the default rate at country and segment level. The PD multiples derived from these satellite models are attached to the starting point PD PIT of banks. The IMF Top-Down model used historic PDs and LGDs data for countries where the data is available through banks' annual/Pillar 3 reports; and Moody's/CreditEdge Expected Default Frequency date otherwise (for the commercial real estat e, corporate, financial institutions and sovereign classes). The coefficients of the explanatory variables based on the IMF Top-Down model are presented in Table 14 for the IRB and standardized asset classes.

[2] See Moody's, 2015 Sovereign Default and Recovery rates. 1983-2014.

The Luxembourgish corporate portfolio segment was found to be the one in which credit risk parameters are most sensitive to macroeconomic and financial variables. The change in the lending rate has the largest and most significant effect on corporate SME loan PDs. When the lending rate on loans to corporate SMEs increases by one percentage point, the PD rises by 4.7 percentage points; when the euro area GDP growth rate decreases by 1 percentage point, the PD rises by 2.3 percentage points. For the household mortgage loans, the lending rate was found to have the larger effect too: a 1 percentage point rise in the real lending rate results in an increase in PD by 4.6 percentage points, while a decline in the Luxembourg GDP growth by 1 percentage point increases the PD by 2.1 percentage points. For non-financial corporate loans, the euro area GDP growth was found to be the most significant factor explaining increase in PDs too: a one percentage point reduction in the euro area GDP growth translates into a 2 percentage point increase in PDs, while a one percentage point increase in the real lending rate leads to 0.4 percentage point increase in PDs. In the NPL model, a decline in the Luxembourg GDP growth rate increase NPLs: when GDP growth declines by one percentage point, the NPL ratio increases by 3.7 percentage points.

Table A5.2. Luxembourg: Results from the Estimation of the IMF Credit Risk Satellite Models using International Benchmarks (Equation [2])

(Dependent variable: logit transform of the PD except for the sovereigns (Yoy change in one-year EDF))

Exposure class	HH Mortgages	Other retail	Corporate SMEs	Corporate	Institutions	Sovereigns	NPLs
Dependent variable (lagged by 1 period)	-	0.5032*** (9.62)	0.7414*** (6.65)	-	-	0.6049*** (8.12)	0.2068*** (7.02)
YoY real GDP growth (in log) (Contemporaneous or lagged by 1 period)	-8.4138*** (-6.9)	-8.1001 (-1.37)	-9.5102 (-0.33)	-8.0412*** (-8.42)	-24.3615*** (-7.63)	-	-0.15 (-1.49)
Real lending rate (in percent) (lagged by 1 to 6 periods)	0.1972*** (12.1)	0.1509 (1.15)	0.2003 (0.72)	0.0151* (1.64)	-	0.0516* (2.06)	-
Real Euribor rate (in ppts) (lagged by 2 period)	-	-	-	-	0.1843*** (3.52)	-	-
EUR/USD exchange rate level 1/	-	-	-	-1.6414*** (4.43)	-2.1758* (-1.94)	-	-
Constant	-3.9643*** (-36.85)	-1.95*** (-3.98)	-1.1868* (-2.29)	-1.0298** (2.06)	-1.3517 (-0.93)	0.0150* (2.08)	-3.2098*** (-16.02)
R-square	0.75	0.91	0.96	0.55	0.63	0.6	0.32
# of observations	41	79	83	54	54	444	35

Source: IMF staff calculations

Note: 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.

Appendix VI. Household Stress Tests—Technical Details

The 2014 Eurosystem Household Consumption and Finance Survey sample for Luxembourg Households contains detailed data about 1,600 households, including their income, financial and non-financial assets as well as monthly payments for total debt and primary residential mortgage. Data was collected in 2014, prior to the starting date of the FSAP stress test. Therefore, in order to approximate households' financial situation in 2016 before stress, we had to update income and expenditure data with the latest available figures on an aggregate basis from the national accounts. For projections in the stress period (2017–2019), we estimated two econometric models to estimate annual wage and household consumption growth by using real GDP growth and inflation as explanatory variables (Table 15).

