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FINANCIAL SECTOR ASSESSMENT PROGRAM

February 20, 2020

TECHNICAL NOTE

FINANCIAL STABILITY ANALYSIS, STRESS TESTING, AND INTERCONNECTEDNESS

Prepared By

Monetary and Capital Markets Department

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

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Glossary

ARNIE	Stress Testing Infrastructure
AUM	Assets Under Management
BMA	Bayesian Model Averaging
CCB	Capital Conservation Buffer
CESEE	Central, Eastern and Southeastern Europe
CET1	Common Equity Tier 1
DGS	Deposit Guarantee Scheme
DSR	Debt-servicing Ratio
DTI	Deposit-taking Institution
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
ECB	European Central Bank
ECL	Expected Credit Losses
FC	Foreign Currency Loan
FSAP	Financial Sector Assessment Program
FVOCI	Fair-value Through Other Comprehensive Income
FVTPL	Fair-value Through Profit or Loss
FX	Foreign Exchange
G-SIB	Global-Systemically Important Bank
GFC	Global Financial Crisis
IFRS	International Financial Reporting Standards
IPS	Institutional Protection Schemes
IRB	Internal Ratings Based
LCR	Liquidity Coverage Ratio
LE	Large Exposures
LGD	Loss Given Default
LoLR	Lender of Last Resort
LTV	Loan-to-Value
MBS	Mortgage-backed Securities
NFC	Nonfinancial Corporate
NII	Net Interest Income
NIM	Net Interest Margin
NPE	Nonperforming Exposure
NPL	Nonperforming Loan
NSFR	Net Stable Funding Ratio
OeNB	Oesterreichische Nationalbank
OSII	Other Systemically Important Institution
PD	Probability of Default
PiT	Point-in-time
P&L	Profit & Loss
ROW	Rest of the World
RWA	Risk-Weighted Assets

STA	Standardized Approach
SyRB	Systemic Risk Buffer
TDS	Total Debt Service-to-Income
TN	Technical Note
TTC	Through-the-cycle
VaR	Value-at-risk

EXECUTIVE SUMMARY[1]

Austria's banking sector presents unique structural vulnerabilities. The banking sector, counting almost 600 banks at an unconsolidated level, is heavily tiered and clustered. It is characterized by complex ownership structures with inverse ownership whereby small lower tier banks own large higher-tier banks and by institutional cooperation arrangements, including institutional protection schemes (IPS), cross-guarantee schemes, and liquidity associations. These features generate significant financial interlinkages among institutions. Banks' operating profits are constrained by structurally high cost-to-income ratios, which have remained elevated despite some consolidation over the recent past. Exposure to Central, Eastern, and Southeastern Europe (CESEE) markets remains substantial, although lower than in the past and though CESEE operations have been profitable, interest margins are thin and exposure to the booming real estate sectors in some countries is on the rise, as is in Austria itself.

Late-cycle financial risks are building. Private credit growth has supported the cyclical boom without jeopardizing household and corporate indebtedness. Profits of Austrian subsidiaries in CESEE have increased recently—however, the cycle is turning and the ability of the sector to maintain a solid net interest margin may be further challenged.

These banking sector vulnerabilities and cyclical conditions were critical in defining the FSAP's team modelling efforts. The solvency stress test adverse scenario featured a financial cycle downturn—with sharp foreign exchange (FX) market disruptions and sovereign stress—which generated a balance-sheet recession in Austria and the CESEE region, alongside a sharp real estate price correction. The liquidity stress test scenarios considered large outflows from the retail and wholesale funding segments—and the two combined. The contagion analysis assessed hypothetical contagious bank defaults including such defaults within the decentralized banking sectors. The resilience of the IPS structures and their ability to provide capital and liquidity support to affiliated members under stress was also tested.

Banks are, in aggregate, resilient to severe macrofinancial shocks. Banks' capital buffers are sizeable relative to potential losses under stress. Capital ratios would still be comfortably above minimum requirements in an adverse scenario, although most banks would fall into the conservation buffer range. While the impact of estimated shocks is broadly consistent across Other Systemically Important Institutions (OSIIs)[2] and non-OSIIs, the drivers of capital depletion are different reflecting diversity of banks' business models and ownership structures. Whereas credit impairments and lower net interest income are key factors driving capital depletion for OSIIs, for the

[1] This Technical Note (TN) was prepared by Dimitrios Laliotis (MCM) and Lucyna Gornicka (MCM), Izabela Karpowicz (EUR) and Sohaib Said (MCD) under the guidance of Laura Valderrama (MCM). The team is grateful to the Oesterreichische Nationalbank (OeNB) and the European Central Bank (ECB) for their excellent collaboration in this exercise.

[2] There are seven OSII banks on a consolidated level; Erste Group Bank, Raiffeisen Bank International, UniCredit Bank Austria, Raiffeisenlandesbank Oberoesterreich, BAWAG P.S.K, Raiffeisen-Holding Niederoesterreich-Wien, and Volksbanken Verbund.

majority of smaller non-OSII banks the impact is mainly attributed to equity participation structures that form the backbone of the heavily tiered Austrian banking system.

For these banks the IPS acts as a shock absorber for idiosyncratic shocks but the inverse ownership structure in the cooperative sector can become a conduit of loss propagation in a systemic event. Institutional cooperation arrangements are shown to act as a shock absorber for idiosyncratic shocks, but holdings among participating members of respective IPSs may lead to substantial inward stability risks in a systemic event. Under favorable economic conditions inverse ownership contributes strongly to their capital generation by allowing partial redistribution of profits higher tier banks in the Raiffeisen sector earn on their more profitable international business. [3] Under unfavorable economic conditions, inverse ownership can become a shock amplifier by propagating losses through the downward revaluation of equity participations, adding to profitability pressures in domestic market operations.

Banks hold sufficient liquidity buffers to withstand sizeable funding outflows. The banking system is resilient to sizeable withdrawals of funding on the back of its strong counterbalancing capacity and sizable deposit funding base. The liquidity associations in the tiered sector allows pooling of liquidity among members, which contributes to overall financial stability.

High banking system interconnectedness warrants close monitoring. The Austrian authorities have targeted vulnerabilities related to interconnectedness by imposing OSII buffers also at the unconsolidated level. However, additional monitoring efforts are warranted. Such efforts should include but are not limited to: (i) compiling detailed breakdowns of exposures within the decentralized sectors to gauge more accurately the true contagion potential; (ii) deploying top-down reverse stress tests to assess the relative resiliency of each IPS structure; and (iii) setting up a permanent data monitoring framework and toolkit for assessing inward spillovers and contagion effects.

[3] This is a structural feature of the Raiffeisen sector, since the equity structure of Sparkassen and Volksbanken has a single consolidating entity at the top level.

Table 1. Austria: Recommendations to Bolster Banking System Resilience		
Recommendations	**Priority**	**Timeframe**
General		
Enhance monitoring capacity and oversight of inward spillover risks due to the inverse ownership structure of the Raiffeisen sector.	H	I
Perform a comprehensive assessment of the systemic importance of the central institution in the decentralized sectors and adjust capital buffers appropriately to offset systemic vulnerabilities linked to the tiered structure.	H	I
Continue to monitor the process of improving structural profitability.	H	NT
Enhance data collection (especially with respect to risk parameters) to better cover the CESEE region and develop more granular approaches in analyzing financial stability risks coming from such exposures.	M	MT
Solvency Stress Testing		
Enhance the stress testing framework to account for second round effects, dynamic balance sheets, and contagion/spillover effects as an effective tool to assess vulnerabilities related to the complexity of the system.	M	MT
Ensure that resources and the organizational structure are adequate to meet the objective of the stress testing framework given the complexity of the Austrian banking system and responsibilities related to supervisory stress testing and European coordination.	M	NT
Further develop the macroprudential and top-down perspective of the stress test infrastructure by developing full top-down satellite models that are complementary to the ones relying on the European Banking Authority (EBA) methodology.	H	NT
Enhance the capacity to calibrate tailored scenarios which target the Austrian banking sector's cyclical and structural vulnerabilities that are complementary to the ones used for microprudential purposes.	H	MT
Liquidity Stress Testing		
Further develop the systemic liquidity stress test components end enhance their macroprudential angle.	L	NT
Enhance the forward-looking aspects of the cash-flow liquidity analysis toolkit by carefully assessing cliff effects over time bands.	M	NT
Fully integrate the analysis on the liquidity support buffers due to the IPS structures in the standard liquidity analysis.	H	MT
Interconnectedness Analysis		
Conduct network analysis on a detailed breakdown of bilateral exposures by instrument, identifying the liquidity reserve held at the central institution and adding equity exposures in the cooperative sector.	L	MT
Monitor interconnectedness on a quarterly basis.	L	MT
Note: Institutions in parenthesis are the agencies with responsibilities. In terms of priorities, H, M and L stand for high, medium and low. In terms of timeframe, I, NT, and MT stand for immediate (within one year), near-term (within 2–3 years), and medium-term (within 3–5 years).		

