LUXEMBOURG

FINANCIAL SECTOR ASSESSMENT PROGRAM

TECHNICAL NOTE ON STRESS TESTING AND SYSTEMIC RISK ANALYSIS

June 2024

This Technical Note on Stress Testing and Systemic Risk Analysis for the Luxembourg FSAP 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 on January 2024.

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LUXEMBOURG

FINANCIAL SECTOR ASSESSMENT PROGRAM

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TECHNICAL NOTE

STRESS TESTING AND SYSTEMIC RISK ANALYSIS

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Glossary

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
CNAV	Constant Net Asset Value
COREP	Common Reporting Framework
CRD	Capital Requirements Directive
CRR	Capital Requirements Regulation
CRS	*Comite du Risque Systémique*
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
EoAoL	Excess of Assets over Liabilities
EOF	Eligible Own Funds
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 Exchange
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
IF	Investment Fund
IMF	International Monetary Fund
IRB	Internal-Rating Based approach of Basel II
LGD	Loss Given Default
LMT	Liquidity Management Tools

LSI	Less Significant Institution
LVNAV	Low Volatility Net Asset Value
MFI	Monetary and Financial Institutions
NAV	Net Asset Value
NFC	Nonfinancial Corporations
NSFR	Net Stable Funding Ratio
OFI	Other Financial Intermediaries
OLS	Ordinary Least Squares
QRT	Quantitative Reporting Template
OTC	Over the Counter
O-SII	Other Systemically Important Institution
PIT	Point-in-time
RAM	Risk Assessment Matrix
RCR	Redemption Coverage Ratio
RFR	Risk-Free Rate
ROW	Rest-of-the-World
RRE	Residential Real Estate
RWA	Risk Weighted Assets
SA	Structural Approach
SCR	Solvency Capital Requirement
SI	Significant Institution
STA	Standardized Approach
STE	Short Term Exercise
STeM	Stress Test Matrix (for FSAP stress tests)
TD	Top-Down
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 Investment in Transferrable Securities
VA	Volatility Adjustment
VAR	Vector Auto Regression
VIX	Chicago Board Options Exchange Volatility Index

EXECUTIVE SUMMARY[1]

The Luxembourg financial system is highly interconnected, diverse and complex. It has displayed a high level of resilience in the past but currently faces a backdrop of heightened economic, financial, and geopolitical uncertainty. Investment funds have grown since the 2017 FSAP, while their connections to other funds, banks, nonbank financial intermediaries, and foreign entities have also increased. The domestic banks are exposed to the ongoing downturn in credit and house price cycles, especially in the high-risk mortgage segment with floating-rate loans. Securities portfolios in large banks are mostly held-to-maturity and spread across euro area issuers. Against the risks, the financial system maintains higher capital ratios than euro area peers, has low but rising nonperforming loans, and benefits from government support measures to the private sector from an AAA-rated sovereign.

The banking, insurance and investment fund sector stress tests were integrated in a number of ways, and included key external and domestic risks. These included a common macroeconomic and financial scenario; the transmission of a fund redemption shock to bank deposits and prices of securities; and the impact of funding stress and fire sales on the solvency of the financial institutions. The key macrofinancial shock replicates a severe global recessionary scenario coupled with high inflation—where a deep recession combines with a sharp increase in short-term rates in the first year of the three-year horizon. The shock also incorporates domestic and international real estate sector risks.

Under the adverse scenario, the banking system would experience a significant decline in the system-wide capital ratio but would still be very well-capitalized, thanks to healthy initial positions. This result derives largely from the significant capital buffers already established by Luxembourg banks, which act as an important shock absorber, despite bank heterogeneity. Key drivers of the capital decline are credit and market risk stemming from the corporate and bond portfolios (under a "no hedge" assumption), respectively. The capital of four banks making up less than 10 percent of the banking sector's assets would fall below the CET1 hurdle rate of 8 percent, with moderate recapitalization needs amounting to 0.6 percent of nominal GDP. Recapitalization needs based on the leverage ratio minimum of 3 percent would reach 0.9 percent of nominal GDP, with five banks making up less than 20 percent of the banking sector's assets under this threshold. Analysis also shows that concentration risk is high, as several banks would be adversely affected if their five individual largest exposures (mostly toward non-parent financial institutions) were to default simultaneously.

The majority of banks would be able to sustain bank runs akin to those experienced in the US and Switzerland in March 2023, but some need attention. While liquidity buffers are sizeable in all banks, several of them would could be dipped-in in the adverse scenario. In a scenario where banks go through a deposit run in line with those experienced by Credit Suisse and First Republic in

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March 2023, six banks could have funding gaps. Moreover, a couple more would have funding gaps with stress in some global parent banks identified as "weak" in the IMF's October 2023 GFSR.

Stress tests on investment funds reveal that all UCITS and the majority of AIFs have sufficient liquidity buffers to face rapid redemptions, with small second-round effects. A small number of mixed fund AIFs (loan funds), representing a very small share of total net assets of the stress test sample, are identified, under a HQLA approach which does not incorporate LMTs and longer redemption frequencies, as not having enough liquid assets to face redemptions. In a scenario where investment funds were to sell securities to stem redemption pressures, price impacts on securities are small, and the second-round impacts on the financial sector are manageable.

Stress tests on Money Market Funds (MMFs) also show strong resilience with a few funds needing closer attention. Four Low Volatility Net Asset Value (LVNAV) funds and two small Constant NAV (CNAV) funds experience falls in shadow NAV above 20 basis points as a result of shocks consistent with the adverse scenario. Given the instantaneous and severe nature of the shocks in the stress test, this result is not alarming, but it signals room to further enhance resilience.

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. Assets decline by 9 percent for the whole sector, largely offset by a similarly sized decline in liabilities due to higher interest rates. While in guaranteed business, the largest decline in capital stems from higher sovereign and corporate spreads, in unit-linked business a significant effect is the reduction in future fee income as assets under management decline after stress.

Despite resilience in the aggregate, the assessment of banking sector vulnerabilities points to several areas where the authorities could prioritize supervisory attention. First, a profitability review and benchmarking exercise of banks by business model could be carried out to try to understand the sharp differences from one bank to another. Second, the CSSF and the BCL should collaborate to improve top-down stress test models in order to incorporate liquidity-solvency interactions. Third, greater monitoring of funding risks in significant currencies is warranted. Fourth, the authorities should continue to closely monitor bank liquidity risk from fund-bank connections, including from same group companies, and connections with potentially weak parent banks.

The increasing share of alternative investment funds and the higher interlinkages both within the investment fund sector and with the rest of the financial sector call for vigilance. These include the increased interconnectedness within the sector and with Other Financial Institutions (OFIs), the rise of Alternative Investment Funds (AIFs) engaging in less liquid assets, the growing trend towards "retailization," and the potential risks presented by funds pursuing strategies akin to Liability-Driven Investments (LDIs). These developments mark an increase in heterogeneity and complexity in the sector and can generate risks which may not be easy to quantify.

In the insurance sector, the CAA is recommended to continue improving the quality of supervisory reporting data, and implement regular top-down stress tests and sensitivity analysis. Data quality reviews should focus in particular on investment and derivatives data. A top-

down stress test model could initially cover only standard formula users and subsequently be amended to cover also—to the extent possible—(full) internal model users.

Given data limitations there can be potential downside risks emanating from OFI and AIF sectors. The authorities are encouraged to better identify the financial intermediation roles and amplification channels of these sectors.

Table 1. Luxembourg: 2024 FSAP: Key Recommendations		
Recommendations	**Authorities**	**Timeline[1]**
Systemic Risk Analysis		
Bank Risk Analysis		
Improve top-down supervisory stress test models to incorporate liquidity-solvency interactions (see ¶ 75 and 86)	CSSF, BCL	NT
Use cash-flow data for all significant currencies and significant jurisdictions to refine liquidity monitoring and stress testing.	CSSF, BCL	I
Continue monitoring bank liquidity risk from fund/bank connections, including depositary-fund manager group links.	CSSF, BCL	NT
Complement market-based indicators, with latest EU-level stress test results to increase monitoring of subsidiaries of foreign parent banks.	CSSF	NT
Insurance sector Risk Analysis		
Further improve the quality of supervisory reporting data, especially on investments and derivative holdings.	CAA	C
Implement regular top-down stress tests and sensitivity analysis for the insurance sector, starting with standard formula users and subsequently expanding, to the extent possible, also to internal model users.	CAA	NT
Investment Fund Risk Analysis		
Carefully analyze interlinkages of investment funds with the OFI sector, including through loans, and with other funds, to better understand vulnerabilities and potential amplification mechanisms.	CSSF, BCL	NT
Further monitor liquidity mismatches in newly emerging investment strategies of large AIF funds, including semi-liquid structures, strategies akin to liability-driven investments, and those promoting "retailization".	CSSF	NT
[1] "C-Continuous"; "I-Immediate" is within one year; "NT-near-term" is 1–3 years; "MT-medium-term" is 3–5 years.		

FINANCIAL SYSTEM STRUCTURE AND INTERCONNECTEDNESS

1.   The steep tightening of global and domestic financial conditions is weighing on the Luxembourg economy, but fiscal support is expected to help in the short term. Real GDP growth has fallen into negative territory in 2023, mostly driven by weak external demand and lower private sector investment especially in real estate. According to the October 2023 WEO, output was expected to contract by ½ a percent in 2023 before rebounding to 1½ percent in 2024. The latest economic outlook published by the national statistical office in December 2023 forecast a recession by 1 percent in 2023 before a recovery by 2 percent in 2024. The increase in real wages and fiscal stimulus provided some support to consumption, while weak consumer confidence led to a further increase in precautionary savings. Unemployment has increased rapidly to 5.6 percent in October 2023 from low levels, especially for youth and low-skilled workers.

2.   The financial system has displayed a high level of resilience in the past but currently faces a backdrop of heightened economic, financial, and geopolitical uncertainty. Since their peak in 2021Q4, investment funds experienced small, persistent outflows. The five main domestically oriented players active in the RRE market are exposed to the ongoing downturn in credit and house price cycles, especially in the high-risk mortgage segment with floating-rate loans. Securities portfolios in large banks are mostly held-to-maturity and spread across euro area issuers. Against the risks, the financial system maintains higher capital ratios than euro area peers, has low but rising nonperforming loans, and benefits from government support measures to the private sector from an AAA-rated sovereign.

3.   The system is facing certain headwinds. The banking sector is experiencing challenges in the current high inflationary environment, although capital buffers are high. Nonperforming loans (NPLs) have increased since 2021Q4, mainly driven by the corporate sector, but are still at a low level of 1¾ percent of gross loans. Stage 2 loans continue to rise following the forbearance afforded during the pandemic. But the Common Equity Tier 1 (CET1) capital ratio increased to 21½ percent in 2023Q2—standing 6 percentage points above the euro area average—as increasing net interest income helped offset rising loan loss provisions, decreasing commissions, and valuation losses in the bond portfolio. Net redemptions from investment funds (IF) picked up in 2023Q3 and reached a cumulative level of 2½ percent of net assets since 2022Q2, driven mostly by bond and equity funds. The sector's deposits in banks fell slightly while maintaining banks' liquidity coverage ratio (LCR) around 150 percent. Insurance redemptions also increased as policyholders aimed to repay variable interest rate loans.

4.   Since the 2017 FSAP the financial sector in Luxembourg has continued to grow and remains one of the key contributors to the economy. The sector employs 55,000 people (about 11 percent of total employment) although only a small portion of them are Luxembourgers. Most of the professionals (over 80 percent) are foreigners. The sector is also important economically and contributes about 25 percent of value-added to GDP, well above other European financial centers such as United Kingdom (9 percent) or Germany (4 percent).

5.   The growth has been driven mainly by the investment fund sector, the second largest in the world after the United States (Figure 1). The funds sector benefitted from the Luxembourg authorities being among the earliest adopters of the EU Directive on Undertaking for Collective Investment in Transferable Securities (UCITS) in 1988, allowing it to sell to cross-border investors, which spurred a rapid growth of the financial ecosystem. Bank assets, having fallen since 2017, are still sizeable at 12 times GDP, while the insurance sector remains at 3 times GDP.

6.   The financial industry engages in diverse activities, some of which have gained importance both domestically and globally. Financial market operations such as bond issuance, investment fund custody services, personal wealth management, and IT-related financial services are prominent, alongside more conventional banking services. Luxembourg is a key player as a center for euro-denominated bond issuance and a global hub for investment funds. Furthermore, the sector has strong connections to various supporting services, including consulting, legal, and IT.

A.   Investment Funds

7.   One of the key pillars of the Luxembourg financial system structure is its investment fund industry. The country is the largest investment fund center in Europe with over 3,300 traditional and multi-compartment directly regulated Undertakings for Collective Investment and 122 money market funds registered in Luxembourg as of August 2023. Since the time of the last FSAP in 2017 the directly regulated sector has expanded by over 70 percent in terms of total assets. The balance sheet of non-MMF funds held over 6 trillion euro worth of total assets and another 0.5 trillion euro belonged to the MMFs as of August 2023. In terms of the number of entities there was a decline in the number of market participants for both types of funds suggesting higher degree of consolidation as well as valuation growth.

8.   Luxembourg maintains its status as the top domicile for UCITS, but Alternative Investment Funds (AIFs) are on the rise. In 2016, 84 percent of the net assets of Luxembourg's funds were UCITS, with only 16 percent as AIFs. By 2023, the landscape had changed: UCITS now comprise 71 percent, while AIFs have grown to 29 percent, nearly doubling their share (Figure 2). Particularly within AIFs, unregulated structures (indirectly regulated through the investment fund manager) are increasingly preferred, especially for new funds. This trend is driven by a growth of fund strategies involving the investment in less liquid assets. These include funds such as real estate, private equity or private debt funds. Despite the growth in the crypto assets markets since 2016, funds domiciled in Luxembourg have very small exposures to this type of assets—direct and indirect exposures were roughly €1 bn in 2022.

Figure 1. Luxembourg: Financial Sector Size Compared to the U.S. and the Euro Area

United States: Banks, 2023Q2
(Trillions of USD)

Euro Area: Banks, 2023Q2
(Trillions of USD)

Luxembourg: Banks, 2023Q2
(Trillions of USD)

US: Insurance Companies and Pension Funds, 2023Q2
(Trillions of USD)

EA: Insurance Companies and Pension Funds, 2023Q2
(Trillions of USD)

Luxembourg: Ins. Companies and Pension Funds, 2023Q2
(Trillions of USD)

United States: Investment Funds, 2023Q2
(Trillions of USD)

Euro Area: Investment Funds, 2023Q2
(Trillions of USD)

Luxembourg: Investment Funds, 2023Q2
(Trillions of USD)

United States: Money Market Funds, 2023Q2
(Trillions of USD)

Euro Area: Money Market Funds, 2023Q2
(Trillions of USD)

Luxembourg: Money Market Funds, 2023Q2
(Trillions of USD)

United States: Other Financial Intermediaries, 2023Q2
(Trillions of USD)

Euro Area: Other Financial Intermediaries, 2023Q2
(Trillions of USD)

Luxembourg: Other Financial Intermediaries, 2023Q2
(Trillions of USD)

Sources: Flow of funds accounts; and IMF staff calculations.
Note: The definition of Other Financial Intermediaries varies across jurisdictions. Debt for EA and LUX is loans and debt securities issued.

**9.   Within UCITS, the share of assets held by bond funds has decreased, being
compensated by an increase in the share of equity funds.** The fall in the share of AUM of bonds
funds was mostly driven by valuation effects caused by an underperformance compared to equity
markets, rather than by net outflows. For equity funds, the growth was driven to a large extent by an
expansion of the value of holdings of US equities. Overall, the market share of the largest categories
of UCITS (bonds, equity and mixed funds) has reduced slightly, standing at roughly 80 percent of
total UCITS' assets in 2023.

Figure 2. Luxembourg: Investment Funds' Market Share by Type of Structure and Strategy

Share of UCITS and AIFs domiciled in Luxembourg 2008-2023
(Percent)

Share of Investment Funds domiciled in Luxembourg by Strategy, 2016-2023
(Percent)

Sources: CSSF; and IMF staff calculations.
Note: 2023 number refers to March 2023.
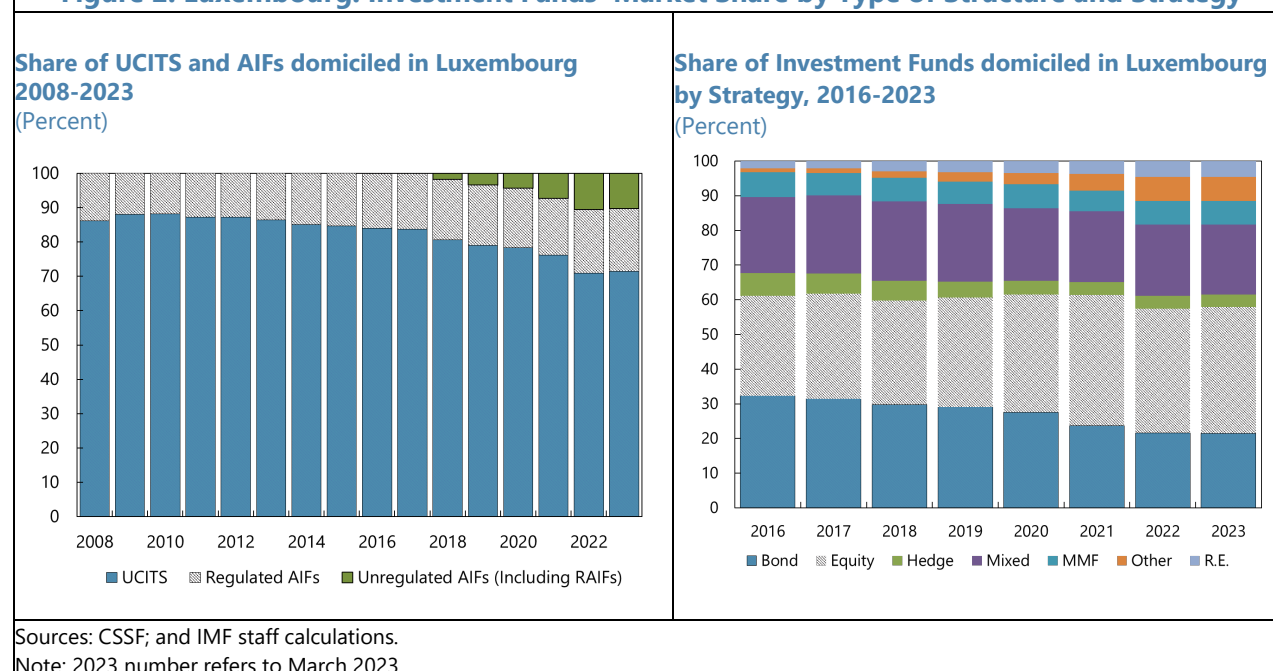
**10.   Since the last FSAP, investment funds are more interconnected within the financial
system in Luxembourg, through other domestic investment funds and OFIs.** These deepening
of ties can be partly attributed to the growth of alternative investment funds (AIFs), including real
estate, private equity, and debt funds. For a sample of large open-ended funds, those classified as
mixed funds and, naturally, funds of funds present the highest holdings of equity of other
investment funds. This interconnectedness poses potential systemic risks to the sector. A surge of
net redemptions in some funds could cascade into more generalized redemption pressure, as the
funds holding IF equity redeem their shares to meet their initial redemptions. This is especially true
in the case of liquidity mismatches, which may be increasing in some types of funds, as an emerging
segment of funds of funds have, been investing in funds holding less liquid assets (often through
financial intermediaries in the OFI sector). Some AIFs are also using strategies like diversification to
couple investment in less liquid assets with more frequent redemptions, contributing to a trend of
"*retailization*" in the investment fund market. The shares of financial derivatives, interfund loans and
loans from OFIs in funds' liabilities have also increased significantly since 2015, but in absolute terms
show lower levels, though they remain small compared to funds' aggregate balance sheet.

11.   Money Market Fund assets stand at roughly 5 times domestic GDP, with a considerable share held in Constant NAV (CNAV) and Low Volatility NAV MMFs (LVNAV). This makes Luxembourg the second largest domicile for MMFs in the euro area after Ireland. LVNAVs and CNAVs are an attractive product as they offer redemptions at par, providing more certainty to investors and being closer to cash equivalent assets. However, LVNAVs have to use the variable NAV based on mark-to-market/model valuation when meeting subscriptions and redemptions, if the market value of their portfolio deviates from the book value by more than 20 basis points, which could trigger a loss of confidence in the sector. MMFs funds have been able to withstand the interest rate hikes and the periods of market turmoil in recent years and thus remain an attractive investment vehicle for investment in liquid assets.

12.   Real estate funds have increased rapidly in recent years, with the majority of CRE holdings concentrated in Europe, outside Luxembourg. Total exposure to the CRE market, which makes up the majority of real estate holdings of funds, stood at 330 billion euros in December 2022, roughly 5 percent of total AUM of the entire sector. Most of the exposure is to the European market. The country representing the largest exposure is Germany, accounting for 23 percent of total CRE holdings of IFs (Figure 3). Direct exposure to the domestic real estate market is small, about 3.3 billion euros, implying a fall in domestic real estate prices would have muted direct effects on Luxembourgish funds.

Figure 3. Luxembourg: Stock of Investment Funds' Direct CRE Investments by Country
(Billion euro)

Sources: CSSF; and IMF staff calculations.
Note: Data as of December 2022.
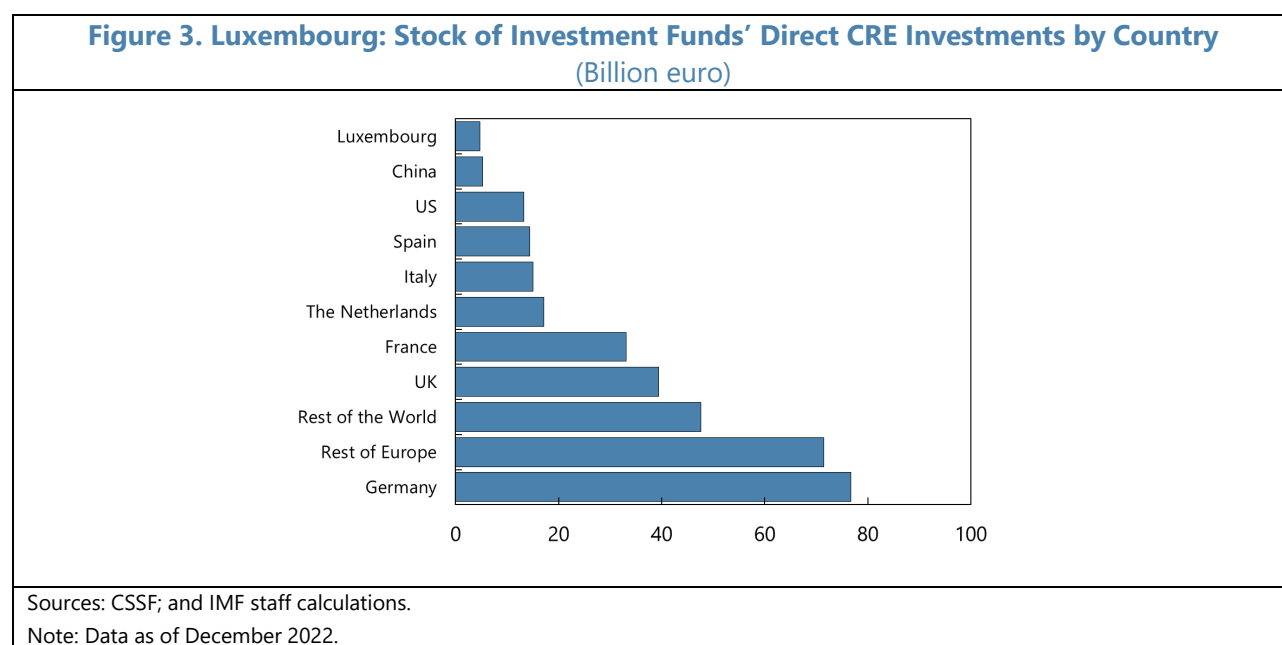
13.   Effective usage of Liquidity Management Tools (LMTs) by fund managers can mitigate, risks, including those stemming from the growth of alternative funds. Work by the CSSF has demonstrated that the usage of LMTs, specifically swing pricing, is effective in containing the materialization of risks. However, as the industry becomes more heterogeneous, fund managers will have to explore the efficacy of LMTs under different circumstances. Monitoring the outcomes and developing a framework to provide guidance to the sector in terms of best practices could be important in bolstering resilience, as being envisaged by future ESMA and IOSCO work in 2024, to which the CSSF is contributing.

14.   The analysis of risks in the investment fund sector by the Luxembourg authorities improved substantially since the last FSAP and plans to improve it further are in motion. Recommendations from the 2017 FSAP were diligently carried out. CSSF and BCL have improved their liquidity stress testing framework and also implemented MMF specific stress testing (Lo and Carpentier (2023) details the methodology using a time to liquidation approach). At the same time ample guidance has been provided to the market via CSSF circulars transposing the ESMA guidelines on liquidity stress testing and stress tests for MMFs, as well as the IOSCO recommendations on liquidity risk management for open-ended UCI. in order to strengthen risk assessments by funds. The data collection framework has been expanded and enhanced. Luxembourg authorities continue to contribute to the development of new regulation at the European and global levels. On the research front, the CSSF has carried out important work, with notable examples being the recent papers on LMTs (Carpantier and others (2022)) and on large redemptions during the covid crisis (Carpantier (2021)). Additionally, the authorities have acted swiftly in addressing emerging issues, such as the risks posed by LDI funds in the wake of the UK mini-budget crisis.

15.   Net redemptions from investment funds (IF) picked up in 2023Q3, cumulatively reaching 2½ percent of net assets since 2022Q2. Bond and equity funds faced the highest outflows while real estate saw some positive changes in total net assets (Figure 4). While these developments, given the size of redemptions and their protracted nature, do not pose liquidity risk concerns and have not led to instability so far, it might place the investment fund sector in a less robust starting point to face future potential periods of market stress, relative to the previous trend of positive net flows driving the growth in the sector.

Figure 4. Luxembourg: Investment Funds—Net Redemptions and Change in Assets

Investment Funds' Net Redemptions and Total Assets
(Percent and billions of euros)

Sources: ECB and IMF staff calculations.

Luxembourg: IF Change in Total Net Assets by Type of Fund
(Billions of euro; change from peak in 2021Q4 to 2023Q3)

Source: Haver Analytics and IMF staff calculations.
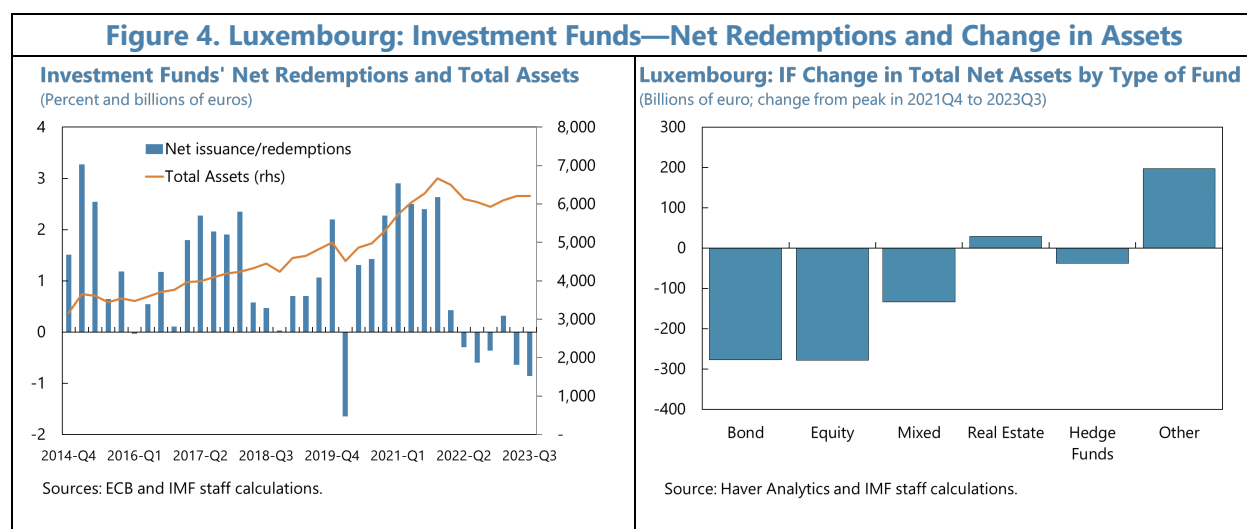
B.   Banking Sector

16.   Another important component of the Luxembourg financial system structure is its banking sector. The country is home to 118 banking institutions. Slightly over 70 percent of them have European origin and only nine banks are of Luxembourgish origin. Banks from the United States, China, Brazil and other non-European countries are also represented. Total assets of the banking system stood at 12 times of GDP in 2023Q1 and about 92 percent of them were owned by

foreign banking groups and institutions. Banks provide a wide range of banking services to both domestic and international clients, among which corporate finance, private banking, and custodian banking and activities linked to investment funds are offered by close to 80 percent of the banking institutions domiciled in the country (Figure 5).

Figure 5. Luxembourg: Banks by Business Model
(Number of Banks and Percent Share in Total Number)

Banks by Businiess Model
(Number of banks and percent share in total number)

- Universal
- Retail and commercial
- Private banking
- Covered bonds banking
- Custodian banking and activities linked to IFs
- Corporate finance
- Clearing, treasury and/or payment services

Sources: BCL; and IMF staff calculations.
Note: Data as of March 2023

17.   The structure of the banking sector balance sheet reflects the interconnectedness and its outward business orientation. Share of loans in total assets has remained fairly stable, fluctuating between 80-83 percent over the last five years, while securities' holdings have shrunk by a few percentage points. Out of the outstanding loan stock of 782 billion euro in 2023Q1, loans to affiliated banks and other deposit-taking corporations represent about 37 percent, reflecting the outward business links to parent banks (Figure 6, panels 1-4). Loans to other sectors, including nonfinancial corporations, constitute about a third of the total volume. On both the liabilities and asset sides, the share of banks and other deposit taking corporations'[2] deposits have been declining while other sectors' deposits have gained more importance.

18.   Banks in Luxembourg rely on affiliated banks as well as other financial institutions for funding. In 2023Q1, deposits from other banks, investment funds, non-bank financial institutions, and other financial intermediaries accounted for 78 percent of total bank deposits (Figure 6, panels 5 and 6), making them the most significant funding source at the aggregate level. The working balances of investment funds provide a stable source of funding for custodian banks, which are liquidity-rich due to limited credit activities with the non-financial sector. On average, ¾ of deposits from banks represent deposits from affiliated entities, although the share has declined somewhat most recently due to an outflow of deposits driven mostly by a reduction of deposits by investment

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[2] Financial intermediaries other than credit institutions whose business is to receive deposits and/or close substitutes for deposits from institutional units (including from non-MFIs) and to grant loans and/or make investments in securities on their own account as well as electronic money institutions.

funds and banks. Most banks in Luxembourg are involved in international business operations and operate under a cross-border business model.

Figure 6. Luxembourg: Banking Sector Balance Sheet

Sources: BCL; and IMF staff calculations.

Note: NPISH = non-profit institutions serving households; DTC = deposit taking corporations; ICPF = insurance companies and pension funds.
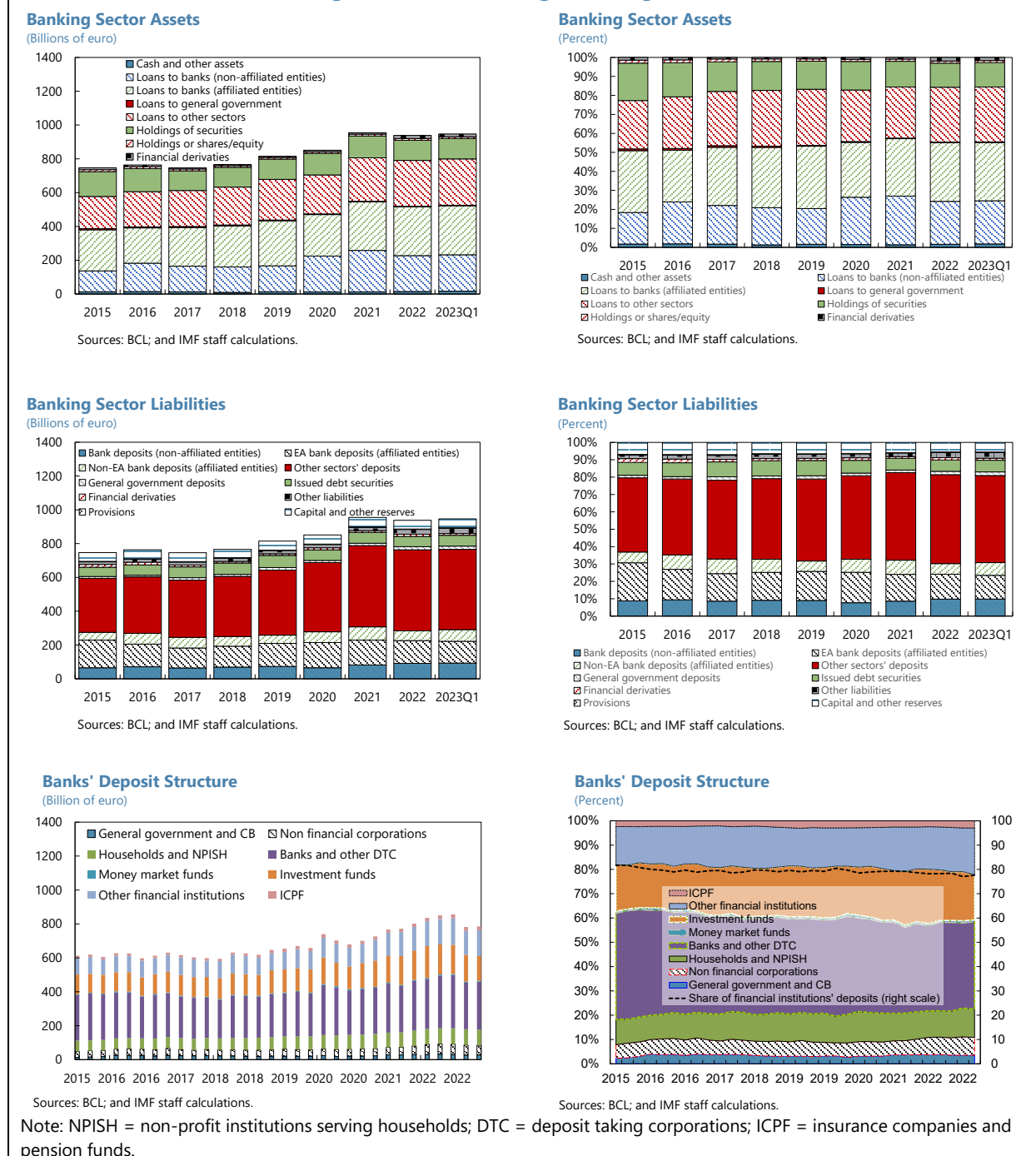
19.   Despite a series of shocks experienced during the recent years, the Luxembourgish banking sector appears in strong shape based on Financial Soundness Indicators (Table 2):

- *Capitalization is comfortable.* Capital ratios and quality are high, with a capital adequacy ratio of the banking sector of 23 percent as of June 2023 and Tier 1 capital representing 96 percent of total regulatory capital. The average risk weight is quite low by international comparisons at

36 percent, with a wide dispersion across banks' business model, from 21 percent for the custodian banking group to close to 62 percent for the corporate finance group. This low asset risk density reflects both the large share of custodian banks in our sample, which typically do not lend to the private sector and thus carry low risk-weighted assets, and the impact of financial guarantees granted by foreign parent companies to their Luxembourgish subsidiaries, lowering the level of the LGD at the latter. Moreover, there are nine banks using internal models (IRB banks), making up 56 percent of total assets of our sample, displaying typically low regulatory PDs and LGDs for those banks using the advanced IRB approach.

- *The liquidity position is strong.* Luxembourgish banks exhibit ample liquidity buffers, indicated by an aggregate LCR of 150 percent and a loan-to-deposit ratio of 68 percent. As expected, custodian banks display the highest level of liquidity, while corporate finance banks have the highest loan-to-deposit ratio, at 95 percent.

- *Asset quality remains adequate but is deteriorating.* While the aggregate nonperforming loan ratio has increased since the 2017 FSAP, from 1.0 percent to 1.8 percent in June 2023, asset quality has remained remarkably high despite the series of shocks experienced since then (Covid-19 pandemic, inflationary tensions and ensuing sharp rise in interest rates that followed Ukraine war). Stage 2 loans continue to rise following the forbearance afforded during the pandemic and the bleak economic outlook after the beginning of the Russian war in Ukraine. The forbearance measures have since been withdrawn (see Technical Note on Banking Supervision).

- *Profitability is rising but variable across business models.* Profitability has picked up in 2023 after a downward trend between 2016 and 2020. Luxembourg banks' return on assets recently rose to 1.1 percent in June 2023, an unprecedented level since the 2007/2008 global financial crisis. Banks have strongly benefited from the rise in interest rates through a large widening of their net interest margin thanks to the variable lending rate environment in the Luxembourgish banking system. Indeed, banks have been able to quickly translate the policy rate increase into a rise in their lending rates, while the increase in their funding costs has been more muted. Moreover, given the share of fixed-rate loans in banks' loan portfolio, banks have only been able to pass on the increase in the policy rates to their customers on half of their portfolio. Therefore, the net interest margin can be expected to widen further as current loans mature and new loans are priced at higher lending rates. At the same time, the negative impact of higher lending rates on borrowers' creditworthiness has not fully materialized yet and has not brought about a sharp rise in the cost of risk for the time being. Universal, retail and commercial bank seem to be the category that benefited most from the rising interest rate environment, with a return on assets of 0.8 percent in June 2023, while the returns of assets of private and custodian banks lagged behind, at respectively 0.5 and 0.4 percent.