Table 6.1. Luxembourg: Dynamics of the Household Stress Test Parameter Before and After Stress, 2016–2019
(in percent)

	Stress test scenario			
	2016	**2017**	**2018**	**2019**
Growth in expenditure	2.5%	0.9%	1.1%	2.1%
Growth in social transfers	0%	-5%	-5%	-5%
Growth in wages	3.7%	-5%	-5%	-5%
Unemployment rate	6.4%	9.1%	11%	10.5%
Interest rate shock (change in lending rate for house purchase, in ppts)	0	1.3 ppt	0.6 ppt	0.4 ppt
Growth in house prices	5.4%	-17%	-15%	-1%

The analysis of initial data reveals that 23 percent of households have debt and receive some social transfers. 9percent of households have negative financial margin and debt (see Table 16).[1] Expenditure data was taken from HCFS variables on consumption of food, goods and services and expenses on utilities.

Table 6.2. Luxembourg: Descriptive Characteristics of Households with Debt
(as a percent of total number of households)

Are unemployed (i.e. no member of the household is employed)	6.3%
Households which receive social transfers	23%
Have negative financial margin	9%

[1] Negative financial margin means that the household's income derived from occupation, social transfers or other sources is lower than the sum of their current expenditure and their mortgage payment.

Households having both negative financial margin and negative assets were those deemed the most likely to face financial difficulties in repaying their debt. The financial margin was calculated as follows:

$$FM = [Employee\ income * (1 + g_i^e) * (1 + \alpha) + Regular\ Social\ Transfers * (1 + g_i^t) * (1 + \beta) + Other\ Income * (1 + g_i^o) * (1 + \gamma)] - Expenditure * (1 + \delta) - Residential\ Mortgage\ Payments * (1 + \varepsilon)$$

All income and expenditure data was annualized, with regular social transfers excluding pensions; current expenditure excluded residential mortgage and other debt payments to avoid double counting. α,β,γ ,δ, ε– were respective shock parameters and g – growth rates. If financial margin (FM) is negative, we can assume that such a household would first use other resources, like savings, borrow money from family member and other relatives, finally sell real estate before it defaults. So, we calculated net assets by assuming:

$$NA = Total\ real\ assets * (1 + \mu) + Total\ financial\ assets * (1 + \theta) - Total\ outstanding\ balance\ of\ household's\ liabilities$$

where μ and θ are shocked growth rates of real estate prices and financial assets respectively. If a household has negative FM and negative net assets (NA) (i.e. higher total liabilities than the value of real and financial assets) we assume that such a household is in a default position.[2] We calculated implied PD using the following formula:

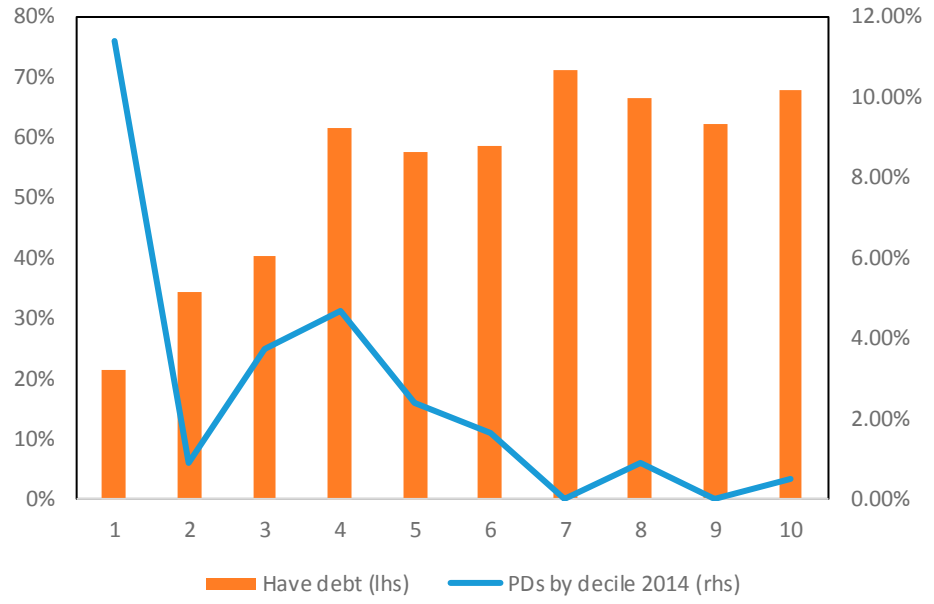
$$PD = \begin{cases} 1, if\ FIM < 0, and\ NA < 0 \\ 0\ otherwise \end{cases}$$