INTRODUCTION

A. A Strong Economy but Late-cycle Risks are Building

1. Growth in Austria has been strong and broad-based, but the outlook has moderated. Austria's GDP picked up markedly in 2017–18, averaging 2.7 percent supported by a rise in domestic demand and favorable external conditions, notwithstanding rising trade barriers, high oil prices, and market volatility. Unemployment had dropped to 4.7 percent in 2018. Inflation was steady at 1.9 percent. The medium-term outlook is for a gradual growth convergence towards potential. Growth is expected to ease to 1.6 percent in 2019, settling around the potential of 1.75 percent thereafter. While the Euro Area (EA) recovery has been uneven, CESEE[4] countries—with which Austria has strong trade and financial links—have been witnessing a strong economic expansion since 2008, although economic activity has softened in 2019.

2. The financial sector has benefited from these favorable cyclical environments, but late-cycle risks are building. Private credit growth has supported the cyclical boom without jeopardizing household and corporate indebtedness.[5] During 2019Q1, the year-on-year credit growth rate was 4.2 percent for households, and 7.0 percent for the nonfinancial corporate (NFC) sector. Bank loans to corporates have grown strongly in recent years, mostly due to real estate activities, but more recently, internal financing of NFCs has gained importance.[6] Given the late stage of the cycle, risks in the CESEE region and potential spillovers are accentuating.

3. House prices have become overvalued in recent years, but vulnerability to real estate is mitigated by buffers.[7] House prices grew rapidly at around 7 percent over 2018 and are estimated to be overvalued by around 10-15 percent nationally, and by over 20 percent in Vienna (Figure 7). The historically high growth in real estate transaction volumes, of 13.3 percent in 2018, is also suggestive of real estate market overheating. At the same time, construction activity is expected to decelerate reflecting fewer construction building permits. A range of built-in structural mitigating elements in the housing market could soften the impact of shocks in the real economy. These include a large and regulated rental market in Vienna and other urban areas with a unitary market structure—where the rent level is determined by both the private and social housing sectors—

[4] Central, Eastern and Southeastern Europe (CESEE) countries are: Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kosovo, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovak Republic, Slovenia, Turkey, and Ukraine.

[5] The easing of underwriting standards observed in the first half of 2018 decreased in the second half of 2018 and 2019.

[6] The Austrian capital market is small and is dominated by a small number of companies and the role of equity financing remains limited.

[7] House prices and real estate vulnerabilities are further explored in technical note on Macroprudential Policy and Oversight produced during the FSAP.

moderate leverage, low ownership ratios (55 percent), and alternate arrangements for housing finance.[8]

4. Although there are some signs that the risk profile of new mortgages has been deteriorating, households' indebtedness remains broadly stable. At 50 percent of GDP in 2018Q4, households' debt is moderate and well below the EA average of 58 percent of GDP (Figure 5). [9] However, a significant share of new mortgage loans shows high Loan-to-Value (LTV), and Debt-Service-to-Income (DSTI) ratios.[10] The share of variable-rate mortgages in new loans has declined considerably from 83 percent to 44 percent in over the last four years, but remains elevated relative to the EA average, and leaves households exposed to interest rate risk.[11] FX mortgage loans have continued to decline and stand at 9 percent of total outstanding loans, driven by housing loans in Swiss francs.[12]

B. A Large and Complex Banking System

5. The financial system is dominated by banks and is heavily exposed to CESEE countries. The banking sector assets amounted to about 250 percent of GDP (EUR986 billion) and about 75 percent of total financial system assets (EUR1,314 billion) at end-2018 (Figure 1). Mutual funds, insurance firms, and pension funds account for 14 percent, 10 percent, and 2 percent of financial system assets, respectively. Though financial system's exposure to CESEE countries has declined in recent years due to a major bank restructuring in 2016, it remains high at 22 percent of banking system assets. Austria has the highest exposure to CESEE countries—representing 22 percent of CESEE related claims of EU-15 banks. Banks' reliance on the region for profit generation is at 42 percent of total.

6. Despite significant consolidation over the recent past, the banking system corporate structure remains complex and diverse. The banking sector is comprised of almost 600 unconsolidated institutions, down from nearly a thousand, two decades ago. The LSI sector is large, with total assets amounting to 32 percent of total banking system assets. The banking system can be divided into a few broad categories based on legal form and traditional business focus: joint stock banks, cooperatives banks, savings banks, regional banks, and other institutions.

[8] Alternative arrangements for housing finance include regional mortgage banks (Landes-Hypobanken), contract savings banks (Bausparkassen), and housing construction banks (Wohnbaubanken). Housing subsidies—both direct and indirect—also play an important role as alternative sources of housing finance.

[9] Household debt, at 87 percent of disposable income, is lower than the EA average.

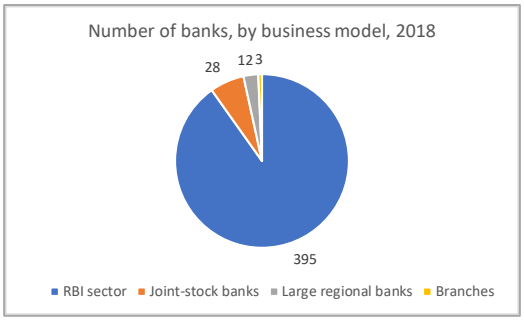
[10] Mortgages consist of 73 percent of loans to households.

[11] The average mortgage tenor is between 20-30 years.

[12] More generally, for households, risks also stem from market shocks as more than three-quarters of which are bullet instruments linked to repayment vehicles. Due to unfavorable exchange rate movements and the underperformance of repayment vehicles, these loans may face a funding shortfall at loan maturity.

Figure 1. Austria: Banking System Structure, 2018

(Percent, unless otherwise specified)



	LSIs					SIs
	Austria					
	SSM	HP	MP	LP	Total	
Total Assets (eur bn)	4,777	96	114	106	317	500
Loan/Deposit Ratio	101.2%	145.3%	122.5%	75.4%	105.0%	96.6%
NII/Total Assets	1.4%	1.0%	1.3%	1.6%	1.3%	2.0%
ROE	6.1%	7.6%	6.0%	5.6%	6.3%	10.7%
CIR	69.4%	56.2%	65.7%	71.5%	65.3%	63.5%
TC Ratio	19.1%	19.0%	17.0%	20.9%	18.8%	17.8%
CET1 Ratio	17.3%	16.7%	14.8%	19.7%	17.0%	13.6%
NPL Ratio	2.9%	2.6%	2.0%	3.0%	2.5%	2.8%
LCR	195.4%	139.7%	180.6%	190.0%	165.9%	144.4%

Source: OeNB

Note: The chart shows the number of consolidated entities which is is below the number of unconsolidated banks (i.e., 600). Banks in Austria are classified as belonging to eight sectors, depending on their legal form and the traditional focuse of their business. The chart illustrates the main sectors. The table shows core financial indicators for Austrian banks disaggregated according to SSM classification (i.e., significant institutions (SIs), and less significant institutions (LSIs), with the latter broken down into high-priority (HP), medium-priority (MP), and low-priority (LP). To facilitate peer benchmarking, financial indicators for SSM banks have been added to the table.

7. Banks with a tiered corporate structure and layers of institutional cooperation account for half of banking system assets. Cooperation arrangements include liquidity associations, cross-guarantee schemes and institutional protection schemes (IPS). The IPS has the legal obligation to grant solvency and liquidity support to participating members, is subject to comprehensive supervision due to extended aggregation levels, has consistent risk management practices, is required to establish an ex-ante fund and is subject to external audit. Financial support may take the form of loans, guarantees, or capital and liquidity injections, and is subject to the conditions determined by the IPS's decision-making body—the Risk Council for the Raiffeisen sector. The IPS must carry out stress tests at regular intervals and take preventive action to help its members recover before any resolution measure.

- **The Raiffeisen sector** has a three-layer structure: the first-tier accounts for 386 local banks which hold shares in one of the eight regional banks (RLBs) that form the second tier. The local banks and their respective RLBs form liquidity associations in which the RLBs are central institutions. The central institution provides liquidity management and payment facilities to participating members. At the regional level, the eight RLBs form liquidity associations with the third-tier bank, the RBI, as central institution. The RLBs hold around 60 percent of RBI ("inverse ownership"). RBI is a listed bank with several foreign subsidiaries in CESEE, including Russia (Figure 2). There are six "regional" IPSs in place between the local banks and their RLBs.[13] There is also a federal IPS with RBI and the RLBs as members. IPS is in addition to statutory deposit insurance.

[13] The two remaining RLBs form a solidarity association with the local banks rather than an IPS.

- **The Sparkassen segment** has 49 credit institutions including the central institution Erste Group Bank AG (Erste). Together they have created a banking group and an IPS, thus forming a cross-guarantee scheme, *ex lege* according to CRR. The Sparkassen-IPS has been recognized as a deposit guarantee scheme (DGS). Erste controls five savings banks trough majority ownership, and 43 banks through the cross-guarantee scheme. Erste is internationally active in CESEE and has 70 percent of free float equity.