C. Insurance Sector

20. **The insurance sector in Luxembourg is very large and serves as a European hub, specifically in the non-life (re)insurance sector and in unit-linked life insurance.**[3] Sector assets equaled €289 bn in June 2023, corresponding to 372 percent of GDP, significantly higher than in

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[3] Further details on the structure and performance of the insurance sector can be found in the Technical Note on Insurance Oversight.

other European peers (Figure 7a). Luxembourg insurance business is conducted mainly cross-border, both in the life and the non-life sector and even more pronounced in reinsurance (Figure 7b). The sector's international role has been strengthened further after the Brexit vote when several U.K. insurers resettled to Luxembourg to continue cross-border business in the European Economic Area through the passporting system. Both the life and the non-life sector have undergone some consolidation recently, and most Luxembourgish insurers are subsidiaries of foreign groups.

Table 2. Luxembourg: Banks' Financial Soundness Indicators (Based on the Stress Test Sample)

	Whole sample of 39 banks	Universal, retail and commercial banking	Private banking	Custodian banking and activities linked to investment funds	Corporate finance	Other (covered bonds banking, clearing, treasury or payment services)
Solvency						
Regulatory Capital to Risk-weighted Assets	22.6%	21.7%	27.5%	49.3%	17.8%	42.5%
Tier 1 Capital to Risk-weighted Assets	21.7%	21.1%	26.8%	42.2%	15.9%	42.4%
CET 1 Capital to Risk-weighted Assets	20.9%	20.9%	25.2%	42.2%	14.6%	42.4%
Tier 1 capital to Total Assets	7.7%	7.3%	5.8%	8.7%	9.8%	7.8%
Average Risk Weight	35.6%	34.4%	21.5%	20.6%	61.5%	18.3%
Liquidity						
Liquid assets to Total Assets	39.7%	28.6%	43.5%	78.0%	47.1%	50.3%
Loans to Deposits	67.7%	70.8%	59.0%	19.5%	95.0%	57.1%
Liquidity Coverage Ratio (LCR)	229.1%	179.8%	204.0%	471.7%	297.2%	258.6%
Asset quality						
Nonperforming Loans to Total Gross Loans	1.8%	2.0%	1.0%	0.4%	2.3%	0.4%
Profitability						
Return on Equity	5.3%	9.4%	7.2%	4.5%	1.7%	16.6%
Return on Assets	0.8%	0.8%	0.5%	0.4%	0.6%	1.9%

Sources: ECB; and IMF staff calculations

21.   Insurance liabilities are dominated by technical provisions for unit-linked business with a share much higher than in most other European countries (Figure 7c). While technical provisions for traditional life insurance and non-life insurance account for 15 percent each of aggregated insurance liabilities, unit-linked life insurance accounts for 63 percent. Only Swedish and Irish hold a higher share on their balance sheets. Even in absolute numbers, Luxembourg is the sixth largest market for unit-linked business in the European Union with around EUR 164bn.

22.   The investment asset allocation is largely reflecting the high share of unit-linked life insurance and is rather conservative and geared towards bonds for non-life insurers. Assets backing unit-linked insurance account for 75 percent of life insurers total assets (up from 67 percent in 2017)—59 percent of these assets are investment funds. Other life insurers' investments have been partially shifted from bonds towards investment funds over the last years. In the non-life sector, conservative investments like sovereign and corporate bonds are the most important asset class (34 percent of total assets). Investments are geographically diverse: While in unit-linked business, assets (before applying a look-through) are concentrated in markets with large investment fund sectors (besides Luxembourg also France and Ireland), assets backing traditional business are more diversified.

23.   Profitability in the Luxembourgish insurance sector is rather subdued (Figure 7d). In the non-life sector, inflation had some impact, especially in 2022. While domestically, policyholders are rather insensitive to prices, and contracts in property and third-party liability are typically subject to an automatic indexation, more specialized business was characterized by rising claims. Overall,

however, underwriting is still profitable. Life insurers' profitability has been impacted by declining investment yields which stood at 1.6 percent on average in 2022. Return on equity is subdued, both in the life and the non-life sector. This can be partly explained by competitive forces in the life insurance market targeting high net worth individuals, while in the non-life sector, captive insurers which only conduct business for a related group of corporates are typically not aiming for high profit margins.

Figure 7. Luxembourg: Insurance Market Structure

Assets of the insurance sector amount to 372 percent of GDP, much higher than in other European countries.

More than 90 percent of gross written premiums stem from cross-border business.
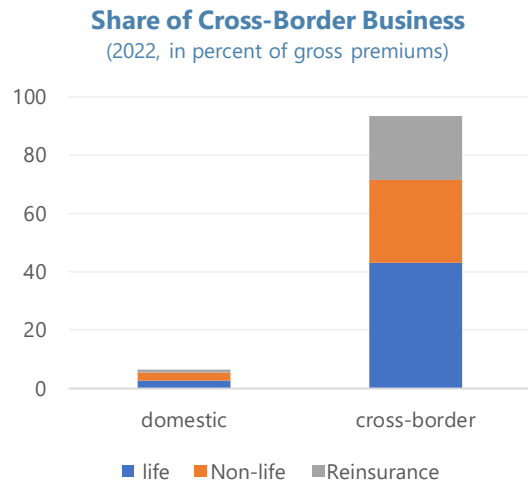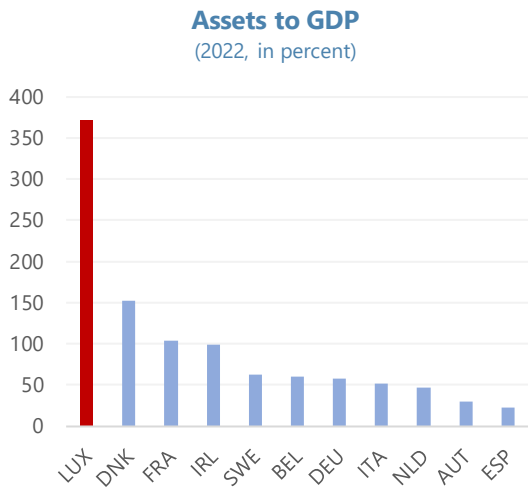
Compared with European peers, the share of unit-linked business is amongst the highest, similar to Sweden and Ireland.

Profitability in the life sector is subdued: For the median life insurer, the return on equity amounted to 5 percent in 2022, slightly below the five-year average.
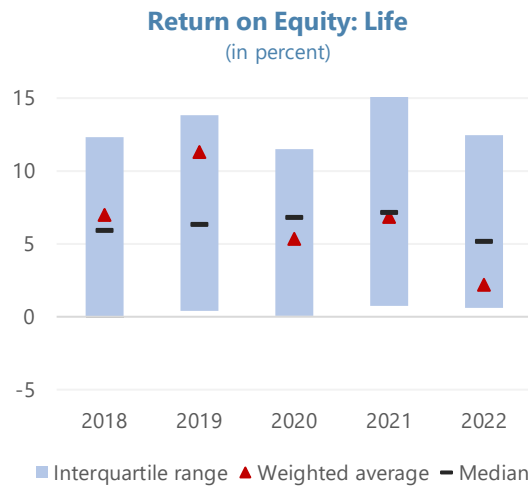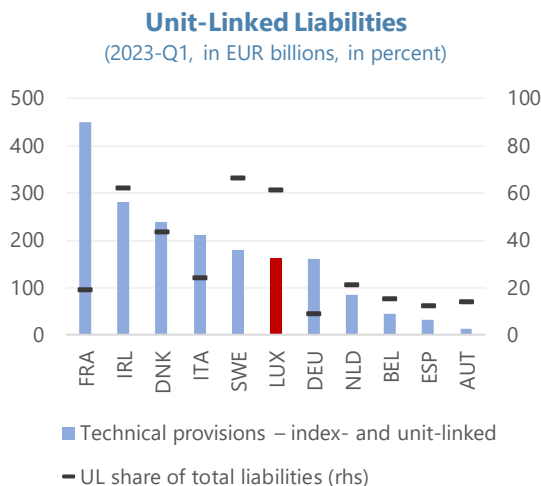
Sources: EIOPA, Eurostat, CAA, IMF staff calculations.

D. Captive Financial Institutions and Money Lenders

24.   The Other Financial Intermediaries (OFI) sector is large and diverse. In part, the size can be explained by the tendency of multinational corporations to establish their presence in the form of holding companies through Foreign Direct Investments. Locations with close proximity to or directly at financial centers, which also have stable political and business environments and cross-border access to various sources of financing are often preferred and Luxembourg provides both. Activities in the sector are numerous: intragroup lending, debt issuance, loan origination, financial leasing, treasury management, accounting, compliance and reporting, risk management, intellectual property management, and carbon trading.

25.   Despite its size, there is limited information available about the sector's economic activities. The most readily available statistics are provided by the financial sector accounts, according to which over 90 percent of assets are held by the largest subgroup of the OFI sector termed "captive financial institutions and money lenders" (also known as sector S127 in European System of Accounts 2010). This is a "catch all" term for the type of an institution which is usually owned, controlled, and used by only its parent. According to Di Filippo and Pierret (2020), based on the subsample of firms that report to BCL, there were about 2,700 captive financial institutions and money lenders with assets of more than 500 million euros representing 85 percent of the whole population (by asset size) at the end of 2018. When extrapolated to the whole population of the firms in the sector, this translates into more than 50,000 entities in terms of the total number of institutions, which belong to the S127 sector. About 80 percent of their assets were held by holding companies or institutions set up to facilitate intragroup lending (Figure 8).

26.   Seven industries account for roughly 80 percent of assets held by the sector entities. To establish the asset ownership, Di Filippo and Pierret (2020) classified assets of the sector by economic activity of the respective affiliate group or owner of the entity. The results revealed that finance and insurance together with corporations manufacturing chemicals and non-metallic mineral products capture close to 40 percent of the sector holdings, followed by electrical, medical and optical equipment, IT-related, mining, food and beverage, and wholesale activities. In terms of geographic representation, US-based entities appear to represent close to 60 percent of assets based on this criterion. At the same time Luxembourg is represented strongly when the counterparty of assets/liabilities of S127 firms is considered. Luxembourg-domiciled entities represent respectively 27 and 35 percent on the asset and liability sides when one looks at where exposures are directed geographically. In addition, close to 50 percent of parent companies have 2 or more entities registered in Luxembourg, which indicates that many S127 entities hold exposures within their own group and within the S127 sector.

Figure 8. Luxembourg: Captive Financial Institutions and Money Lenders

Classification of Captive Financial Institutions and Money Lenders by Number of Companies, 2018
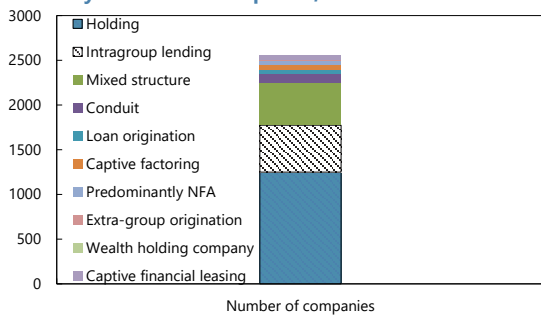
Sources: Adapted from Di Filippo and Pierret (2020).
Note: NFA = non-financial assets.

Classification of Captive Financial Institutions and Money Lenders by Assets, 2018
(Billion of EUR)
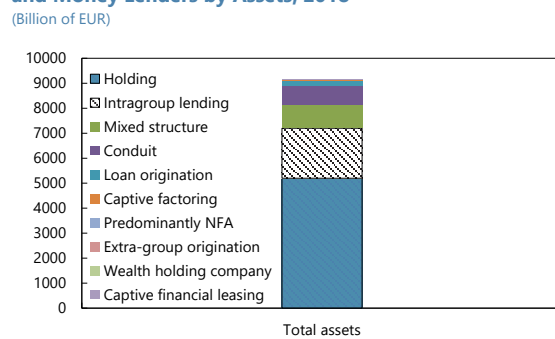
Sources: Adapted from Di Filippo and Pierret (2020).
Note: NFA = non-financial assets.

Total Assets of S127 Entities by the Affiliated Group Activity, average for 2014-19
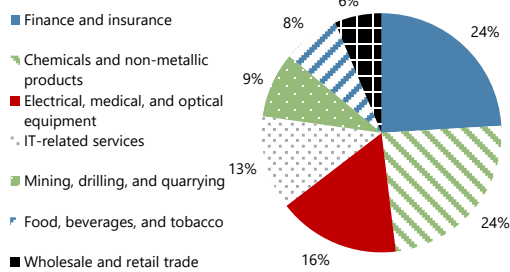
Source: Adapted from Di Filippo and Pierret (2020).
Note: Calculations are based on the seven industries accounting for roughly 80% of assets held by the sector entities.

Total S127 Assets by the Affiliated Group Domicile/Country, average for 2014-19
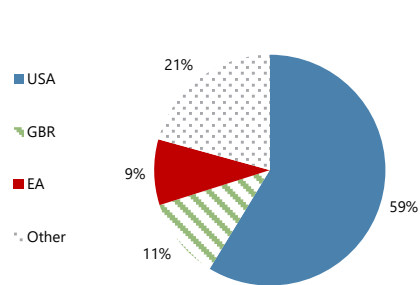
Source: Adapted from Di Filippo and Pierret (2020)

Asset Side by Balance Sheet Counterparty of S127 Entities, average for 2014-19
(Percent)
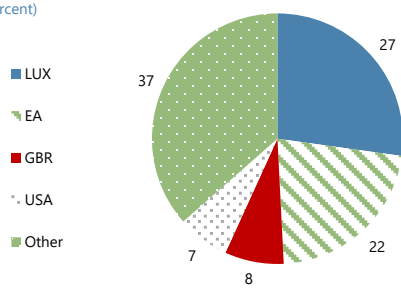
Source: Adapted from Di Filippo and Pierret (2020)

Liabilities Side by Balance Sheet Counterparty of S127 Entities, average for 2014-19
(Percent)
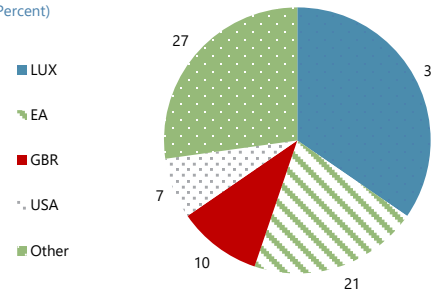
Source: Adapted from Di Filippo and Pierret (2020)

Note: Captive financial institutions and money lenders are also known as "sector S127" in the European System of Accounts 2010.

E. Interconnectedness

27.   Based on the analysis of the Quarterly Integrated Financial Accounts data the financial system in Luxembourg is complex and interlinked within itself as well as highly connected to the rest of the world (ROW). Investment funds are outwardly oriented and have the highest exposure to the rest of the world in terms of absolute size of balance sheet positions compared to other sectors. The same observation holds in terms of shares of assets and liabilities connected to ROW: close to 80 percent of asset and 90 percent of liabilities are with ROW (Figure 9).

28.   The Other Financial Intermediaries sector is a close second after the IF sector in terms of financial links with the ROW. It has somewhat smaller balance sheet positions in terms of absolute size as well as relative to the size of its balance sheet (about 60 percent of assets and 45 percent of liabilities represent cross-border positions). This sector also has significant linkages within itself—about 30 percent and 46 percent of assets and liabilities respectively belong to entities within the sector.

29.   The Monetary Financial Institutions (MFI) sector[4] can be also characterized as highly exposed to the ROW. Even though the absolute size of the positions on its balance sheet are smaller than IF and OFI sectors, the share of assets related to the ROW approaches 90 percent, and it is over 50 percent for liabilities.

30.   Sectors are also interlinked with each other. Nonfinancial corporations have significant balance sheet positions with MFIs, OFIs, and IFs. Funds' holdings of MMF shares and bank deposits account for about one-fourth of MFIs' financial liabilities. Household assets are held predominantly in MFIs and IFs, while their liabilities are almost exclusively directed at the MFI sector in the form of mortgage and consumer loans. Additionally, OFIs issue sizable amounts of debt securities mostly held by other OFIs and the ROW as they grant loans to them.

31.   Given the complexity of the linkages and their rather non-transparent nature it is difficult to uncover their relative importance and assess potential channels of contagion with aggregated data. More granular data would be beneficial for this purpose and Di Filippo (2024) can serve as an example. The study attempts to shed some light on the foreign direct investment (FDI) links between IFs and affiliated OFIs and determine, at the entity level, the investment position/exposure of the sectors with respect to each other as well as in relation to the ROW. The analysis covers only funds with affiliated entities connected to operations in private equity and real estate. It distinguishes between (i) inward FDI investments/positions (into Luxembourg), often originating in the U.S. or U.K.; (ii) outward investments/position in the target acquisitions located across the world; (iii) intra-Luxembourg positions, which are structured through captive financial institutions/OFIs in Luxembourg specifically for this purpose. The author notes, that intra-Luxembourg positions are larger then inward and outward FDI positions, suggesting that captive financial institutions often engage in additional financial transactions (including borrowing) to help fund the outward investments of the investment funds into private equity and real estate target acquisitions.

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[4] Excluding Central Bank and including MMFs in this context.

Figure 9. Luxembourg: Interconnectedness

IFs and OFIs have largest positions...

Financial Balance Sheet by Insitutional Sector, 2022
(Billion of euro)
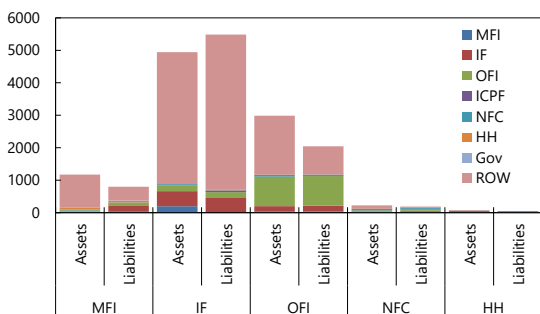
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

with ROW exposures constituting the highest shares.

Financial Balance Sheet by Insitutional Sector, 2022
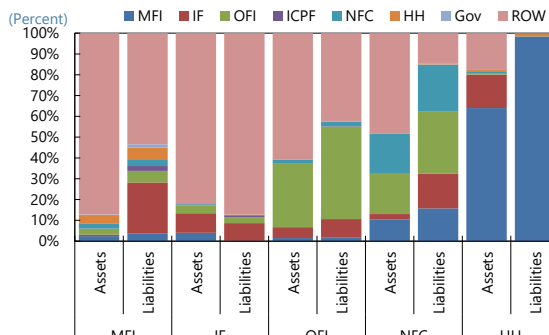
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

Most foreign debt securities are held by IFs...

Debt Securities Holdings by Insitutional Sector, 2022
(Billion of euro)
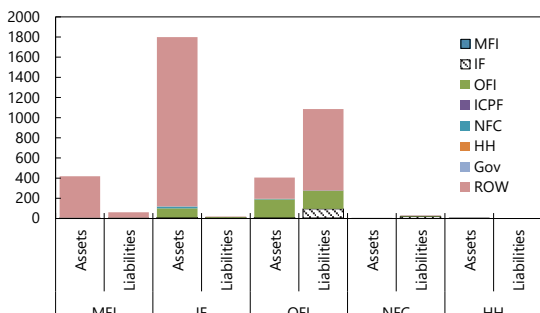
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

but MFIs, OFIs, and NFCs also issue and cross-hold other sector's debt.

Debt Securities by Insitutional Sector, 2022
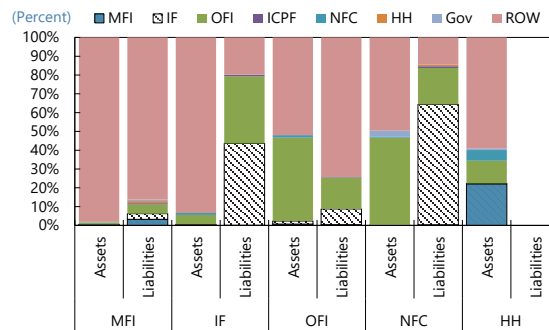
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

OFIs serve to a large degree as intra-group financing entities....

Loans by Institutional Sector, 2022
(Billion of euro)
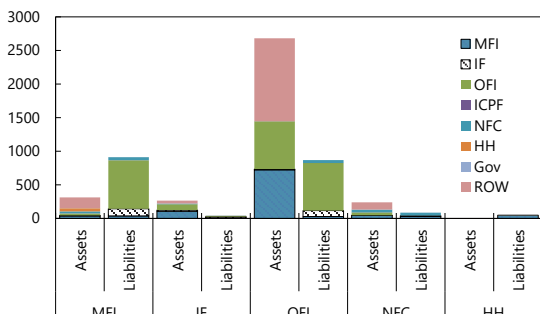
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

important for domestic as well as cross-border affiliated entities.

Loans by Insitutional Sector, 2022
(Percent)
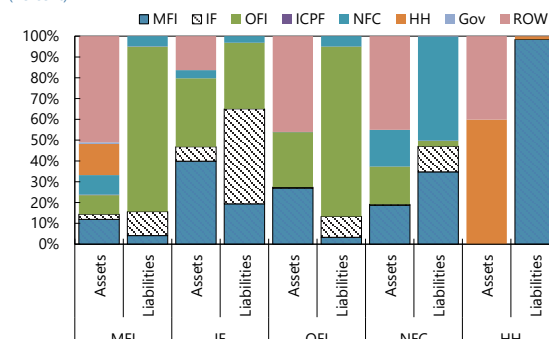
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

Figure 9. Luxembourg: Interconnectedness (Concluded)

Investment fund shares...

Investment Fund Shares by Institutional Sector, 2022
(Billion of euro)
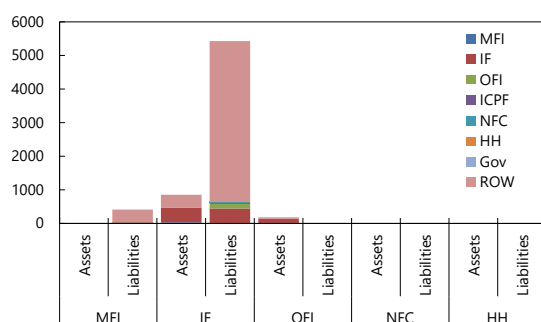
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

are predominantly owned by the ROW.

Investment Fund Shares by Institutional Sector, 2022
(Percent)
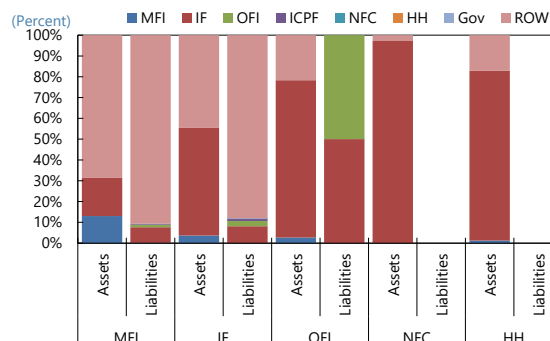
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

MFIs and OFIs keep most of their deposits abroad...

Deposits by Institutional Sector, 2022
(Billion of euro)
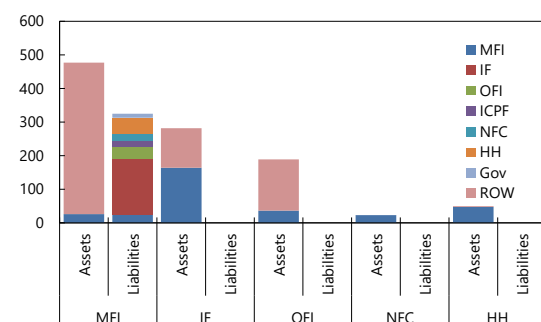
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

while households and NFC's use domestic MFIs.

Deposits by Institutional Sector, 2022
(Percent)
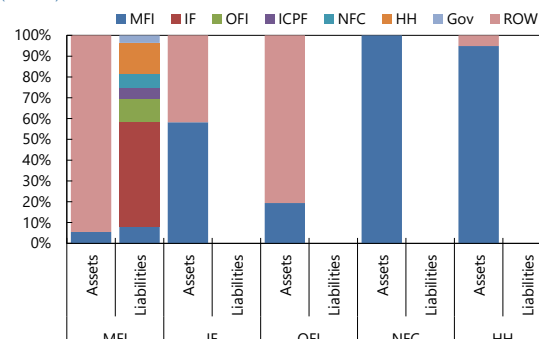
Sources: ECB, Integrated Quarterly Financial Accounts; and IMF staff calculations.

Note: Some categories are reported at an aggregate level, which includes Central Bank.

STRESS TEST STRATEGY

A. FSAP Stress Testing and Methodology

32.   In general, the objective of the FSAP stress testing exercise is to assess the capacity of the financial system to withstand baseline and adverse macroeconomic shocks. The baseline relates to the October 2023 IMF *World Economic Outlook* (WEO) macroeconomic projections for 2024-2026. The adverse scenario is a set of 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.

33.   FSAP stress tests may differ from stress tests conducted by other institutions, including those previously undertaken by the CSSF, the BCL, the European Banking Authority (EBA) and the European Central Bank (ECB). 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 CSSF, the BCL and 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.

34.   **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. Hence, by construction, adverse scenarios should not be interpreted as macroeconomic "forecasts." Finally, it should be noted that possible mitigating actions including those under the recovery and resolution legal framework are not considered.

35.   **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, differences in methodologies and hurdle rates may translate into different results for similar risk profiles.

36.   **The top-down stress tests examined the resilience of the financial sector to solvency, liquidity, and contagion risks** (Figure 10). The banking sector stress tests included a top-down (TD) exercise based on macroeconomic scenarios and sensitivity analyses, conducted by the FSAP team. 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 (2024–2026), based on data available through June 2023. 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 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.

37.   **The stress test for investment funds is designed to evaluate liquidity risk, focusing on determining the resilience of these funds against severe yet plausible redemption shocks.** This assessment aims to identify which categories of funds are more vulnerable to liquidity risks and to evaluate their potential to propagate shocks through the financial system. While the stress test primarily addresses individual funds (microprudential perspective), it also incorporates second-round effects from asset sales (macroprudential perspective). This is an important extension compared to recent fund stress tests in other FSAPs. In addition, "solvency" stress tests are conducted on the deviation of constant NAV and shadow NAV of Money Market Funds (MMFs) to evaluate their resilience to interest rate hikes and widening credit spreads, and on the impact on

value of assets and liabilities for all funds in the sample. It is important to note, however, that the liquidity risk stress test does not take into account use of liquidity management tools (LMTs)) and the often lower redemption frequency of AIFs (typically monthly or quarterly for several ones), which could mitigate the impact of shocks to some extent (as was seen during the pandemic in 2020).[5]

Figure 10. Luxembourg: Stress Test Strategy
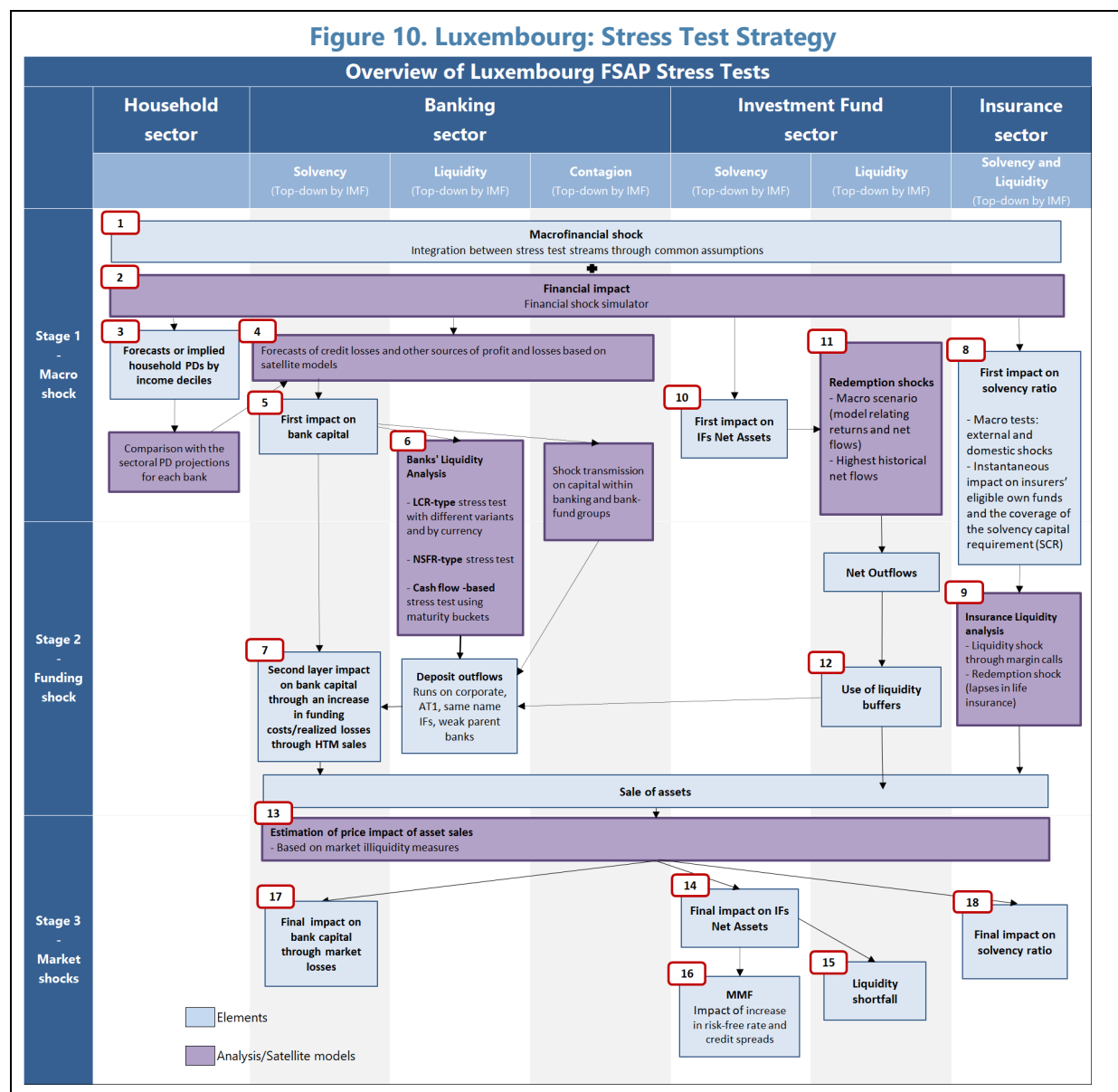
B. Financial Market Shocks (First Round)

38.   The calibration of shocks to financial asset prices is implemented with the help of the Financial Shock Simulator (Gross, Henry, and Rancoita 2022). This modelling technique employs estimation of an empirical copula via a Monte Carlo simulation. The approach assumes a number of risk factors, each following a stochastic process with independent increments (Markov property). A group of factors, also called conditioning or driver variables, is presumed to be under stress. A

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[5] See Carpantier and others (2022).

Monte Carlo simulation/bootstrapping routine is used to estimate a joint probability density function to calculate conditional expected shortfall of all risk factors at the tail of the conditional distribution.

39.   In this particular application, 27 risk factors are included in the simulation[6]. Sovereign and corporate bonds and equities from France, Germany, Japan, Luxembourg, United States, other Euro Area, and the rest of the world at daily frequency constituted the universe of risk factors. U.S., Germany, and U.K. corporate bonds and equities were chosen to be conditioning variables. Forward paths are simulated 10,000 times for the horizon of 1-year and conditional expected shortfalls are calculated for the tail of the estimated empirical distribution (Figure 11).

Figure 11. Luxembourg: Financial Shock Calibration

Financial Shock Calibration: Sovereign Bond Prices
(Percent)

Sources: Haver Analytics L.L.C.; and IMF staff calculations.

Financial Shock Calibration: Corporate Bond Prices
(Percent)

Sources: Haver Analytics L.L.C.; and IMF staff calculations.

Financial Shock Calibration: Price of Equity
(Percent)

Sources: Haver Analytics L.L.C.; and IMF staff calculations.

C.   Macrofinancial Scenario—Baseline and Adverse (First Round)

40.   The three segments of the financial sector (investment fund, insurance and banking sectors) were subjected to stress tests incorporating information from the same macro scenarios. Solvency stress tests are aimed at assessing whether financial institutions have enough capital to withstand a range of economic and financial shocks. This note presents the solvency stress

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[6] The Financial Shock Simulator was calibrated separately from the main adverse scenario, which was based on Bayesian VAR.

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 and methodological choices to model interactions between the shocks affecting the different sectors. Sensitivity tests also assessed the impact of individual shocks.

Baseline

41.   For the design of the macroeconomic scenarios, key domestic and euro area variables were calibrated over a three-year horizon. The baseline scenario was based on the October 2023 World Economic Outlook projections.

Adverse

42.   In the stress test adverse scenario, a severe recessionary scenario coupled with inflation would affect the solvency of banks, funds, and insurers. The adverse scenario would be driven by external geopolitical and financial shocks, resulting in an increase in investors' risk aversion and confidence losses. This scenario, based on the Risk Assessment Matrix (see Appendix I), assumes three external shocks transmitted through international macroeconomic spillovers and pure financial channels.

43.   The Luxembourgish financial system could be exposed to several external risks. The risks that are most likely to materialize are the following:

- An escalation of war in Ukraine would lead to a complete disruption of gas supply, in a context of already low gas reserves, causing a severe recession in the euro area and amplifying inflationary tensions. The renewed blow to globalization resulting from the more acute international tensions would bring about further retrenchment in trade and financial flows,

- Rising geopolitical concerns and related inflationary pressures could increase short-term rates further, with impact on the financial sector. Banks would initially gain from rising interest margins, as they have recently, but also encounter marked-to-market losses on bond portfolios and higher loan losses from the private sector eventually over the next three years. Funds and insurers would encounter marked-to-market losses on their securities holdings, which in turn could lead to redemptions and lapses by policy holders, and

- An abrupt tightening of financial conditions would translate in a sharp rise in risk aversion and risk premia, a flight to quality and dollar assets and sharp redemption flows from international investors in investment funds.

44.   The scenario is composed of three layers: (i) a global layer assuming the realization of geopolitical risks in the systemic advanced economies, (ii) a euro area layer simulating a severe recession in a context of a deepened recession coupled with high inflation and an escalating risk aversion, and (iii) a Luxembourg-specific layer associated with a shock to Luxembourg's financial sector, and feeding through to the domestic real estate market and to domestic economic confidence.

45.   In Luxembourg, the main transmission channels of the external shocks would go through external services demand, financial flows into investment funds and the real estate

market. The renewed recession in the euro area would bring about a drop in Luxembourg exports. The decompression of credit spreads resulting from rising interest rates in the markets would aggravate market volatility and liquidity.

46.   **Moreover, the higher financial volatility would bring about stress in domestic funding markets.** This would be accompanied by a contraction in banking intragroup exposures between foreign parents and their local subsidiaries, manifesting through intragroup deposit outflows and a reduction in large intragroup assets of the Luxembourgish subsidiaries. Lastly, domestically oriented banks' lending to the real economy would experience a rise in their funding costs, notably due to the rise in deposit rates and the switch from sight to term deposits on the part of non-financial customers.

47.   **The rise in market rates would rapidly translate into higher lending rates for loans to Luxembourg non-financial customers, in a market in which variable rate loans still account for a large share of total loans.** The rise in funding costs would translate into an (imperfect) pass-through to lending rates, which in turn would affect both the demand for credit and the creditworthiness of corporates requiring funding for investment or working capital. Meanwhile, demand for mortgage loans and the creditworthiness of borrowers with variable rate loans would affect banks' incomes, partly compensating the positive effect of rising lending rates on the banks' net interest margin. The decline in economic confidence would hit residential and commercial real estate prices. A negative consumer confidence transmission channel would then operate as the decline in property prices would in turn trigger adverse wealth effects, creating a negative feedback loop with domestic demand and a deflationary process.

48.   **Finally, the shocks affecting the financial sector would have an adverse effect on the fiscal balance.** This would result in an increase in credit risk of the sovereign debt portfolio and a widening of credit spread against Germany, would limit the fiscal space for conducting countercyclical fiscal policy and amplify the domestic consumption shock and the house price correction.

49.   **Stress tests used such an adverse scenario to assess whether solvency buffers are sufficient to withstand such a shock over a three-year horizon (Appendix II).** The tests covered 39 banks (19 SIs and 20 LSIs, with only a small number of the SIs being headquartered in Luxembourg, as most of them are Luxembourgish subsidiaries of other euro area SIs), over 1000 open-ended funds subject to the full reporting scope,[7] and 20 insurers—with 80–90 percent of asset coverage in each sector. In particular, the stress test sample included 8 universal, retail and commercial banks, 14 private wealth management banks, 9 corporate finance banks, 5 custodian banks, 2 covered bond banks and one payment services bank. 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 2024 and the

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[7] UCITS fulfilling at least one of the following two criteria: net assets above EUR 500 million; or use of VaR for the calculation of global exposure covered by Article 42(3) of the 2010 Law with an average gross leverage during the semester greater than 250 percent.