Pre-shock data analysis confirms that there are around 2.5% of defaulted households in our sample. This result is higher than the average PDs of banks' mortgage portfolios.

Household analysis by income, unemployment status and PD (i.e. negative assets and negative financial margin) shows that, as expected, households with a lower income have a higher probability of being unemployed as well as higher PDs. At the same time, PDs are highest in the 1st, 4th and 3rd deciles, which is hardly surprising. In line with reality, households towards the highest income deciles have the highest proportion of debt and the lowest PDs. In our sample, households in decile 9 did not default.

[2] This is a simplification as even in such a case households' might tap other resources, like support from families and relatives.

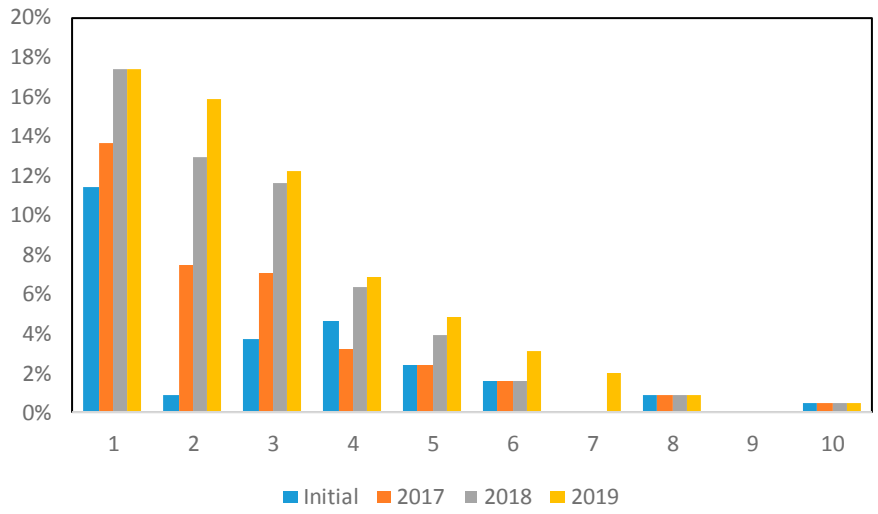
Figure A6.1. Distribution of Household Loans and Implied PDs by Income Decile, Pre-stress Period



Source: IMF staff calculations.

Household loan distribution analysis (see Figure 32) reveals that distribution of household loans has an inverted U-shape, i.e. more households in the higher income deciles have debt than households in the lower income deciles up to the 4th decile, but beyond the 4th decile the proportion of households with a loan declines. The final distribution of PDs in the stress test scenario is shown on Figure 33.

Figure A6.2. Distribution of Household PDs by Income Decile, Before and After Shocks



Source: IMF Staff calculations.

Under the adverse scenario, the average implied PD for the household loans would increase from 2.5 to 6.4 percent. These projections are in line with those obtained from macroeconometric satellite models used in the banking sector stress test using Irish benchmarks and with the Central Banks of Luxembourg's own estimates. It should be noted that the share of outstanding balance of mortgage debt for the 1st decile (households with highest PD) is equal to 4.1 percent of total outstanding balance of mortgage debt.