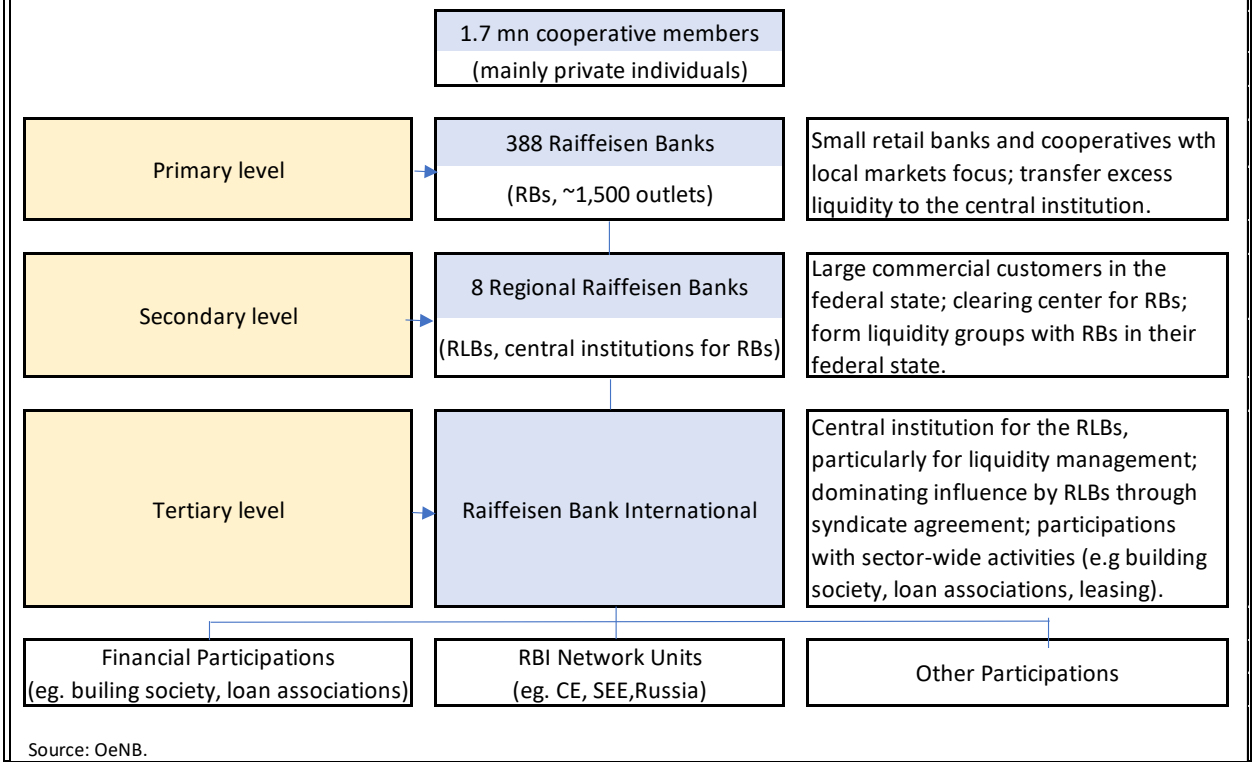
- **The Volksbanken (VB) segment** features eight regional banks, including the central institution VB Wien AG and one specialized institution. The VB segment has formed a liability association with unlimited cross-guarantee scheme, which increasingly operates as a single institution with uniform risk management, accounting consolidation and centralized processes.

8. As the Raiffeisen IPS is an explicit contractual obligation to support each member in case of need, there are requirements that must be met by all affiliated members. Each member must contribute to the ex-ante fund available for support. The amount is benchmarked annually against the results of a stress test and confirmed by the regulator. If the ex-ante fund is not sufficient to cover a shortfall, members are required to provide ex-post contributions.[14] Every member of the federal IPS must first exhaust all reasonable resources at the regional level to meet its needs before resorting to its rights under the federal IPS. Each IPS is governed by a Risk Council which decides on measures if an institution triggers early warning indicators. The Risk Council has considerable leeway in its decisions, especially when members face solvency or liquidity pressures. The contractual arrangements constitute the basis of regulatory exemptions including 0 percent risk weights on exposures and elimination of multiple gearing of capital at institution level (no multiple gearing on IPS level). [15]

[14] In a first step, the Risk Council requires ex-post payments up to a maximum of 50 percent of the sum of the last three years average operation results of all members. If this amount is insufficient, it can require additional payments. In case the Risk Council does not come to a decision within two weeks about the amount of the further payment, the Risk Council must decide that the members have to contribute at the maximum 25 percent of their total capital in excess of regulatory requirements. Additional payments can be given voluntarily. Each contribution of a member (*ex-ante* or *ex-post*) is limited by the members own capital requirements plus a cushion of 10 percent.

[15] Authorized privileges for IPS members are reflected in the Article 113.7 CRR (0 percent risk weight) and 49.3 CRR (non-deduction of participations in central institution). Exemptions are automatically withdrawn if a member becomes insolvent or enters resolution because not all available support is provided.

Figure 2. Austria: The Raiffeisen Sector - Organizational Structure



Source: OeNB.

C. Recent Banking Sector Performance

9. The banking system has strengthened capitalization and enjoyed significant improvement in credit quality since the 2013 FSAP. Despite the weak domestic profitability, Austrian banks have managed to increase their capital ratios (narrowing the gap with the EU peers) due to the enhanced net interest margins on international exposures and the significant reduction of credit impairments (Figure 3). Capital levels were raised from 11.6 percent common equity Tier 1 (CET1) in 2013 to 15.4 percent in 2018. However, the increase has subsided in the last two years, partly due to higher dividend payouts.[16] LSI institutions are better capitalized than SIs (at 17.0 percent CET1 relative to 13.6 percent for SIs), but they are also exposed to higher structural risks through the risk-sharing mechanisms (see above). Nonperforming loans (NPLs) shrank from 8.6 percent in 2013 to 2.6 percent in 2018. The increase in credit quality was especially pronounced among subsidiaries in CESEE where NPLs declined from 14.0 percent in 2013 to 3.2 percent in 2018. Sizable customer deposits at around 40 percent of liabilities underpin banking system stability. Debt securities issuance is mostly used by larger banks and accounts for around 14 percent of total liability outflows.

[16] According to EBA, Austrian banks' CET1 ratio reached 14.2 percent in 2018 against 14.7 percent for the European average. However, Austrian banks have a leverage ratio that is markedly better due to higher risk weights.

10. While in 2018 Austrian subsidiaries in CESEE saw above average profitability, performance has likely peaked.[17] Austrian banks' exposures to the CESEE region have remained largely the same since 2009 except for the 2016 carve-out of the CESSE portfolio from Bank Austria UniCredit to its parent bank in Italy. Profitability of Austrian subsidiaries in the CESEE region has increased on the back of a favorable cycle driving down loan-loss provisions and growing loan volumes. Net interest margins have been declining but remain considerably higher than in Austria.[18] Austrian subsidiaries' cost-to-income (CTI) ratios are lower than at the consolidated level (51 percent) but they have been on the rise during the last decade. After the introduction of the Sustainability Package, the reliance on local funding for the purposes of lending in the CESEE region has improved considerably, and the share of intragroup liquidity transfers between Austrian parent banks and the CESEE subsidiaries declined from 15 percent of subsidiaries' assets in 2011 to below 9 percent in 2018.

11. Internal income generation remains modest and mainly driven by CESEE profitability with high overall cost to income ratios. Profitability has been supported by extremely low credit-linked impairments with banks reversing credit impairments in some CESEE core markets. Despite recent improvements, banks' operating profits are affected by a structurally high CTI ratio, at around 65 percent in 2018, with Austrian SIs posting CTIs slightly below the EA average. Progress on containing the structural high CTI ratio through restructuring and reforms has been slow on aggregate, and uneven across banks.

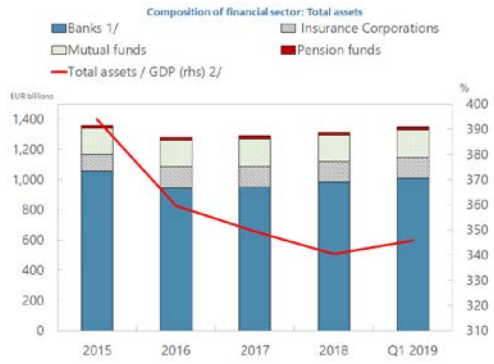
12. Going forward, the ability of the sector to maintain a solid net interest margin may be further challenged. Domestic margins can be further compressed as the low-for-long interest rate environment has encouraged borrowers to opt for fixed rates, locking-in low rates for the duration of the loan. In an economic downturn, shocks to margins on foreign operations could by further amplified by elevated costs of risk, impairing internal capital generation capacity. On the international front, rising competition and market maturation effects might also challenge profitability.

[17] While low loan impairment charges may not be sustainable, coverage ratios of Austrian banks at 52.8 percent remain above the SSM average of 46.6 percent, indicating a sound level of risk provisions on NPLs.