[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.

scenario would run until 2026, based on risks included in the Risk Assessment Matrix. The mission explored the effects of such a shock on banks' CET1 ratio over 2024–26, and on fund's net assets and insurers' solvency capital for 2024.

50.   The adverse scenario projections were based on a suite of models. These models were the IMF Global Macro-Financial Model (GFM) for the external variables, and on a Bayesian VAR developed for the domestic variables for the purpose of this FSAP (Appendix III). These included real GDP growth, HICP and 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 adverse shock envisaged a 5.9 percent cumulative drop in the level of GDP over 2024-25 (Figure 12), with spikes in inflation that require sharp increases in global short-term rates, which increases short-term interest rate in Luxembourg (Figure 13) and decreases prices of residential and commercial real estate. The GDP shock would correspond to -10 percentage points compared to the baseline level of output at the trough, representing a 2.3 standard deviation shock from the baseline and a 1.4 standard deviation shock from the mean of the historical distribution.

51.   The macrofinancial adverse scenario would also have an impact on investment funds and insurance companies. Both the sectors would experience valuation losses on assets due to the financial shocks, and in turn would experience related redemptions and lapses.

Figure 12. Luxembourg: Scenario Severity from a Historic Perspective
(Real GDP in year Y_0=100)
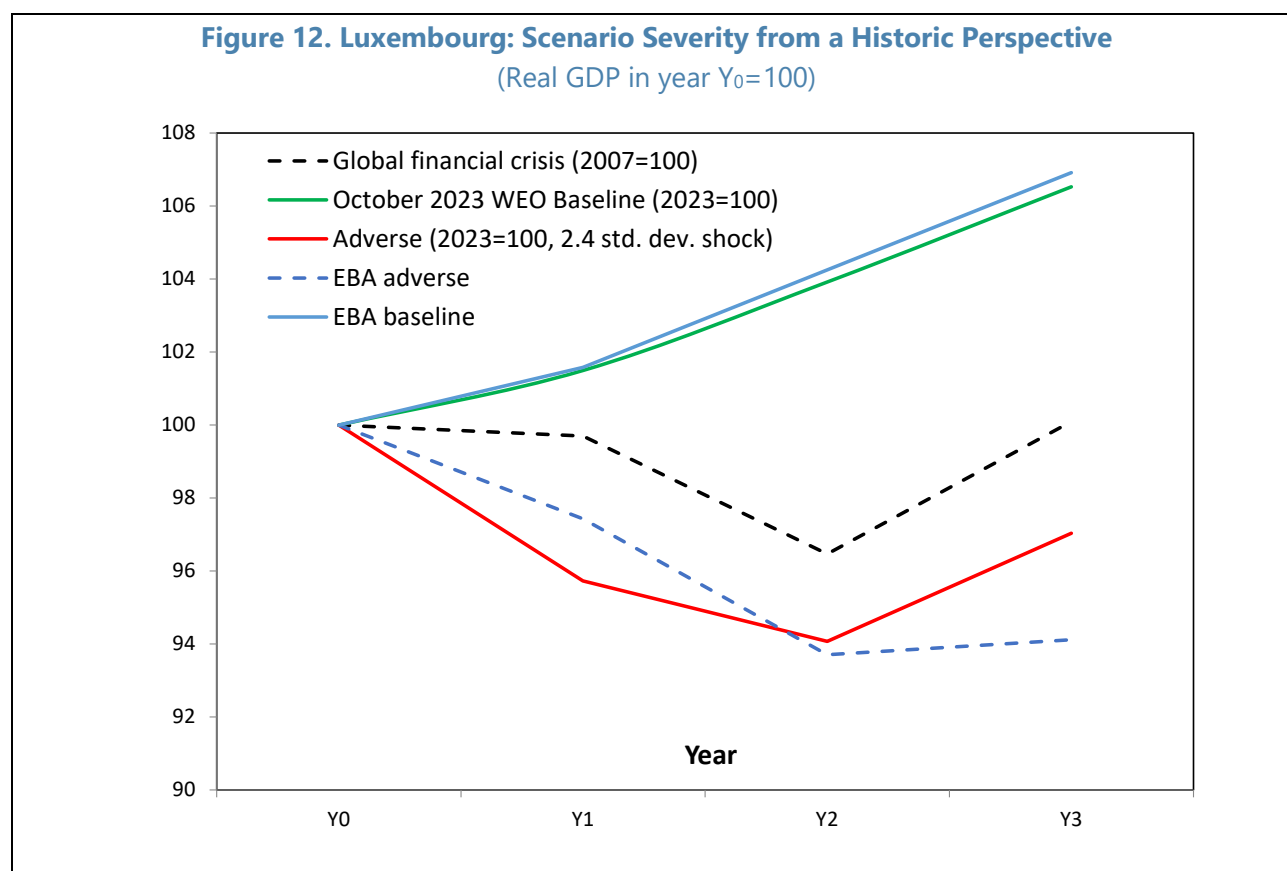
Figure 13. Luxembourg: Macroeconomic Baseline and Adverse Scenarios

GDP Growth (in percent)

HICP Inflation Rate (in percent)

Unemployment Rate (in percent)

Housing Price Change (in percent)

Short-term Nominal Interest Rate
(3-Month Euribor Interbank Rate, in percent))

Long-term Nominal Interest Rate
(10-Year Government Bond Rate, in percent))
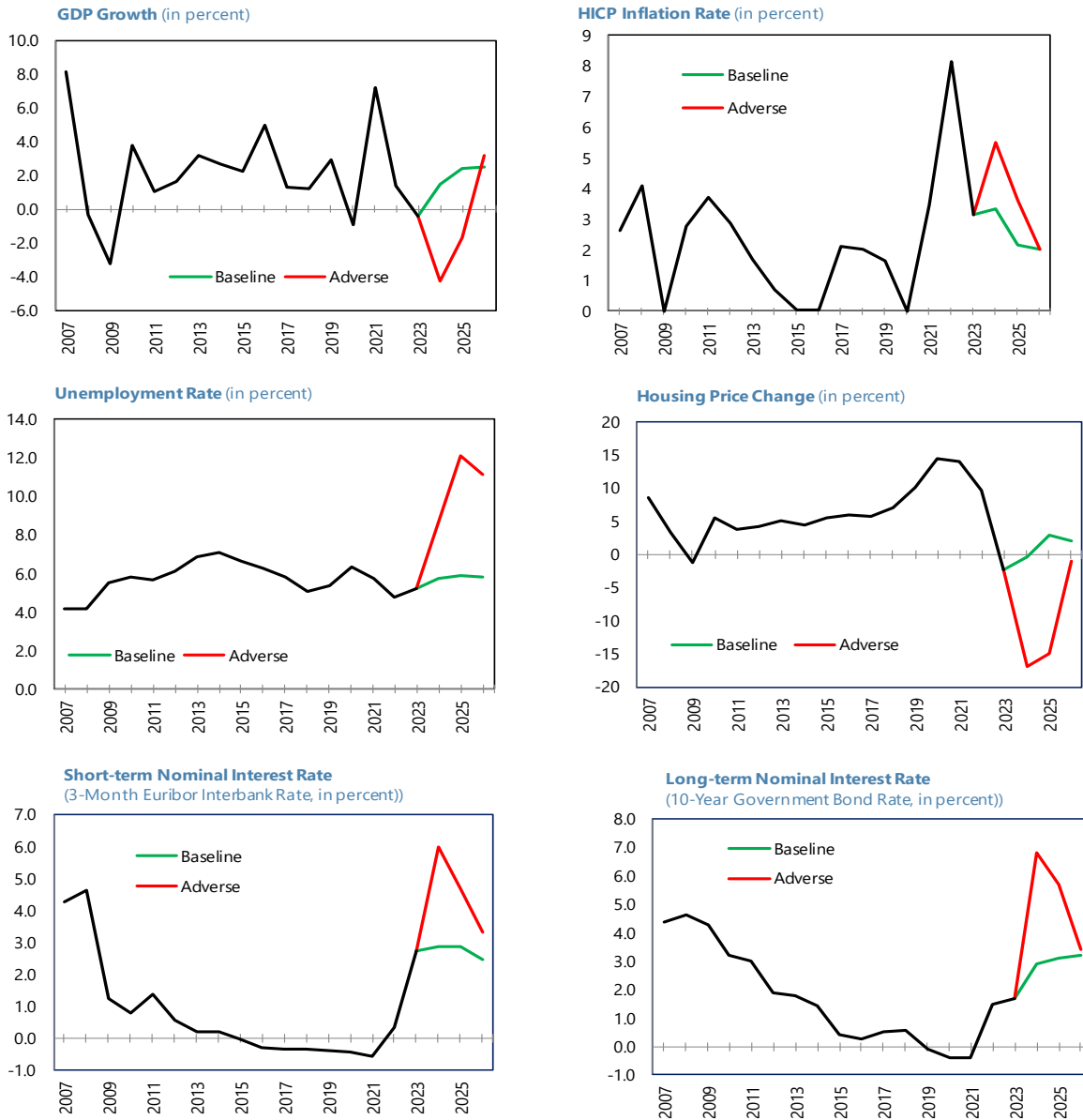
Sources: WEO, national sources, and IMF staff estimates.

D. Market Contagion and Liquidity-Solvency Interations Effects (Second and Third Rounds)

52.   The materialization of macroeconomic and financial risks in the adverse scenario would also trigger second and third round effects resulting from market contagion and liquidity-solvency interactions. In the second-round of shocks, investment funds might need to sell cross-border liquid assets (assuming they do not sell Luxembourg securities) that might have an impact on prices, which would have a second-round impact on NAVs of funds and valuation of securities in banks and funds (see section on Investment Funds). In a third round, selling liquid assets to stem bank deposit outflows would entail capital costs for banks, if standing facilities were not available at the central bank. Almost half of the banks with 20 percent of assets in the stress test sample, all foreign subsidiaries with diverse business models, do not have standing facilities set up with BCL. In the event a bank seeks to meet liquidity needs and starts selling held-to-maturity (HTM) assets—almost 80 percent of large banks' securities portfolios with unrealized losses—there could be liquidity-solvency interactions from realizing losses (from sales) on capital. This was explored in the stress tests. In addition, selling a large number of securities—especially if other sectors are also selling to stem redemption and lapses—could have additional fire-sale implications on the price of securities, with spillovers on the whole financial sector (see below).

BANK SOLVENCY STRESS TESTS

A. Types of Stress Tests

Scenario-Based Stress Test

53.   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 (TD) exercise based on macroeconomic scenarios and sensitivity analyses.

54.   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 Fifth Capital Requirements Directive (CRD V), Regulation on Prudential Requirements, national law and CSSF regulation. The main hurdle rates for the exercise were related to the Common Equity Tier1 capital ratio and the leverage ratio, set according to the Basel III fully-loaded definitions of capital requirements (see Table 3 below).

55.   The stress tests were based on minimum capital ratios under Pillar I and bank-specific Pillar II requirements. Hurdle rates used were: (i) for CET1: the Overall Capital Requirement Ratio (OCR, including the minimum requirement of 4.5 percent, the capital conservation buffer of 2.5 percent, average Pillar 2 requirement of 0.5 percent as well as an average Countercyclical buffer of 0.5 percent, and triggering restrictions for dividend distributions.), averaging 8 percent in our sample; (ii) for the leverage ratio: the minimum requirement of 3 percent (see Table 3 and Figure 14).

		Actual ratio before stress		
Scenario	Stress test hurdle rate	39 banks	Domestically-oriented	Internationally-oriented
Common Equity Tier I Capital ratio (CET1 capital to RWAs, in percent)	Bank-specific, average of 8 percent	20.9	20.9	20.9
Leverage ratio (Tier 1 capital to total assets, in percent)	3 percent	7.7	8.1	7.5
Tier I Capital ratio (Tier 1 capital to RWAs, in percent)	-	21.7	21.2	21.9
Total Capital ratio (total capital to RWAs, in percent)	-	22.6	21.8	23

Table 3. Luxembourg FSAP: Stress Test Average Hurdle Ratios vs. Current Ratios

Source: IMF staff calculations.

Figure 14. Luxembourg: Stacking Order for Overall Capital Requirement/Maximum Distributable Amount
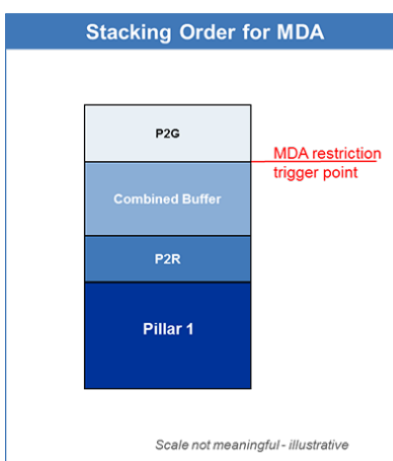
Source: European Central Bank

56. **The effects of the shocks on individual bank profitability and capitalization were assessed using satellite models and methodologies developed by Fund staff.** Satellite models link credit risk parameters (PDs) with various macrofinancial variables (see Appendix IV and Appendix V).

Sensitivity Analysis

57. **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 or decline 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. The tests also assessed the banks' sensitivity to default of the 2–10 largest exposures—a measure of concentration risk. 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 2023. 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. Comparison Between Macro Scenario Projections and Sensitivity Test Assumptions		
	Adverse scenario	Sensitivity test
Lending rate shock	324 bps	+/- 500 bps
Domestic sovereign interest rate shock	510 bps	+/- 500 bps
Foreign exchange rate shock	-7 percent	+/- 30 percent
Equity price shock (to Luxembourg stock price index)	-48 percent	-50 percent
Source: IMF staff calculations.		

B.   Banking Sector Solvency Stress Test Results

58.   In the baseline scenario, the aggregate CET 1 ratio would remain stable slightly below 22 percent. The profit creation by banks would be offset by the strong growth in banks' assets and the dividend distribution. Still, two banks—three banks if hedging is not considered—would struggle to meet the 3 percent leverage ratio hurdle ratio due to faltering profitability and a low initial leverage buffer.

59.   In the adverse scenario, the aggregate CET 1 ratio would drop by about 4 percentage points in 2024 to 17.6 percent before gradually recovering from 2025. Credit loss provisions, market losses and the change in risk-weighted assets would be the main drivers of the capital depletion. Four banks making up less than 10 percent of total banking sector assets would see their CET 1 ratio fall below the 8 percent hurdle rate, translating into a capital shortfall equivalent to 0.6 percent of nominal GDP. With regard to the leverage ratio hurdle rate, five banks would become undercapitalized in 2024 after the realization of the first round macrofinancial shock. A sixth bank would become so after additional funding costs resulting from liquidity stress and the need to pledge some Held-to-Maturity securities with the BCL. Two banks would have capital ratios below both thresholds.

Credit Risks in the Loan Book

60.   Credit risk in the loan book constitutes the large risk factor for the banking system. Total loans represent 51 percent of the assets of the 39 banks in the stress test sample (Figure 6). Loans to households make up 12 percent of total assets but 19.5 percent of the assets of the five domestically oriented banks. Debt securities (12.5 percent of total assets), most of which are held-to-maturity, 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 thirty-nine banks composing our stress test sample are to non-financial corporations, followed by credit institutions (including parent banks), reflecting intragroup positions

(Figure 15). Credit institutions compose the largest exposure class for custodian banks and private banks.

Figure 15. Luxembourg: Distribution of Banks' Exposures by Asset Class
(as a Percent of Total Assets)

Source: IMF staff calculations
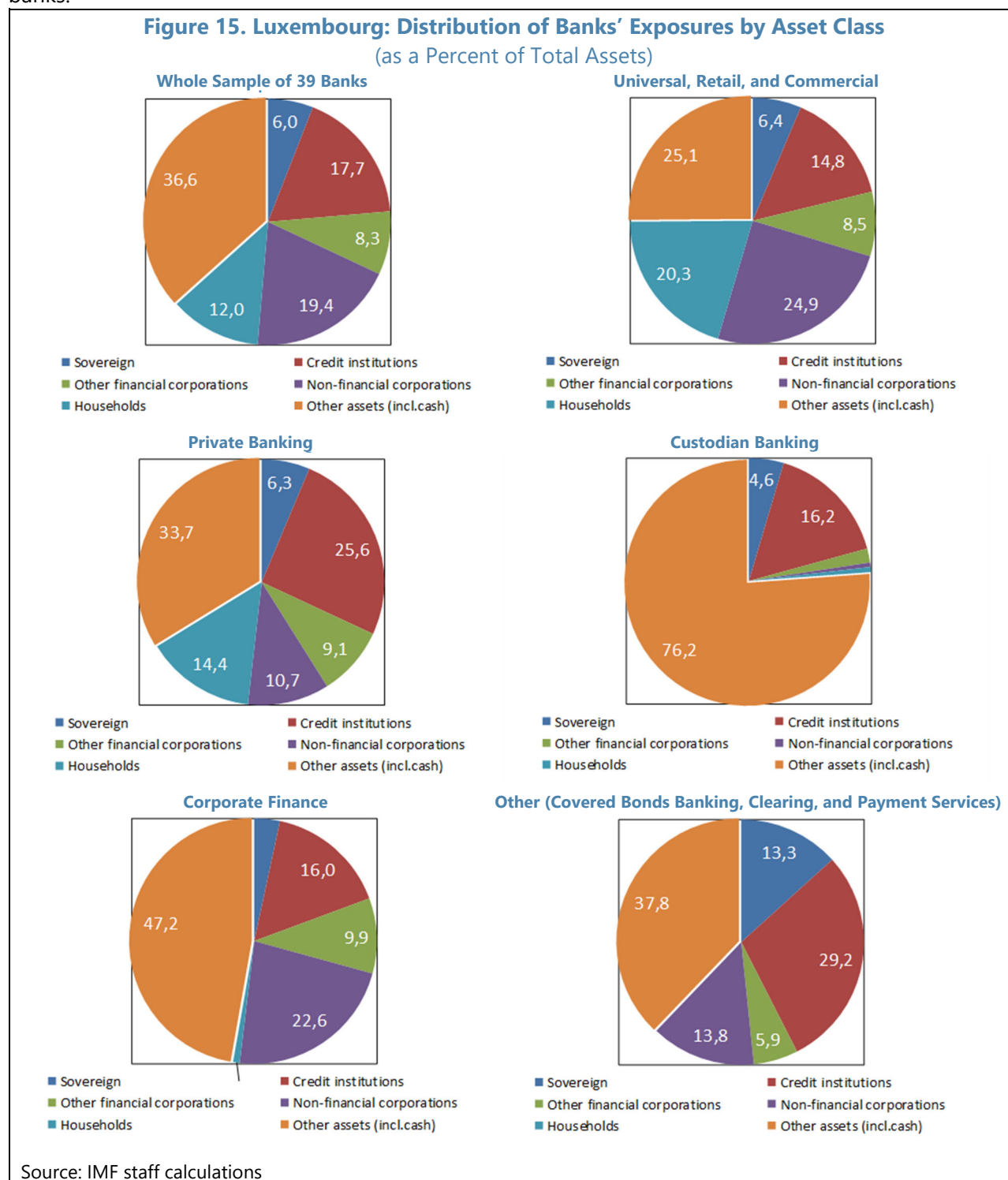
61.   Potential credit risk losses in the loan book represent a large but concentrated vulnerability in the banking sector. Top-down stress test results suggest that banks are likely to experience significant increases in Point-in-Time (PiT) PDs under the adverse scenario (see Figure 16), in a much sharper manner than under the baseline scenario. The combined effects of the economic slowdown and the rise in interest rates increase the banking system's average PD (weighted by banks' exposures at default) in the mortgage retail segment from 0.9 percent as of June 2023 to a peak of 3.5 percent under the adverse scenario, according to model results applying an international benchmark taken from the 2008/2013 Irish banking crisis. A floor was imposed on PDs on financial institutions so that they could not go in the adverse scenario below the level experienced during the 2008/2009 global financial crisis. Further details on the choice of assumptions employed in the stress modeling are provided in Appendix V.

62.   Expected credit losses under IFRS-9 in the adverse scenario are mostly driven by the corporate portfolio. The retail (non-mortgage) portfolio segment, including consumer loans and the credit card business, was found to be the one in which credit risk parameters are most sensitive to macroeconomic and financial variables. This resulted into a higher value of the PD multiplier for retail (non-mortgage) loans in the adverse scenario compared to the starting PD. Nevertheless, the rise in PDs would be sharp in the corporate loan portfolio, climbing from 1.9 percent in June 2023 to 5 percent in 2025 in the adverse scenario. The large losses in the euro area corporate portfolio also reflect the largest initial exposures at default in this segment. Conversely, the more benign corporate PD peak level in the adverse scenario compared to the previous 2017 FSAP resulted from the application of similar PD multiples to a much lower initial level.

63.   The rise in PDs requires additional provisions that worsen bank profitability in the stress scenario. Expected credit losses over the three-year horizon in the loan book amount to €3.8 billion in the adverse scenario, equivalent to 1.9 percent of total banking system RWAs, 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 €1 billion, equivalent to 0.5 percent of total banking system RWAs. These new provisions in the baseline scenario are more than offset by net income before losses (6.4 percent of total RWAs).

Market Risks in the Scenario Analysis

64.   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)

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[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). In the case of Luxembourgish banks, the main hedging counterparty is usually the parent company or another intra-group entity. The FSAP team assumed as part of the stress test that intra-group counterparties would not be able to respect their contractual obligations, for conservatism purposes with regard to risk endogeneity. However, a special treatment was made for some banks whose main hedging counterparty is not an intra-group entity.

held by the banks. Interest, exchange rate and equity risks were the three market risks included in the stress tests.

Figure 16. Luxembourg: PD Projections in the Baseline and Adverse Macroeconomic Scenarios
(IMF model)
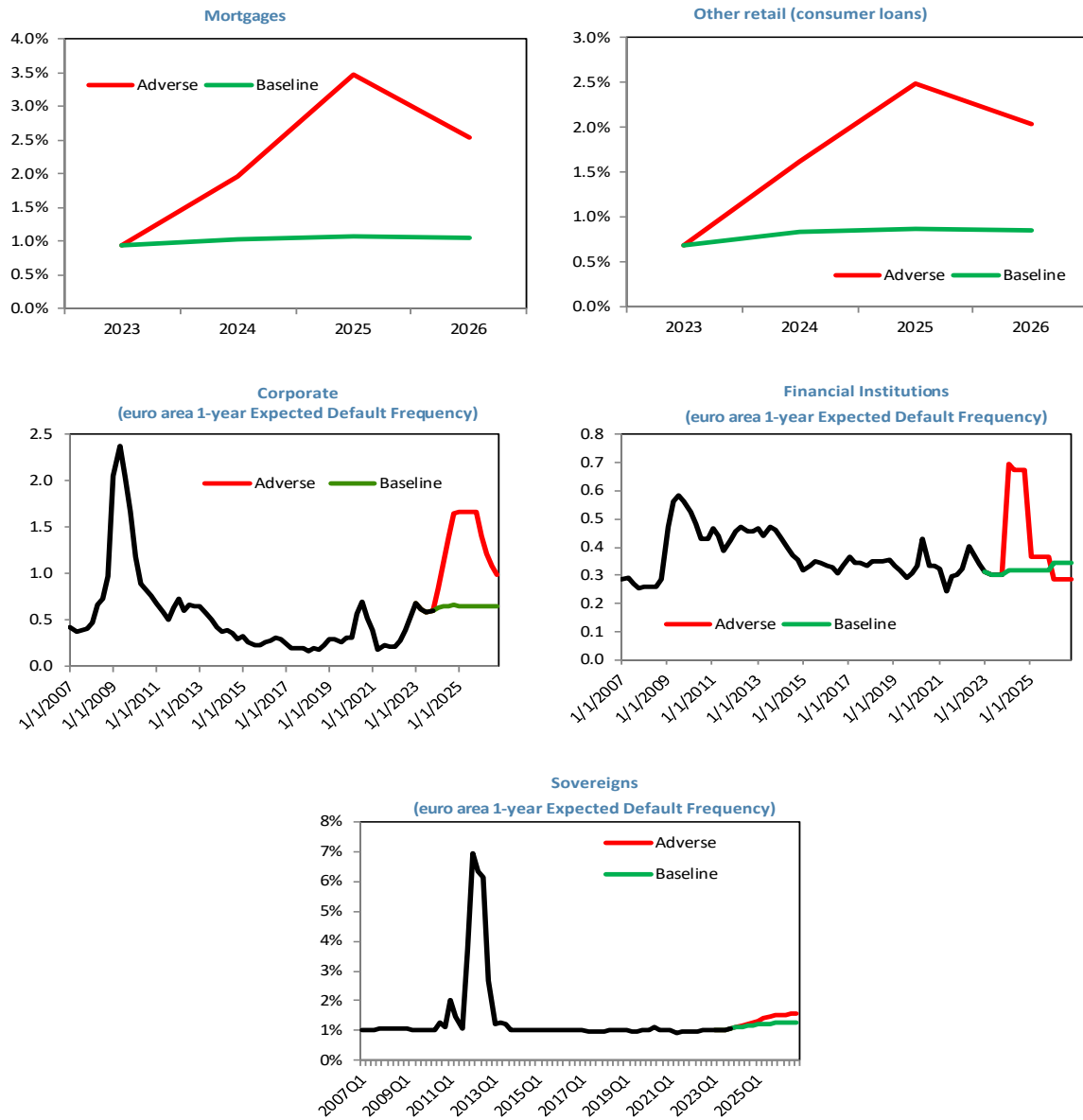
Source: IMF staff calculations

Interest Rate Risk

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

66.   In the adverse scenario, Luxembourgish banks gain a significant amount of net interest thanks to the widening of the net interest margin. Banks' net interest income is a main source of profits for banks and is sensitive to changes in interest rates, as these could increase or 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 10-year German government bond rate (chosen as the risk-free rate) is projected to increase by 3.2 percentage points in 2024 and then to decline by 1 and 2 percentage points in 2025 and 2026, respectively, in the adverse scenario. Thirteen banks in our stress test sample display a negative time-to-repricing gap (i.e. liabilities are repriced faster than assets) for maturities shorter than 1 year, leading them to lose interest income when interest rates rise. At the aggregate level for the thirty-nine banks, the repricing gap in the balance sheet amounted to €118 billion as of June 2023 for maturities below one year. In the adverse scenario, this repricing gap and the change in interest rates translate into a material positive effect on the Capital Adequacy Ratio of €5.4 billion, equivalent to 2.7 percent of Risk-weighted Assets, over the entire stress horizon. For the thirteen banks displaying a negative repricing gap, all private or custodian banks, this gap amounted to -€7.5 billion in June 2023; it would translate into a decline in the amount of CET1 capital by €1.2 billion, equivalent to -4.4 percent of their Risk-weighted Assets, after the first year of the scenario. The negative interest income in the first year of the scenario, despite the widening of the interest margin, reflects this negative repricing gap, the negative interest income at one bank at the starting date of the scenario and the surge in funding costs. These banks would start benefiting from a positive net interest margin from the second year of the scenario.

67.   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 securities portfolio by accounting category (FVPL, FVOCI, AC) was taken as a proxy for Luxembourgish banks based on data from BCL. Exposures to general government debt, the debt of financial corporations and corporates were taken from the European Financial Reporting (Finrep) template. Using a modified duration approach for bond valuation analysis, losses were calculated as the product of the size of the bond portfolio,

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[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.

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.

68.   Potential valuation losses on foreign sovereign and corporate debt are significant under the stress test despite the fact that most exposures are located in the held-to-maturity portfolio. 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 in the first two years of the scenario, with an impact on the Capital Adequacy Ratio (CAR) by 1.2 percentage points (ppts). This rather manageable result can be explained by two factors: (i) the small size of the marked-to-market bond portfolio of Luxembourg banks, with an average AFS and HFT exposure of only 2.8 percent of total assets and 22.6 percent of the total securities portfolio; (ii) a moderate average maturity of Luxembourgish banks' bond portfolio, averaging 4 years. Interest rate risk hedges were not taken into consideration for the other comprehensive income calculations (AFS portfolio) due to the endogeneity of risk within a group when the counterpart to the derivatives contract is the foreign parent company. However, a sensitivity analysis was carried out for three weaker banks to determine the changes to the main results brought about by the assumption of 50 percent of the marked-to-market bond portfolio being hedged, based on some data confidentially shown to the team during the mission (see paragraph ¶72 below).

69.   Banks benefit from modest gains on their net foreign exchange positions in the adverse scenario. The direct effects of exchange rate risks were assessed based on banks' net open FX positions (see the sensitivity analysis subsection for the detailed methodology). In this scenario, the euro is expected to depreciate against the U.S. dollar over the whole period, which results in a small gain of €45 million.

First Round Effects: Impact of the Macrofinancial Scenario

70.   In the adverse stress scenario, expected credit 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 17.

71.   Under the adverse scenario, the banking system would remain very well capitalized despite a marked decline in the system-wide capital ratio and some weaker banks (Figure 17 and Table 18). 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:

- The ratio of banks' Common Equity Tier 1 capital relative to their total risk-weighted assets (the aggregate CET1 ratio) would drop by 4.1 percentage points, from 21.7 percent as of December 2023 (after integration of the expected net result of the year based on data as of June 2023) to 17.6 percent in 2024, before gradually recovering from 2025. Credit losses (-1.9 percentage points of RWAs), decline in other comprehensive income (-0.6 percentage points of RWAs), and the change in risk-weighted assets (with an effect of –0.6 percentage points) would drive the decline in the CET1 ratio throughout the adverse scenario. The capital of four banks making up

less than 10 percent of the banking sector's assets, including 1 SI and 3 LSIs, would fall below the CET1 hurdle rate of 8 percent, entailing moderate recapitalization needs amounting to 0.6 percent of nominal GDP. The higher vulnerability of these banks stems from three factors: lower initial profitability, a lower initial solvency position and a higher exposure to the domestic corporate and retail sectors. If banks were allowed to dip into the capital conservation buffer and the countercyclical capital buffer, then two banks would still be below the CET1 hurdle rate. If the Basel III minimum of CET1 ratio of 4.5 percent were used as the threshold, then one small bank would not pass it.

- With regard to business models, domestically oriented banks would be slightly more impacted than internationally oriented banks by the adverse scenario during the first year of the adverse scenario (Figure 18). Private banks would experience the largest capital depletion, reflecting their lower initial profitability and their negative repricing gap (see ¶ 66), but corporate finance banks would end up with the lowest average level of capitalization (Table 5).

- The ratio of banks' Tier 1 capital relative to their total (not adjusted) assets (the leverage ratio) would decline from 7.7 to 6.8 percent in 2024 and 7.4 in 2025. Five banks would see their ratios decline below the hurdle rate of 3 percent in 2024, by an amount equivalent to 0.9 percent of nominal GDP, with two banks below both (CET1 and leverage ratio) hurdle rates.

72.   In the baseline scenario, the aggregate banking system would remain well capitalized, but a few banks were identified as weak. Three banks (8½ percent of total assets of the sample, with 1 SI and 2 LSIs) would struggle to meet the leverage ratio of 3 percent in the baseline in 2024. Furthermore, one bank would see its CET1 ratio fall below the regulatory CET1 hurdle rate in 2025/2026. This is due to its low initial level of capitalization and low profitability.

73.   Some caveats should be borne in mind resulting from data and methodological limitations. These limitations are likely to affect FSAP credit loss estimates and solvency projections in the adverse scenario. On the one hand, the top-down stress test did not take into account loan write-offs and cures. Intragroup risk mitigants such as economic hedges and financial guarantees were not considered, because of the assumption on their enforceable nature during a crisis. With a hedging assumption of 50 percent of the AFS and trading books for three weaker banks, the average CET1 ratio of these three banks whose main hedging counterparties are not intra-group entities would be improved by 0.3 ppts but they would remain under the hurdle rate of 8 percent. 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.

Figure 17. Luxembourg: Bank Solvency Stress Test Results

Common Equity Tier 1 Capital Ratio
(Fully-Loaded, in percent)

Baseline — Adverse — Hurdle rate

Leverage Ratio
(Fully-Loaded Tier 1/Total Assets, in percent)

Baseline
Adverse
Hurdle rate

Net Profit Components in the Adverse Stress Scenario (EUR billions)

Net Interest income

Loss provisions (Credit Risk)

Net non-interest income

Other comprehensive income (AFS portfolio)

Others

Taxes

Net effect

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

Net Profit before stress

Loss provisions (Credit Risk)

Trading and AFS book repricing risk

Change in Risk weighted assets

Net effect

Capital Shortfalls (based on CET1 and leverage ratios, as a percent of nominal GDP)

Baseline — Adverse - Leverage

Adverse - CET1

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

CET1> =10%

CET1< 10%

CET1< 8%

CET1< 5,5%

CET1< 4.5%

CET1< 2%

CET1< 0%

Sources: ECB; and IMF staff calculations

Figure 18. Luxembourg: Bank Solvency Stress Test Results: Breakdown Between Domestically-Oriented and Internationally-Oriented Banks

Domestically oriented Banks

Internationally oriented Banks
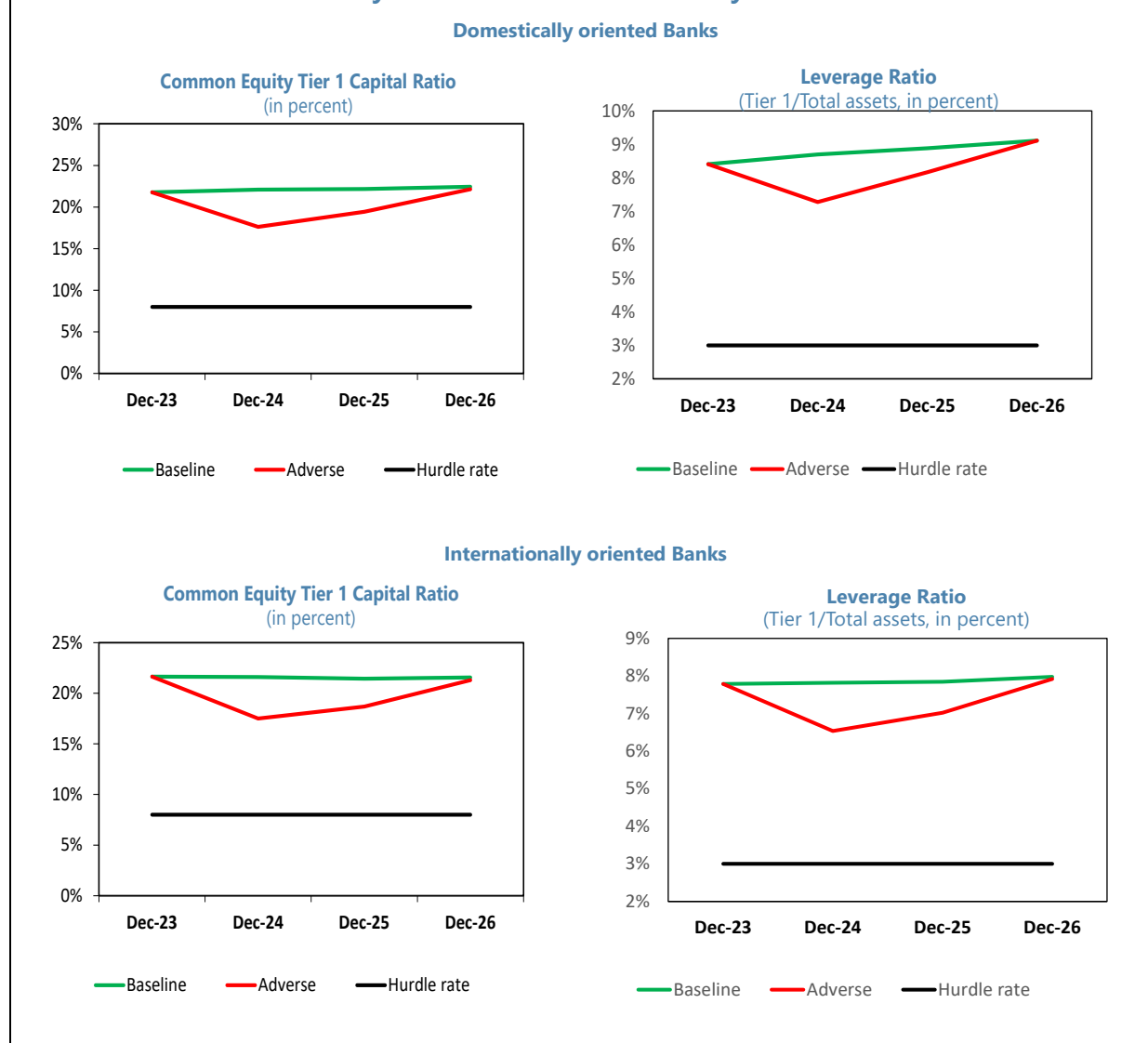
Table 5. Luxembourg: Bank Solvency Stress Test Results: Breakdown by Business Model

	Universal, retail and commercial banking	Private banking	Custodian banking and activities linked to investment funds	Corporate finance	Other (covered bonds banking, clearing, treasury or payment services)
CET 1 ratio before stress	20.9%	25.2%	42.2%	14.6%	42.4%
CET 1 ratio - baseline (end of 1st year)	22.0%	26.7%	43.5%	15.2%	47.6%
CET 1 ratio - adverse (end of 1st year)	17.0%	16.8%	42.6%	13.8%	46.5%
Capital depletion in the adverse scenario (-/+ implies declines/increases)	-3.8%	-8.5%	0.4%	-0.9%	4.1%

Source: IMF staff calculations.

Household Stress

74.   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' 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 (see Technical Note on Macroprudential Policies).