Appendix VII. Technical Details on the Solvency Stress Test for MMFs

Methodology

The solvency stress test for CNAV MMFs estimates the impact of increase in risk-free rates and credit spread on the mark-to-market value of the CNAV ('shadow' NAV). For each CNAV in the sample, the duration of the portfolio is computed using data on each security holding.
The change in NAV for a change in yield is calculated as the product of the shock times the duration:

$$\Delta NAV = \Delta Yield \times duration$$

Sovereign holdings are subject to increase in the risk-free rate, while other securities are subject to both an increase in the risk-free rate and in credit spreads.

Appendix VIII. Technical Details on the Liquidity Stress Test for UCITS Funds

Calibration of the Redemption Shock: Historical Approach

Using monthly data on net flows over January 2007–March 2016 for each fund in the sample, the redemption is calculated at the 1 percent highest outflows (in percent of TNA) observed during the sample period (Table 17). While the data used is monthly, worst weekly outflows, which are often used by market participants for liquidity stress tests, typically range between 10 and 20 percent.

Table A8.1. Luxembourg: Redemption Shocks Under the Historical Approach
(in percent of total net assets)

	Historical approach			
	Average	1st Quartile	Median	3rd Quartile
	Bond funds			
EM	18%	10%	16%	26%
HY	19%	13%	17%	23%
Mixed funds	9%	3%	7%	13%
Other bond funds	18%	8%	17%	21%
	MMFs			
Short Term CNAV	19%	15%	17%	23%
Short Term VNAV	23%	19%	23%	27%
Other MMFs	18%	13%	15%	22%

Sources: BCL, CSSF, and IMF staff calculations.

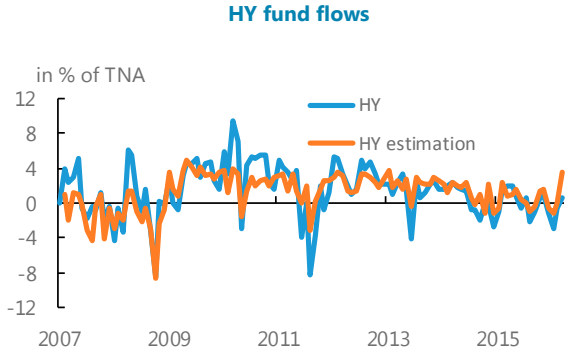
Calibration of the Redemption Shock: Forward Looking Approach

An econometric equation is used to relate monthly net flows, aggregated at the fund strategy level (EM, HY, Mixed and other bond funds), to macrofinancial variables. The macrofinancial variables come from the macroeconomic model used for the banking sector solvency stress test: 3-Month Euribor, euro area 10-year rate, Eurostoxx 50, VIX index. Additional variables are also used: the term spread (euro area 10-year rate minus 3-Month Euribor) and two bond spreads: a HY bond spread (only used for HY funds net flows and mixed funds) and an EM bond spread (for EM and other bond funds) using Bank of America Merril Lynch indices.

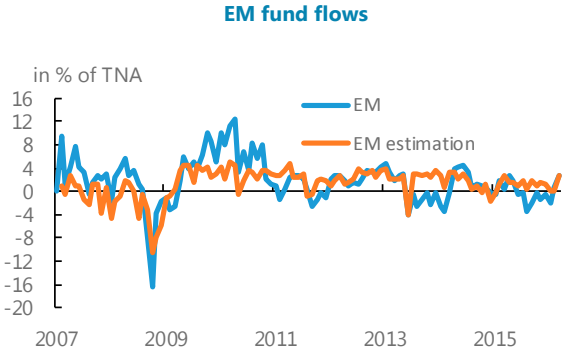
Explanatory variables are included in the equation in differences (3-Month Euribor, 10-year rate and term spread) or variations (Eurostoxx50, VIX index, bond spreads).