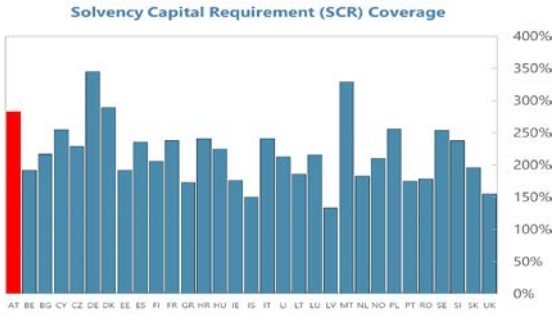
[18] While the net interest margin of Austrian banks at the consolidated level stood at 1.0 percent, margins in the CESEE region reached around 1.6 percent.

Figure 3. Austria: Recent Performance of the Financial System

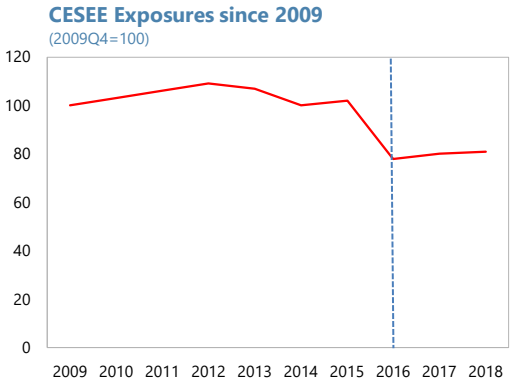
Financial assets have declined. The system remains dominated by banks.



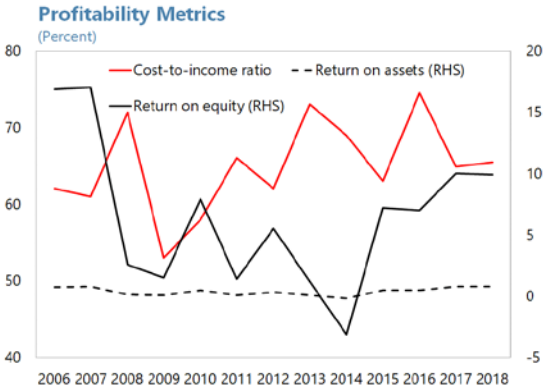
Austrian insurance entities are more resilient than other European counties at individual level.



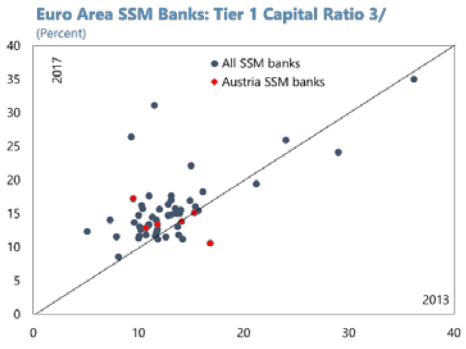
CESEE exposures has declined since 2016 due to the restructuring of Bank Austria UniCredit.



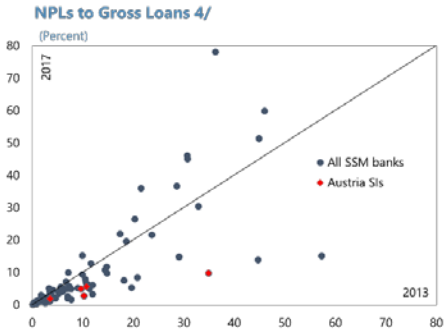
Profitability has risen recently but costs remain elevated and some banks have limited earnings capacity.



The CET1 ratio increased from 10 to 15.1 over 2013–18, while the leverage ratio remained above the SSM.



NPLs have declined from 8.6 percent at end-2013 to 2.8 percent in 2018, led by Austrian banks' CESEE subsidiaries.



1/ Per Austrian Banking Act, the term "credit institution" refers to an institution authorised to carry out banking transactions on the basis of Article 4 or Article 103 no. 5 of this federal act, or on the basis of special provisions under Austrian federal law. Therefore, the terms "credit institution" and "bank" are used interchangeably.

2/ GDP for year 2019 based on actual data for Q1 2019 and on WEO projections for Q2-Q4 2019.

3/ Austria SIs include the six SIs supervised by the SSM (Raiffeisen Bank International, BAWAG Group, Erste Group Bank, Raiffeisenbankengruppe, Volksbank, and Sberbank Europe AG).

4/ Data was not available for Volksbank for 2013.

Sources: OeNB, Bloomberg,; SNL; Haver; IMF, Financial Soundness Indicators; and IMF staff estimates.

D. Scope of the FSAP Analysis

13. The FSAP team performed a macroprudential stress test in collaboration with the OeNB to assess the resilience of the banking sector taking into account domestic sectoral linkages and cross-border exposures.[19] In total, 440 banks were included in the exercise, accounting for over 95 percent of banking system's total assets. The stress test was conducted using supervisory data as of end-2018. The scope of the exercise included:

- **Solvency stress test**: The FSAP team conducted a top-down exercise based on the balance sheet approach, using regulatory and supervisory data and using Q4 2018 as the cut-off date. The exercise considered two scenarios; a baseline scenario, based on the July 2019 World Economic Outlook (WEO) forecast, and an adverse scenario. Both scenarios covered a three-year horizon (i.e., years 2019 to 2021) under a static balance sheet assumption and included a set of sensitivity tests.[20] For the solvency stress test, OeNB's permanent stress testing infrastructure (ARNIE) was used with inputs estimated based on FSAP team's satellite model estimations.

- **Liquidity stress test:** The FSAP team performed a top-down exercise, using regulatory data. Liquidity risks were assessed using Liquidity Coverage Ratio (LCR) tests, cash-flow analysis, and NSFR stress tests. The LCR tests were conducted—in total and by significant currencies—based on three scenarios that considered large outflows from i) retail funding segments, ii) wholesale funding segments, or iii) the two combined. The cash-flow analysis assessed banks' overall counterbalancing capacity, i.e., capacity to manage funding outflows with varying degrees of severity (from mild to severely adverse). The NSFR stress tests conducted were exploratory, given that compliance with NSFR as a binding minimum requirement is not yet in place.

- **Network analysis:** The FSAP team conducted a network analysis to assess how distress in an individual banking institution could impair financial stability through default cascades in the interbank market. The analysis included a credit shock simulation whereby a credit counterparty default erodes the lender's capital buffers, and a funding shock simulation whereby the default of a funding counterparty induces a liquidity shortfall and triggers losses through fire sales.

[19] The Austria FSAP stress test has an entirely different focus than the 2018 EA FSAP or the EBA exercise as it explores the resilience of all credit institutions (i.e., SIs and LSIs) and includes the structural features of the decentralized sectors (i.e., equity holdings and IPS contingent liabilities).

[20] The OeNB's supervisory stress test results were broadly in line with IMF results; see FSR 38 (December).

MACROFINANCIAL RISKS UNDERPINNING STRESS TESTING AND FINANCIAL STABILITY ANALYSIS

A. Overview of Key Vulnerabilities and Risks

14. Structural vulnerabilities include a large and interconnected banking sector, clustered CESEE exposures across the largest banks and insurers,[21] and structurally low domestic profitability. Stress in the central institution of the "decentralized sectors" or in Austrian foreign subsidiaries has the potential to spread into the domestic financial system due to significant equity participation and collaboration arrangements including IPS, cross-guarantee schemes, liability associations, and DGS. Structural profitability in domestic operations is on the lower end of the peer average due to margin compression, reflecting overcapacity and weak cost efficiency.

15. Austrian banks remain exposed to cyclical risks from bouts of volatility in the CESEE and spillover risks from other parts of the EA. The CESEE region is vulnerable to financial market volatility, capital outflows, and foreign exchange (FX) swings. Although the stock of foreign currency (FC) loans has declined, it is still high and susceptible to home currency depreciation.[22] Despite some successful de-risking (and refocusing) of exposures across the region by major Austrian banks, subsidiaries' real estate exposures—especially in Czech Republic and Slovakia—have increased against rising vulnerabilities in real estate markets.

16. Vulnerabilities are building up in residential real estate. Although household credit has been growing in line with real incomes, and household debt—at 87 percent of disposable income—is lower than the EA average, vulnerabilities are on the rise. House price overvaluation continues to inflate the value of collateral underlying new mortgages, while low borrowing costs support households' demand for loans and debt servicing capacity. A considerable share of new mortgages still does not comply with the recommended DSTI limit or the minimum down-payment. In parallel, real estate exposures have increased across various parts of the Austrian financial sector. Given the increasing importance of the real estate market for financial stability, these trends point to a build-up of systemic risk.

B. Macrofinancial Scenarios

17. The FSAP team's assessment of tail risks is reflected in the narrative of the stress test exercise (Annex I). The adverse scenario **i**ncludes the materialization of four sources of systemic risk which are viewed as key threats to the resilience of Austrian banks: (i) a sharp weakening in the

[21] System cluster risk arises from the large CESEE exposure both in relation to the total assets of Austrian banks and in relation to the size of the respective foreign markets.