Second and Third Rounds of Shocks: Impact of Investment Fund Sales and Liquidity-Solvency Feedback Loop in the Banking Sector

75.   In a second round of shocks, the decline in market value of marked-to-market bonds resulting from the fire sales by investment funds would have a negligible impact on banks' capital ratios. Based on the results of the investment fund liquidity stress test (see section on Investment Funds for the modeling assumptions), the price impact of these sales would correspond to a 1 percent drop in the market value of German and French bonds. This would translate into an aggregate market loss of €156 million for the 39 banks composing our sample, with a negligible impact of -0.1 percentage point on the aggregate CET 1 ratio and no additional undercapitalization in 2024.

76.   In a third round of shocks, market losses stemming from fire sales of Held-to-Maturity securities or increased funding costs in response to liquidity stress would add a moderate additional stress to the banks. The liquidity stress tests (see section on Bank Liquidity for the modeling assumptions) revealed that, among our sample of 39 banks, fifteen would experience a funding gap in the combined liquidity stress test scenario. These fifteen banks were assumed to need to sell or pledge part of their Held-to-Maturity portfolio to cope with the net liability outflows. Nine would have directly activated access to central bank facilities and would thus be able to pledge their Held-to-Maturity securities with the BCL to get refinancing in cash. For these banks, it was assumed that they would have to pay 100 bp penalty rate over the main refinancing rate of the ECB. This refinancing of the HTM securities would translate into additional funding costs of €1.1 billion and a further decrease in their CET1 ratio by 1.4 ppts for these nine banks, causing the undercapitalization of one more bank with regard to the leverage ratio hurdle rate in 2024. Six banks that have not activated access to central banks facilities would thus have to sell part of their HTM securities and to realize a market loss on this part that has been marked-to-market for this exercise. The losses would be estimated at € 88 million, translating into a further decrease in their CET1 ratio by 0.8 ppts for these five banks (Figure 19). The system-wide impact would be equivalent to a decline of 0.5 percent of the aggregate CET1 ratio and of 1.3 percentage points of the CET1 ratio of the banks with funding gaps (Figure 19).

Figure 19. Luxembourg: Bank Liquidity-Solvency Interactions

Liquidity-Solvency Interactions: Impact of Increase in Funding Costs and Market Losses Resulting from Liquidity Stress (Banking System's CET1 Capital in Percent of RWAs)

Source: IMF staff calculations
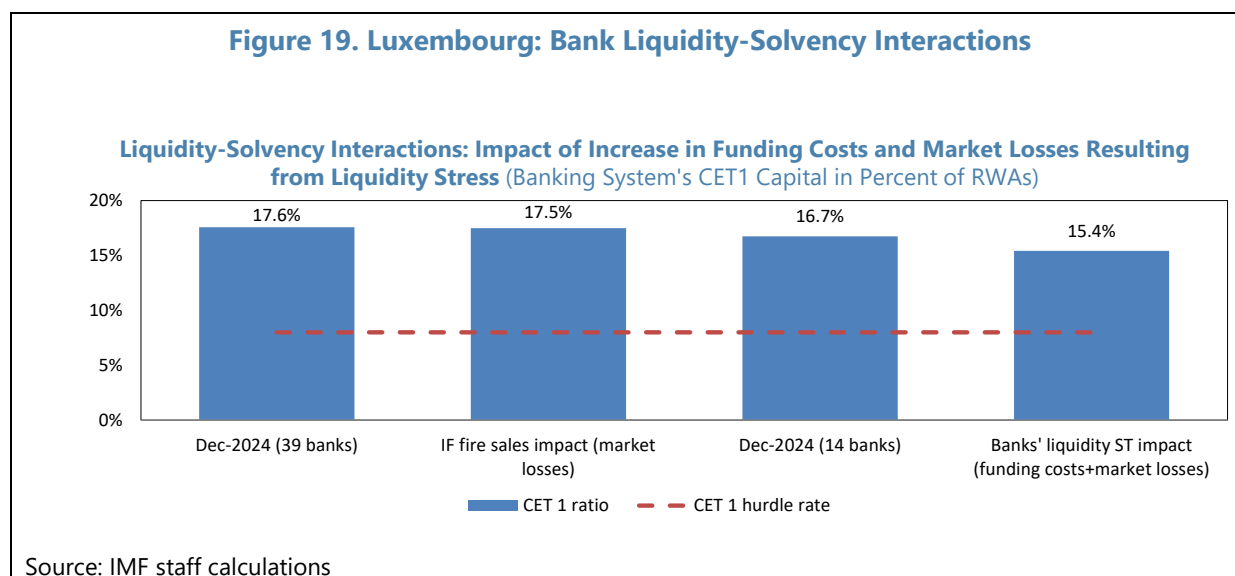
C. Results of Sensitivity Analysis

Market Risks Based on Sensitivity Analysis

A Decline in the Prices of Domestic Sovereign Securities

77.   Sensitivity tests assessed the impact on the portfolio under the fair value approach from increases in the domestic sovereign interest rate. The tests assessed the sensitivity of banks' domestic sovereign bond AFS portfolio to a 500 basis points (bp) increase in interest rates. In the absence of data on the duration of banks' AFS portfolio, the average maturity of the AFS portfolio of domestic sovereign exposures was taken as a proxy for Luxembourgish banks based on the data transmitted by the BCL. 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.

78.   The results show that Luxembourgish banks are very little exposed to domestic sovereign bond risks. The impact of domestic sovereign bond portfolio losses would be very limited. Specifically, the CET1 ratio in the system would remain flat after the realization of these losses taken in isolation (assuming that no other shocks trigger simultaneous losses for these banks). Indeed, only one bank has a moderate marked-to-market exposure to the Luxembourgish sovereign and no bank would become undercapitalized with regard to the hurdle rate of 8 percent (Figure 20).

79.   However, if the entire Held-to-Maturity securities were marked to market under the adverse scenario, then additional market losses would amount to €13.1 billion in 2024, causing a drop in the aggregate CET1 ratio by 6.5 percentage points and recapitalization needs equivalent to 8 percent of GDP.

Figure 20. Luxembourg: Sensitivity Analyses for Sovereign and Credit Concentration Risks

Sovereign Shock on Banks and Credit Concentration Tests (Banking system's CET1 capital in percent of RWAs)
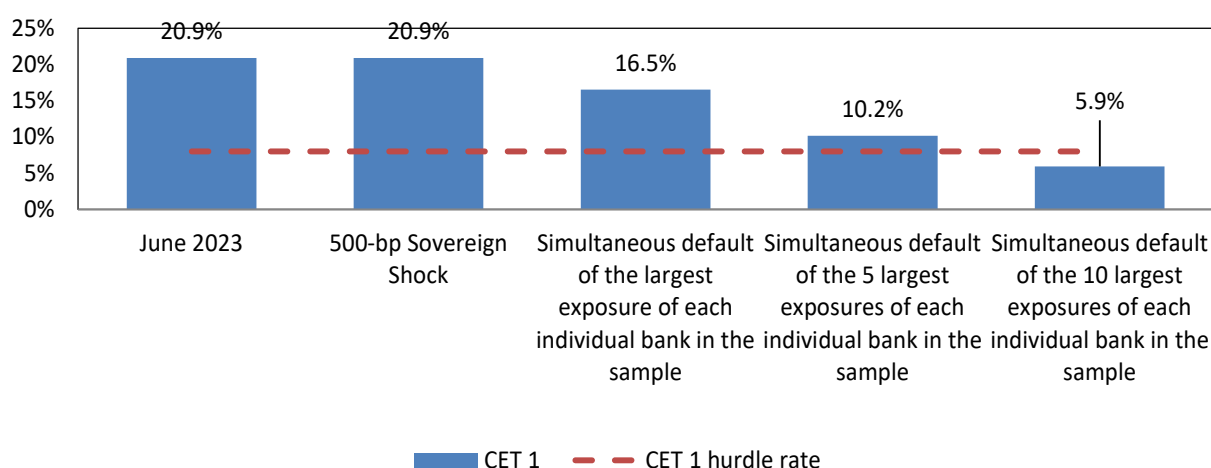
Source: IMF staff calculations

Interest Rate Risk: Net Interest Income Effects

80.   A sensitivity test based on a maturity ladder (gap) analysis suggests that the banking system would gain a large 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 increase the total banking system's net interest income by €5.9 billion, with a positive impact on the aggregate CET1 capital ratio by 3 percentage points. It would not cause undercapitalization in any of the thirty-nine banks. Conversely, a decline in interest rates by 500 bps would cause a symmetric aggregate decline in banks' net interest income by 5.9 billion, translating into a 3 percentage point decline in the aggregate CET1 ratio but no undercapitalization of any bank with regard to the CET1 hurdle rate of 8 percent.

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

81.   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. Data on net open FX positions taken as of June 30, 2023 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.

82.   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 twenty-nine of the thirty-nine banks. On an aggregate basis, the thirty-nine banks have a long net open position in foreign currency amounting to €4.7 billion, making up 11.5 percent of their CET1 capital.

83.   The test indicates that a 30 percent depreciation of the euro nominal effective exchange rate would cause a gain of €255 million, with a moderate impact on the aggregate CET1 ratio by 0.1 percentage points. Conversely, a 30 percent appreciation of the euro nominal effective exchange rate would cause a loss of €255 million. This shock, taken in isolation, would not cause the undercapitalization of any bank.

A Decline in Stock Prices

84.   A decline in stock prices would have a negligible impact on banks' capitalization. Marked-to-market equity investments makes up a moderate share of banks' CET1 capital, averaging 0.1 percent, and net open positions are even smaller. 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 €430,000, with no material impact on the aggregate CET1 ratio. This shock, taken in isolation, would not cause undercapitalization in any of the thirty-nine banks.

Concentration Risk: Failure of a Number of Large Exposures

85.   Name concentration risk (i.e., exposure to a single large 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 interconnected clients. 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. In our sensitivity analysis, we used the recovery rate calculated by banks within the national regulation framework.

86.   Sensitivity tests show that a large number of Luxembourgish banks would be vulnerable to the simultaneous default of their largest to five largest exposures, excluding central bank and intragroup exposures. On average, the size of the single largest exposure net of credit mitigation measure reaches 21 percent of CET1 capital and this exposure often corresponds to a foreign financial institution (different from the parent company which is exempted). The default of the net largest exposure of each of the thirty-nine banks would cause the aggregate CET 1 ratio to decline by 4.4 percentage points (Figure 20), and the undercapitalization of five banks, translating into a capital shortfall of 1.8 percent of nominal GDP. The simultaneous default of the five net largest exposures would lead fourteen banks to be undercapitalized with regard to the CET1 capital ratio hurdle rate of 8 percent, translating into a capital shortfall of 7.8 percent of nominal GDP.

Finally, the default of the ten net largest exposures would cause twenty banks to be undercapitalized in terms of CET1 capital, raising the capital shortfall to 14.4 percent of nominal GDP.

Policy Recommendations

87.   Taken in aggregate, the assessment of banking sector vulnerabilities points to several areas where the authorities could prioritize supervisory attention going forward. First, the CSSF and the BCL should collaborate to improve top-down supervisory stress test models in order to incorporate liquidity-solvency interactions. Second, supervisory reviews, including for SREP and Pillar II capital requirements, should consider strengthening the banks' concentration risk treatment in their large exposures to non-intragroup clients.

BANK LIQUIDITY STRESS TESTS

A. Methodology

88.   Three types of liquidity stress tests were conducted to assess banks' resilience to large withdrawals of funding and market liquidity shocks. LCR, NSFR, and cash-flow based tests. The LCR-based stress test measures banks' capacity to meet short-term liquidity needs in a 30-day horizon against the initial level of high-quality liquid assets (HQLA). The NSFR analyzes whether banks' available stable funding is sufficient to cover their required stable funding over a one-year period. The cash-flow based stress test leverages information on maturity profile over a wide range of time buckets, from overnight to more than one year, to investigate potential maturity mismatches and assess the availability of bank counterbalancing capacity to offset net cash outflows.

89.   The tests used June 2023 data for the sample of 39 banks, the sample analyzed in the bank solvency stress tests. The sample includes eight universal, retail and commercial banks, 14 private wealth management banks, nine corporate finance banks, five custodian banks, two covered bond banks and one clearing, treasury and payment service bank. In addition, the liquidity stress tests also consider a sub-sample of 16 banks including 15 banks with parent banks or subsidiaries in Europe identified as weak in the October 2023 Global Financial Stability Report Chapter 2 and two banks with deposits of funds from the same group (one of the two overlaps with the 15 banks with weak parents).

90.   Both the LCR and cash-flow based stress tests used four scenarios: baseline, deposit run, "combined," and weak parent bank scenarios. In the "baseline" scenario, the FSAP team used the regulatory parameters as applied by EBA for NSFR and LCR calculations. For the cash-flow analysis, the parameters are in line with the baseline scenario considered in the ECB 2019 Sensitivity Analysis of Liquidity Risk. In the "deposit run" scenario, higher deposit outflow rates were applied based on the empirical data collected from past deposit runs.[11] The "combined" scenario is a combination of high deposit run-off rates and market stress. In addition to the outflow parameters applied in the "deposit run" scenario, the "combined" scenario also captures the effect of market dislocations, by applying larger haircuts on asset values (HQLA in the case of LCR analysis, and counterbalancing capacity in the case of cash-flow based analysis) and lower coefficients on inflows

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[11] October 2023 Global Financial Stability Report Box 2.1 provides more details on the size of deposit outflow rates in past bank runs.

from the wholesale and retail segments. The "weak parent bank" scenario is only applied to the weak parent bank sub-sample. In addition to the "combined" scenario, even higher deposit outflow rates are used in this most adverse scenario to capture potential contagion effects and deposit runs triggered by parent companies or other entities from the same group that could be in trouble.

91.   Deposit run-off rates and paths were set to reflect the bank liquidity stress periods in history, especially based on the late 2022–early 2023 banking turmoil data, for example the cases of Credit Suisse in 2022Q4 and First Republic in 2023Q1 from which the numbers on deposit outflow rates for sub-categories were available.[12] These historical events have their idiosyncratic characteristics and may not be the same for Luxembourgish banks, therefore, the actual run-off rates could be lower in Luxembourg and results from the stress tests shall be considered conservative. In the LCR analysis, historical data were adjusted to match the 30-day horizon considered in the tests (Table 8). In the cash-flow based analysis, runoff rates for deposits, credit, and liquidity facilities are calibrated using similar daily rates as the ECB (2019),[13] while assuming outflows of a period of six months and 40 percent of the total outflows happen in the first five days (Table 6).

Table 6. Luxembourg: Cash-Flow Based Stress Tests Outflow Rates from Deposits, Liquidity, and Credit Lines
(Cumulative over Six Months, Percent)

	Deposit Run	Combined	Weak Bank
Stable retail deposits	5%	5%	10%
Other retail deposits	23%	23%	30%
Operational deposits	26%	26%	52%
Non-operational deposits from non-financial corporates	40%	40%	60%
Non-operational deposits from other counterparties	40%	40%	60%
Committed credit facilities	12%	12%	15%
Liquidity facilities	60%	60%	75%
Source: IMF staff.			

92.   Haircuts on assets are consistent with other European FSAPs and calibrated starting from the haircuts applied by the ECB in its collateral framework.[14] In the cash-flow based analysis, for each asset in the COREP C66 template, following the approach applied in other European FSAPs, haircuts are computed based on quantiles of a lognormal distribution centered around the haircut applied by the ECB for comparable types of assets. In particular, haircuts under "combined" and "weak parent bank" scenarios correspond to the 99.5th percentile together with country-specific adjustments (Table 7).

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[12] In the case of Credit Suisse 2022Q4, the deposit outflow rate was 23 percent for other retail deposits, 26 percent for transactional wholesale deposits, and 39 percent for other wholesale deposits. In the case of First Republic 2023Q1, the deposit outflow rate was 64 percent for checking deposits, 21 percent for time deposits, 5 percent for insured deposits, and 58 percent for uninsured deposits.

[13] ECB (2019), "ECB Sensitivity analysis of Liquidity Risk – Stress Test 2019 Methodological note".

[14] Guideline ECB/2022/49 amending Guideline (EU) 2016/65 on the valuation haircuts applied in the implementation of the Eurosystem monetary policy framework (europa.eu).

Table 7. Luxembourg: Cash-Flow Based Stress Tests—Haircuts on Counterbalancing Capacity		
	Deposit Run	Combined and Weak Bank
Level 1 tradable assets		
Level 1 (CQS 1)	2%	15%
Level 1 (CQS2, CQS3, CQS4+)	3.5-10%	17-23%
Level 2A tradable assets	3.5-4.5%	17-18%
Level 2B tradable assets		
Level 2B ABS, covered bonds	3%	25-30%
Level 2B (CQS 3-5)	13%	50%
Other tradable assets		
Central government (CQS1)	14%	29%
Central government (CQS 2 & 3)	25.5%	39%
Other tradable assets	25.5%	39%
non tradable assets eligible for central banks	25.5%	90%
undrawn committed facilities received	30%	75%
Source: IMF staff.		

Table 8. Luxembourg: LCR Stress Test Parameters (Percent)					
Parameter	Position	Scenario			
		Baseline	Deposit Run	Combined	Weak Bank
Run-off rates	Stable retail deposits	5%	10%	10%	10%
	Other retail deposits	10%	23%	23%	30%
	Retail deposits subject to higher outflows	15-20%	25-40%	25-40%	25-40%
	Operational deposits	5-25%	15-35%	15-35%	15-45%
	Excess operational deposits	20-40%	30-60%	30-60%	30-80%
	Non-operational deposits	20-40%	30-60%	30-60%	30-80%
	Committed facilities to retail customers	5%	10%	10%	10%
	Committed facilities to corporate customers	10-30%	20-40%	20-40%	20-50%
	Committed facilities to credit institutions	5-40%	10-50%	10-50%	10-60%
Change in liquidity assets weights	Level 1 assets	/	/	-5/0%	-5/0%
	Level 2A assets	/	/	-30/-10%	-30/-10%
	Level 2B assets	/	/	-15%	-15%
Source: IMF staff.					

93.   The resilience of banks to large retail deposit outflows was assessed through a targeted LCR-based reverse-stress-testing exercise. Increments of five percent from zero percent to 40 percent of retail deposit outflow rates were tested, and the LCR was computed for each bank at each of these different values.[15]

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[15] Retail deposits include: "retail deposits exempted from the calculation of outflows;" "retail deposits where the payout has been agreed within the following 30 days;" "retail deposits subject to higher outflows, category 1;" "retail deposits subject to higher outflows, category 2;" "stable deposits," "derogated stable deposits;" "other retail deposits."

94. **The cash-flow analysis was used to assess solvency risks originating from the sale or pledge of held-to-maturity (HtM) assets during liquidity stress.** Banks are assumed to counterbalance negative funding gaps using their existing cash and central bank reserves first, next undrawn committed facilities (but excluding facilities from intragroup and other counterparties), then available-for-sale securities, and lastly HtM securities. The amount of HtM assets banks have to sell or pledge for central bank facilities access due to liquidity stress was computed as a function of the approximated shares of HtM assets in banks' counterbalancing capacities together with additional liquidity needed when banks run out of their counterbalancing capacities. The amounts used in the bank liquidity-solvency interaction were the maximum cumulative use of HtM for the period of one year in the cash-flow analysis.

B.   Results

95. **All banks have regulatory NSFRs above 100 percent.** From its initial composition of available stable funding, banks have a high reliance on deposits and other liabilities from financial institutions for all types of business models. For universal, retail and commercial banking, and private banking, corporate deposits and retail deposits are also important sources of funding (Figure 21, left panel). As of mid-2023, the weighted average NSFR of sample banks stood at 187 percent, comfortably above the minimum requirement of 100 percent with no single bank below the threshold (Figure 21, right panel).

Figure 21. Luxembourg: Bank NSFR Stress Test Results

Sources: ECB; CSSF; and IMF staff calculations.
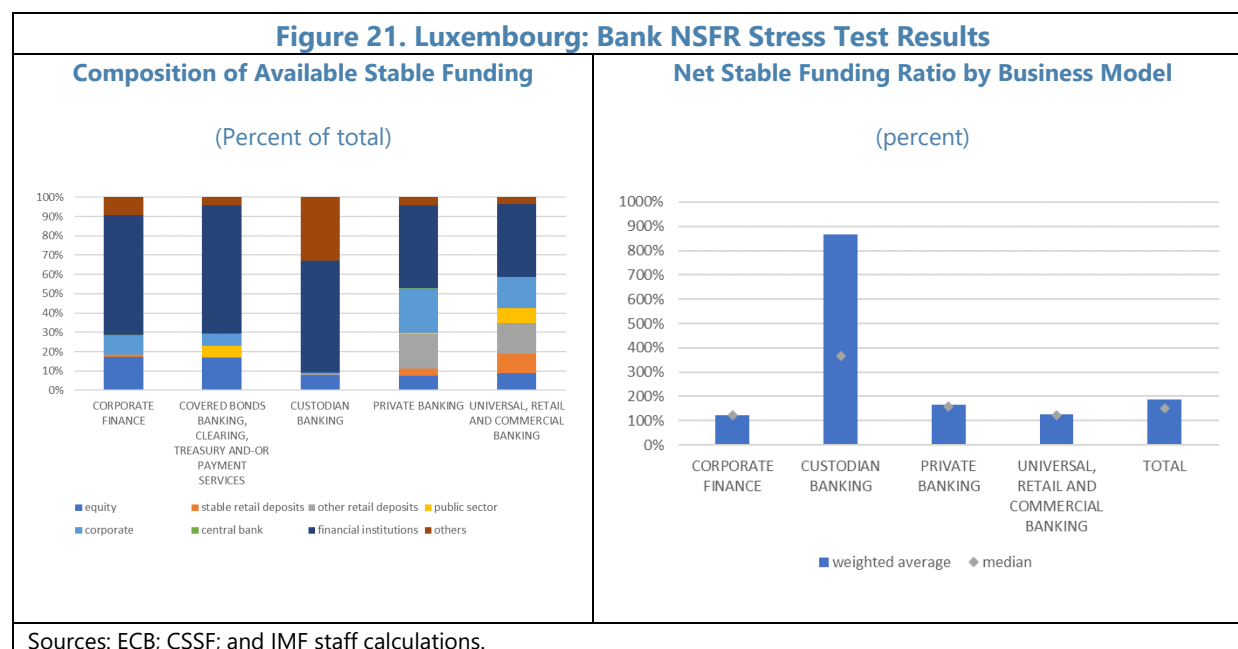
96. **The HQLA of all sample banks are concentrated in HQLA level 1, while most liabilities are in the form of wholesale deposits** (Figure 22, first and second panels). HQLA level 1 comprised more than 90 percent of total HQLA for all types of business, which indicates high levels of liquidity. Central bank reserves are the largest portion of HQLA, accounting for around 70 percent of total HQLA. On the liability side, retail deposits are mainly concentrated in more traditional banks and private banking. Wholesale deposits account for a large portion of liabilities in all types of banks, especially non-operational deposits which are subject to high outflow rates in stress periods.

97.   Banks' all-currencies LCRs are overall strong, while some banks could be weak in adverse scenarios (Figure 22, third panel). The weighted average liquidity coverage ratio (LCR) in the baseline scenario is 229 percent for the full sample, while 180 percent for the sample of retail and universal banks. Under the "deposit run" scenario, five banks would fall below the 100 percent LCR threshold, and under the "combined" scenario, one additional bank (in total six banks accounting for 23.8 percent of total assets in the sample) would fall below the 100 percent LCR requirement. Moreover, under the "weak parent bank" scenario, three banks would have their LCRs under the threshold. Among six banks identified in the combined scenario, four of them are SIs. Part of the reason for the relatively weak liquidity positions for these SIs, which are mostly subsidiaries of global banks, is strategic consideration from their parent companies. Consistent with the centralized liquidity management approach that is typically adopted by large internationally active banking groups (degree of centralization may vary between groups), some subsidiaries are found to up-stream part of their excess liquidity to the group. Thus, these entities tend to operate with relatively lower liquidity ratios.

98.   Banks lack liquidity buffers in U.S. dollars and GBP as LCRs in both currencies are below 100 percent for all types of business models (Figure 22, fourth panel). Banks have net outflows in a wide range of currencies, including CAD, CHF, DKK, GBP, PLN, SEK, USD, and YEN, but most banks have very limited or no liquidity buffers in these currencies. In particular, 11 banks with GBP liabilities in the stress test sample are found to be falling short of GBP HQLA. In case of large outflows in currencies other than EUR, banks would need to rely on the monetization of their EUR HQLA and/or FX swaps to fund gaps.

Figure 22. Luxembourg: Bank LCR Components and Stress Test Results

Sources: ECB; CSSF; and IMF staff calculations.
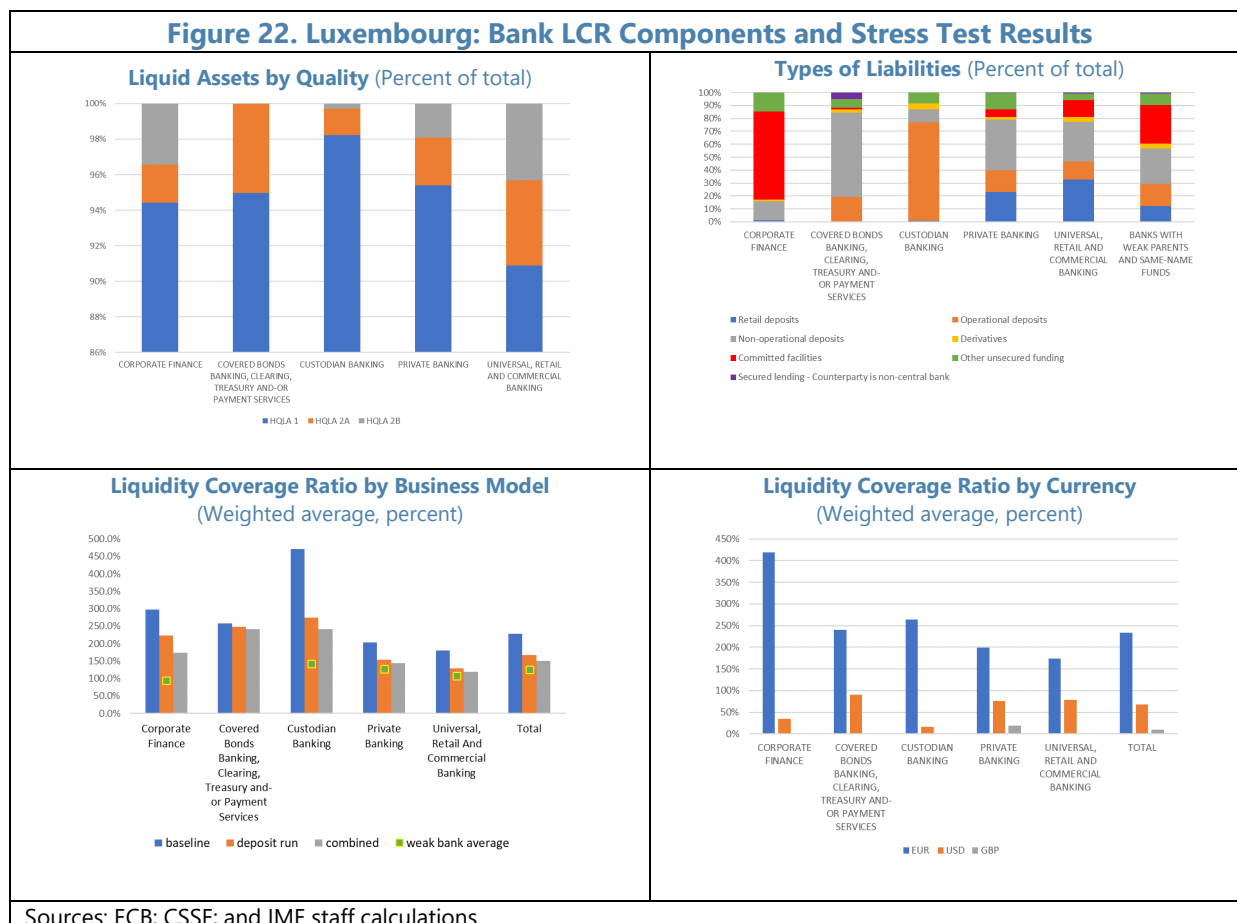
99.   Banks are resilient to retail deposit runs up to 20 percent (Figure 23). Based on the reverse stress, all banks have an LCR above 100 percent if retail deposit runoff rates are below 20 percent. When the retail deposit run-off rate reaches 21 percent, one bank has its LCR fall below 100 percent. At a 40 percent run-off rate, three banks (accounting for 14 percent of total assets in the sample) have their LCRs below the regulatory threshold.

Figure 23. Luxembourg: Sensitivity of LCRs to Retail Deposit Run-Off Rates

Source: ECB, CSSF, and IMF staff calculations.
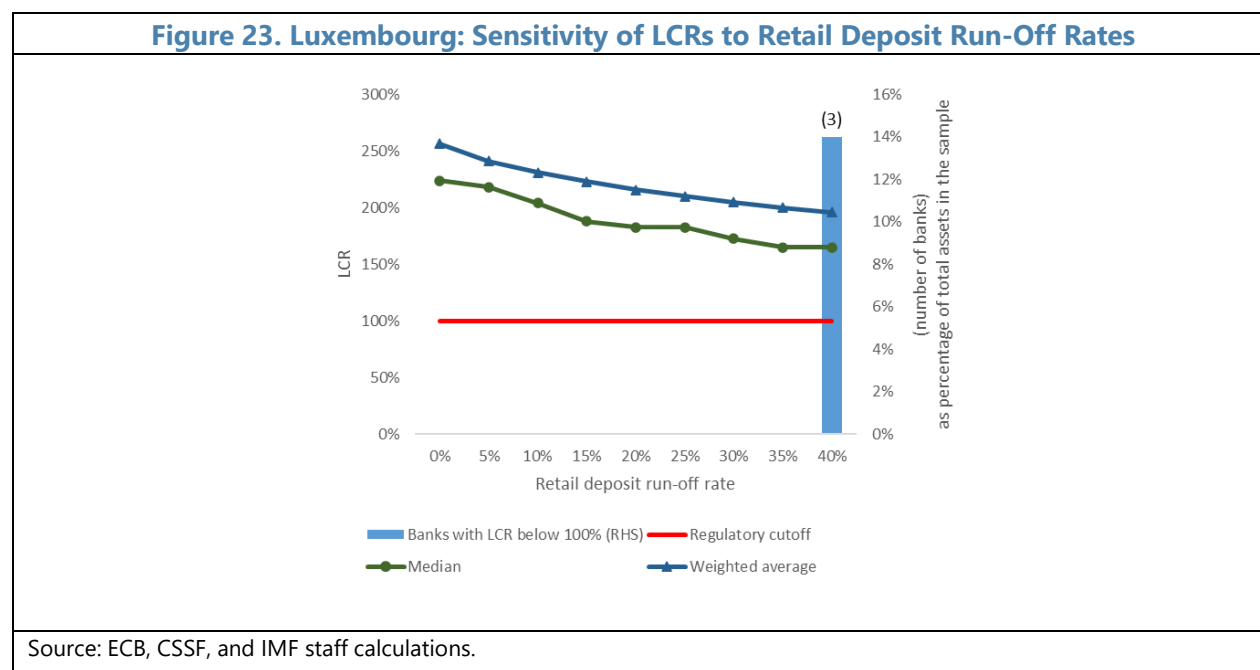
100.   The cash-flow analyses confirm that banks have generally strong liquidity positions, but a number would face net funding gaps in adverse scenarios. The counterbalancing capacity against liquidity risks is of high quality, as it mainly comprises central bank reserves in most business models, followed by Level 1 liquid assets (Figure 24, first panel). Based on the stress test results, many banks (15 out of 39 in the "Combined" scenario) would use up their cash and central bank reserves, as well as available-for-sale securities in their counterbalancing capacity. Therefore, these banks would need to either sell, repo, or pledge HTM assets for central bank facilities in the scenarios considered. Aggregate cash-flow results show most banks remain liquid in stress scenarios (Figure 24, second to fourth panels). Nevertheless, within the 12-month horizon, one bank would face a net funding gap in the baseline scenario, three banks in the deposit scenario, six banks in the combined scenario, and in the sub-sample five banks (including three identified in the combined scenario) in the weak parent bank scenario (Figure 24, the bottom panel).

101.   The liquidity gap was the widest for the 3–6 month and 6–12 month time buckets. These are not monitored based on the regulatory LCR or NSFR, which only oversee the 30-day and one-year horizon, respectively. Similar to the LCR results, five out of six banks identified with potential net funding gaps are subsidiaries of significant banking groups from an SSM perspective.

Figure 24. Luxembourg: Cash-Flow Based Analysis Results

Composition of Counterbalancing Capacity
(Percent of total)

Legend:
- Coins and bank notes
- Withdrawable central bank reserves
- Level 1 excluding covered bonds
- Covered bonds
- Corporate bonds
- ABS
- Shares
- Other tradable assets
- Non tradable assets eligible for central banks
- Undrawn committed facilities received

Aggregate Cash-flow Results: Deposit Run
(Billion, EUR)

Legend:
- Cumulative outflows
- Cumulative CBC
- Cumulative inflows
- End-of-period CBC

Figure 24. Luxembourg: Cash-Flow Based Analysis Results (Continued)

Aggregate Cash-flow Results: Combined

(Billion, EUR)
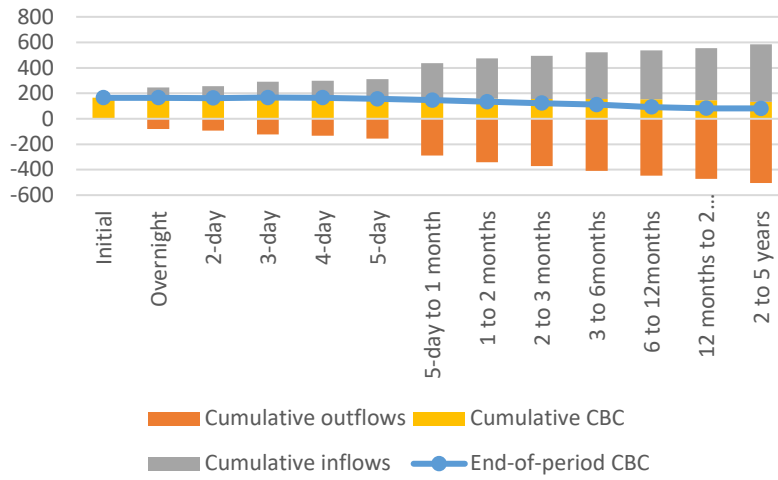
Aggregate Cash-flow Results: Potentially Weak Parent Bank

(Billion, EUR)
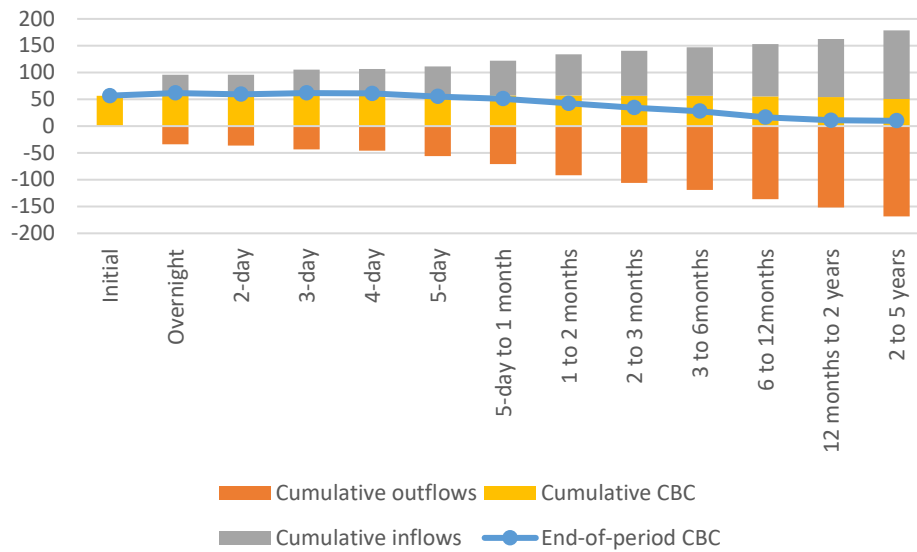
Figure 24. Luxembourg: Cash-Flow Based Analysis Results (Concluded)

Number of Banks with Net Funding Gap

(Cumulative)

Sources: ECB; CSSF; and IMF staff calculations.
Note: CBC: counterbalancing capacities.
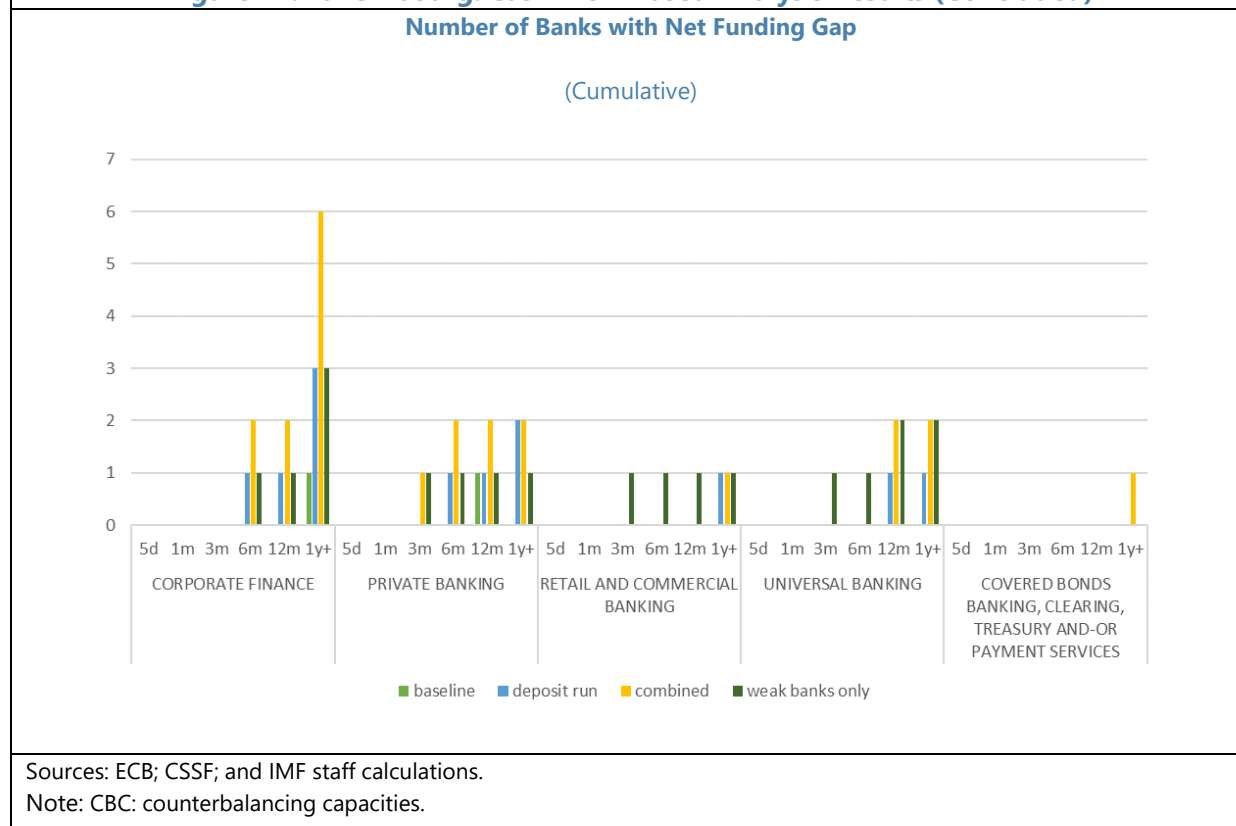
Table 9. Luxembourg: Summary of Bank Liquidity Stress Test Results

Stress Tests	Scenarios	Baseline	Deposit Run	Combined	Weak Bank/ Same-name Funds
LCR	Number of banks below threshold (<100%)	0	5	6	3
	Share of total sample assets (%)	0	21.7	23.8	17.6
NSFR	Number of banks below threshold (<100%)	0	/	/	/
	Share of total sample assets	0	/	/	/
Cash-flow Based	Number of banks with net funding gap (eop CBC<0)	1	3	6	5
	Share of total sample assets (%)		14.2	23.8	19.0

Notes: "Baseline": for LCR and NSFR, European Banking Authority (EBA) assumptions; for Cash-flow based analysis, ECB 2019 Sensitivity Analysis of Liquidity Risk baseline. "Deposit Run": deposit run rates based on Credit Suisse (Switzerland) and First Republic Bank (US) run episodes (also see October 2023 GFSR Chapter 2, Box 1). "Combined": Deposit run + market stress (lower inflow rates and higher haircuts of assets). "Weak Bank": Higher deposit run rates + market stress, only for the sub-sample of 16 banks with global parent banks found to be weak in the October 2023 GFSR Chapter 2 or banks that have same-name funds within the group. eop CBC: end-of-period counterbalancing capacities.