Figure 34 shows that the model used for each type of funds is able to replicate past evolutions. A model was also estimated for MMFs but none of the explanatory variables were significant, resulting in the exclusion of MMFs in the forward looking approach.

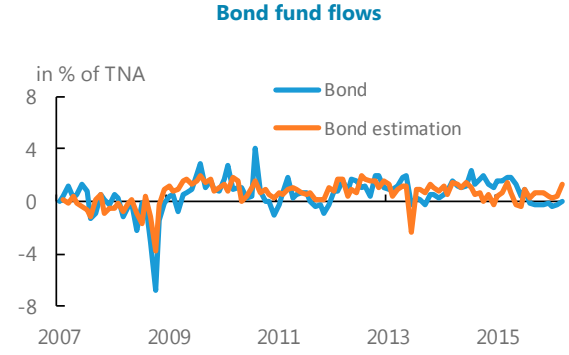
Figure A8.1. Observed and Estimated Net Flows by Fund Strategy



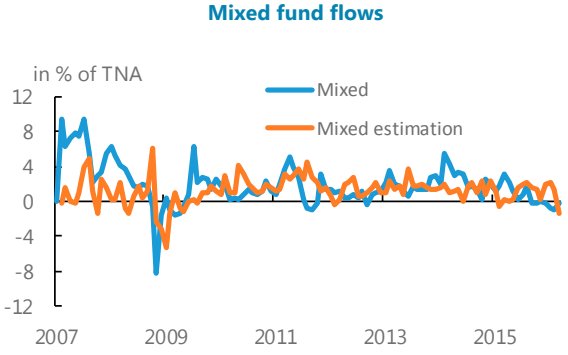
Sources: CSSF; BCL; and IMF staff calculations.



Sources: CSSF; BCL; and IMF staff calculations.



Sources: CSSF; BCL; and IMF staff calculations.



Sources: CSSF; BCL; and IMF staff calculations.

The model is then used to forecast net flows under the adverse scenario. Values of the explanatory variables are taken from the baseline scenario as of 2016Q4 and projected values are derived from 2017Q1 values in the adverse scenario, converted to monthly frequency assuming constant monthly change. Since HY and EM spreads were not included in the adverse scenario, it is assumed that they are subject to the highest monthly increase observed since 2007. Table 18 indicates the values of the explanatory variables used in the adverse scenario.

Table A8.2. Luxembourg: Value of the Macrofinancial Variables

	Explanatory variables		
	Initial value	Forecast	Change
3M-Euribor	-0.33	-0.13	0.20
EA 10-Year	1.00	1.32	0.33
Term spread	1.33	1.45	0.13
Eurostoxx 50	100	94	-6%
VIX	14.80	23.44	58%
EM spread (bps)	478	858	380
HY spread (bps)	498	1076	578

Sources: Thomson Reuters Datastream, and IMF staff calculations.

Table 19 shows the projected net outflows under the adverse scenario. For mixed funds, outflows are negative, amounting to net inflows under the adverse scenario.

Table A8.3. Luxembourg: Net Outflows Under the Forward-looking Approach
(in percent of total net assets)

	Net flows
Bond funds	
EM	9%
HY	11%
Mixed funds	-11%
Other bond funds	6%

Sources: BCL, CSSF, and IMF staff calculations.

Measure of Liquid Assets: Short-Term Assets

One metric used to assess the liquidity buffers of each fund is based on cash and debt securities with a residual maturity of less than one year, similar to the one used in the risk dashboard of the ESRB. The data used is collected by the BCL on a regular basis.

However, this measure of liquidity excludes any security with a maturity higher than one year, even when it is a sovereign bond from an investment grade issuer such as Luxembourg, Germany or the U.S. Therefore, an alternative measure was used based on the HQLA approach used for banks for the LCR.