[22] Following the 2010 FMA Guiding principles, Austrian banks have refrained from granting new loans in FX except in Euro to unhedged households and SMEs in the CESEE region. Most of the FX loans are in euro with the borrower split of 34 percent households, and 66 percent NFCs.

global outlook resulting in a prolonged growth slowdown in Austria; (ii) a sharp increase in risk premia due to an abrupt deterioration in market sentiment that would increase debt servicing costs for firms and households and trigger asset repricing; (iii) a balance sheet recession in CESEE countries amplified by large FX moves, lower asset price valuations, and worsen credit risk performance; and, (iv) a sharp correction in real estate prices in Austria, resulting in higher impairment charges for banks, caused by defaults or delayed loan repayments.

18. To assess Austrian banks' resilience to severe macrofinancial conditions, the team calibrated two scenarios over a three-year horizon.

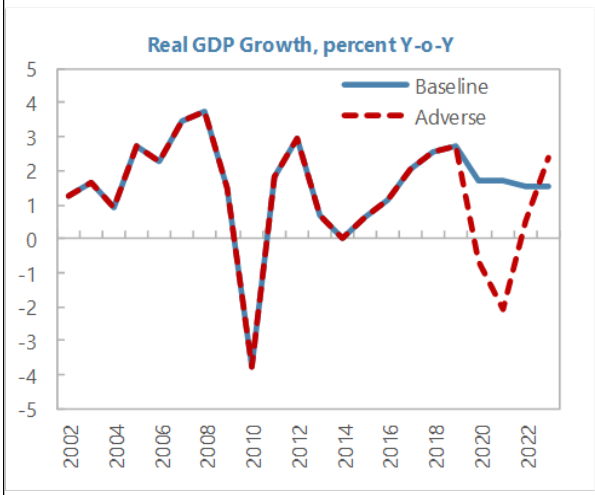
- **The baseline scenario** expects GDP growth to slow in the near-term to 1.6 percent in 2019 and settle around the potential growth of 1.75 percent in the medium term. Domestic demand growth will moderate from over 2.50 percent to around 1.25 percent in 2019 as consumer confidence declines. Inflation will decelerate below 2 percent, in line with the anticipated cyclical weakening (Figure 4).

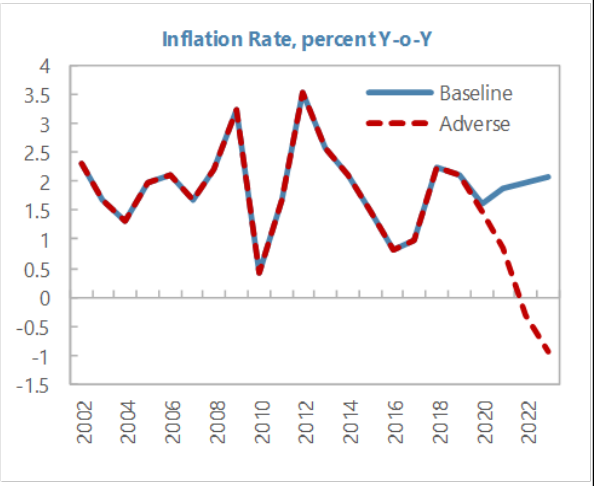
- **The adverse stress scenario** is calibrated using the Global Macrofinancial Model (GFM). The scenario features a financial cycle downturn—with sharp FX market disruptions and sovereign stress—generating a balance-sheet recession in Austria and the CESEE region.[23] In terms of severity, the scenario implies a deviation of Austrian real GDP growth from its baseline of 6.9 percent by 2021, with a 2.3 standard deviation move in two-year cumulative real GDP growth rate, and a 20 percent peak-to-trough decline in real estate prices. Output shocks in the CESEE region range between 8.1 and 13.6 percent deviation from baseline (Figures 4 and 5). [24]

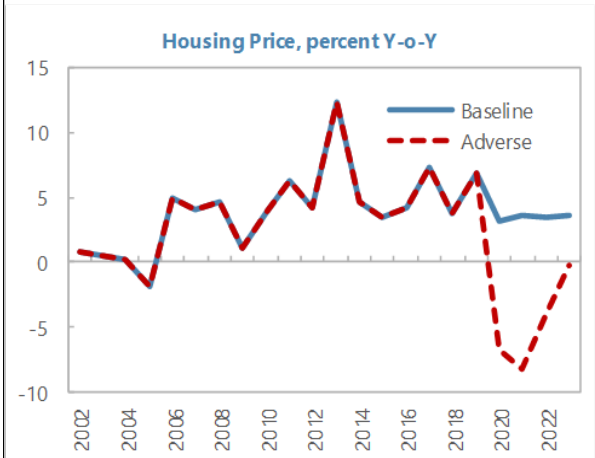
[23] The scenario includes Austrian, global, and CESEE macroeconomic stress parameters (across 18 geographies that are material for the Austrian banking system). It also includes financial parameter shocks linked to a financial market scenario which is coherent with the calibration of macroeconomic stress.

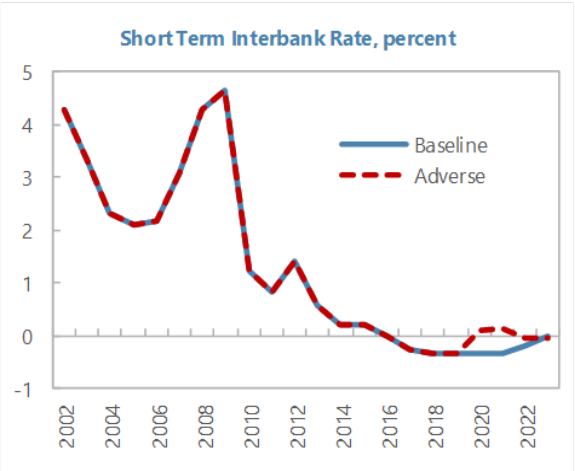
[24] At -2.4 percent GDP contraction over the first two years of stress, the adverse scenario is more severe than the global financial crisis (-2.0 percent GDP contraction over 2009–10) and the 2018 EA FSAP scenario for Austria (-2.0 percent GDP contraction over 2018–19). Relative to the 2018 EBA stress test scenario, CESEE geographies were more severely stressed under the IMF scenario. The standard deviation was computed over 1995-2018 and hence, includes the 1998 Russian crisis.

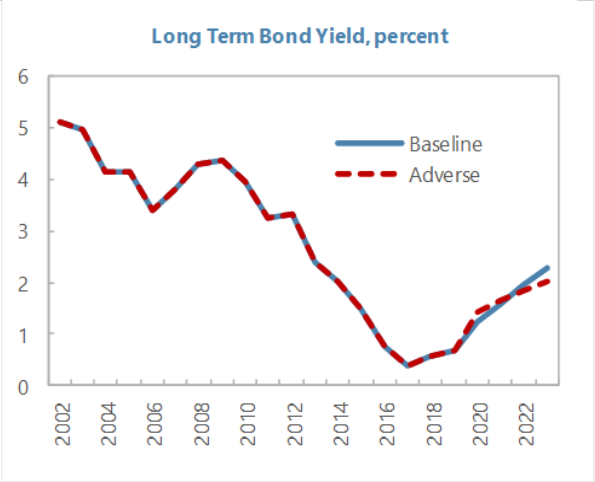
Figure 4. Austria: Domestic Macroeconomic Assumptions, 2019-2022