LIQUIDITY STRESS TEST FOR INVESTMENT FUNDS

A. Objective and Scope

102.   The stress test for investment funds evaluates liquidity risk within investment funds in Luxembourg, aiming to determine their resilience against severe, yet plausible, redemption shocks. The time horizon for the stress test is one month. It seeks to pinpoint which fund categories are more susceptible to liquidity risks and gauge their potential to spread shocks throughout the financial system. It is important to note that the stress test does neither account for liquidity management tools (LMTs) nor for the redemption frequency of the included AIFs, which could lessen the impact of shocks to a degree. Although primarily focused on individual funds (microprudential), the test has wider implications for financial stability. Potential inability of funds to handle redemption shocks by means of liquid assets (in accordance with the HQLA approach) would point to a risk of substantial asset liquidations during market stress, potentially overwhelming the market. Therefore, the stress test also incorporates second-round effects from asset sales (macroprudential perspective).

103.   The stress test rests on five key components. The final impact on the balance sheet and consequent final redemptions are estimated based on these components. For each fund, the test assesses the available highly liquid assets against the redemption scenarios. The components are: (i) estimating the initial impact on the balance sheet through Net Asset Value (NAV); (ii) estimating the resulting redemption shock; (iii) determining the composition of asset sales to meet redemptions; (iv) estimating the price impact of those sales; and (v) estimating the second-round impact on NAVs due to the price impact of securities sales.

104.   Interconnectedness with other domestic sectors, both direct and indirect, is also assessed in the stress test. Direct spillovers are assessed based on the holdings of assets of investment funds in other domestic sectors, mostly through deposits in Luxembourg banks. To face redemption pressures, investment funds withdraw funds from bank deposits, thereby creating liquidity pressures on the banks. Indirect spillovers are assessed through the impact of the sales of assets on market prices. Given the size of the investment fund sector relative to the rest of the financial sector, these indirect spillovers mostly run from the investment fund sector to the others, rather than the reverse. The second-round impacts imposed on banks' and insurers' securities holdings are estimated to be negligible.

105.   The stress test includes nearly 70 percent of the universe of UCITS falling withing the full reporting scope and half of open-ended AIFs, covering roughly half of the AuM of the entire sector. Table 10 shows the breakdown of the 1082 funds in the stress test sample by fund type and the respective aggregate total net assets, reaching almost 2,700 billion euros in total net asset for the whole sample.[16] The sample is comprised of all the open-ended investment funds with NAV greater than 1 billion euros, encompassing 895 UCITS and 187 AIFs.[17] UCITS make up 74

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[16] Although not featured in the liquidity stress results, MMFs are included in the initial stage to assess impact on NAV and consequent need to sell assets, in order not to exclude their impact on second-round price effects.

[17] Seven funds were dropped from the analysis due to data consistency issues.

percent of the total net assets in the sample. AIFs are much more heterogeneous than UCITS regarding their investment strategies and liquidity profile, having, for example, longer redemption frequencies, or imposing limits on the amount that can be redeemed in a given time period, even when classified as open-ended. Nevertheless, given the growth in the AIF space, these large open-ended AIFs were included to test their resilience in a standard liquidity stress test. Due to their specific characteristics, the discussion of the stress test results takes into account the special characteristics of AIFs.

Table 10. Luxembourg: Investment Fund Stress Test Sample—Statistics by Fund Type

Category	Number	Total Net Assets (Billions of euros)
All	1082	2675.5
By Strategy:		
Bond funds	314	195.6
EM	37	78.5
ETF/Index funds	30	42.0
HY	29	75.0
Others	218	489.1
Equity Funds	435	1125.2
EM	54	141.5
ETF/Index funds	79	196.3
Others	302	787.5
Mixed funds	168	514.9
EM	4	5.8
ETF/Index funds	3	8.7
Others	161	500.3
Hedge funds	25	46.7
Fund of funds	85	166.9
Real estate funds	32	95.4
Other funds	20	35.8

Source: BCL, CSSF and IMF staff calculations.
Note: EM stands for Emerging Market funds, HY stands for High-Yield funds

B. Methodology

106.   The stress test comprises alternative redemption shocks based on the adverse scenario, a scenario mirroring the GFC market stress episode and historical scenarios based on past fund flows. The adverse scenario is used for the integrated stress test on all sectors and constitutes the main results of the stress test for investment funds, however, the other redemption scenarios can also offer important insights anchored in realistic past events for funds which do not experience large redemptions in the adverse scenario. The calibration of the redemption shock following the adverse macroeconomic shock scenario is constructed using historical flow-

performance relationships at the fund strategy level. This allows for the transposition of the shock in the Funds' NAV into outflows, consistent with historical relationship.[18] The scenario based on the global financial crisis takes the change in asset prices observed during September and October of 2008 and uses the same flow performance relationships to estimate redemptions.

107.   Another set of exogenous redemption shocks is based on historical redemption data. This approach uses both homogeneity and heterogeneity approaches. In the homogeneity approach, shocks are determined from net flow distributions of all funds in a category, applying the same shock to each fund within that category, though it varies between broad investment strategies. Conversely, the heterogeneity approach calculates fund-specific shocks based on each fund's historical net flow distribution. For both approaches, shocks are derived from the first and fifth percentiles of the historical net outflow distribution, expressed as a percentage of the previous total net assets using a VaR assumption. Appendix VI, section B provides a more detailed methodology behind each historical redemption shock.

108.   Assets on the balance sheet are grouped into assets classes and their value following the scenario is estimated based on the estimated change in asset prices. Investment funds' balance sheet assets (with data from BCL) are organized into 42 groups, each experiencing its own price shock, and categorized by asset classes like Equities, Sovereign Bonds, Corporate Bonds, Deposits, MMF investments, and others, as well as by key regions from Luxembourg to the Rest of the World. The balance sheet data is from March 2023. The initial shock is determined by applying estimated price changes to tradable assets via a financial simulator model (Appendix VII), assuming assets like liquid short-term deposits retain their value. Market-sensitive assets are aligned with market price indices, then adjusted for price changes in line with asset price scenario, ensuring consistency with historical price movements. Real estate price shocks, being illiquid, are derived from a House Price at risk model for CRE, to forecast commercial real estate price changes in key economies. See Appendix VII for more details on the methodology of the price shocks.

109.   In the stress test, liquidity buffers are determined through a liquidity buckets approach, assigning different liquidity weights to each portfolio asset. This method employs the Basel III high-quality liquid assets (HQLA) criteria to calculate these weights for investment fund assets. Although initially developed for banking liquidity requirements, the HQLA method serves as a valuable benchmark for assessing investment liquidity buffers in stressed market conditions. Figure 25 shows the 10th, 50th and 90th percentile of HQLA measured as a percentage of total net assets. Even the 10th percentile of the overall sample exhibits HQLA of roughly 40 percent of net assets, highlighting the capacity to withstand large redemption shocks for the majority of funds. Particular investment strategies, however, have considerably lower levels of HQLA buffers. Namely, high-yield bond funds, real estate funds (which are AIFs, and thus usually operate under different liquidity pressures) and, to a lesser extent, other funds (with a relatively high share of AIFs).

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[18] In the case of fund types for which the historical flow-performance relationship is not statistically different from zero, it is assumed zero outflows following the adverse and GFC scenarios. For assessing the resilience of those funds, the stress test relies on the historical redemption scenarios.

Figure 25. Luxembourg: Investment Funds' HQLA Distribution by Strategy (Percent)
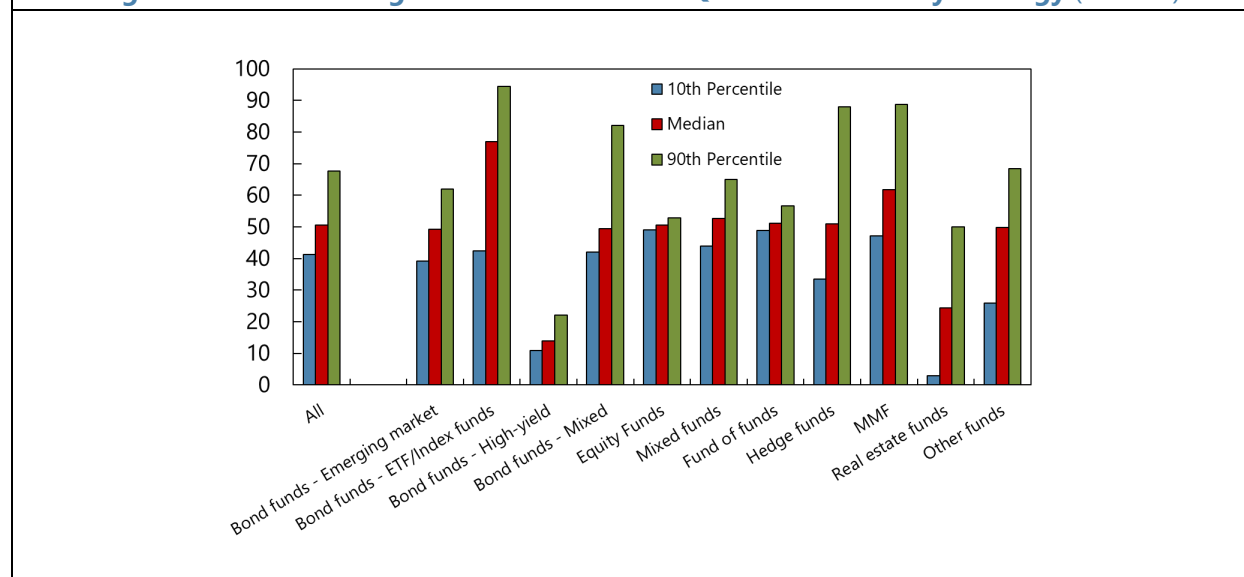
Source: BCL, CSSF and IMF staff calculations.
Note: The figure shows the the levels of estimated High Quality Liquid Assets (HQLA) at different points of the distribution (10th, 50th ad 90th percentiles) for the sample of funds in the stress test, broken down by different types of fund. HQLA measures the stock of liquid assets which can be quickly sold to meet redemptions. The measure applies liquidity haircuts to some assets which may be harder to liquidate. See Appendix VII for more details.

110.   When confronted with redemption demands, fund managers have various liquidation strategies at their disposal. Upon facing redemption shocks, it is presumed that managers will liquidate certain assets to satisfy investor withdrawals. They might opt for vertical slicing (pro rata), which implies selling HQLA assets in line with their portfolio weight in HQLA, or choose the waterfall method, prioritizing the sale of specific assets. The stress test assumes three alternatives regarding liquidation strategy of investment funds: (i) slicing; (ii) waterfall, using highly liquid securities before cash; and (iii) waterfall, using cash first, before moving to highly liquid assets. Each of these assumptions will have consequences for the stress test results. The analysis will focus particularly on the results based on the assumption of a waterfall method of liquidation where securities are sold first, as this assumption maximizes the price impact of asset sales for second-round impact. The cash-first waterfall strategy, on the other hand, would have the most implications for banks' liquidity risk. See Appendix VI, section B for details.

111.   Investment funds hold considerable shares of outstanding value of securities in both advanced and emerging economies. Despite minimal investment in domestic markets, funds own 2.5 percent of Luxembourg's sovereign debt and nearly 15 percent of its equities. Since 2015, there has been a considerable rise in U.S. investments, primarily in nonfinancial corporate equities. They also hold 1.5–2.5 percent of sovereign debt and 3–5 percent of equities in France, Germany, and the United Kingdom. In emerging markets, characterized by shallower markets, funds in Luxembourg hold more than 2 percent of total sovereign debt for a number of countries.

Figure 26. Luxembourg: Investment Funds—Asset Exposures

Bond Market Capitalization and Luxembourg IF Holdings, 2023
(Trillion of USD)

Sources: Haver Analytics LLC; BCL; CSSF; and IMF staff calculations.

Equity Market Capitalization and Luxembourg IF Holdings, 2023
(Trillion of USD)

Sources: Haver Analytics LLC; BCL; CSSF; and IMF staff calculations.
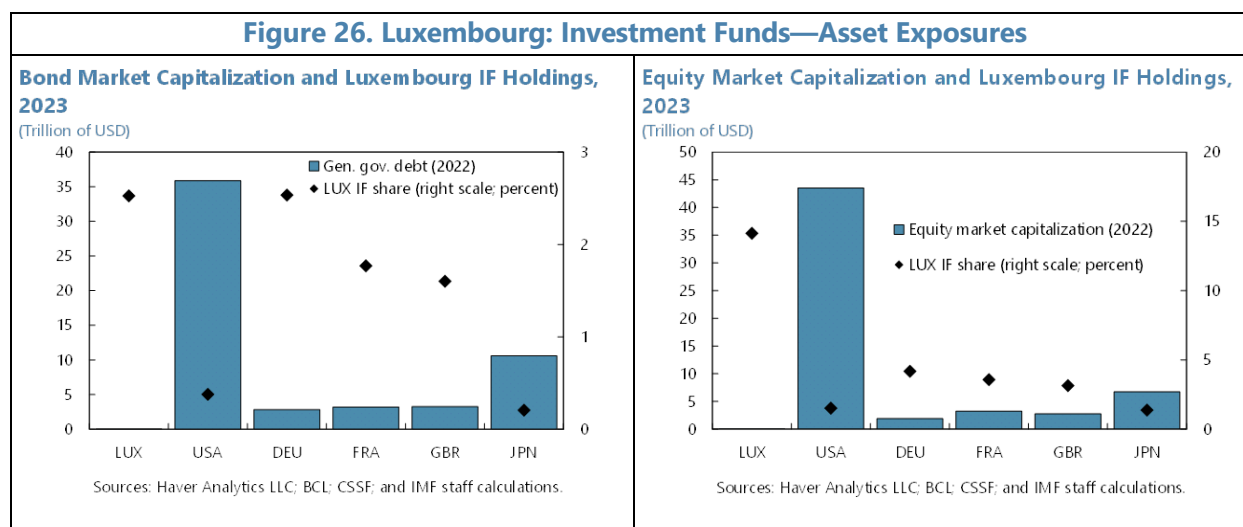
112.   Given the substantial size of Luxembourg's financial sector, significant asset sales by investment funds, banks, and insurance companies are likely to influence market prices of some securities. These price changes affect the remaining securities' value on balance sheets, introducing further solvency and liquidity risks. To estimate the price impact, the volume of sales is measured against market depth, with estimates sourced from previous FSAPs, academic literature, and specific methodologies for different types of securities. These estimates consider factors like volatility and the asset sale period, with primary figures based on market depth during stress, assuming a 7-day sale period. Additionally, for investment funds, the asset price impact is factored in by recalculating outflows after NAV drops due to reduced prices of assets in the balance sheet. After estimating the price impact, each fund's NAV is adjusted to reflect the costs of liquidating assets, leading to potential second-wave redemptions estimated by the flow-performance relationship once again. A more detailed methodological account can be found in Appendix VII.

113.   The resilience of funds is evaluated using the redemption coverage ratio (RCR) and liquidity shortfall metrics. The RCR compares a fund's available liquidity, at both individual and category levels, to the magnitude of the redemption shock. It is calculated as the ratio of high-quality liquid assets (HQLA) to the 30-day redemption shock. An RCR above 1 suggests sufficient liquidity to manage redemption shocks, while an RCR below 1 indicates a need to sell less liquid assets, possibly at significantly reduced prices. The liquidity shortfall measures the difference between the redemption shock and the fund's level of HQLA, for the funds with deficient RCR.

C.   Results

Initial Impact on Fund's Balance Sheet and Net Redemptions

114.   The initial impact on investment funds following the adverse scenario financial shocks produces valuation losses of 13.1 percent of the aggregate NAV (Table 11). The aggregate decline in NAV in the adverse scenario broadly aligns with the fall in NAV of the investment fund sector coming from the Bayesian VAR model used in designing the Macro scenario (13.1 vs 14.1), highlighting the consistency of the two approaches. The shock is heterogenous across strategies in line with the heterogeneity of the financial impact on different asset classes. Funds with a significant proportion of equities in their portfolios face a more severe impact, reflecting the largest drop in

equity prices relative to bond prices coming from the financial shock model results, with the average NAV of equity funds declining by over 17 percent. For the most affected funds, those in the 95th percentile of the distribution, the average decrease in NAV is 21.8 percent. The aggregate NAV of funds beyond the 95th percentile is equal to 142.8 billion euros, roughly 5 percent of the total NAV of the funds in the sample.

115.   In the GFC scenario, average NAV falls by 19.8 percent. Once again, equity funds are the most adversely impacted, reflecting the characteristics of the GFC, with an average drop in NAV of 27.9 percent, while bond funds fall by 10.6 percent. Funds in the 95th percentile see their NAV fall by almost 40 percent.

Table 11. Luxembourg: Estimated Initial Valuation Change in NAV Following Adverse and GFC Scenarios

Estimated Initial Valuation Change in NAV following Adverse Scenario

Strategy	Initial Fall in NAV following Adverse scenario (percent)					Total NAV of funds above percentile... (Billions of euros)	
	Average	Median	StdDev	Percentile 95	Percentile 99	95	99
All	-13.1	-14.1	5.7	-21.8	-27.5	142.8	35.9
By Strategy:							
Bond funds	-8.0	-7.4	2.6	-14.1	-18.1	26.7	6.0
Equity funds	-17.4	-17.1	4.2	-23.2	-28.0	64.6	11.8
Fund of funds	-16.0	-16.5	3.8	-22.0	-22.9	11.5	1.0
Hedge funds	-12.1	-10.4	8.1	-29.4	-34.7	3.7	2.5
Mixed funds	-12.6	-12.8	4.0	-17.5	-22.0	21.5	3.1
Other funds	-14.4	-15.7	5.7	-22.4	-26.5	3.1	1.7
Real estate funds	-14.4	-13.3	4.9	-22.2	-24.1	9.2	8.1

Sources: BCL, CSSF and IMF Staff calculations.

Estimated Initial Valuation Change in NAV following GFC Scenario

Strategy	Initial Fall in NAV following GFC scenario (percent)					Total NAV of funds above percentile... (Billions of euros)	
	Average	Median	StdDev	Percentile 95	Percentile 99	95	99
All	-19.8	-19.6	10.4	-39.5	-41.3	133.9	28.4
By Strategy:							
Bond funds	-10.5	-10.6	4.8	-18.8	-23.2	27.2	6.1
Equity funds	-27.9	-26.0	6.8	-40.4	-40.8	50.9	8.8
Fund of funds	-22.9	-20.8	8.4	-39.0	-53.1	13.2	1.8
Hedge funds	-15.9	-14.8	9.8	-36.3	-39.3	3.7	2.5
Mixed funds	-18.0	-17.8	7.2	-30.3	-39.7	18.5	3.1
MMF	-6.8	-7.0	3.5	-12.0	-13.2	14.4	6.1
Other funds	-23.6	-24.0	12.4	-41.8	-52.5	2.5	1.3
Real estate funds	-23.1	-19.1	15.6	-54.5	-59.3	9.2	8.1

Sources: BCL, CSSF and IMF Staff calculations.

116.   Redemption shocks resulting from the different scenarios and from historical redemption data provide alternative starting points for the stress test. Figure 27 shows the histograms for the distribution of net outflows broken down by broad investment strategy. Following the results from the impact on NAV, the net outflows in the adverse and GFC scenarios, estimated through the flow-performance relationship, are, on average, more severe for equity funds than for bond and mixed funds. The levels of outflows resulting from the adverse and GFC scenarios are considerably milder than those coming from the historical data on redemptions, reflecting the fact that the estimates for the flow-performance relationship imply a relatively low elasticity of NAV to net outflows. This relatively low elasticity is a feature contributing to the sector's stability in managing liquidity risk.

Figure 27. Luxembourg: Net Outflows Under Different Scenarios

Sources: BCL, CSSF and IMF staff calculations.
Note: Charts on the distribution of net flows show the flows used in different scenarios of the liquidity stress test as a percentage of the NAV of the funds in the sample.
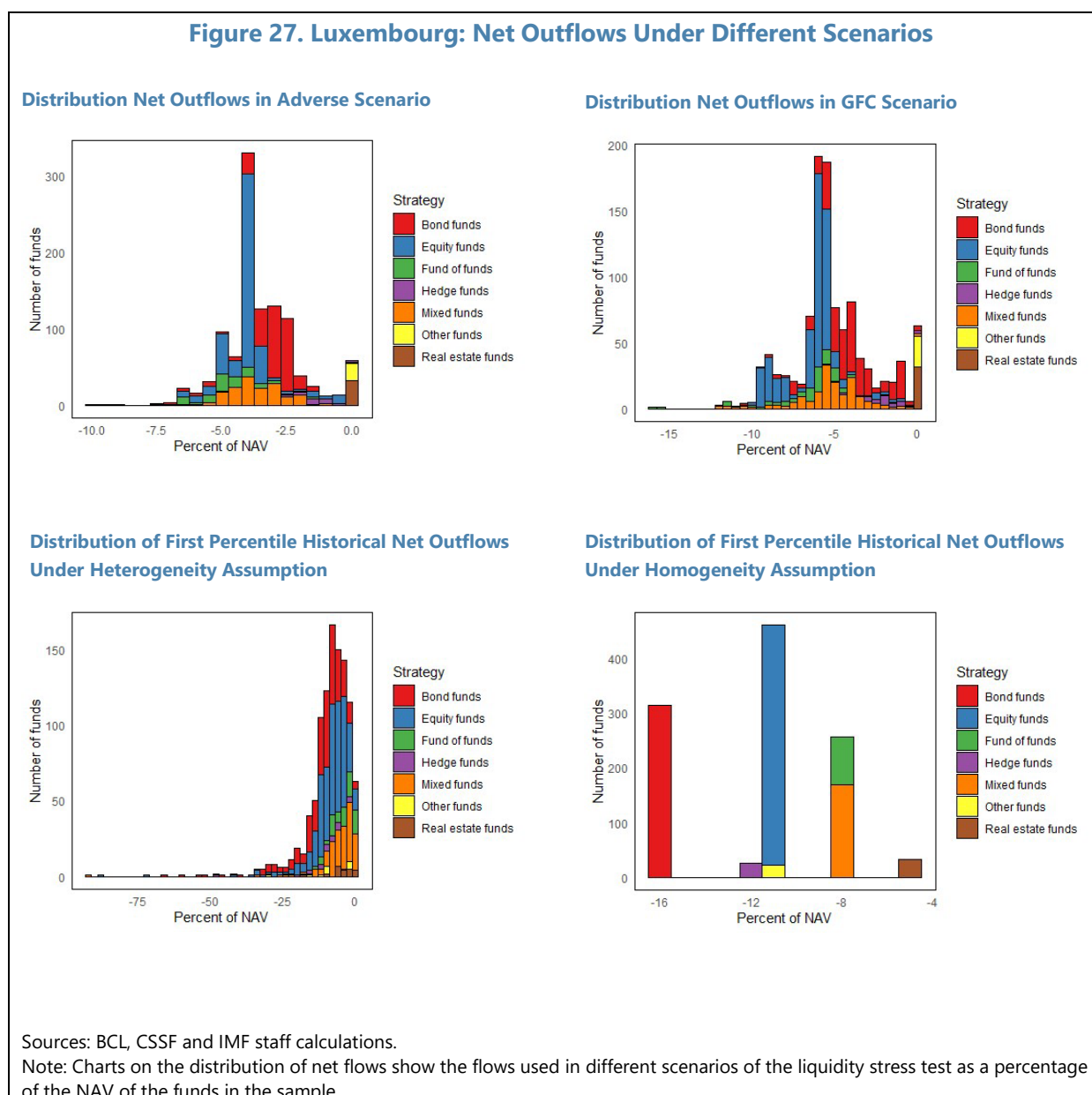
Impact of Asset Sales on Market Prices

117.   In the adverse scenario, investment funds may need to sell up to 150 billion euros in liquid securities to face redemptions. This estimate assumes that fund managers will initially focus on selling liquid securities before moving to the usage of deposits and other liquid assets. The projected breakdown of these sales includes nearly 50 billion euros from sovereign bonds, 20 billion from corporate bonds, and 70 billion from equities. Geographically, the US securities represent the largest portion of these sales, totaling 44 billion euros, followed by France at 16 billion euros and Germany at 13 billion euros. In the scenario mirroring the conditions of the Global Financial Crisis (GFC), the total value liquidated under similar assumptions increases to 200 billion euros. The composition of this liquidation across various asset classes and countries remains largely consistent. Asset sales coming from the banking and insurance sector are too small relative to the magnitude of sales by investment funds to move market prices and were not included in the estimation of the price impact.

118.   Selling of liquid assets to meet large redemptions could lead to a meaningful impact on prices of some securities, especially in European markets. The analysis of second-round impacts following asset sales, predicated on market depth estimations at the level of the same asset groups used in the estimation of financial shocks, reveals significant price effects, particularly for some European securities. In an adverse scenario, the liquidation of assets to fulfill redemptions could lead to a decline in bond prices (both corporate and sovereign) within Germany, France, and other Eurozone countries, ranging from 0.2 to 1.2 percent. This price adjustment aligns with an approximate yield increase of 5 to 30 basis points. Conversely, this phenomenon appears to exert a more subdued impact on other major markets, including the United States and the United Kingdom, where such movements are less pronounced (with the exception of US corporate bonds). Due to the very small size of the market for Luxembourg bonds and equities, rapid selling of Luxembourg securities is not considered in the exercise. The price impact under the GFC scenario largely follows the same pattern in terms of which securities are most affected, however, it produces more extreme price swings, in line with the higher level of redemption in the scenario. Price declines can reach almost 4.5 percentage points for some securities.

119.   The price effect of asset sales produces mild effects on the NAV of the sector and muted effects in terms of additional redemption pressures under the adverse scenario (Table 12). Upon incorporating the second-round effects and re-estimating the impact of the total fall in asset prices in the value of the balance sheet, the average fall in NAV for the funds in the sample goes from 13.1 to 13.8 percent in the adverse scenario. For bond funds, the change is slightly larger, from 8.0 percent in the first round to 9.1 percent fall in NAV in the second round. This increase, although not negligible, is not large enough to produce significant changes in estimated net outflows, compared to the initial levels shown in Table 11. For the GFC scenario, the fall is larger, reflecting the sharper drop in asset prices in that scenario. In that case, the average NAV falls by 20.8 percent instead of 19.8 percent. Again, not enough to meaningfully alter net outflows relative to the initial impact.

Figure 28. Luxembourg: Price Impact of Asset Sales for Selected Asset Groups (Basis points)
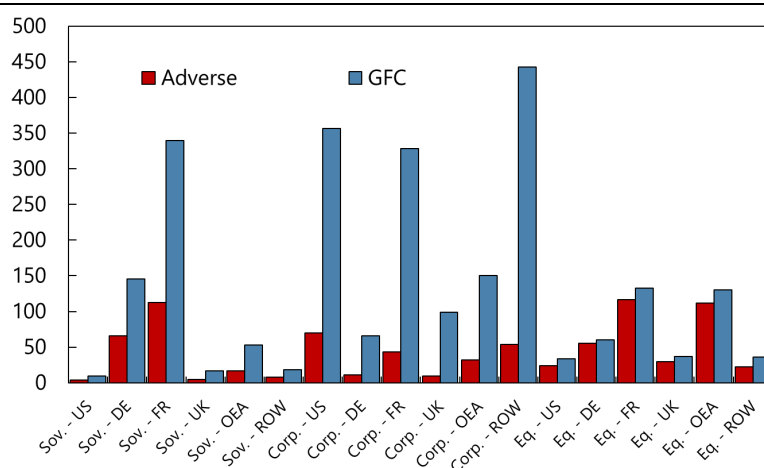
Source: BCL, CSSF and IMF staff calculations.
Note: Chart shows the price impact (in basis points) of asset sales by investment funds of Sovereign bonds (Sov.), corporate bonds (Corp.) and equities (Eq.) in selected markets, following the Adverse and GFC scenarios under the assumption of asset liquidation using a waterfall method where liquid securites are sold first.

Table 12. Luxembourg: Estimated Final Valuation Change in NAV Following Adverse Scenario

Strategy	Final Fall in NAV following Adverse scenario (percent)					Total NAV of funds above percentile... (Billions of euros)	
	Average	Median	StdDev	P95	P99	95	99
All	-13.8	-14.4	5.5	-22.5	-27.9	140.7	35.9
By Strategy:							
Bond funds	-9.1	-8.5	2.7	-14.4	-19.1	35.1	6.0
Equity funds	-17.8	-17.4	4.2	-24.1	-28.3	64.6	11.8
Fund of funds	-16.4	-16.7	3.9	-22.9	-23.2	9.6	1.0
Hedge funds	-12.8	-11.6	8.4	-31.3	-35.7	3.7	2.5
Mixed funds	-13.3	-13.3	3.8	-17.9	-22.8	21.5	3.1
Other funds	-14.7	-15.7	5.6	-22.4	-26.8	3.1	1.7
Real estate funds	-14.5	-13.4	4.9	-22.3	-24.1	9.2	8.1

Sources: BCL, CSSF and IMF Staff calculations.

Source: BCL, CSSF and IMF staff calculations.
Note: Table shows the impact of final NAV valuation changes (intial NAV valuation changes plus valuation changes from second-round price effects of asset sales).

120. Connections between the banking and investment fund sectors via deposits are not a source of risk for the investment fund industry or for banks. In a hypothetical situation where investment funds utilize cash resources before selling other securities (waterfall liquidation using cash first), withdrawals from banks under adverse conditions would represent about 25 percent of the total bank deposits held by funds. Typically, banks have factored in a 25 percent withdrawal rate of fund deposits in their standard LCR ratios (taken as the baseline in the Bank Liquidity Stress

Tests), indicating their capacity to manage such withdrawals. Additionally, the results from the banking sector's liquidity stress test reveal that domestic banks possess the resilience to handle even more substantial deposit outflows from investment funds.

Final Stress Test Results

121.   Investment funds are resilient to the redemptions following the main stress scenarios. Only four AIFs exhibit a Redemption Coverage Ratio (RCR) below one in the adverse scenario following the final redemption shock, incorporating second-round price effects. These AIFs, which all follow a loan fund strategy, despite being classified as open-ended funds, all have longer redemption frequencies (typically monthly). This means that although their HQLA level is lower than the net outflow estimated in the stress test, the fund managers will have considerably more time to liquidate assets to meet redemptions than a regular UCITS fund. In addition, these AIFs have LMTs at their disposal (gating and redemption deferral). The final results of the stress test are identical to those obtained in the case of no second-round effects, highlighting the channel is unlikely to pose relevant additional risks to the sector. The results for the GFC scenario are also identical to the adverse scenario, despite the higher outflows and second-round effects under that scenario.

122.   Some high-yield bond funds and additional AIFs have insufficient liquid assets to meet historical redemption levels. A considerable share of funds pursuing high yield strategies, making up 44 percent of total NAV of high-yield bond funds, would have problems meeting large but plausible redemptions, given historical net flows at the fund and strategy level. Additionally, six real estate AIFs also have RCR below one. Again, these real estate AIFs all have redemption frequencies which are quarterly or longer and dispose of liquidity management tools (mainly redemption deferral power).

Table 13. Luxembourg: Results of the Investment Fund Liquidity Stress Test

	Adverse and GFC			Historical (Homogeneity, First Percentile)			Historical (Homogeneity, Fifth Percentile)		
	Funds with RCR<1	% Funds with RCR<1	% NAV with RCR<1	Funds with RCR<1	% Funds with RCR<1	% NAV with RCR<1	Funds with RCR<1	% Funds with RCR<1	% NAV with RCR<1
Bond funds									
Emerging market	0	0.0	0.0	1	2.7	2.4	0	0.0	0.0
ETF/Index funds	0	0.0	0.0	0	0.0	0.0	1	3.3	0.0
High-yield	0	0.0	0.0	17	58.6	44.1	0	0.0	0.0
Others	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Equity Funds	0	0.0	0.0	1	0.2	0.1	0	0.0	0.0
Mixed Funds	4	2.5	0.3	4	2.5	0.3	4	2.5	0.3
Fund of funds	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Hedge funds	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Real estate funds	0	0.0	0.0	6	18.8	26.1	2	6.3	18.5
Other funds	0	0.0	0.0	1	5.0	1.5	0	0.0	0.0

Source: BCL, CSSF and IMF staff calculations.
Note: The table shows the results of the stress tests for the adverse and GFC scenarios incorporating second-round effects of asset sales (here presented as one, since the results are equivalent) and for a redemption scenario based on the first and fifth percentiles of historical outflows based on the homogeneity assumption (assuming homogeneous levels of redemptions across broad investment strategies). For each scenarios the three columns show i) the of number of funds with RCR below one; ii) the share of the number of funds with RCR below 1, as a percentage of the total number of funds in the group; and iii) the share of the NAV of the funds with RCR below 1, as a percentage of the aggregate NAV of the corresponding group.

Sensitivity Analysis

123.   The stress test results are robust to other assumptions on the liquidation strategy or method for calculation of redemptions based on the historical approach. Variations of the liquidation strategy, or changes in the method for calculating redemptions based on the historical approach, produce similar results to those discussed in the previous paragraphs.

124.   A sensitivity analysis based on reverse stress testing was conducted to assess the limits of the sector's resilience. The reverse stress consists of uniformly applying various degrees of exogenous redemptions, expressed as a percentage of the NAV, across all funds in the stress test sample. At each level, the net outflows are then compared to the fund's holdings of HQLA and aggregate results for the sector are derived from the fund level results. Figure 29 shows the results of this analysis, with the exogenous level of redemption shock in the x-axis and the aggregate results for the sector as a function of the shock.

125.   A wave of redemptions surpassing historical precedents would be necessary to significantly impact the robustness of a large segment of the investment fund sector. Findings indicate that, even with redemption shocks nearing 40 percent, over 90 percent of funds in the sample maintain a RCR above one. Additionally, the cumulative liquidity shortfall, as a fraction of the total net assets, remains minimal. Beyond the 40 percent threshold, there is a marked increase in the number of funds with an RCR falling below one. However, redemptions exceeding 40 percent are uncommon, even at the individual fund level, suggesting that the likelihood of such widespread outflows is negligible.