Measure of Liquid Assets: High-Quality Liquid Assets

For the 191 funds in the sample, the full portfolio of securities was obtained and each security was assigned a weight depending on the rating of the issuer and the type of instrument following ESMA (2015).[1] The different weights are outlined in Table 20. Cash is given a 100 percent weight. Non-investment grade corporate bonds are given a 0 percent liquidity weight, which implies that under stress they are not considered part of the liquidity buffers of investment funds.[2]

Table A8.4. Luxembourg: Liquidity Weights

	Sovereign bonds	Corporate bonds	Securitization	Equities
AAA to AA-	100%	85%	85%	50%
A+ to A-	85%	50%	50%	
BBB+ to BBB-	50%	50%	0%	
Below BBB-	0%	0%	0%	

Sources: Credit Quality Step, and IMF staff calculations.

Table 21 provides aggregated data on the measures of liquid assets by type of funds in the sample.

Table A8.5. Luxembourg: Liquid Assets
(average by fund type in percent of TNA)

	Cash and short-term debt	HQLA
Short Term CNAV	98%	^
Short Term VNAV	99%	^
Other MMFs	88%	^
EM	16%	42%
HY	12%	12%
Mixed funds	31%	55%
Other bond funds	20%	56%

Sources: BCL CSSF, and IMF staff calculations.

[1] The analysis is based on 21,911 securities. Due to data gaps, 2,667 securities were excluded. The final sample covers 88 percent of the securities and 84 percent of the .portfolio of securities. All funds except two had a coverage of at least 95 percent of their TNA.. For funds with missing data, as a robustness check, adjusted-HQLA measures were computed to take into account that less than 100 percent of TNA was covered. Stress test results were similar.

[2] The split by ratings is based on Credit Quality Steps defined by the European Banking Authority, while the liquidity weights come from the Basel Committee for the liquidity coverage ratio.

Assessment of the Resilience of Individual Funds

Liquidity buffers are compared to redemption flows through the Redemption Coverage Ratio:

$$\text{RCR} = \frac{\text{Liquid assets}}{\text{Net outflows}}$$

For funds with RCR below one, the liquidity shortfall is given by the difference between liquid assets and net outflows (all in percent of TNA):

$$\text{Liquidity shortfall} = \text{Net outflows} - \text{Liquid assets}$$

Deposit Outflows from Funds

Under the forward-looking approach, each fund in the sample facing a redemption shock has to use its liquid assets and cash to meet redemptions. Under the waterfall approach, the fund uses first its most liquid assets (securities included in the HQLA measure) and then uses the cash if HQLA securities are not enough to cover the redemption shock. Under the prorata approach, the fund liquidates a proportion of its securities included in the HQLA measure and its cash proportional to the composition of the liquidity buffers. For example, if cash accounts for 5 percent of TNA and HQLA securities for 15 percent, then cash accounts for 25 percent of the liquidity buffers (5/20). If this fund faces a redemption shock of 10 percent of TNA, under the prorata approach, cash will be used to cover ¼ of the shock (2.5 percent of TNA) and HQLA securities to cover the rest (7.5 percent of TNA). Under the prorata approach, if the proportional liquidation of HQLA and cash is insufficient, then the fund draws on the remaining cash to meet redemptions. Results presented in this technical note are based on the average of the results obtained under the waterfall and prorata approaches. Table 22 summarizes the main results.

Table A8.6. Luxembourg: Deposit Outflows
(in EUR billion and percent of TNA)

	Including mixed funds	Without mixed funds
Total deposits	24.7	21.6
Deposit outflows (waterfall)	3.0	3.3
Deposit outflows (waterfall, in % of fund deposits)	*12%*	*15%*
Deposit outflows (prorata)	6.8	7.2
Deposit outflows (prorata, in % of fund deposits)	*28%*	*33%*
Deposit outflows (average of waterfall and prorata)	4.9	5.3
Deposit outflows (average of waterfall and prorata in % of funds deposits)	*20%*	*24%*

Sources: BCL, CSSF, and IMF staff calculations.

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