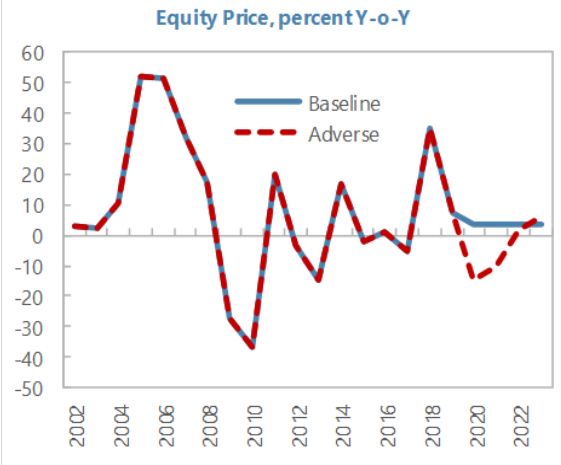






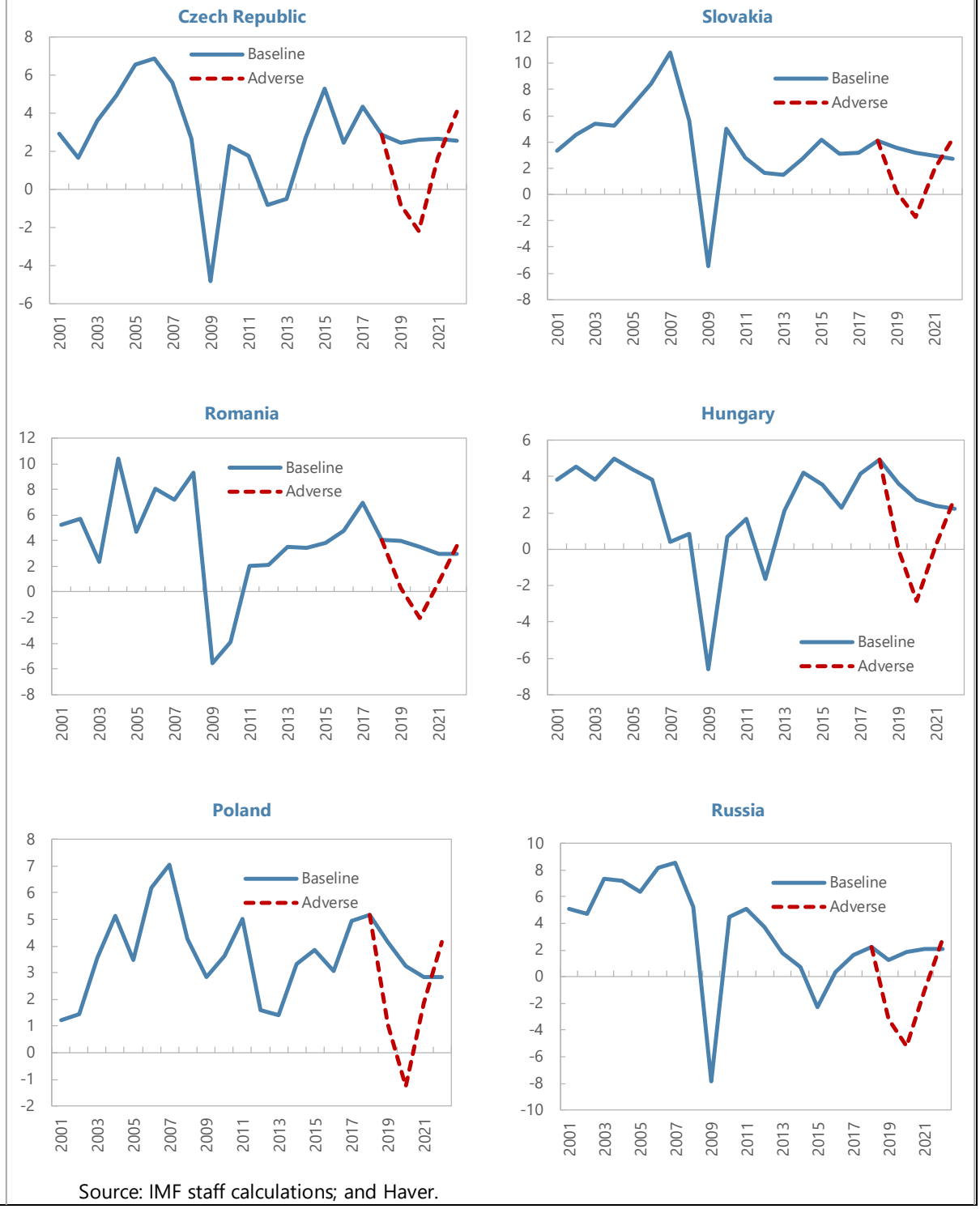






Source:IMF staff calculations; OeNB; and Haver.

Figure 5. Austria: Foreign Countries GDP Growth Assumptions, 2019-2022
(Percent, Y-o-Y)



Source: IMF staff calculations; and Haver.

SOLVENCY STRESS TESTS

A. Overview

19. The FSAP top-down solvency stress test accounted for a comprehensive set of risks. The FSAP team used IMF's internally developed solvency stress testing models to capture credit risk (covering both credit impairments and scenario impact on risk-weighted assets, funding, and interest rate risk), market risk (covering repricing and spread risks for interest rate sensitive assets, as well as equity and commodity risks), net interest income and non-interest income risks. [25]

20. The FSAP team used the OeNB's advanced stress testing infrastructure for the solvency ST exercise.[26] This choice was dictated by the increased computational complexity and the potential large investment that would have been required in terms of IMF's own infrastructure of implementing a fully-fledged top down stress test exercise for all 440 consolidated Austrian banks. The choice was also supported by the fact that the network structure representing equity participations between domestic banks in the tiered and multi-layered Austrian banking sector structure was already incorporated in the ARNIE framework, making the calculation of the participation impact on Profit and Loss (P&L) and capital due to equity participations a straightforward task. Under this arrangement the FSAP team's estimated satellite model outputs were imported as calculation parameters in the ARNIE core engine which was responsible for the subsequent calculation of the solvency stress test results .[27]

B. IMF Top-down Stress Tests: Methodology

Balance Sheet, Income Projections, and Hurdle Rates

21. The exercise was performed under a static balance sheet assumption. The allocation of assets and the composition of funding sources remained constant as of Q4 2018 cut-off date during the stress test horizon. The sum of performing and nonperforming exposures was also kept constant following overall exposure levels at the cut-off date. For the purpose of calculating net interest income the asset and liability compositions remained static throughout the horizon of the scenario and no increases in capital or other managerial actions were assumed.

22. The exercise assumed that accounting impairments match the regulatory expected losses. This was mandated by the fact that only some of the banks in the sample report accounting

[25] Operational risk capital requirements were not stressed in the analysis but were kept at the levels of the cut-off year as this is a standard practice in FSAP solvency stress tests and a common approach in most macroprudential stress tests due to the weak linkages between operational risk and macroeconomic scenarios.

[26] This comes under the name ARNIE which stand for Applied Risk, Network and Impact assessment Engine.

[27] Either in the form of risk parameters that were further deployed in the calculation of P&L and capital impacts or in the form of outright P&L overlays which also accounted for some calculations taking place outside the ARNIE core engine.

losses under IFRS 9 and the rest report under national GAAP; therefore, the full incorporation of both regulatory and accounting layers could not be implemented in a consistent way. Furthermore, for the time being, OeNB's solvency stress test infrastructure does not distinguish between accounting impairments and regulatory expected losses. In that context, the assumption on expected losses matching the accounting impairments was the only feasible one.

23. Projection of Risk-Weighted Assets (RWAs) accounted for defaulted credit exposures formation, and changes in the credit quality characteristics of IRB portfolios as well as rating migrations of securitization portfolios. RWA were kept constant (at the level of the cut-off date) for STA portfolios.[28] RWAs for operational and market risk were also kept constant at the level of the cut-off date. As a result, and because of the static balance sheet assumption, the capital impact due to RWA changes was confined to the deteriorating quality of IRB portfolios and rating migrations of securitization portfolios.

24. Income (profit or loss) and regulatory capital were projected based on the overall impact of all risk factors considered in the stress test. Specifically, total net income reflected projections for net interest income, non-interest income and expenses, trading income, "fair value through profit or loss" (FVTPL) portfolios, credit loss provisions, and tax charges. Changes to regulatory capital also accounted for the revaluation of the "fair value through other comprehensive income" (FVOCI), dividend distribution payout ratios, and minority interest payments.

25. The hurdle rate for the adverse scenario included minimum capital requirements. The stress test results were benchmarked against the regulatory minimum and target values for CET1, T1, and total capital that also include a capital conservation buffer (CCB) of 2.5 percent and a Systemic Risk Buffer (SyRB) for OSIIs. Under the baseline scenario, banks are expected to maintain capital ratios above the total target requirements (including minimum, CCB, SyRB, and P2R). In the adverse scenario, preserving the CCB and the SyRB was not required.

26. Regarding tax rates and dividend payout ratios, the exercise followed the default implementation in OeNB's stress test framework ARNIE. The implementation in ARNIE is following the basic principles of the EBA stress test approach; under both scenarios, tax rates and the dividend pay-out ratio were set at 30 percent.[29] If a bank made losses during a year, a zero dividend was applied.

[28] The technical options to extend the RWA update in the adverse scenario also for STA portfolios were also discussed with the authorities and agreed but could not be implemented in the core engine of ARNIE in a timely fashion because other tasks and overlays were prioritized during the FSAP mission.

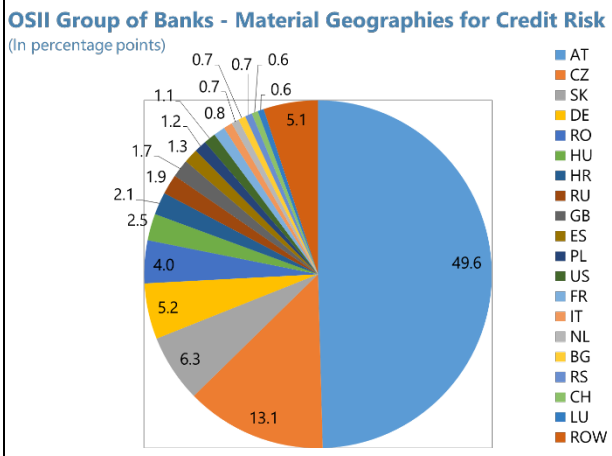
[29] Some alternatives were also discussed with OeNB regarding the need to also incorporate in ARNIE some alternative options whereas dividend distribution is restricted when banks "eat" into the CCB. Due to the small materiality of this enhancement (dividends are practically zero in the adverse scenario because of loss-making results) it was decided to deprioritize this development.