Figure 29. Luxembourg: Investment Funds' Reverse Liquidity Stress Test Results (Percent)
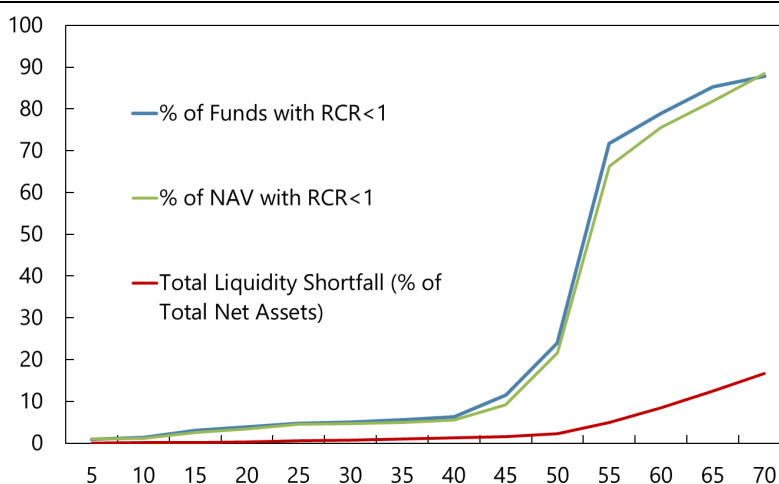
Source: CSSF and IMF staff calculations.
Note: Chart shows in the x-axis different levels of exogenous redemption shocks in percentage of NAV applied homogenously to all funds in the stress test sample. The blue line shows the share of the number funds for which the HQLA is insufficient to match the net outflow (RCR<1). The green line shows the corresponding share of the NAV of funds with RCR below 1 in percentage of total NAV. The red line depicts the associated cumulative value of the liquidity shortfall of funds with RCR below 1.

Policy Recommendations

126.   The investment fund sector is resilient to liquidity risk, but the AIF space would benefit from further monitoring liquidity mismatches especially in newly emerging investment strategies. UCITS, making up the majority of the investment fund sector, are in their vast majority prepared to handle liquidity crisis. A minority of UCITS might struggle to meet very high redemptions, but most of these are in the high-yield category, which does not comprise a significant share of the sector and which is known by investors to be riskier. Concerning AIFs, the risks are higher, and more challenging to assess due to their heterogeneous characteristics. Enhancing the monitoring of these funds, as well as of interlinkages they may have to the OFI sector and to other investment funds (see first chapter), and eventually develop methods better tailored to assess their liquidity risk is, therefore, desirable.

MONEY MARKET FUNDS STRESS TESTS

A.   Objective and Methodology

127.   MMFs are subject to a separate solvency analysis due to their particular characteristics and regulatory requirements. Solvency risk refers to the likelihood that a CNAV or LVNAV might be unable to redeem at par value (known colloquially as 'breaking the buck'). These funds allow investors to redeem shares at face value due to amortized cost accounting. They invest in short-term fixed-income instruments like commercial paper and certificates of deposit, valued at amortized cost rather than market price. Commonly used by corporate treasurers for cash management, CNAVs and LVNAVs are sometimes viewed as alternatives to bank deposits. However, they do involve market and liquidity risks. Due to the relative similarity in investment instruments of MMFs, a LVNAV failing to comply with requirements could trigger a run on other MMFs of the same type. As such, the analysis focuses on the change in NAV for these funds in particular.

128.   The MMF stress test aims to assess the likelihood of Constant Net Asset Value (CNAV) and LVNAV (Low Volatility Net Asset Value) MMFs breaking the 20 bp threshold. [19] Using more detailed data on the balance sheet of MMFs, solvency stress tests are conducted assess the resilience to interest rate and credit spread shocks. These tests incorporate two distinct shocks: a change in interest rates and an expansion of spreads on non-public instruments held by MMFs. The size of these shocks is consistent with the adverse macrofinancial scenario of the stress test exercise. The effect of these shocks is gauged by calculating the duration of each instrument in every MMF's portfolio and using this data to estimate the potential mark-to-market losses resulting from the shocks. The shocks are assumed to be instantaneous, which represents a conservative assumption, as even a few days can be enough for a meaningful share of the portfolio of MMFs to mature, allowing it to adapt to new market conditions. Table 14 shows statistics for the number of funds, total net assets and weighted average maturity (WAM) of MMFs domiciled in Luxembourg by MMF type.

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[19] As defined in the EU Money market fund regulation (MMFR) for LVNAV MMFs.

		Total Net Assets (billions of euros)				Average WAM (days)
MMF Type	Number of Funds	Total	Average	Median	Maximum	
CNAV	10	72.0	7.2	1.4	51.0	25.8
LVNAV	15	220.9	14.7	6.1	101.1	23.2
VNAV	79	136.7	1.7	0.8	18.5	57.9

Table 14. Luxembourg: Money Market Funds—Statistics by Fund Type

Source: CSSF and IMF staff calculations.

Note: Data as of 2023 Q1. Weighted Average Maturity (WAM) is a measure capturing the average time to maturity of assets in the fund's portfolio.

B. Results

Impact of Adverse Scenario on MMFs NAV

129.   Results of MMF stress test show the median fall in NAV in LVNAVs is 14 basis points and that 4 LVNAVs would 'break the buck' under the adverse scenario. Figure 30 shows boxplots of the change in shadow NAV as a result of the application of the severe interest rate and spread shocks in the adverse scenario.[20] Results for LVNAVs show that 4 funds cross the 20-bps threshold that would require them to meet subscriptions and redemptions on the basis of Variable NAV (VNAV). Two of these LVNAVs are based in USD and the other two are in GBP. The findings of the stress test, while noteworthy, do not raise concerns, especially considering the magnitude of the applied shocks. Specifically, the interest rate and spread shocks incorporated in the stress tests are sharper than those observed in historical contexts. However, it is imperative to acknowledge the reality of such extreme market conditions, as evidenced by recent incidents of significant market volatility. Notable examples include the 'mini-budget crisis' in the United Kingdom, which saw government bond yields surge by as much as 130 basis points within a span of seven days, and the banking crises of March 2023 in the United States and Switzerland. These episodes underscore the potential for such tail risks to materialize within condensed timeframes.

130.   Two small CNAV MMFs were found to experience declines in NAV larger than 20 basis points. For CNAVs the relevant regulatory threshold is 50 basis points, rather than 20 basis points, however, it is conceivable that fluctuations of the NAV beyond 20 bp might cause market uncertainty and lead investors to redeem their shares in CNAVs. Results for CNAVs show that two funds, totaling under 2 billion euros in net assets, cross the 20-bps threshold as a consequence of the shocks. VNAVs are not subject to similar regulatory requirements and their NAV change is reported in the Figure for reference only.

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[20] The interest rate shock is in the range of 130 to 150 basis points for the main currencies. The spread shock consists of a homogenous 200 basis point shock to corporate spread. No spread is applied to public sector money market instruments.

Sensitivity Analysis

131.   Reverse stress tests of MMFs shed light on the sensitivity of the MMF market to interest rate and spread shocks. These reverse stress test consist of applying different levels of interest rate and spread shocks (keeping the level of the other equal to that of the adverse scenario) to test how many funds fail to maintain a NAV fluctuation within 20 basis points and their respective cumulative total net assets. Figure 31 shows 4 panels, with interest rate and spread shocks for CNAVs and LVNAVs. In the x-axis the level of the interest rate (spread) shock and in the y-axis the share of funds that fail to comply with the threshold for a given level of the shock, as well as the share of the total net assets of those funds in relation to the total net assets of their MMF type.

Figure 30. Luxembourg: MMF Stress Test Results—Boxplots with Fall in NAV by Type of MMF
(Basis Points)
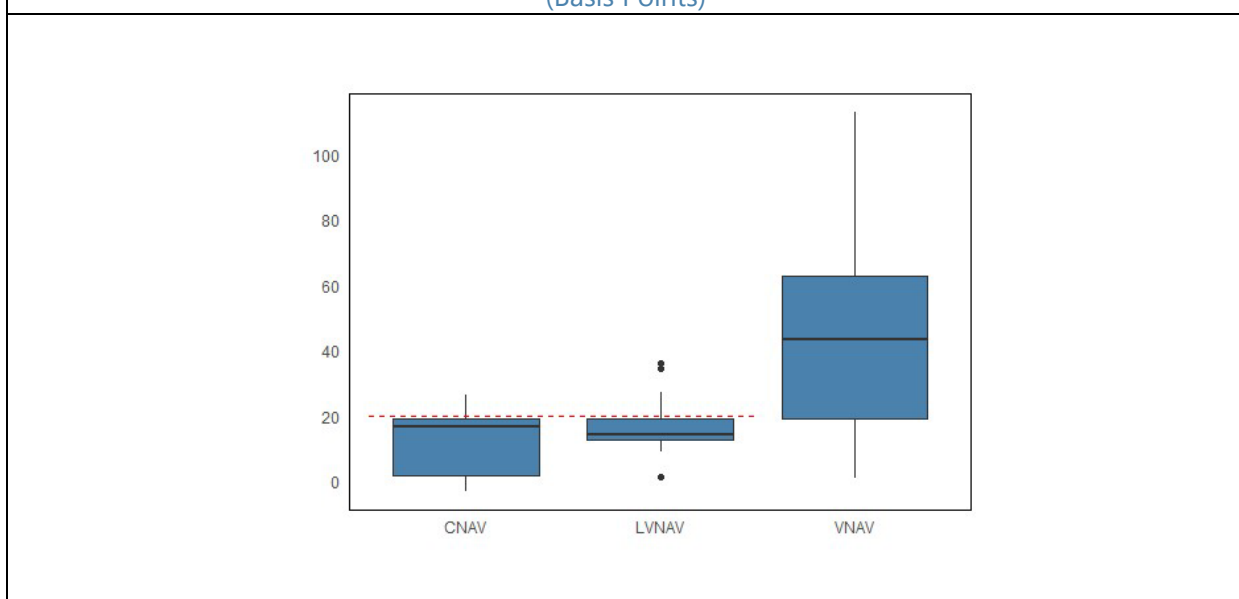
Source: CSSF and IMF staff calculations.
Note: Chart depicts boxplots with the distribution of the decline in NAV of MMFs by type (CNAV, LVNAV, and VNAV), following the combination of interest rate and corporate spread shocks from the macrofinancial scenario. The blue box represents the interquartile range of the distribution, the black line inside the box represents the median, the whiskers extend to the maximum and minimum of the distribution, or up to 1.5 times the interquartile range, while outliers beyond that threshold are shown as dots. The red line represents the 20 basis points threshold beyond which LVNAV funds are automatically converted to VNAVs, which is also a threshold usually considered as relevant for CNAVs, as a measure of their stability, even if it does not have any automatic implication for these funds.

132.   The majority of LVNAVs and CNAVs MMFs demonstrate resilience to instantaneous cumulative shocks of interest rates and spread up to approximately 200 basis points. Although the response of individual funds to changes in interest rates and corporate spreads varies, the overall sensitivity of the MMF sector to these shocks is fairly homogeneous. Furthermore, a majority of these funds, measured by percentage of total NAV, can withstand cumulative increases of 300 bps. Additionally, the two largest CNAV funds are mostly engaged in short term reverse repurchase agreements which are highly insensitive to these shocks. Almost all LVNAVs cross the 20-bps threshold for combined shocks of 400 basis points.

Figure 31. Luxembourg: MMF Reverse Stress Test Results (Percent)

MMFs with NAV Declines Greater than 20 bp for Various Levels of Interest Rate Shock Keeping Baseline Spread Shock (Percent)

MMFs with NAV Declines Greater than 20 bp for Various Levels of Spreads Shock Keeping Baseline Interest Rate Shock (Percent)
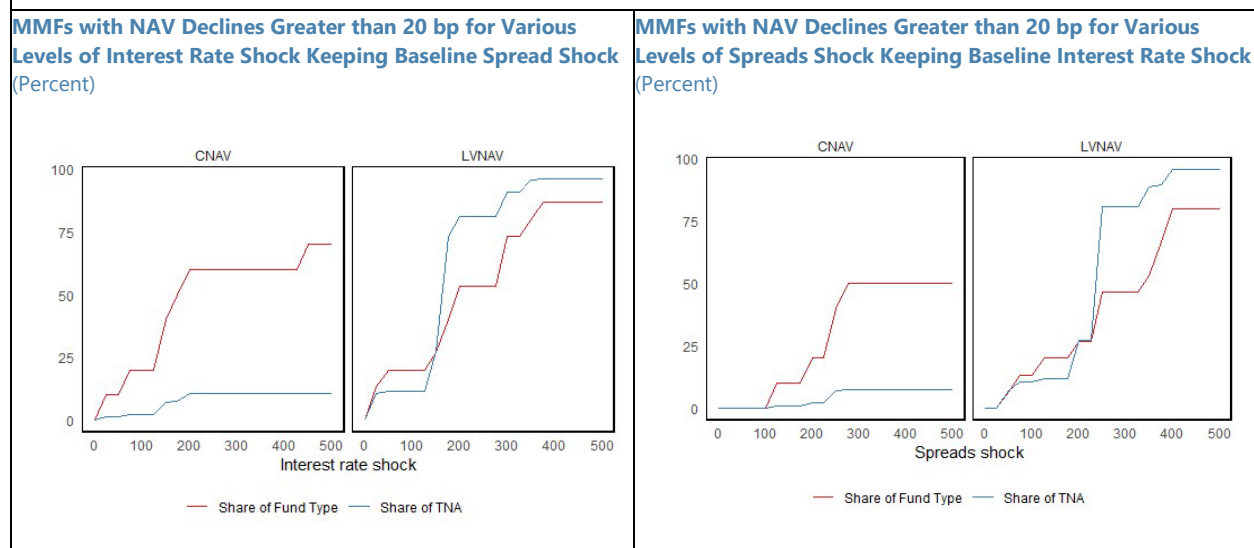
Source: CSSF and IMF staff calculations.
Note: Charts show on the x-axis instantaneous shocks, measured in basis points, to interest rates (left chart) and corporate spreads (right chart) for CNAV and LVNAV MMFs. The red line shows the percentage of number of funds of the type (CNAV or LVNAV) for which the NAV falls by more than 200 basis points in each scenario, while the blue line shows the total total net assets of the funds crossing the 20 basis points threshold as a percentage of the total net assets of each group. For each shock plotted in the x-axis, the other shock is kept constant relative to the baseline value of the main MMF stress test.

Recommendations

133.   Market guidance aimed at enhancing the resilience of outlier LVNAVs could further safeguard the sector against tail risks. Luxembourg's Money Market Funds (MMFs) have demonstrated resilience in the face of recent shocks, and the stress test indicates that only a highly unusual, extreme event could compromise this stability. However, the financial landscape in recent years has been characterized by periods of significant volatility, with the potential for future episodes that could be even more severe. Given that a single LVNAV fund failing to meet the 20-bps requirement could potentially instigate a ripple effect among other MMFs, it is prudent to mitigate this risk. To ensure uniform safety across the sector, it is advisable to engage with those market participants currently employing riskier strategies to challenge their lower level of resilience to encourage alignment with the more conservative practices commonly adopted by other LVNAVs in Luxembourg.

INSURANCE SOLVENCY STRESS TEST

A.   Scope and Sample of the Solvency Stress Test

134.   A top-down (TD) solvency stress test was performed for 22 large insurers, on a solo-entity basis. The sample was composed of ten life insurers—resulting in a coverage of around 83 percent of assets in this sector—as well as twelve non-life insurers and reinsurers, with a market

coverage of 81 percent in terms of gross written premiums.[21] The participants' aggregated balance sheet assets amount to EUR 239bn, of which 187bn (78 percent) can be attributed to life insurers. Of the total technical provisions in the life sector, 83 percent stem from unit-linked business (Table 15).

135.   All 22 participants record pre-stress solvency ratios above the regulatory threshold of 100 percent, but the heterogeneity within the sample and the use of internal models by some insurers complicate a direct comparison. Three insurers in the sample calculate their Solvency Capital Requirement (SCR) with a full internal model. Sector-wide, Luxembourgish insurers hold high-quality capital, with 88 percent of eligible own funds being unrestricted Tier 1 capital, while only 1 percent is comprised of Tier 3. The Long-Term Guarantee (LTG) measures, an integral part of Solvency II, have only a minor effect in Luxembourg: eleven insurers in the sample (mainly from the life sector) use the Volatility Adjustment (VA),[22] making it the most relevant LTG measure. For the median life insurer which uses the VA, the SCR ratio at the end of 2022 would have been 2 percentage points lower without this measure. Three insurers prepare their accounts in US dollars.

Table 15. Luxembourg: Insurance Stress Test Sample

	MIN	MEDIAN	MAX
Life insurance			
Assets (in EUR bn)	9,300	15,530	46,684
Share of Unit-linked (in percent of all technical provisions)	53	84	100
SCR pre-stress (in percent)	132	150	218
Share of unrestricted Tier 1 capital (in percent of eligible own funds)	59	79	100
Share of Tier 3 capital (in percent of eligible own funds)	0	0	4
Reduction in SCR ratio without the VA (in percentage points)	-8	-2	1
Non-Life / Reinsurance			
Assets (in EUR bn)	667	1,356	17,326
SCR pre-stress (in percent)	125	203	295
Share of unrestricted Tier 1 capital (in percent of eligible own funds)	73	99	100
Share of Tier 3 capital (in percent of eligible own funds)	0	1	12

Source: IMF staff calculations based on CAA data.

B. Scenario for the Solvency Stress Test

136.   The macrofinancial adverse scenario developed for this FSAP was adjusted for the purpose of the insurance stress test. The scenario features a disruption of supply chains (including for oil and gas) causing a severe recession in the euro area and amplifying inflationary tensions, rising geopolitical concerns, an abrupt tightening of financial conditions, higher risk aversion and sharp redemption flows from international investors in investment funds; domestically, the scenario also assumes a correction of house prices. Overall, this narrative is highly relevant for the Luxembourgish insurance sector, especially given its significant international footprint. Market

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[21] The reinsurers do not exclusively underwrite non-life risks, but are also active in life reinsurance.

[22] The VA is a measure by which (re)insurers are allowed to adjust the risk-free discount rate used to value liabilities to mitigate the effect of short-term volatility of bond spreads on their solvency position. In that way, the VA reduces procyclical investment behavior of (re)insurers, particularly in a downturn.

stresses, such as declines in equity and bond prices, were derived with the Financial Shock Simulator (see Chapter II) which also produced the scenario for the investment fund stress test. The end of June 2023 was used as the reference date for the stress test.

137.   To cover the most relevant risk factors for an insurer's balance sheet—specifically the market risk—shocks have been defined in a rather granular way. The scenario includes shocks to the risk-free interest rate (RFR), equity and property prices, as well as credit spreads of corporate and sovereign bonds (Table 16). Given the increase of credit spreads in the scenario, the VA also increases, following the Solvency II calculation method. For insurers using the VA measure, this results in a higher discount rate which partially offsets the negative impact of the credit spread shock. The scenario furthermore incorporates—in the post-stress recalculation of the SCR—a downgrade of corporate bonds, specified as one full rating category for one third of the bonds.

138.   Additional sensitivity tests, which assume single-factor shocks, were utilized to complement the stress test.

- Interest rates: parallel upward and downward shift of the EUR risk-free term structure (liquid part only, followed by an extrapolation towards the ultimate forward rate) by 200 basis points,

- Stock prices: decline by 50 percent (30 percent for unlisted stocks and private equity funds),

- Luxembourgish sovereign spread: increase by 500 basis points,

- Currencies: appreciation and depreciation of the Euro external value by 20 percent, and

- Counterparty risk: default of the largest banking counterparty and the three largest banking counterparties. The largest counterparties were determined based on investment asset data in the Quantitative Reporting Template (QRT) S.06.02, at the level of the issuer group. It was assumed that equity exposures and subordinated bonds need to be fully written off (i.e., a 100 percent haircut). Furthermore, an LGD of 15 percent was applied to secured bonds, and an LGD of 70 percent to other on-balance sheet exposures including unsecured bonds, uncollateralized loans, and deposits.

Table 16. Luxembourg: Insurance Stress Test Specification

Equity

Luxembourg	-22.3%
Euro Area	-23.8%
United States	-13.1%
Other advanced economies	-19.5%
China	-16.8%
Emerging economies	-16.8%
Unlisted	-12.0%

Property

RRE, domestic	-15.0%
CRE, domestic	-18.0%
RRE, other countries	-10.0%
CRE, other countries	-13.0%

Corporate bonds (financials, in bps)

Credit Quality Step 0	+50
Credit Quality Step 1	+70
Credit Quality Step 2	+90
Credit Quality Step 3	+120
Credit Quality Step 4	+180
Credit Quality Step 5	+300
Credit Quality Step 6	+420
Unrated	+120

Corporate bonds (non-financials, in bps)

Credit Quality Step 0	+45
Credit Quality Step 1	+65
Credit Quality Step 2	+85
Credit Quality Step 3	+120
Credit Quality Step 4	+180
Credit Quality Step 5	+300
Credit Quality Step 6	+420
Unrated	+120

Investment funds

Equity	-16.8%
Debt	***
Money-market	+/-0.0%
Asset allocation	***
Real estate	-13.5%
Alternative	-8.0%
Private equity	-12.0%
Infrastructure	-4.0%
Other	-8.0%

Structured notes and collateralised securities

Structured notes	-6.0%
Collateralised securities	-4.0%
Other investments	-8.0%

Sovereign bonds (in bps)

Luxembourg	+60
Euro Area	+75
United States	+60
Other advanced economies	+70
China	+100
Emerging economies	+110
Supranational	+/-0

Loans and mortgages (in bps)

Mortgages	+45
Other collateralized loans	+60
Uncollateralized loans	+100

Interest rates (in bps)

EUR 1Y	+50
EUR 10Y	+5
USD 1Y	+20
USD 10Y	+36

*** company-specific shock based on rating breakdown and duration of direct holdings

Source: IMF staff.

C. Capital Standard and Modeling Assumptions

139.   Solvency II was implemented in the European Union in 2016 and forms the basis of the insurance stress test.[23] As a general principle of Solvency II, assets and liabilities are valued mark-to-market. However, Solvency II also allows for some notable deviations from the market-consistent framework in the valuation of insurance liabilities, especially for the discount rate which can incorporate LTG measures and transitional measures.

140.   The main output of the FSAP stress test calculations is the effect on own funds, and the respective coverage of the solvency capital requirement. As the stress also affects the capital requirement, the SCR was partially recalculated after stress.

141.   Data for the TD solvency stress test was gathered from the Solvency II quantitative reporting templates. Solvency II has introduced a very granular supervisory reporting specifically on the asset side. Reported data must meet several automated validation checks, while the *Commissariat aux Assurances* (CAA) also has undertaken initiatives to improve the quality and consistency of data. Still, a few inconsistencies and remaining data gaps pose limitations to a TD stress test, notably with regard to investments and derivative data. For the stress test, the following QRTs were used:

- Balance sheet (S.02.01),

- Assets and liabilities by currency (S.02.02),

- Asset-by-asset investment holdings (S.06.02),

- Derivative positions (S.08.01),

- Cash-flow projections (S.13.01, S.18.01),

- Impact of LTGs measures and transitionals (S.22.01),

- Own funds (S.23.01),

- Calculation of the SCR (S.25.01, S.25.02, S.25.03),

- Calculation of the SCR for market risks and life underwriting risks (S.26.01, S.26.03).

142.   For the TD stress test, the shocks specified in the scenario were applied to the investment assets and insurance liabilities. Haircuts in line with the adverse scenario were applied to the market value of directly-held assets. A look-through to the level of individual securities held through an investment fund was not applied, so investment fund holdings were stressed with the corresponding shocks for the underlying asset classes. Fixed-income assets were re-valued with the stressed term structure (for each major currency). Similarly, technical provisions (except for unit-linked business) after stress were approximated with the stressed term structure including the VA where applicable.[24] For unit-linked business, the decline in liabilities mirrored the market value loss

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

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

of underlying assets. Deferred tax liabilities were adjusted in line with the reduction in the excess of assets and liabilities.

143.   The recalculation of the SCR after stress was limited to selected risk modules. In the market risk module, the capital charges for equity risk, spread risk and property risk were proportionately adjusted in line with the change in exposures due to the stress. Furthermore, the equity risk capital charge was corrected for the symmetric equity adjustment which changes from +1.2 to -10.0 percentage points after the fall in equity prices in the adverse scenario. The capital charge for life underwriting risk was assumed to change proportionately with the technical provisions after the application of the stressed discount curve. All other components of the basic SCR, including the capital charge for counterparty default risk, non-life underwriting risk and operational risk were assumed unchanged. For internal model users, the relative change in the SCR including the aggregation and resulting diversification effects was approximated through a simplified approach building on the standard formula. In a last step, the loss-absorbing capacity of deferred taxes was recalculated based on the modeled valuation losses in the excess of assets over liabilities.

144.   Insurance stress tests, particularly when conducted as part of an FSAP, should not be seen as pass-fail exercises nor as implying additional regulatory capital requirements for individual insurers. As a macrofinancial stress test, the ambition is to detect sector-wide and potentially systemic vulnerabilities.

145.   Insurance companies have a broad range of risk-mitigating mechanisms in place which cannot be fully captured in a TD stress test, and potential reactive management actions were not modeled in the stress test. Data granularity of the supervisory reporting does not allow for a comprehensive recognition of financial hedges, stop-loss arrangements, or financial reinsurance. In times of financial stress, insurers have several options to restore their capital adequacy or their profitability, including implementing changes in underwriting standards and in the reinsurance program or by withholding profits. An even more effective way to improve the solvency position relatively quickly is a de-risking of the balance sheet, e.g., by selling stocks or high-yield corporate bonds and buying sovereign bonds instead—such a change in the asset allocation can significantly reduce required capital. For solo entities, there would also be a possibility of receiving capital as group support from the parent. As the stress test assumed a static balance sheet, these types of management actions were not modeled.

D.   Results of the Solvency Stress Test

146.   Life insurers are largely immune through the large share of unit-linked business, where market risks are borne by policyholders (Figure 32). In the adverse scenario, assets of life insurers decline by 9.1 percent on average, largely offset by a similar decline in liabilities (-8.8 percent)—a result of the upward interest rate stress. The excess of assets over liabilities (EoAoL) therefore declines by 28 percent (from EUR 3.4bn to 2.5bn). The resulting ratio of assets to liabilities of the median life insurer amounts to 101.6 percent after stress, down by 0.3 percentage points. While in guaranteed life business, the largest decline in capital stems from higher corporate and sovereign spreads, a significant effect in unit-linked business is the reduction in future fee income as assets under management decline after stress.

147. Non-life insurers and reinsurers exhibit lower sensitivities to market and are therefore highly resilient in the adverse scenario. Assets decline by only 2.8 percent and liabilities by 1.3 percent. The ratio of assets to liabilities declines from 124.2 to 122.6 percent, but both before and after stress the dispersion across the sample is very large. The excess of assets over liabilities declines by 9 percent, driven mainly by higher corporate spreads.

Figure 32. Luxembourg: Insurance Solvency Stress Test—Valuation Impact

Assets in the life sector decline by 9.1 percent, almost offset by an 8.8 percent reduction in liabilities (through higher interest rates). Non-life insurers see relatively small valuation changes in their balance sheet.

The ratio of assets to liabilities in the life sector shrinks by 0.3 percentage points to 101.6 percent for the median life firm and by 1.6 percentage points to 122.6 percent for the median non-life insurer.
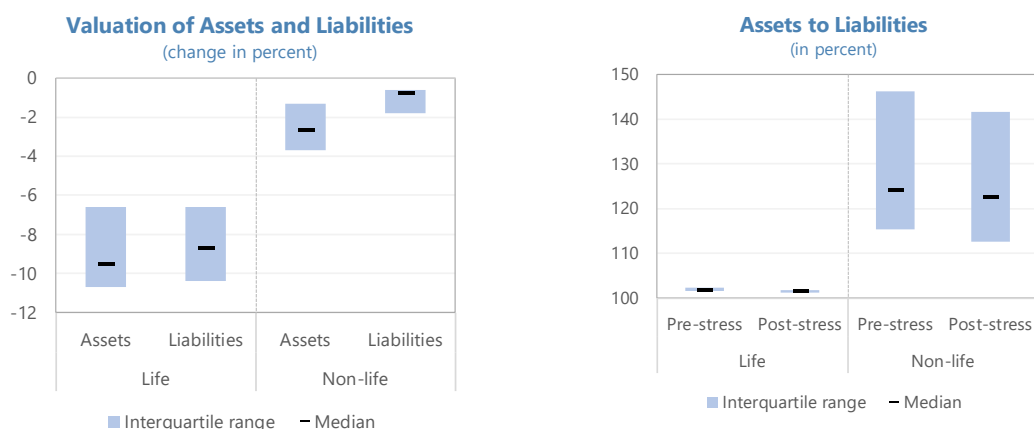
Source: IMF staff calculations based on CAA data.

In the life sector, the excess of assets over liabilities declines from EUR 3.43bn to 2.46bn (-28 percent), mainly driven by higher sovereign and corporate spreads and the impact of lower assets under management on future fee income in unit-linked business.
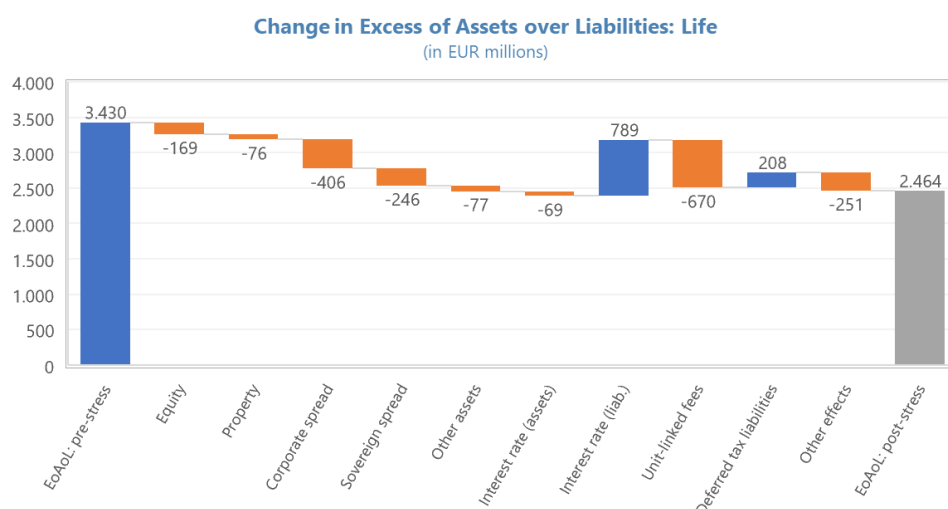
Figure 32. Luxembourg: Insurance Solvency Stress Test—Valuation Impact (Continued)

For non-life insurers, the excess of assets over liabilities declines by 9 percent (from EUR 9.95bn to 9.05bn), with the largest impact coming from higher corporate bond spreads.

Change in Excess of Assets over Liabilities: Non-Life
(in EUR millions)
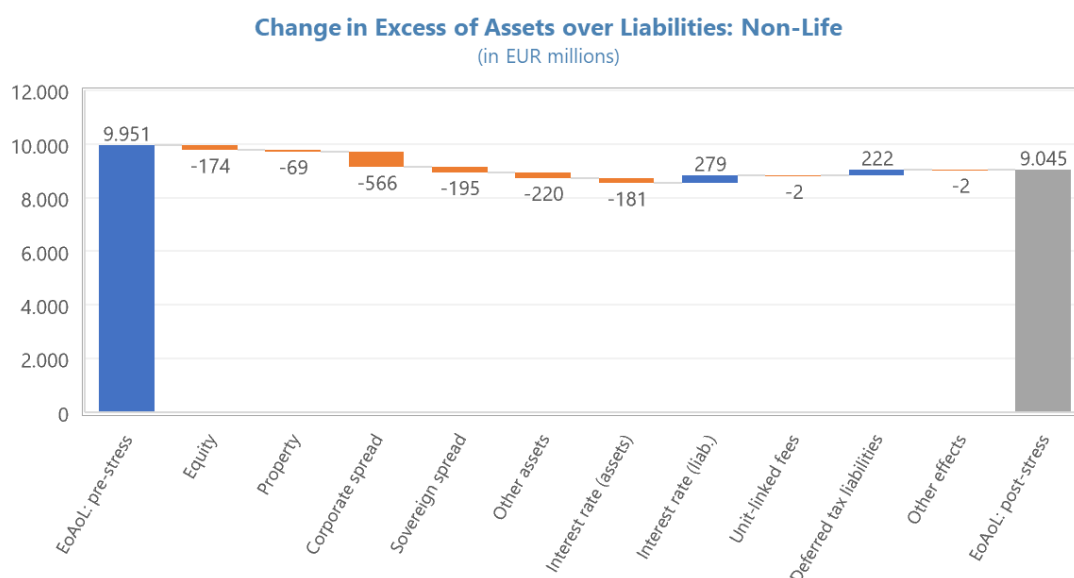
Notes: "Other effects" comprise mainly the valuation impact on reinsurance recoverables for guaranteed life insurance.

Source: IMF staff calculations based on CAA data.

148.   **The solvency impact of the adverse scenario on life insurers is notable, but not revealing major systemic vulnerabilities** (Figure 33). For the insurers in the sample, eligible own funds decline by 22 percent, and the median life insurer records a coverage of its post-stress SCR of 127 percent, down from 150 percent prior to the stress. No life insurer falls below the regulatory threshold of 100 percent, but a few would get close to this mark.

149.   **The non-life sector experiences a relatively limited impact of the adverse scenario on the capital position, also due to pre-stress SCR ratios which are considerably higher than in the life sector.** Eligible own funds decline by 8 percent, while the post-stress SCR remains almost unchanged. The median SCR ratio after stress amounts to 179 percent, down by 17 percentage points.

150.   **The risk analysis furthermore incorporated the price impact of investment fund redemptions ("Stage 2"), with only a marginal impact on insurers' balance sheets and solvency positions** (Figure 33, second panel). Assets of life insurers decline by less than 0.5 percent, and the median SCR ratio declines by another 1 percentage point to 126 percent. The effect is slightly larger in the non-life sector, where the median SCR coverage ends up at 175 percent, 4 percentage points lower than after the first-round impact of the adverse scenario.

<figure>

Figure 33. Luxembourg: Insurance Solvency Stress Test—Solvency Impact

Eligible own funds (EOF) would decline by 21 percent for the median life insurer and by 7 percent in the non-life sector, while the SCR would only decline marginally (and remains almost unchanged for non-life insurers).

The median life insurer's SCR ratio declines from 150 to 127 percent after stress. The non-life sector starts from a higher pre-stress level and is less impacted by the market stress scenario.

Eligible Own Funds and SCR
(change in percent)

SCR Coverage
(in percent)
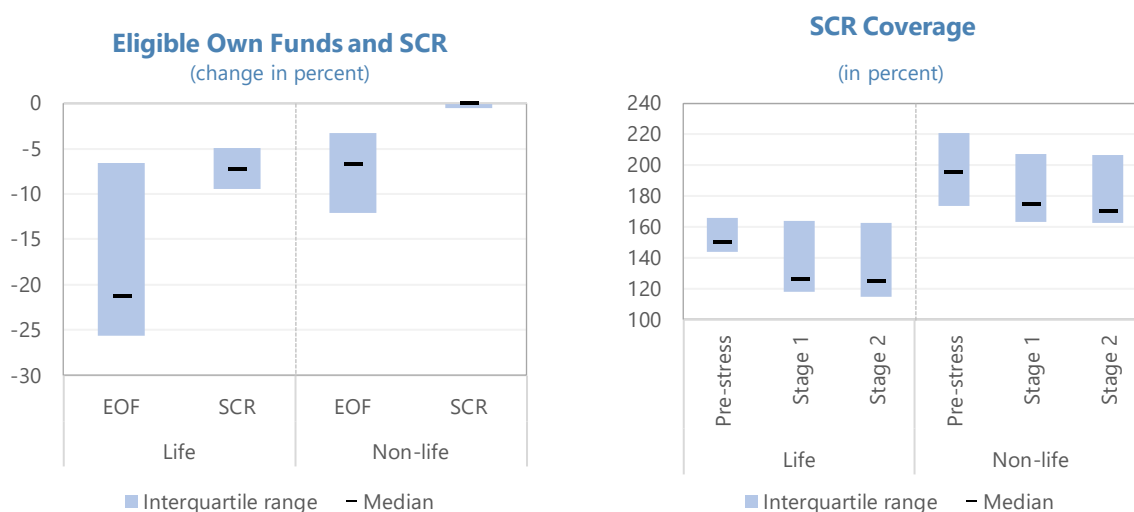
Source: IMF staff calculations based on CAA data.
</figure>

E. Sensitivity Analyses

151.   Sensitivity analyses underline the broad resilience of the insurance sector but highlight the large effect that changes in interest rates and stock prices could have on the solvency rates of life insurers (Figure 34). While an increase in risk-free interest rates would benefit most life insurers, a return to (ultra-)low rates would deteriorate solvency positions, for the median life insurer by 12 percentage points. A 50 percent decline in stock prices would reduce the SCR ratio by 30 percentage points, mainly through the impact on future fee income in unit-linked business. A default of the largest, and even of the three largest banking counterparties would have a limited first-round impact on solvency, and a steep in the credit spread for Luxembourgish sovereign bonds would leave solvency rates almost unchanged given very low exposures.