Credit Risk Analysis and Estimation

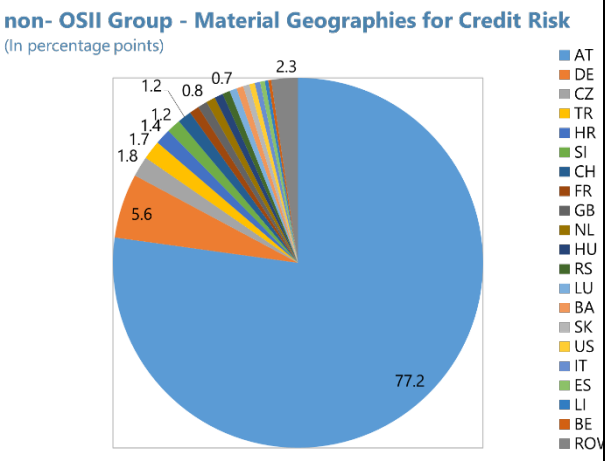
27. Credit risk is the most important risk factor for the Austrian banking system given that credit exposures are the most important segment of total assets. One very important feature is the relative importance of non-domestic credit exposures. The significant international presence, in particular in CESEE countries[30], warrants a large dispersion of exposures in terms of material geographies for credit risk which is illustrated in Figure 6. This feature is mainly associated with banks classified as OSII banks that have a strong international presence, while non-OSII banks tend to be domestically oriented in terms of direct[31] credit exposures.

Figure 6. Austria: Material Geography Analysis

The dispersion of credit exposures is significant for OSII banks due to the important international exposures.



Non-OSIIs are far more concentrated in terms of material geographies.



Sources: IMF and OeNB staff estimates.

[30] In total, CESEE exposures correspond to 32.3 percent and 6.8 percent of total exposures for OSII and non-OSII banks respectively.

[31] An indirect exposure comes in the form of equity participations, therefore, enabling local domestically focused banks to also share the benefits (or losses) from international operations through equity stakes in the institutions at the higher layers that are the parent institutions for the subsidiaries in the CESEE region, an equity participation scheme that is usually referred to as 'inverse ownership".

28. A variety of approaches for modelling credit parameters was used under the two scenarios. For SIs, exposures were initially allocated to asset types based on an exposure segmentation scheme that included corporates, financials, retail mortgages, retail consumer, sovereign, and sub-sovereign. Satellite models were estimated (or proxied) to cover all these segments across all material geographies. A different segmentation was used for LSIs in order to benefit from granular data available in the Austrian Credit Register.[32] A mapping of these segments to the ones used for SIs enabled the use of the same satellite forward path for both groups of banks. The FSAP exercise made full use of the LGD PiT scenario projection models and the estimated starting points for all credit parameters as they were estimated by OeNB for the purposes of their own stress test. Table 3 illustrates the full segmentation scheme, with seven asset exposure classes for 18 geographies and 2 regulatory approaches (IRB and STA).

Table 2. Austria: Credit Risk Exposure Segments for SIs and LSIs

SI segments	LSI segments	Model used for PD Paths
Corporates	Agriculture Construction Production Services Tourism Trade Transportation	Corporates
RE-Related	Other privates (households or corporates) Households Residual exposures (<350k Eur)	Mortgages
Consumer Credit		Consumer
Banks & Institutions	Banks Financial Services (non-banks)	Financials
Other		Other
Sovereign	Sovereign (central government plus sub-sovereign)	-
Sub-Sovereign		-

Note: The segmentation is implemented by material geography and regulatory approach, namely IRB (IRB) and Standardized (STA).

[32] To infer starting point data and granular information on collateral by segments class for each LSI bank.

29. For the projections of PDs, the stress test approach made use of satellite models to project scenario-dependent forward paths. This framework was used for the corporate and financial asset class segments for all material geographies. For these corporate asset classes historical default rates by asset class obtained from third party data providers were used to inform the calibration. [33] Based on the estimated econometric models, a PD path for each scenario and asset segment/class was generated. Bayesian Model Averaging (BMA) was used as the core modelling approach in the estimation of econometric models for the projection of default probabilities under both scenarios. Details of the BMA PD PiT satellite models and the estimation approach can be found in Annex III.

30. A structural model was used to project loss rates for mortgage and real estate-related retail portfolios. This was driven by the absence of reliable historical time series on mortgage defaults across all material geographies. The model uses borrower affordability metrics (i.e., DSR) and how they get affected under a specific scenario to infer default probabilities. House price shocks are used to estimate losses in the default event. For the needs of this model the historical DSR/LTV joint distributions of the most recent yearly vintages were used to infer a system-wide DSR/LTV distribution. This distribution was further assumed to be common across all material geographies. Scenario shocks (country specific) on interest rates, unemployment and house price shocks were used on the same mortgage exposure DSR/LTV distribution using the same structural model to estimate country specific scenario dependent losses. A detailed presentation of the approach underpinning the implementation and use of the structural model for mortgage portfolios can be found in Annex IV. [34]

31. PD paths for retail and other exposure segments were proxied using applicable multipliers of the corporates and mortgages segments respectively. Given the low materiality and the lack of historical data that would enable the use of standard econometric models for those segments the use of a proxy was chosen as the preferred solution. For retail exposures a scaled aggregate of the PD paths for mortgages and financials by material geography was used. For other exposures the PD paths were defined by the aggregate of corporates and financials PD paths. Finally, there was no separate model estimated for sovereign and sub-sovereign segments due to the very low starting PD PiT level and therefore, the small materiality of these segments for the overall credit impairment impact.

32. Additional impairment charges were calculated on FC loans and repayment vehicle (RV) loans. Although the stock of FC loans has declined, it is still relatively high and susceptible to home currency depreciation. Most FC loans in Austria are structured as bullet loans in the form of an

[33] Moody's CreditEdge historical default rates for all relevant geographies/countries' corporate and financial segments were used to estimate the respective satellite models.

[34] The model assumes a "double trigger" of default, i.e., the borrower cannot longer service the loan, and, in addition, he cannot sell the collateral to prepay the loan.

RV.[35] Against this background and given that the scenario incorporates significant foreign exchange shocks, the additional risk (default risk attributable to FC shocks) was captured as an impairment add-on. The FSAP team decided to fully adopt OeNB's approach on quantifying such risks in their regular macroprudential analysis stress tests by estimating an impairment charge by segment and country that is conditional on the exchange rate movement of the domestic currency versus the currency of the original exposure.[36] This is done by assessing RV underperformance and by linking loan-loss-provisioning charges with currency depreciation for direct FC exposures that are not linked to a RV structure. The approach is presented in more detail in Annex V.

Market Risk Analysis

33. The analysis for market risk captured the valuation risks of the securities due to changes in risk-free interest rates and credit spreads for interest sensitive instruments, as well as equity and commodity risks. Based on regulatory reports at the cut-off date each bank's sovereign, corporate and financial issuers' debt, equity and commodity portfolios by accounting category and maturity bucket and sovereign issuer (where applicable) were collected and used to estimate the impact on P&L under both scenarios. The macrofinancial scenario was further extrapolated to produce financial variable shocks (mainly interest rate spread shocks by security type).

34. The analysis covered the impact of interest rate risks and spread risks on sovereign and corporate debt securities in FVTPL and FVOCI accounting portfolios.[37] Losses from FVPL portfolios were assumed to have an impact on regulatory capital through net profits, while those for FVOCI portfolios affected capital through other comprehensive income. For conservatism, existing hedges were assumed to be ineffective during the scenario horizon. Data limitations made it impossible to include counterparty credit risk and credit valuation adjustment (CVA) risk in the scope of the market risk analysis.

35. Market valuation losses from interest rate risks in the debt portfolios were derived using a modified duration approach. First, the analysis captured the re-pricing losses in the FVOCI and the FVTPL books due to shocks to sovereign yield curves. Second, it also accounted for the valuation impact due to shocks to spreads of corporate debt securities. Spread projections on corporate, bank and financials bonds were proxied based on average yield per maturity tenor of the relevant type of security from Bloomberg and were anchored to reflect the macrofinancial conditions in the two scenarios.

[35] A repayment vehicle there are no regular installment for the servicing of the loan, but borrowers contribute on a frequent basis into an investment account which is usually held with the bank that originated the loan. The NAV of this account is used to repay the full loan at maturity (thus the bullet structure). Any shortfalls on the investment account would incur additional losses for the borrower at maturity.

[36] Which was initially developed in cooperation with the 2014 FSAP team, but further refined in the following years by OeNB.

[37] Amortized Cost (AC) portfolios were not stressed.

36. Equity and commodity price risks were also accounted for using shocks provided in the scenarios. Given the lack of data on the country breakdown of equity exposures, all equity positions were assumed to pertain to the domestic equity market. For commodities the applied shocks were aligned with the oil shock in the scenario, however, the banking sector's exposure to these types of risks is relatively limited when compared to interest rate and spread risks.

Net Interest Income Analysis

37. An approach following the spirit of the 2018 EBA Stress Test Methodology was also used to project the Net Interest Income (NII) under the two scenarios.[38] To preserve the concept of calculating NII separately for all material geographies the approach was tailored to make best use of available data.