152.   In the non-life sector, the impact of single-factor shocks is even lower than in the life sector. Only one of the shocks, the 200 basis points decline in the EUR risk-free rate, would move the median SCR ratio by more than 10 percentage points. Lower stock prices and the banking counterparty default would have a very minor effect. The impact of an appreciation and a depreciation of the EUR is somewhat mixed for the sector as a whole, as some insurers in the sample prepare their accounts in U.S. dollars, resulting in opposite exchange rate effect for those as compared to the other entities.

Figure 34. Luxembourg: Insurance Sensitivity Analyses

Life insurers are most sensitive to changes in the risk-free interest rate (RFR), with an increase significantly benefiting some of them. A large decline in stock prices (-50 percent) would lead to a relatively large decline in SCR ratios.

SCR Coverage: Life
(in percent)
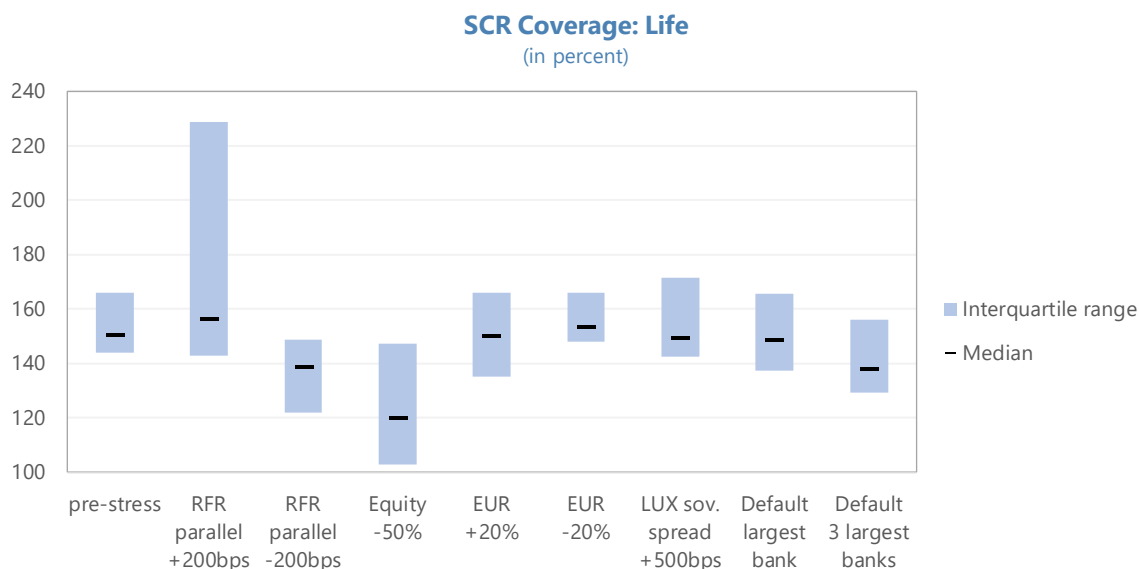
Source: IMF staff calculations based on CAA data.

Non-life insurers are very resilient to all of the single-factor shocks applied in the sensitivity analysis. The largest negative impact would stem from a large decline in the RFR, but even in that case the median SCR ratio would not fall below 170 percent.

SCR Coverage: Non-Life
(in percent)
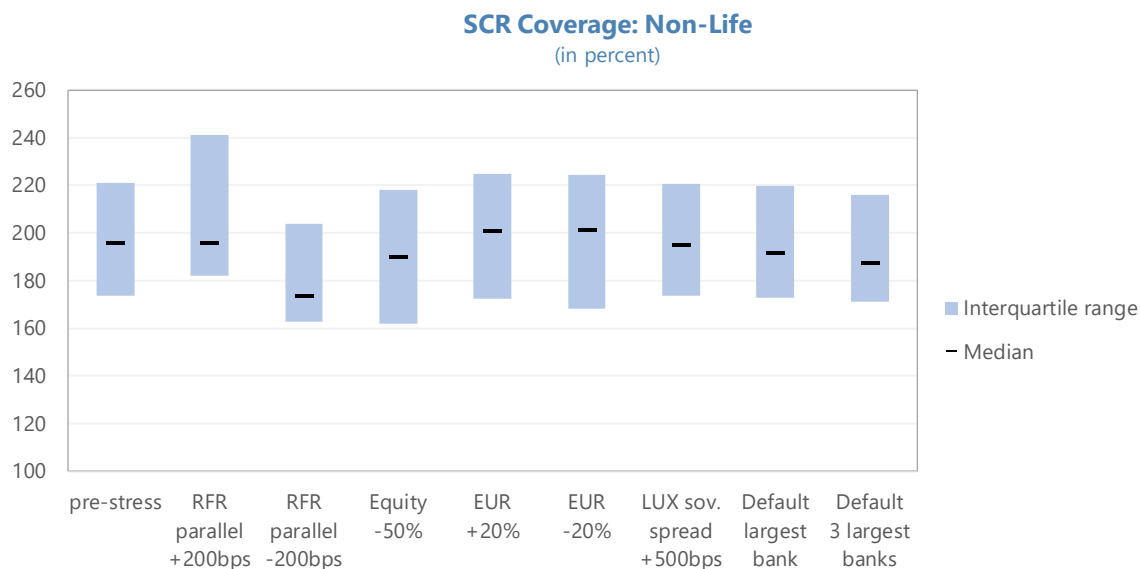
Source: IMF staff calculations based on CAA data.

Policy Recommendations

153.   The CAA is recommended to continue improving the quality of supervisory reporting data, especially on investments (S.06.02) and derivative holdings (S.08.01). Horizontal reviews and automatically cross-checking reported data against other data sources (e.g., the database on Legal Entity Identifiers) could assist in evaluating the completeness and consistency of certain reporting items. Based on the findings of these evaluations, insurers should occasionally be reminded of best practices in reporting.

154.   The CAA should implement regular top-down stress tests and sensitivity analysis for the insurance sector. The top-down model should, in a first step, cover those insurers which use the standard formula for calculating the solvency capital requirement. Subsequently, stress testing could be rolled out—to the extent possible—also to (full) internal model users, building on insights gained in the internal model supervision and the insurers' Own Risk and Solvency Assessments (ORSA). As an intermediate step, sensitivity analyses could be approximated based on the assumption of standard formula use, also with new supervisory reporting under Solvency II which is available from 2024 onwards.

INSURANCE LIQUIDITY ANALYSIS

A. Approach and Scope for the Liquidity Risk Analysis

155.   Lapse rates in life insurance have been substantially elevated in 2022-23, particularly in guaranteed business. In an environment of rapidly rising interest rates, policyholders have switched from guaranteed products to higher-yielding investments, both within and outside the insurance sector. In addition, redemptions were made to repay variable interest rate loans. Monthly lapse rates—defined as claims payments to statutory reserves—had typically hovered between 0.5 and 1 percent and have peaked at 3.5 percent in late 2022 and early 2023 (Figure 35, first panel). Since the third quarter of 2023, lapse rates have started to normalize. In unit-linked business, lapse rates have been more stable since 2020 and only during a few months exceeded 1 percent. Generally, unit-linked redemptions are not significantly correlated to (gross) redemptions in Euro area investment funds (Figure 35, second panel).

156.   Liquidity risk from redemptions is mitigated through several contractual procedures and a prudent regulatory framework. First, life insurers would typically pay out to the policyholder only about one month after receiving the notification of the intention to lapse. Second, for a large part of unit-linked business—the so-called dedicated funds which account for about 80 percent of the total market—it is possible for the insurer to redeem the underlying assets in kind to the policyholder, eliminating the need to liquidate these before the payout. Third, some of the large life insurers have fully reinsured their guaranteed life business including the lapse risk. As often the group parent acts as the reinsurer, the CAA requires full collateralization of such reinsurance arrangements to mitigate the counterparty default risk.

Figure 35. Luxembourg: Life Insurance Lapse Rates

Monthly lapse rates in guaranteed life insurance have peaked at 3.5 percent in late 2022 and early 2023 and have started normalizing thereafter.

Gross redemptions of Euro area investment funds are not significantly correlated to outflows in the Luxembourgish unit-linked life insurance business.

Lapse Rates
(monthly claims to statutory reserves, in percent)

Unit-Linked Claims and Euro Area Investment Fund Redemptions
(deviations from 2020-23 average, in percent)
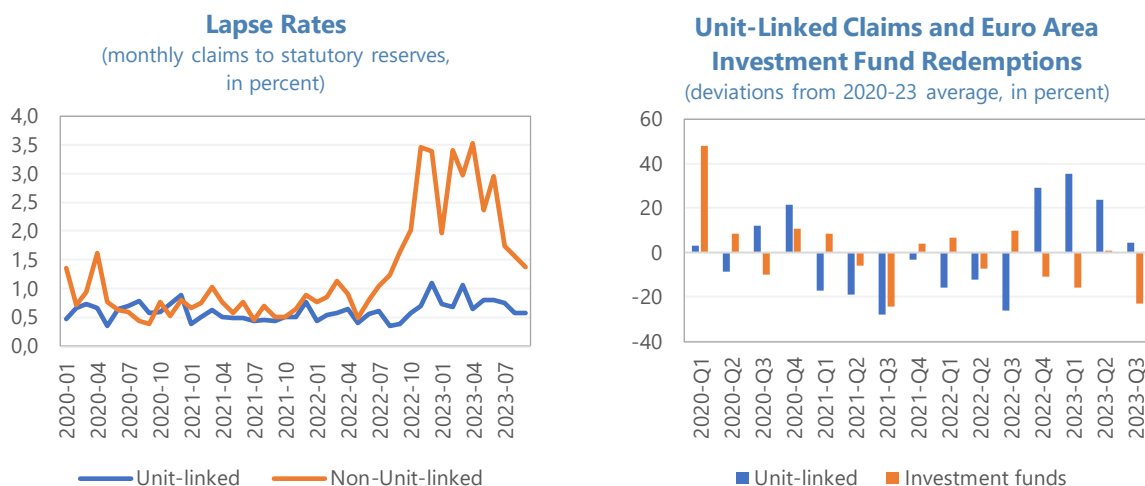
Source: IMF staff calculations based on ECB data and company submissions.

155.   The FSAP tested the vulnerability of eight large life insurers in a scenario where monthly lapse rates in guaranteed business increase by an additional 50 percent compared to the highest level observed—individually for each insurer—since 2020. As detailed lapse data is not available from the Solvency II QRTs, data was directly collected from the life insurers.

156.   The output of the analysis is the redemption coverage ratio (RCR), i.e., relating the outflow to the available total amount of liquidity sources. Besides cash deposits and high-quality liquid assets (HQLA), the recoverables from reinsurance arrangements are also considered. Haircuts are applied to HQLA, in line with those set by the Basel Committee (2013) in the definition of the Liquidity Coverage Ratio (see Table 25).

B.   Results of the Liquidity Risk Analysis

157.   Life insurers are highly resilient to severe lapse shocks. The simulated outflow for the full sample amounts to EUR 2.4bn, about 7.6 percent of the statutory reserves in guaranteed business as of June 2023. This number compares against total sources of liquidity of EUR 32.5bn, comprising cash holdings of 1.2bn, high-quality liquid assets (after haircuts) of 9.3bn, and reinsurance recoverables of 22.0bn (Figure 36, first panel). Hence, the aggregated redemption coverage ratio amounts to 13.6.

158.   Sources of liquidity vary across insurers and are sufficient for each insurer in the sample. Even for the least liquid life insurer, the RCR amounts to 9.6. While half of the sample firms relies on reinsurance arrangements (each with a different reinsurer), the others hold more cash and/or HQLA (Figure 36, second panel).

Figure 36. Luxembourg: Life Insurance Redemption Shock

A simulated monthly outflow of EUR 2.4bn could easily matched with cash, HQLA assets and through reinsurance arrangements, totaling EUR 32.5bn.

Redemption coverage ratios are rather dispersed across life insurers, both in terms of the total coverage and in the composition of liquidity sources.

Redemption Shock vs. Sources of Liquidity (in EUR billions)

Redemption Coverage Ratio by Source of Liquidity (distribution)
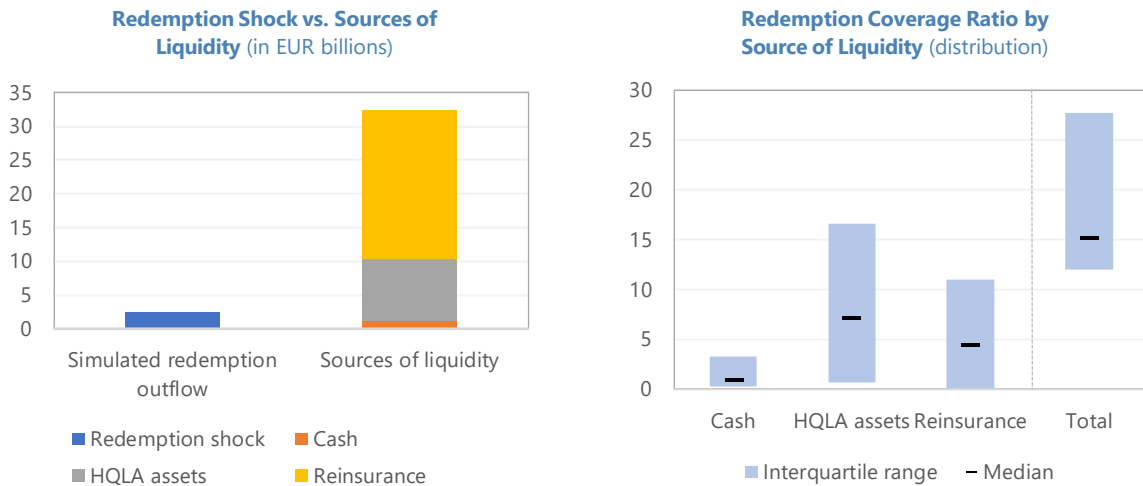
Source: IMF staff calculations based on company submissions.

159.   Besides lapse risks, margin calls from derivative exposures could be a source of liquidity risks for insurers, but these are very limited in Luxembourg. The total notional of derivatives held by Luxembourgish insurers as of September 2023 amounts to EUR 3.6 bn (with a market value of EUR 88m), of which 1.4bn are interest rate swaps and 1.3 bn are foreign-exchange forward rate agreements. The use of derivatives is limited to a very small number of insurers.

Appendix I. Risk Assessment Matrix

Source of Risks	Relative Likelihood	Impact if realized
A sharp and prolonged rise in inflation expectations. Geopolitical tensions and inflationary pressures fuel market interest rate surges amid high economic uncertainty and volatility, , de-anchoring inflation expectations .	Medium	**High/Medium.** Higher inflation, including through commodity price rises, will feed into wages, through automatic indexation, hindering competitiveness, or increase fiscal cost for the government. Tighter financial conditions could heighten credit risk. In particular, higher for longer interest rates could severely affect the performance of banks and non-banks, increase unemployment and lower fiscal revenue.
Commodity price volatility. A succession of supply disruptions (e.g., due to conflicts and export restrictions) and demand fluctuations (e.g., reflecting China reopening) causes recurrent commodity price volatility, external and fiscal pressures, and social and economic instability.	Medium	
Abrupt global slowdown or recession. Global and idiosyncratic risk factors combine to cause a synchronized sharp growth downturn, with recessions in some countries, adverse spillovers through trade and financial channels, and markets fragmentation.	Medium	**High/ Medium.** Luxembourg export demand could weaken further, with potentially more severe impact on the economy. Inflation is lower due to lower commodity prices.
In Europe, intensifying fallout from the war in Ukraine, worsening energy crisis and supply disruptions, and the increase in market interest rates in an environment with sluggish decrease in inflation towards target exacerbate economic downturns and housing market corrections.	Medium	
Systemic financial instability. Sharp swings in real interest rates, risk premia, and assets repricing amid economic slowdowns trigger insolvencies in countries with weak banks or non-bank financial institutions, causing markets dislocations and adverse cross-border spillovers.	Medium:	**High.** Banks appear resilient but some banks may face capital shortfalls in an adverse scenario. Private and custodian banks are vulnerable to market risks while corporate and universal banks are more exposed to credit risks. Investment funds could face large redemptions, resulting in fire sales and further liquidity pressures in all sectors.
Cyber-attacks Cyberattacks on critical domestic and/or international physical or digital infrastructure (including digital currency and crypto ecosystems) trigger financial and economic instability.	Medium ST/MT	**High.** Payment and financial systems are disrupted, with potential risk to delivery of collateral in time, with large negative impact on financial institutions' ability to meet margin calls and stem funding outflows.
Sharp correction in house prices. A sharp drop in demand for housing could lead to a large correction in prices.	Low ST/MT	**Low.** Structural imbalances render a large correction unlikely. Risks on the financial sector are mitigated by banks' strong capital and liquidity positions, households' high level of income and financial wealth, as well as strong labor markets.
Possible changes in international corporate and personal taxation.	Medium ST/MT	**Medium.** This could weaken Luxembourg's attractiveness for businesses, weakening fiscal revenues and foreign investment.

Appendix II. Stress Test Matrix (STeM)

Banking Sector STeM

Banking Sector: Solvency Stress Test		
Top-down by IMF		
1. Institutional Perimeter	Institutions included	• 39 banks • 19 banks subcategorized as SIs. • One bank is domestically owned, 24 are subsidiaries of euro area banks, 14 are subsidiaries of non-euro area banks
	Market share	• 90 percent of the banking sector's assets • 100 percent of residential mortgage loans • At least 80 percent of the different business models (retail and commercial, private banking, custodian and corporate finance)
	Data and baseline date	• Supervisory data: bank balance sheet and supervisory statistics (including FINREP and COREP), information on interest rate risk in the banking book (IRRBB), liquidity risk and market risk sensitivities (including STE templates) provided by the national authorities and the ECB. • Market and publicly available data • Baseline date: October 2023 • Scope of consolidation: highest consolidation level in Luxembourg: bank consolidated level data for banks having their headquarters in Luxembourg and sub-consolidated level data for the subsidiaries of foreign banks
2. Channels of Risk Propagation	Methodology	• FSAP team satellite models and methodologies • Balance-sheet regulatory approach • Market data-based approaches • The losses for securities portfolios are based on duration approach • Provisioning for IRB and STA are modeled using IFRS9 transition matrix approach.
	Satellite models for macro-financial linkages	• Models for credit losses, funding costs, lending rates, net fee and commission income and risk weights • Models to integrate solvency-funding interactions through changes in funding costs and the impact of fire sales
	Stress test horizon	• 3-years (2024-2026)
3. Tail shocks	Scenario analysis	• Two scenarios: • A baseline scenario based on the October 2023 WEO macroeconomic projections • An adverse scenario that captures the key risks in the RAM, External assumptions are given by GFM, a structural macroeconometric model of the world economy, disaggregated into 40 national economies.

Banking Sector: Solvency Stress Test		
Top-Down by IMF		
3. Tail shocks	Scenario analysis	As Luxembourg is not included into the GFM projections, a specific Bayesian VAR model was estimated for Luxembourg domestic variables, taking some of the exogenous variables given by GFM as explanatory variables, • The TD analysis covered three main sources of risk: domestic real estate, exposures to parent companies and investment funds and sovereign risks.
	Sensitivity analysis	• Sensitivity analyses was conducted in the TD exercises, evaluating financial shocks and concentration risks. • In particular, 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 through sensitivity analysis.
4.Risks and Buffers	Risks/ factors assessed	• Risks covered include credit (on loans and debt securities), market (instantaneous shocks with valuation impact of debt instruments through repricing and credit spread risk as well as the P&L impact of net open positions in market risk factors such as foreign exchange risks) and interest rate risk (IRRBB) on the banking book (hedging not considered); • Solvency and liquidity risk interactions, mainly through funding costs.
	Behavioral adjustments	• Quasi-static approach followed for the banks' balance sheet size growth: balance sheet grows in line with nominal GDP, but with a floor set at 0 percent in order to prevent banks from deleveraging. • Interest income from nonperforming loans is not accrued; • 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 regulatory framework of Basel III regulatory minima: CET1 ratio of 4.5 percent and leverage ratio of 3 percent. The hurdle rate for the CET1 ratio is equal to the Overall Capital Requirement, including the minimum requirement, the Pillar II requirements, the Capital Conservation Buffer, the Countercyclical Buffer as well as the O-SII Buffer.
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 regulatory minima; • Outputs also include information on impact of different result drivers, including profit components.

Banking Sector: Liquidity Risk		
Top-Down by IMF		
1. Institutional Perimeter	Institutions included	• 39 banks
	Market share	• 90 percent of banking sector's assets
	Data and baseline date	• Latest data: June 2023 for LCR, NSFR and cash flow analysis • Source: supervisory data (COREP, ST exercise) • 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, instantaneous shocks) • Market liquidity (price shocks, instantaneous shocks)
	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

Investment Funds STeM

Investment Funds Sector: Change in NAVs/Solvency Risk		
Top-Down by IMF		
1. Institutional Perimeter	Institutions included	• 1135 largest open-ended funds. • Largest UCITS Investment Funds covering EM bond funds, HY bond funds, Mixed funds, Equity funds and MMFs with total net assets over 1 billion euros, totaling close to 2.7 trillion euros in total net assets. • Largest open-ended AIFs with total net assets over 1 billion euros subject to same reporting standards as UCITS, totaling close to 400 million euros in total net assets.
	Market share	• 80 percent of total net assets of UCITS within full reporting scope. • Roughly 50 percent of total net assets of open-ended AIFs subject to same reporting standards as UCITS in full reporting scope.
	Data and baseline date	• Source: Supervisory data • Baseline data: March 2023
2. Channels of Risk Propagation	Methodology	• IMF's Financial shock simulator • Market data-based approaches • Specifically, for MMFs, increase in risk free rates and credit spreads that would result in deviations between shadow Net Asset Value (NAV) and Constant Net Asset Value
	Satellite models	• IMF's Financial shock simulator
3. Tail shocks	Scenario analysis	• Two scenarios: • An adverse scenario (same as for other sectors) that captures the key risks in the IMF's RAM. External assumptions given by GFM. • A GFC scenario based on changes in asset prices during September and October 2008.
	Sensitivity analysis	• Reverse stress test for MMFs based on different levels of exogenous shocks to interest rates and corporate spreads.
4. Risks and Buffers	Risks/ factors assessed.	• Market risk (valuation impact through repricing and credit spread risk) and interest rate risk on the investment fund portfolio. • For MMFs, inability to maintain Constant NAV due to interest rate and corporate spread shocks from adverse scenario. • For AIFs and UCITS, there is no buffer requirement. The change in NAVs affects outflows (see Liquidity Risk).
5. Regulatory and Market-Based Standards and Parameters	Regulatory/ accounting and market-based standards	• According to the IMMFA Code of Practice and ERSB Regulation, 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	• Impact on value of assets and liabilities for all funds in the sample from. No pass/fail threshold applied.

Investment Funds Sector: Change in NAVs/Solvency Risk		
Top-Down by IMF		
		• For MMFs, deviations between constant NAV and shadow NAV. Number of MMFs and share of funds for which the deviation crosses the 20-basis points threshold.
Investment Fund Sector: Liquidity Risk		
Top-Down by IMF		
1. Institutional Perimeter	Institutions included	• 1,085 largest open-ended funds. • Largest UCITS Investment Funds covering EM bond funds, HY bond funds, Mixed funds and Equity funds with total net assets over 1 billion euros, totaling close to 2.3 trillion euros in total net assets. • Largest open-ended AIFs with total net assets over 1 billion euros subject to same reporting standards as UCITS, totaling close to 400 million euros in total net assets.
	Market share	• 70 percent of total net assets of UCITS within full reporting scope. • Roughly 50 percent of total net assets of open-ended AIFs subject to same reporting standards as UCITS in full reporting scope.
	Data and baseline date	• Source: Supervisory data • Latest data: March 2023
2. Channels of Risk Propagation	Methodology	• Liquidity measure based on ii) cash and high-quality liquid assets. • Flow-performance Model to integrate impact of macro shock on redemptions. • Models of market depth to integrate second round effect coming from sales of assets, taking into account illiquidity of assets. • Incorporation of intersectoral linkages, especially with Luxembourg banks, to assess liquidity access capacity.
3. Risks and Buffers	Risks	• Severe redemption shock following asset devaluations. • Funding liquidity (liquidity outflows) and inability to sell assets to cope with redemptions. • Market liquidity (price shocks) leading to second round effects.
	Buffers	• Stock of highly liquid assets (HQLA)
4. Tail shocks	Size of the shock	• Initial shock coming from impact of scenarios on Total Net Assets and redemption shock estimated from a model relating funds flows to macrofinancial variables. • Second round effects coming from price effect due to sales of assets. • Separately, exogenous monthly redemption shock equal to the first percentile of historical net flows
	Sensitivity Analysis	• Reverse stress test based on exogenous levels of redemptions (as a percentage of NAV) applied homogeneously to all funds in the test sample.
5. Reporting Format for Results	Output presentation	• Number of funds with a redemption coverage ratio (ratio of highly liquid assets to redemptions) below one.

Investment Fund Sector: Liquidity Risk		
Top-Down by IMF		
5. Reporting Format for Results		• Total net assets of funds with RCR below one, as a percentage of aggregate total net assets. • Liquidity shortfall amount for individual funds after redemptions.

Insurance Sector STeM

Insurance Sector: Solvency Risk		
Top-Down by IMF		
1. Institutional perimeter	Number of institutions	• 10 life insurers • 12 non-life insurers and reinsurers
	Market share	• Life: ~83 percent of investment assets • Non-life: 81 percent of gross written premiums
	Data	Supervisory reporting (Solvency II Quantitative Reporting Templates)
	Reference date	30 June 2023
2. Channels of risk propagation	Methodology	• Investment assets: market value changes of assets after price shocks • Liabilities: valuation change due to interest rate shock • Impact on available capital (net assets as the difference between stressed assets and liabilities) • Recalculation of the solvency capital requirement
	Time horizon	Instantaneous shock
3. Scenario analysis	Scenario analysis	Adverse scenario: aligned with the scenario used for the investment fund risk analysis, but with additional granularity on market and interest rate risks
	Single-factor sensitivities	• Additional interest shocks: EUR risk-free rate term structure +/-200bps • Additional currency shocks: EUR external value +/-20 percent • Equity prices shock: -50 percent • Domestic sovereign shock: +500bps • Default of largest and the three largest banking counterparties
4. Risk factors		• Market risks (equity, property) • Interest rate risks • Credit risks (credit spread risk, default of largest counterparty) • Currency risks
5. Buffers and mitigating factors		• Eligible own funds • Loss-absorbing capacity of deferred taxes • No management actions
6. Regulatory/ accounting standards		• Solvency II • National GAAP
7. Reporting format for results		• Impact on value of assets and liabilities • Impact on solvency ratio (SCR coverage) • Aggregated capital shortfall • Dispersion across companies • Contribution of individual shocks

Insurance Sector: Liquidity Risk		
Top-Down by IMF		
1. Institutional perimeter	Number of institutions	8 life insurers
	Market share	Life: ~90 percent of investment assets in non-unit-linked business
	Data	• Supervisory reporting (Solvency II Quantitative Reporting Templates) • Additional data request to life insurers
	Reference date	30 June 2023
2. Channels of risk propagation	Methodology	Outflow through surrenders of guaranteed life insurance policies
	Time horizon	One month
3. Scenario analysis	Scenario analysis	Simulated monthly outflow which exceeds highest historical outflow by 50 percent
4. Risk factors		Liquidity risk
5. Buffers and mitigating factors		• Holdings of highly liquid assets • Surrender payouts to policyholders according to contractually allowed periods. • No management actions
5. Regulatory/accounting standards		• Solvency II • National GAAP
6. Reporting format for results		• Cash in- and outflows • Coverage of net outflows by liquid assets • Distribution across companies

Banking sector solvency

	Hurdle rates		Number of institutions below the hurdle rates:			Asset shares of institutions below the hurdle rate:
	CET1 ratio (percent of RWAs)	Leverage ratio (percent of total assets)	After 1st round of shocks	After 2nd round of shocks	After 3rd round of shocks	After all rounds of shocks
Baseline (end of 1st year)	8%	3%	3	3	3	8.5%
Adverse (end of 1st year)	8%	3%	5	5	6	18.2%

Banking sector liquidity

	Hurdle rates			Number of institutions below the hurdle rates			Asset shares of institutions below the hurdle rate	
	Liquidity coverage ratio (percent)	Net Stable Funding Ratio (percent)	Cash-flow based analysis end-of-period counterbalancing capacities (within 12 months)	Liquidity coverage ratio	Net Stable Funding Ratio	Cash-flow based analysis	Liquidity coverage ratio	Cash-flow based analysis
Baseline	100%	100%	0	0	0	1	0	0.5%
Deposit run	100%	100%	0	5	...	3	21.7%	14.2%
Combined (deposit run + market stress)	100%	100%	0	6	...	6	23.8%	23.8%
Weak parent bank	100%	100%	0	3	...	5	17.6%	19.0%

Investment fund liquidity

	Redemption coverage ratio (RCR)	Number of institutions with RCR<1		Asset shares of institutions with RCR<1
		UCITS	AIF	< 0.1%
Adverse	1	0	4	

MMF solvency

	Threshold	Number of institutions crossing the threshold		Asset shares of institutions crossing the threshold (% of total MMF sector)	
	Change in NAV	CNAV	LVNAV	CNAV	LVNAV
Adverse	20 basis points	2	4	< 0.1%	11.6%

Insurance solvency

	SCR ratio (eligible own funds to solvency capital requirement)	Number of institutions with RCR<100 percent		Asset shares of institutions with RCR<100 percent	
		Life	Non-life	Life	Non-life
Adverse (instantaneous)	100%	0	0	...	0%

Insurance liquidity

	Redemption coverage ratio (percent of simulated claims)	Number of institutions with RCR<100 percent		Asset shares of institutions with RCR<100 percent	
		Life	Non-life	Life	Non-life
Adverse	100%	0	...	...	0%

Sources: IMF staff calculations.

Appendix IV. Technical Details on the Stress Test Adverse Scenario Calibration

1.   The stress scenario provides the basis of all the stress test exercise projections.
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. The scope of the Global Macro-Financial Model (GFM) 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.

2.   Two benchmarks were used to calibrate the severity of the Luxembourg stress test adverse scenario:

*   The first one results from the application of at least a 2 standard deviation shock in terms of Luxembourg 2-year GDP growth, taking the 1990-2022 period as the benchmark for GDP growth: the cumulative decline of GDP relative to the baseline over two years would then reach 8.7 percentage points and the cumulative drop in GDP level compared to 2023 would reach 4.7 percent,[1] and

*   The second one corresponds to the use of the 5th percentile of the Growth at Risk framework, in which quantile regression is used to regress Luxembourg year-on-year GDP growth on a set of foreign and domestic macroeconomic and financial variables. The five groups of variables are the following: (i) world financial condition index (FCI); (ii) euro area FCI, (iii) euro area macroeconomic index; (iv) domestic leverage; and (v) domestic FCI. The FCIs mostly comprise credit spread, interest rate and asset volatility indices.

3.   The two-year GaR for Luxembourg at the 5 percent threshold is estimated at -12.8 percent (Figure 1). The left skewed shape of the distribution suggests a heightened downside risks to GDP growth given the country's current economic and financial conditions and reflect broadly the aforementioned external and domestic vulnerabilities.

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[1] As a benchmark, in the recent 2023 Ireland FSAP, the shock to GDP and GNI growth was equivalent to 2.6 and 3.1 standard deviations, respectively, from their baselines.

Appendix IV. Figure 1. Luxembourg: Two-Year Ahead GDP Growth Distribution

Quarterly T-skew quantile fit for 12/31/2022 growth rate forward 8

Sources: IMF staff calculations.
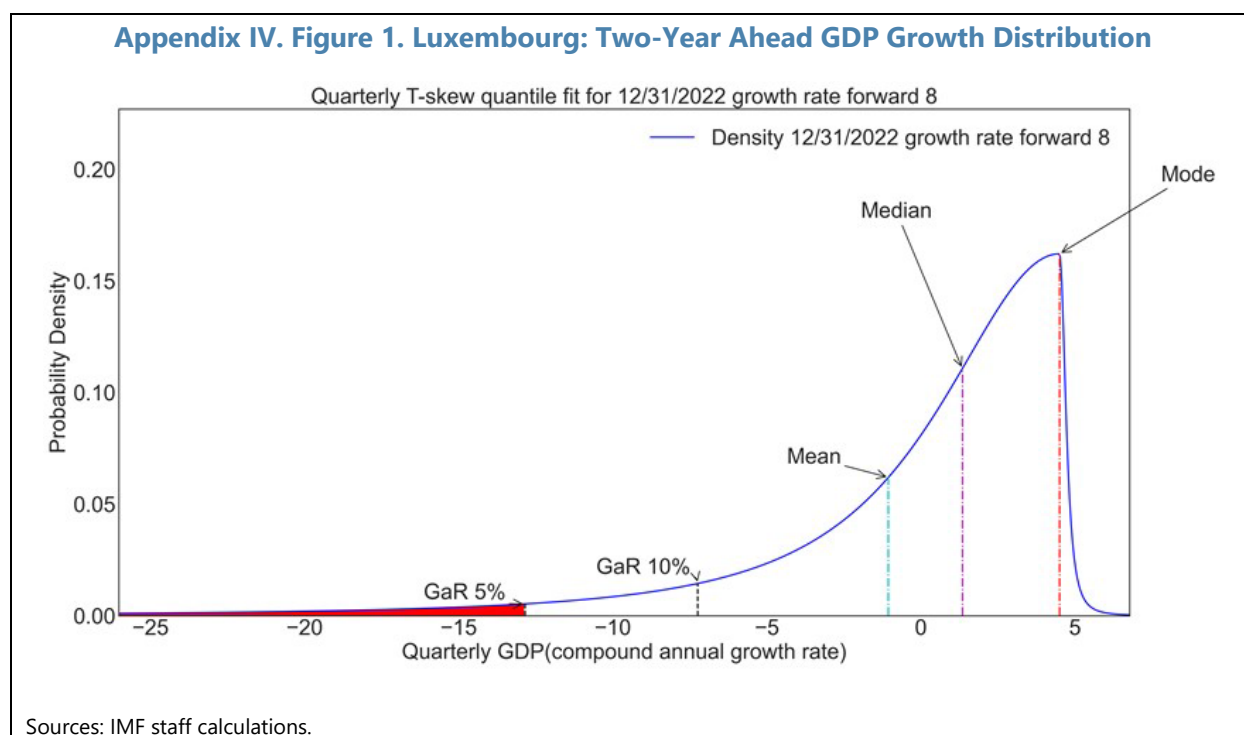
4.   The adverse scenario projections were obtained through the combination of external projections given by a world economy structural model and a specific model estimated by the mission for Luxembourg. The adverse scenario would span over three years, starting in 2024. It corresponds to a recessionary scenario coupled with high inflation. The projections concerning the euro area came from the latest update of the Global Macrofinancial Model (GFM). They imply a severe recession in the euro area in 2024, with a decline in GDP by close to 3 percent in 2024. However, GFM does not include Luxembourg. That is why the FSAP mission had to estimate a Luxembourg-specific Bayesian VAR model (with Minnesota prior), close to the one which had been developed during the previous Luxembourg FSAP in 2017. The model included 3 endogenous domestic variables: Luxembourg year-on-year GDP growth, HICP inflation rate, and the growth in Luxembourg-domiciled investment funds net assets. The model included six explanatory variables: the euro area GDP growth, the US GDP growth, the euro are inflation rate, the Brent oil price inflation, the 10-year average long-term rate for euro area countries and the VIX index. The model was estimated over the 2000-2022 period at a quarterly frequency (see Table below).

5.   The projections given by the Bayesian VAR model are within the range given by the benchmarks mentioned previously in terms of degree of severity. The projected path of the Luxembourg GDP growth obtained through the Bayesian VAR estimation would be equivalent to a 2.4 standard deviation shock, with a cumulative decline in GDP over two years by 6.3 percent (with the following GDP growth path: -4.3 percent in 2024, -1.7 percent in 2025, +3.1 percent in 2026). The higher degree of severity of the scenario compared to the GDP growth path projected for the euro area results from additional financial shocks (in particular domestic) and the sensitivity of the Luxembourgish economy to external financial conditions, reverberating into the growth of investment funds' net assets.

6.   Some variables had to be projected outside the model due to endogeneity issues and for the sake of conservatism. This concerned the unemployment rate, aggregate credit growth, the house price growth rate and the 10-year Luxembourg government bond yield. In particular, the unemployment rate was assumed to start rising sharply and to peak at 12 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 1990-2022 period as a benchmark.

7.   House prices were assumed to decline by 30 percent in cumulative terms over the three- 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),[2] 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.

8.   Finally, the projections of 10-year Luxembourg government bond yield were based on the assumption that the Luxembourg sovereign spread would converge to the euro area average in the adverse scenario.

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[2] 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.

Appendix IV. Table 1. Luxembourg: Bayesian VAR Estimates

Bayesian VAR Estimates
Date: 10/18/23   Time: 16:07
Sample (adjusted): 2000Q2 2022Q4
Included observations: 91 after adjustments
Prior type: Litterman / Minnesota
Initial residual covariance: Univariate AR
Constant included in covariance calculation
Hyper-parameters: Mu1: 1, L1: 0.1, L2: 0.99, L3: 1, L4: inf
Standard errors in ( )

	LUXRGDPG	LUXINFL	IFAG
LUXRGDPG(-1)	0.611103	-0.016038	-0.075644
	(0.06848)	(0.01681)	(0.24007)
LUXINFL(-1)	-0.169449	0.440132	-0.879412
	(0.26210)	(0.06492)	(0.92306)
IFAG(-1)	0.026492	0.009321	0.829616
	(0.01798)	(0.00443)	(0.06357)
C	0.844879	-0.303691	0.917942
	(1.00601)	(0.24813)	(3.54342)
EARGDPG	0.308955	0.061485	-1.858989
	(0.18462)	(0.04553)	(0.65019)
USGDPG	0.110085	0.080327	2.484381
	(0.24101)	(0.05944)	(0.84875)
VIX(-1)	-0.020281	0.011732	-0.011943
	(0.03581)	(0.00883)	(0.12611)
EAINFL	0.151807	0.528031	0.130916
	(0.27865)	(0.06889)	(0.98150)
OILINFL(-1)	-0.022349	0.006011	-0.019049
	(0.00962)	(0.00237)	(0.03386)
LT RATE(10Y)_CHGE(-1)	-0.335131	-0.217532	-0.623397
	(0.50535)	(0.12463)	(1.77950)
R-squared	0.563681	0.919559	0.720052
Adj. R-squared	0.515201	0.910622	0.688947
Sum sq. resids	392.7980	26.42476	4634.956
S.E. equation	2.202126	0.571167	7.564501
F-statistic	11.62710	102.8838	23.14881
Mean dependent	2.698631	2.465393	10.12696
S.D. dependent	3.162723	1.910498	13.56322

Source: IMF team calculations

Note: LUXRGDPG stands for the year-on-year Luxembourg real GDP growth rate; LUXINFL for the year-on-year percentage change in the Harmonized Consumer Price Index; IFAG for the year-on-year growth rate in the net assets of investment funds domiciled in Luxembourg.

Appendix IV. Table 2. Luxembourg: Scenario Projections

| External assumptions (in percent, except for VIX)					
	Realized		Est.		Proj.	
	2021	**2022**	**Y0=2023**	**Y1=2024**	**Y2=2025**	**Y3=2026**
Euro area GDP growth rate						
Baseline	5.6	3.3	0.7	1.2	1.8	1.7
Adverse	5.6	3.3	0.7	-3.0	0.2	1.7
Euro area inflation rate						
Baseline	2.6	8.4	5.6	3.3	2.2	2.0
Adverse	2.6	8.4	5.6	6.3	3.3	1.6
Euro area unemployment rate						
Baseline	7.7	6.7	6.6	6.5	6.4	6.3
Adverse	7.7	6.7	6.6	7.0	8.0	8.2
Euro area ST rate						
Baseline	-0.4	0.3	3.3	3.4	3.0	2.7
Adverse	-0.4	0.3	3.3	6.0	4.7	3.3
Euro area LT rate						
Baseline	0.1	1.8	3.0	3.3	3.5	3.4
Adverse	0.1	1.8	3.0	6.8	5.7	3.4
US GDP growth rate						
Baseline	5.9	2.1	2.1	1.5	1.8	2.1
Adverse	5.9	2.1	2.1	-1.9	1.0	2.7
Oil price growth						
Baseline	63.5	39.8	-16.8	-1.4	-4.7	-4.0
Adverse	63.5	39.8	-16.8	20.1	0.2	2.1
3-month Euribor rate						
Baseline	-0.5	0.3	2.7	2.9	2.9	2.5
Adverse	-0.5	0.3	2.7	6.0	4.7	3.3
VIX index (historical benchmarking)						
Baseline	19.6	25.6	20.0	20.0	20.0	20.0
Adverse	19.6	25.6	20.0	48.3	35.0	20.0

Note: The external assumptions for the adverse scenario are from estimations based on a DSGE model by Vitek (2018).

Appendix IV. Table 2. Luxembourg: Scenario Projections (Concluded)

(Luxembourg-specific) domestic variables (in percent)					
	Realized		**Est.**		**Proj.**
	2021	**2022**	**Y0=2023**	**Y1=2024**	**Y2=2025**	**Y3=2026**
GDP growth rate						
Baseline	7.2	1.4	-0.4	1.5	2.4	2.5
Adverse	7.2	1.4	-0.4	-4.3	-1.7	3.2
Inflation rate (HICP-based)						
Baseline	3.5	8.1	3.2	3.3	2.2	2.0
Adverse	3.5	8.1	3.2	5.5	3.6	2.0
Inflation rate (CPI-based)						
Baseline	2.5	6.3	3.9	3.1	2.5	1.9
Adverse	2.5	6.3	3.9	4.7	5.1	2.6
Energy inflation (CPI-based)						
Baseline	18.9	32.9	-7.0	2.2	12.0	-2.4
Adverse	18.9	32.9	-7.0	7.0	18.0	0.6
Food inflation (CPI-based)						
Baseline	0.9	7.0	9.9	2.0	2.3	1.7
Adverse	0.9	7.0	9.9	3.0	3.7	2.5
Inflation excl food and energy (CPI-based)						
Baseline	1.6	3.6	4.0	3.4	1.7	2.3
Adverse	1.6	3.6	4.0	4.8	4.1	2.8
House price index growth						
Baseline	13.9	9.6	-2.3	-0.4	2.9	1.9
Adverse	13.9	9.6	-2.3	-17.0	-15.0	-1.0
Unemployment rate						
Baseline	5.7	4.8	5.2	5.8	5.9	5.8
Adverse	5.7	4.8	5.2	8.7	12.1	11.1
10-yr gov.-bond yield						
Baseline	-0.4	1.5	1.7	2.9	3.1	3.2
Adverse	-0.4	1.5	1.7	6.8	5.7	3.4
Credit growth						
Baseline	4.5	6.6	2.4	4.7	5.4	4.9
Adverse	4.5	6.6	2.4	0.0	0.0	0.0
Inv. funds' net asset growth						
Baseline	17.8	-14.2	0.0	0.0	0.0	0.0
Adverse	17.8	-14.2	0.0	-14.1	-7.5	4.5
Wage (comp. per empl.) growth						
Baseline	5.1	5.9	5.5	3.5	2.9	2.3
Adverse	5.1	5.9	5.5	3.6	3.7	3.4

Source: IMF team calculations

Appendix IV. Figure 2. Luxembourg: Bayesian VAR Projections
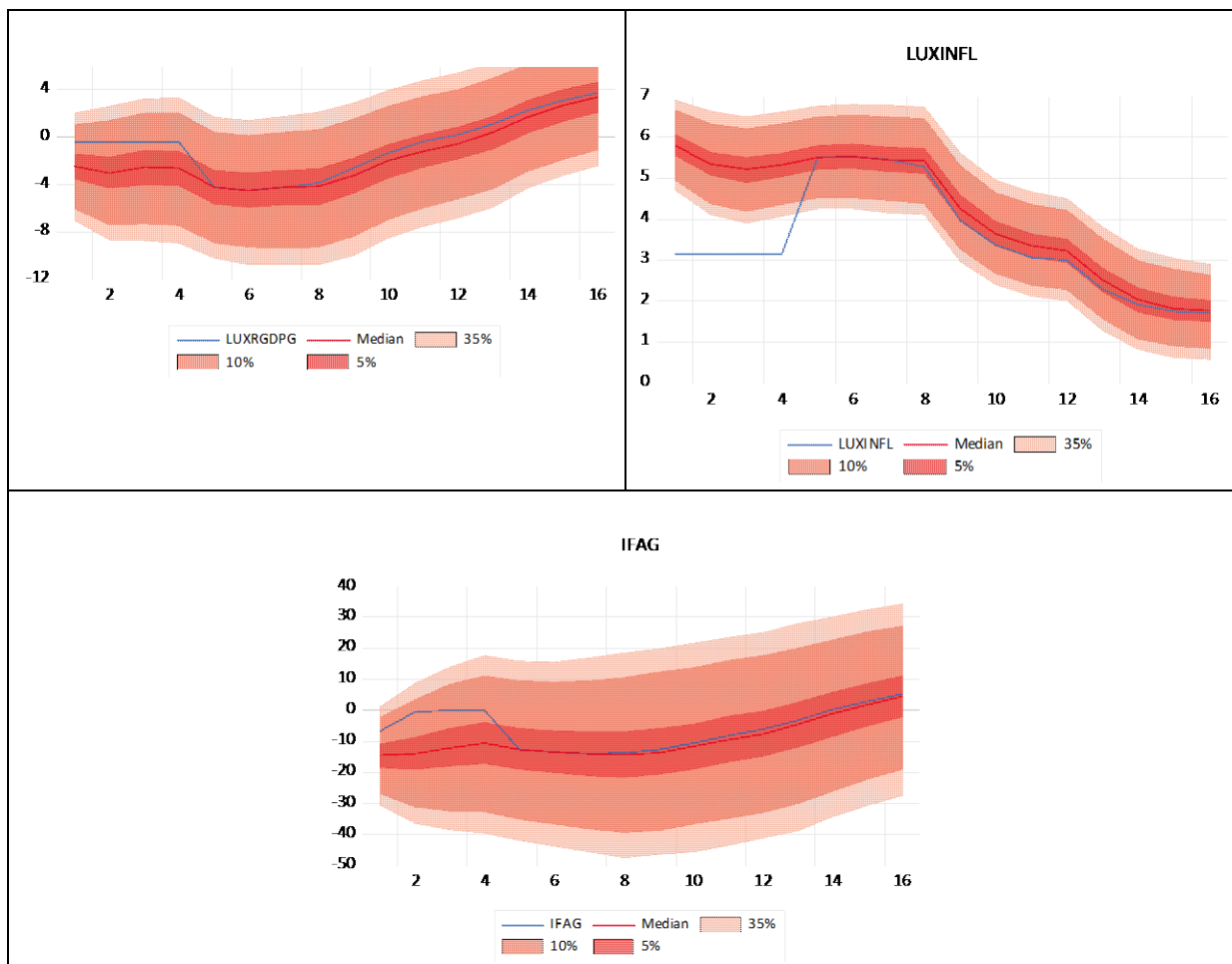
Source: IMF team calculations

Notes: LUXRGDPG stands for the year-on-year Luxembourg real GDP growth rate; LUXINFL for the year-on-year percentage change in the Harmonized Consumer Price Index; IFAG for the year-on-year growth rate in the net assets of investment funds domiciled in Luxembourg.

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

1.   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.* Two different assumptions were made between the baseline and the adverse scenarios. In the baseline, banks' balance sheet size was projected to grow in line with nominal GDP. In the adverse scenario, a quasi-static balance sheet assumption was applied. Therefore, balance sheets would not grow in line with nominal GDP but banks would not be allowed to deleverage. 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 seven 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. 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 in the baseline and to remain flat in the adverse scenario. Non-interest expenses were assumed to grow in line with the inflation rate, due to the wage indexation scheme in place in Luxembourg. It was further assumed that income from extraordinary items did not recur again during the 2024-2026 period in the baseline and the adverse scenarios. Moreover, non-performing loans were assumed to not provide any accrued income.

- *Three income statement items were projected on the basis on econometric satellite models.* Given the very specific business model of custodian banks, separate satellite models were estimated for the latter for funding costs and the net fee and commission income:

    o *Bank's lending rates* (approximated by the ratio of banks' interest income to net loans) were projected based on an econometric panel model with individual bank fixed effects, estimating the annual change in Luxembourgish banks' average interest income to net loans ratio, with annual data over 2005–2022. Explanatory variables were the annual change in the 3-month interbank interest rate (3-month Euribor), and the annual change in the VIX index, measuring the implied volatility in the U.S. stock market (Table 1). For banks with a traditional business model, when the degree of sensitivity of investors to risk aversion increases, 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 change in lending rates was then applied to banks' new loans or loans with a variable lending rate (see Figure 1 for the resulting projections);

- o *Banks' funding costs* (approximated by the ratio of banks' interest expenses to total liabilities excluding own funds) were also projected based on an econometric panel model with fixed effects, estimating the annual change in the ratio of Luxembourgish banks' total interest expenses to total liabilities, with annual data over 2005–2022. Explanatory variables were the same as those included in the model of lending rate estimation. Custodian banks can be distinguished by two elements: (i) the much higher explanatory power of the funding cost model for custodian banks (R-squared of 0.49) compared to other banks, and (ii) the negative (although statistically insignificant) sign of the coefficient of the VIX index variable, which highlights the fact that custodian banks benefit from periods of higher investors' risk aversion which translate into a decline in their funding costs;

- o *Banks' net fee and commission income growth rate* was estimated by a panel data model with fixed effects, comprising two explanatory variables: the annual change in the 3-month interbank interest rate, and the annual growth rate of the Luxembourg real GDP growth rate in percent. Once again, the model estimated on custodian banks show two specificities compared to other banks: (i) the higher R-squared of the equation (0.32), and (ii) the much larger and more significant effect of the change in the 3-month Euribor rate for the growth of custodian banks' net fee and commission income: when the Euribor rate increases by 1 percentage point, the annual growth rate of custodian banks' net fee and commission income declines by 7 percentage points.

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

  - Banks with a total CET1 ratio below the Overall Capital Requirements (OCR)[1] in any year of a given scenario were not allowed to distribute dividend, and

  - Banks that pass OCR distribute their dividends at a rate of 50 percent.

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

Appendix V. Table 1. Luxembourg: Results from the Estimation of Income Statement Items

(Dependent variable: annual change or growth rate in banks' income statement items, panel fixed-effects model)[1]

Item	Change in lending rate	Change in funding costs		Growth rate of net fee and commission income	
		Non-custodian banks	Custodian banks	Non-custodian banks	Custodian banks
Change in 3-month Euribor rate	0.374*	0.384	0.324**	-1.971	-7.082***
	(1.76)	(0.50)	(2.44)	(-0.58)	(-3.03)
Change in VIX index	0.055**	0.021	-0.008		
	(2.07)	(0.81)	(-0.96)		
Luxembourg real GDP growth rate				1.756	1.180
(lagged by one period)				(1.31)	(1.48)
Constant	-0.325***	-0.316**	-0.032	22.896***	17.181***
	(-6.25)	(-2.04)	(-0.55)	(13.38)	(27.80)
Bank Fixed effects	Yes	Yes	Yes	Yes	Yes
R-square	0.14	0.03	0.49	0.15	0.32
# of banks	32	15	32	11	4
# of observations	280	145	4	117	49

Source: IMF staff calculations.
t-statistics in parentheses.
* Denotes significance at the 10 percent level; ** at the 5 percent level; and *** at the 1 percent level.

[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.

Appendix V. Figure 1. Luxembourg: Lending Rate and Funding Cost Projections (in percent)
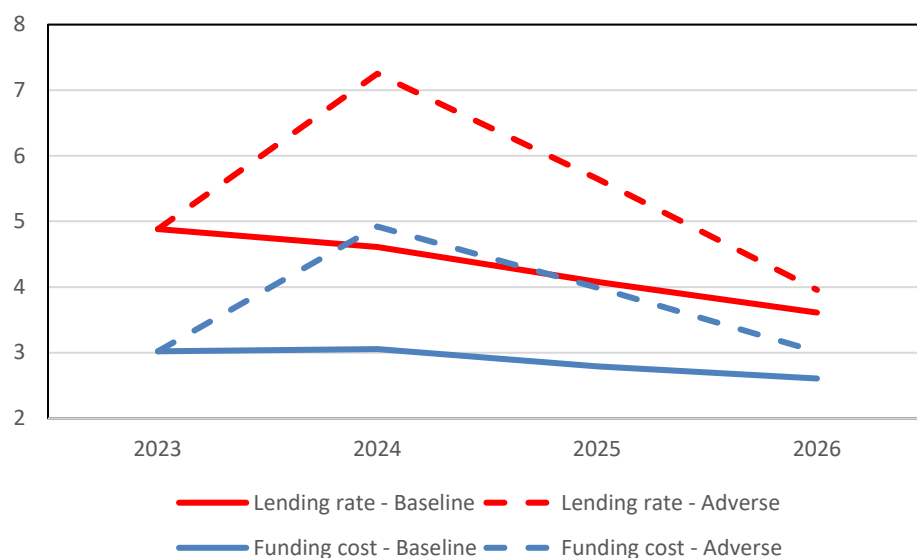
Sources: IMF staff calculations.

Appendix VI. Satellite Models for Credit Risk—Technical Details

Solvency Stress Testing Methodology

1.   **The estimation of expected credit losses (ECL) 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 or 2014 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.

2.   **These shortcomings led the FSAP team to apply international benchmarks for some projections of expected credit losses.** The experience of other advanced countries having experienced severe banking crises such as Ireland in 2008-2013, provides 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. Projections of (point-in-time) probabilities of default were based on quarterly data over the 2005Q1–2022Q4 period. We used different sources of information and of data for the estimation of PD depending of the exposure class:

- For corporate, financial institutions and sovereign exposures, we used the Expected Default Frequencies dataset provided by Moody's/CreditEdge on a sample of seven euro area advanced countries, starting in 2002;

- For the retail (mortgage and non-mortgage) segment, we used the coefficients and elasticities calculated in the recent 2023 Ireland FSAP and cross-checked the results with the projections of the average household PD computed as part of the household stress test of the 2024 Luxembourg FSAP on a sample of Luxembourgish households.

3.   **For exposures booked under both the STA and IRB approach, the calculation of loan loss provisions was consistent with the IFRS9 accounting standard.** This calculation depends on the evolution of loan exposures, stage transition matrices (guided by the stressed PiT PDs) and the PiT LGDs under stress. Provisioning for IRB and STA was modeled using IFRS9 transition matrix approach. The FSAP team estimated panel data models to project PDs, while LGD was assumed to increase by 30 percent in the adverse scenario compared to the initial level.

4.   **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 1). Finally, the team used publicly-available data, including from commercial providers, data from the EBA Transparency exercise as well as banks' annual reports.

<table>
<tr><th colspan="4">Appendix VI. Table 1. Luxembourg: Summary of FSAP Access to Supervisory Data 1/</th></tr>
<tr><th></th><th>Fully available</th><th>Partially available</th><th>Not available</th></tr>
<tr><td>Data at the individual bank level</td><td>✔</td><td></td><td></td></tr>
<tr><td>Data aggregated along groups of banks</td><td>✔</td><td></td><td></td></tr>
<tr><td>Data aggregated at the banking system level</td><td>✔</td><td></td><td></td></tr>
</table>

Source: IMF staff.

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

5.   Probabilities of Default (PDs) for credit risk estimation were projected for five asset classes through a panel-based approach. Through-the-Cycle (TTC) PDs without defaulted exposures are required for Risk-Weighted Assets (RWAs) calculation and one-year Point-in-Time (PIT) PDs without defaulted exposures are typically used for expected credit losses' calculation. Moreover, TTC PDs used for the RWA calculation were smoothed in our model by applying a cyclical parameter of 0.1 to the annual change in our projected PiT PDs.

Starting point PIT PDs were calculated on the basis of the figures provided by the banks in the FINREP templates, with different inputs depending on whether the bank reports the IFRS9 staging of its loans or not:

- For banks reporting the IRFS9 staging of their loans, the initial PIT PDs were derived from the sum of the quarterly inflows into the Stage 3 over one year on a year-on-year basis, according to the following formula:

$$PD_{PiT,t0} = DR_{t0} = \frac{\sum_{s=0}^{3} TR_t^{13} S_{1,t-s} + \sum_{s=0}^{3} TR_t^{23} S_{2,t-s}}{PL_{t-4}} \qquad (1)$$

  where DR=Default rate, PL=stock of performing loans, $S_{1,2}$=IFRS9 Stage 1 or 2, TR=Transition rate, *t* denotes the quarter, write-offs considered as nil.

- For banks not reporting the IRFS9 staging of their loans, the initial PIT PDs were derived from the sum of the quarterly inflows into the nonperforming loan stock over one year on a year-on-year basis, according to the following formula:

$$PD_{PiT,t0} = \frac{\sum_{s=0}^{3} NPLentry_{t-s}}{PL_{t-4}} \qquad (2)$$

6.   The calculation of the expected credit losses was made under the IFRS9 accounting framework. Scenario Transition Matrix projections were estimated from PD paths through the *Beta Linking* methodology (see Gross et al., 2020), where an aggregate PD is projected and adapted to Stage 1 and Stage 2 exposures according to the most recent observed transition matrices (obtained

from the BCL at the banking sector level). TM_t^{13} and TM_t^{23} are derived from PD_t path, which is the weighted average of the two.

7.   PDs were estimated as a linear function of different exogenous macroeconomic and financial factors, according to the following sequence:

- 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:

$$Y = \ln\left(\frac{PD_{it}}{1 - PD_{it}}\right) \qquad (3)$$

- 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:

$$Y_{it} = \delta Y_{i,t-1} + \alpha + \beta X_{t-s} + \varepsilon_{i,t} \qquad for\ t = 1, \dots, T\ and\ i = 1, \dots, N \qquad (4)$$

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 vectors β, δ are parameters to be estimated.

- The determinants of PDs included:

  o   for the retail household mortgage loans: the contemporaneous unemployment rate (in percent), the Luxembourg government 10-year bond yield, the 3-month Euribor rate, the year-on-year growth rate in the Luxembourg stock price index, and the year-on-year growth rate in the Luxembourg house price index (all in percent). The unemployment rate was expected to have a positive effect on PDs because it is associated with lower income, which would lower households' debt repayment capacity. The two interest rates were expected to have a positive effect on PDs as their increase would translate into an increase in the lending rate, and then into a larger debt service burden in Luxembourg due to the predominance of floating lending rates;

  o   for other retail (consumer) loans: the unemployment rate, the Luxembourg government 10-year bond yield, and the 3-month Euribor rate (all in percent);

  o   for non-financial corporate loans: the year-on-year euro area real GDP growth rate (in percent), as Luxembourg banks mostly lend to corporates in euro area countries outside Luxembourg, a proxy for an average euro area 10-year bond yield (in percent), and the lagged dependent variable (PD of the previous quarter) in order to correct for serial autocorrelation of residuals;

- o <u>for loans to financial institutions:</u> the year-on-year euro area real GDP growth rate and the spread between the euro area 10-year bond yield and the 3-month Euribor rate (all in percent);

- o <u>for sovereign exposures:</u> the year-on-year real national GDP growth rate, the 3-month Euribor rate, the national government bond yield, lagged by one period to avoid endogeneity issues, and the lagged dependent variable (all in percent);

- 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:

$$PD_{type,t}^{stress} = \frac{1}{1 + \exp[-(\alpha + \beta X_{t-1})]} * 100 \qquad (5)$$

Appendix VI. Table 2. Luxembourg: Results from the Estimation of the IMF Credit Risk Satellite Models

(Dependent variable: logit transform of the one-year PD or EDF))

Item	HH Mortgages	Other retail	Corporate	Institutions	Sovereigns
Dependent variable (lagged by 1 period)	-	-	0.817*** (17.43)	-	0.923*** (40.45)
Real euro area GDP growth rate (y-o-y, in percent) (Contemporaneous or lagged by 1 period)	-	-	-0.026** (-2.19)	-0.022** (-2.27)	-0.005 (-1.29)
Unemployment rate (in percent)	0.159*	0.086*	-	-	
10-year government bond yield (in percent)	0.015	0.062*	0.059*** (2.83)	-	0.001 (1.11)
3-month Euribor rate (in percent) (lagged by 1 period)	0.024*	0.123*	-	-	0.009*** (2.56)
Spread between the euro area 10-year bond yield and the 3-month Euribor rate (in percent)	-	-	-	-	0.214*** (6.09)	-
Stock price yoy change (y-o-y, in percent)	-0.006*	-	-	-	-
House price growth (y-o-y, in percent)	-0.011*	-	-	-	-
Constant	-5.201***	-5.505***	-1.078**** (-3.93)	-5.828*** (-96.27)	-0.688*** (-3.42)
R-square	0.97	0.99	0.92	0.46	0.86
# of observations			82	83	425

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 VII. Investment Fund Stress Testing Methodology

1.   This appendix outlines the different building blocks of the liquidity stress test. It outlines: i) the methodology related to the transmission of macro shocks in the severe scenario to the balance sheet of investment funds; ii) the transmission from the impact on NAV to the redemption shock faced by funds; and iii) the different assumption regarding liquidation strategies for funds facing net redemptions.

2.   The stress test included the largest open-ended investment funds, covering the majority of the funds under the full reporting scope. All open-ended firms with total net assets over 1 billion euros in March 2023 were included in the analysis, totaling an AUM of 3,100 billion euros. The sample is mostly comprised of UCITS, with AIFs accounting for roughly 13 percent of the AUM of the funds in the sample.

A.   Initial Shock to the Balance Sheet of Investment Funds

3.   The assets in the balance sheet of investment funds are aggregated into 42 asset groups, each subject to its own price shock. The breakdown splits the assets across asset classes (equities, sovereign bonds, corporate bonds, deposits, investments in MMFs, other liquid assets, real estate, other assets) and across the most relevant geographical regions (Luxembourg, US, Germany, France, UK, Japan, Other Euro Area, and Rest of the World). This grouping allows for a sufficiently granular impact on the balance sheet of investment funds, while enabling tractability. Figure 1 presents a breakdown of the total assets of the fund in the sample into main asset groups used in the stress test sample.

Appendix VII. Figure 1. Luxembourg: F Holdings of Asset Groups as a Share of Total Assets for the Stress Test Sample (Percent)
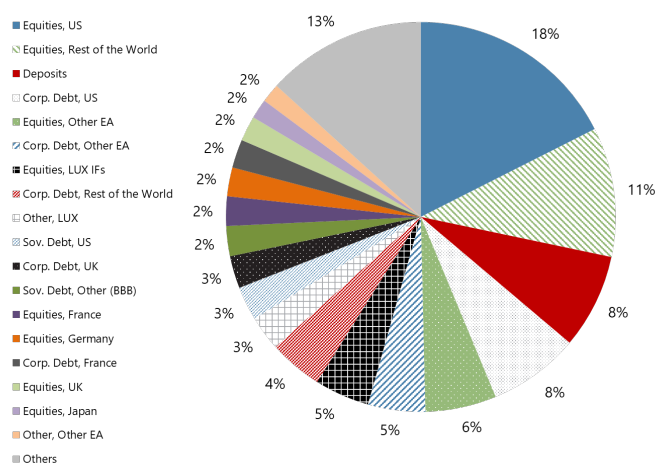
Source: BCL and IMF Staff calculations.
Note: Data as of March 2023

4.   The initial shock to investment funds is based on the application of estimated changes in asset prices using the financial simulator model (outlined in the Stress Test Strategy,

Section B) to tradable assets. Asset groups such as liquid short-term deposits are assumed to retain their full value. Assets subject to market fluctuations were, first, matched to market price indices and, subsequently, estimates for the change in price were made, consistent with the results of the adverse stress test scenario. This methodology ensures the changes in prices are consistent with the historical co-movement of the price of these assets, creating a coherent financial scenario.

5.   **Shocks to real estate holdings are based on IMF model of House Price at risk.** The model from Deghi and others (2021) produces one-year ahead estimates for a group of relevant economies of changes in commercial real estate asset prices based on the fifth percentile of the distribution. The model is estimated using 2023Q2 data. The yearly shock from the model is then translated into a two-month shock and applied to the holdings of investment funds.

B.   Redemption Shock Calibration

6.   **The calibration of the redemption shock following the severe macroeconomic shock scenario is constructed using a historical flow performance relationship**. A model is estimated for the sample of regulated funds using monthly data from 2016 until 2023. The coefficient on the returns is used to establish the statistical relationship between returns and net flows. The model is run separately for funds with different investment strategies to capture different behavioral patterns of investors in different types of funds. $X_{i,t}$ is a vector of fund characteristics that has been shown to impact, including fund size, (negatively related with redemption levels) investor concentration (positively related with redemption levels), and fund leverage (positively related with redemption levels). The estimated percentage fall in NAV from applying the asset price changes to the funds' balance sheet, is then used as an input in the corresponding strategy-specific model for each fund to predict redemptions.

$$f_{i,t} = \alpha + \sum_{k=1}^{12} \beta_k f_{i,t-k} + \sum_{h=1}^{12} \gamma_h \, return_{i,t-h} + \theta_{i,t} X_{i,t} + \varepsilon_{i,t}$$

7.   **Complementarily, estimates from the literature are used establish the relationship for strategies where the flow-performance model produces lower estimates.** Mirza and others (2020) use a similar methodology with Fama-Macbeth regressions for a sample of European funds. Their results point to stronger effects of returns on net redemptions for some of the fund strategy types. Given its relevance, and in order to generate a more conservative distribution of net outflows in the stress test, their parameters for the relationship between the flow and the immediate lag returns is used for the fund strategies where coefficient estimates are higher than those coming out of the flow-performance model ran with CSSF data. Funds for which the estimated coefficient is not statistically different from zero are assumed to not experience redemptions following changes in NAV. Their liquidity risk is tested through the scenarios based on historical exogenous redemptions. Table 1 shows the flow-performance elasticities used in the analysis.

8.   **To provide a historical context, a redemption scenario based on the global financial crisis is also estimated.** This scenario uses the same asset groups of the main scenario but applies to those asset groups the change in asset prices during September and October of 2008 based on

aggregate market indices. These changes in asset prices are then applied to the balance sheet of the investment funds in the stress test sample in the same way as the main severe scenario.

9.   Exogenous redemption shocks based on historical net flows are also used to assess resilience in the stress test. For each fund in the sample, the shock is calibrated as an instantaneous shock on the distribution of net flows. This calibration is made under different assumptions. Under the homogeneity assumption, each fund within the same strategy (e.g., equity funds, bond funds) face the same redemption shock. The shock is based on the distribution of all individual fund net flows belonging to this category. Under the heterogeneity assumption, the redemption shock is calibrated separately for each fund based only on its own historical data. The exercise uses the first, third and fifth percentile of the distribution of net flows.

	Appendix VII. Table 1. Luxembourg; Flow-Performance Elasticities	
Strategy	**Coefficient in ECB paper**	**Parameter in ST**
Bond funds	0.40	0.40
Equity funds	0.20	0.23
Mixed funds	0.29	0.29
Hedge funds	0.14	0.14
MMF	0.99	0.99
Real estate funds	-0.01	0.00
Commodities	0.29	0.29
Fund of funds	0.29	0.29
Other funds	-0.03	0.00
Source: Mizra and others (2020) and IMF staff calculations.		

Source: Mirza and other (2020) and IMF staff calculations.

C.   Liquidation Strategies

10.   Each security was assigned a weight depending on the rating of the issuer and the type of instrument following Basel Committee on Banking Supervision. The different weights are outlined in Table 2. Cash is given a 100 percent weight. Noninvestment 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.[1] Table 2 shows the liquidity weights assigned to each asset group.

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[1] Data on corporate bond holdings does not include the associated credit rating for each security group. Alternatively, the liquidity weight of the corporate bond portfolio was calculated by using the average holdings of bond holdings by credit rating and investment strategy as shares for the liquidity weights of corporate bonds.

		Cash	Sovereign bonds	Corporate bonds	Securitized Products	Equities
	Appendix VII. Table 2. Luxembourg: Liquidity Weights					
Investment Grade	AAA to AA-	100%	100%	85%	85%	50%
	A+ to A-		85%	50%	50%	
	BBB+ to BBB-		50%	50%	0%	
High-Yield	Below BBB-		0%	0%	0%	

Source: IMF.

11.   After experiencing redemption shocks, fund managers need to liquidate assets to fulfill investor withdrawals. Managers might adopt various strategies: the slicing (prorata) method, selling assets in line with their portfolio weight; the waterfall method, prioritizing the sale of the most illiquid assets; or a mixed approach. The chosen strategy significantly affects the remaining investors. Slicing preserves the portfolio's profile and adheres to the investment policy but may involve selling liquid assets at potentially unfavorable prices due to market impact.

12.   The Stress test exercises relies on three alternative assumptions for liquidation methods: a slicing methodology and two waterfall methodologies. The classical waterfall assumptions assumes that managers will first use their cash buffers before liquidating securities. However, empirically, managers often choose to liquidate their most liquid securities first in situations of market stress in an attempt to sell their assets before their price falls due to the sales of other market participants in the same position, delaying the use of deposits. For this reason, the stress test includes a second, securities first, waterfall approach. The order of usage of assets under the different waterfall assumptions can be found in Table 3.

13.   Different assumptions on liquidation will have different implications for stress test results. Under a securities-first waterfall approach, the second-round effects on asset prices due to the sale of assets will be greater than under a cash-first approach, as investment funds will need to sell more securities to match net redemptions. Conversely, under a cash-first approach, the impact on the counterparty of the deposits used to respond to the redemptions will be greater. Specifically, if those deposits are held by Luxembourg banks, the withdrawal of large sums of deposits by domestic investment funds may create liquidity distress in banks. The stress test includes both waterfall assumptions to incorporate the two extreme scenarios which result in different vulnerabilities for the financial system. In the adverse scenario, under the securities-first waterfall approach, funds would not need to withdraw from their deposits at banks, while under the cash-first waterfall approach, they would withdraw 25 percent of deposits. Naturally, the slicing approach yields results that are somewhere in the middle of the two opposing waterfall approaches.

Appendix VII. Table 3. Luxembourg: Order for the Waterfall Liquidation Method

Waterfall Order	Securities first	Cash first
1	Sovereign BBB or higher bonds	Cash/Deposits
2	Corporate bonds	Sovereign BBB or higher bonds
3	Sovereign below BBB	Corporate bonds
4	Equities	Sovereign below BBB
5	Cash/Deposits	Equities
6	MMF	MMF
7	Other liquid assets	Other liquid assets

Source: IMF.

Appendix VIII. Price Impact of Asset Sales

1.   Given the size of the financial sector, the sale of a significant share of assets by investment funds, banks and insurance companies in Luxembourg is likely to move market prices of securities. The change in asset prices will naturally affect the value of the securities that remain in the balance sheet, leading to additional solvency and liquidity risks. Asset sales from the investment fund, banking and insurance sectors to face liquidity needs from the initial price impact are aggregated to arrive at aggregate levels of broad asset classes. This approach intends to capture the impact of asset sales originating in the Luxembourgish financial sector. Likewise, the impact on the value of assets is then incorporated into the balance sheet of each sector for stage three of the stress test.

2.   To estimate the price impact of the sales, the volume of sales is compared to market depth. Following Cont and Schaanning (2017), market depth is equal to a market impact function: $V = -V_0 \varphi(q; D, \tau)$, where

$$\varphi(q; D, \tau) = \frac{q}{D}$$

q is the value being sold, D is the market depth. Furthermore:

$$D = c \frac{ADV}{\sigma} \sqrt{\tau}$$

Where ADV is the average daily volume in the market, σ is daily volatility, τ is the time horizon for liquidation and c is a scaling parameter. Thus, the market depth over a time horizon τ is a function of a scaling factor c, times the ratio between the average daily trading volumes and the asset volatility, multiplied by the square root of the time horizon. The price impact is therefore lower when the time horizon is longer.

3.   Estimates for market depth are taken from past FSAPs and from the literature. Estimates for market depth of US securities rely on estimates from the US 2020 FSAP. Estimates for the sovereign debt of other major countries are taken from Cont and Schaanning (2017) and Coen and others (2019). The market depth for other securities is estimated based either on ratios of equivalent types of securities (ratio of corporate debt to sovereign depth in US is used to estimate the market depth for corporate debt in other countries, for example), or estimated based on the ratio of the total outstanding of the value of securities in the market. Estimates can vary considerably based on the estimates for volatility and the period over which assets are sold. The main estimates for asset impact rely on estimates of market depth under stress (using volatility during the global financial crisis) sold over a period of 7 days. Other estimates are used for sensitivity analysis. Table 1 presents the market impact of 1 bn asset sales for some of the main asset classes in the analysis.

4.   For investment funds, the impact of asset prices of asset sales is incorporated by re-estimating the outflows following the fall in NAV caused by the lower prices. Once the price

impact of sales is estimated, the NAV of each fund is recalculated to reflect the costs due to the liquidation of assets on the remaining portfolio of securities. As a result of negative returns, a second wave of redemption occurs, whose magnitude depends on the flow-performance relationship (as described in Appendix VI).

Appendix VIII. Table 1. Luxembourg: Estimated Price Impact of Asset Sales

	Average Daily Volume ADV (bn)	Asset sale period = 1 day		Asset sale period = 7 days	
		Impact 1 bn sale	Impact of 1 bn sale under stress	Impact 1 bn sale	Impact of 1 bn sale under stress
US FSAP					
UST	545	0.13	0.3	0.05	0.1
Corp IG	21	3.57	7.7	1.35	2.9
Corp HY	12	6.46	22.3	2.44	8.4
US Equities	320	0.88	2.8	0.33	1.1
EM Debt	8	12.50	42.5	4.72	16.1
Schanning					
Sovereign					
UK	34.1	1.76	3.46	0.67	1.31
Germany	18.9	3.17	6.24	1.20	2.36
France	10.2	5.88	11.55	2.22	4.37
Estimated					
Sovereign					
Other Euro Area		1.64	3.23	0.62	1.22
Corporate					
UK		9.21	18.10	3.48	6.84
Germany		16.62	32.65	6.28	12.34
France		30.80	60.50	11.64	22.87
Equities					
UK		11.99	23.55	4.53	8.90
Germany		21.63	42.48	8.17	16.06
France		40.07	78.72	15.15	29.75

Source: US FSAP (2020), Cont and Schaaning (2017), Coen and others (2019) and IMF staff calculations.

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