38. For this purpose, the following changes were incorporated into the core engine of the infrastructure:

- Simplified asset and liability segmentations were used, matched to the ones that could be mapped to COREP and FINREP data sources. Under this segmentation the breakdown for assets contains interbank loans, fixed and variable rate loans, fixed and variable rate bonds and non-interest-bearing assets. On the liability side, the segments covered were interbank deposits, customer deposits, variable and fixed rate issued bonds and equity.

- A combination of data sources was used to infer the starting volumes by asset/liability segment and the effective interest rates (in terms of reference rate and segment margin) by country. These sources included: (i) balance sheet information from national GAAP; (ii) financial stability reporting of domestically operating entities (OeNB's integrated reporting framework), and (iii) FINREP reports of foreign subsidiaries complemented by more aggregate re-pricing information on fixed rate instruments. These sources were also used to compute volumes of maturing, existing and new business over the stress test horizon.

- After defining the outstanding amounts and the effective interest rates by segment and by country for each bank, the macroeconomic scenario was further translated into shifts in the effective interest rates for all segments and countries. The shift includes a delta shift on the reference interest rate and a shift in the margin, as prescribed by the EBA methodological approach.

[38] The full EBA ST Methodological approach on NII can be found in Chapter 4 of 2018 EU-Wide Stress Test: Methodological Note.

- The pass-through constraints on the margin components of the liability positions (idiosyncratic shock) and on asset positions (pass-through constraint) were set as per the EBA stress test methodology.[39]

- The impact of new business repricing was consequently calculated under the assumption that maturing instruments were replaced by identical new instruments (of the same segment and with same initial maturity) but at current reference and margin rates implied by the scenario.

39. The projection of NII was, therefore, based on a semi-structural approach. The model made extensive use of all the available data sources to estimate existing and new business by country and segment in the absence of a pure bottom-up submission. Scenario-based effective interest rates were applied to the repriced business in the way mandated by the structural model and following the pass-through constraints imposed by the methodology. The benefit of this approach is that it incorporates in a straightforward manner the scenario projections on reference rates across all material geographies. The increased complexity in calculating top-down starting points comes with the benefit of being in a position to fully measure the granular NII impact on countries were the reference rate shock is significant. Furthermore, the approach can be further adjusted to account for additional idiosyncratic or geographic overlays (such as liquidity spreads at the country level). On the negative side, in the absence of sufficiently granular data, some strong assumptions are needed in terms of the effective interest rates of maturing business.[40]

Non-Interest Income Analysis

40. Non-interest income has a modest contribution to Austrian banks' overall profitability and internal capital generation capacity. In relative terms total non-interest income during 2018 stood at about 45 percent of net interest income for the entire system. Non-interest income was stressed based on a constrained approach that was already part of the ARNIE implementation.[41] According to constraints imposed by the approach, non-interest income cannot exceed the level realized during the cut-off year (2018), and an additional reduction of 15 percent must be applied for Net Fees and Commissions Income (NFCI) and Net Trading Income (NTI)[42] and 25 percent on

[39] See section 4.4.4 and Boxes 25-27 of the of 2018 EU-Wide Stress Test: Methodological Note. Margin constraints on liability positions are quite conservative given the large deposit base of Austrian banks which reprice at high frequency in a rising interest environment and the sovereign stress assumed in the scenario.

[40] This granular top-down approach on NII calculation at the country level was adopted by OeNB as an optional component of the permanent infrastructure and was integrated in ARNIE as a priority task, given that the delta of the NII impact vs the alternative top-down approach proved to be of significant magnitude.

[41] The approach follows the basic principles of the 2018 EBA methodology but deviates in terms of the applied haircuts and the fact that the impacts are phased-in during each year rather than fully applied in the first year. The methodological approach was selected in order to make the results obtained by the FSAP team comparable to those of the OeNB and because the decomposition of non-interest income (stable vs market dependent sources income) does not suggest a substantially more severe impact under a fully modelled -rather than constrained- approach.

[42] This is a conservative assumption given that the composition of NFCI and NTI is centered around payment and transaction fees which are less sensitive to adverse macroeconomic developments than brokerage, investment fund, or portfolio management fees.

dividend income and the share of the profit of investments in subsidiaries, joint ventures and associates outside the scope of consolidation.[43] Administrative and operating expenses are floored to their respective levels of the cut-off year. In line with the micro-prudential stress test conducted with ARNIE, rather than calibrating the constraints based on cut-off date values, the exercise applied the same constraints on multi-year, exponentially smoothed averages that are confirmed by line supervisors to arrive at calculation starting points for stress test purposes.

41. A business risk charge aiming at capturing the risk emanating from banks which exhibit more volatility in their P&L statement was also included in the solvency stress test result. The business risk charge, which is already a component of the ARNIE infrastructure, is calculated based on the individual volatility of the seven P&L items which form our operating profit before risk (NII, NFCI, NTI, Staff Expenses, Other Expenses, Depreciation, Other Profit before Risk). For each of these items, the cut-off date starting value is weighted based on its historical volatility, such that items with low volatility receive a lower charge than more volatile items. While this calculation is not based on operational loss data, it picks up on more frequent losses through a more volatile P&L figures. It does not and is not intended to capture low frequency, high impact losses.

Addressing Equity Participation Risk in the Decentralized Sectors

42. The unique feature of inverse ownership of the cooperative sector required some additional focus in the solvency stress test. Some features of the Austrian banking system, such as the relatively large cooperative sector, are also relevant for stress testing. In contrast to regular banking groups, where a parent company owns a number of subsidiaries, in the Raiffeisen sector many small local banks together own a few larger banks. The sector is multi-tiered in that the local banks within one federal state own the respective regional upper-tier bank and these in turn own stakes in the top-tier central institution. Therefore, the lower tier banks participate in profits, but also share losses incurred at higher-tier banks.[44] Not including this contagion channel in the stress test would underestimate losses in an adverse scenario.

43. The approach for modelling the participation risk assumes that the book value of each bank's equity stake is revalued in line with the individual participation share in the respective upper-tier bank. [45] Each euro of profit generated is reflected in a *pro-rata* increase in the book value of the equity stake. Each euro of losses is reflected as a *pro-rata* decrease in the book value of the equity stake. Losses are limited by the book value of each equity stake, i.e. banks can face a total loss of their investment but not more. The information required to perform the equity participation

[43] The dividend income from subsidiaries, joint ventures and associates outside the scope of consolidation is not material for Austrian banks.

[44] Through the revaluation of equity participations.

[45] While participation risk is covered for all banks with participations in other banks, this analysis is mainly relevant for the Raiffeisen sector, since the Sparkassen and Volksbanken sectors are consolidated like a group of credit institutions. By contrast, in the Raiffeisen sector there is no consolidating entity and the participation risk is captured at the individual entity level. Double leverage from participation risk is a key vulnerability under stress.

revaluation under stress is sourced from various OeNB business areas and maintained by the OeNB's stress testing team.

C. IMF Top-Down Stress Tests: Results

Main Results

44. Banks appear resilient to severe macrofinancial shocks, with most banks meeting the hurdle rates at the end of the stress testing horizon (Figure 7).

- In the baseline, the aggregate CET1 capital ratio would be on an upward trajectory due to banks' revenue-generating capacity and the mild impact of the scenario on net interest income and credit impairment. The system's aggregate CET1 capital ratio would increase by 2.3 percentage points by 2021.

- In the adverse scenario, the aggregate CET1 capital ratio would decline by 4.4 percentage points to 11.1 percent by 2021. For five small banks (out of a total of 440) the ending CET1 capital ratio would be lower than the minimum CET1 capital requirement, albeit the aggregate capital shortfall would be small.[46]

- Credit impairments and lower net interest income are key factors underpinning the larger system-wide capital depletion in the adverse scenario. Credit losses stand at 4.9 percentage points of CET1 capital under the adverse scenario compared to a 1 percentage point decline in the baseline. The net interest income in the adverse scenario is also lower on average by almost 15 percent for the horizon.

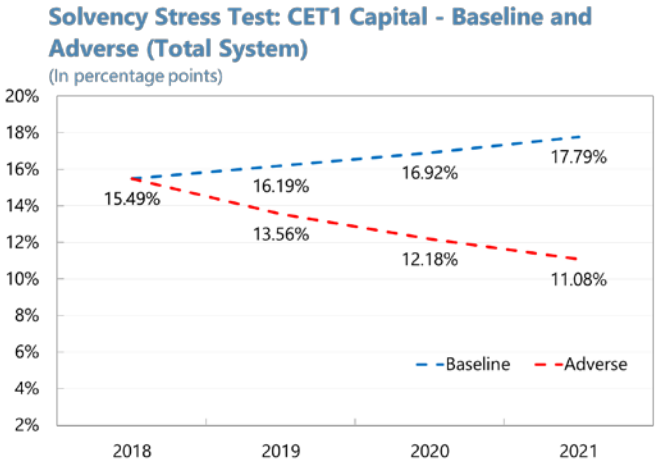
- The stressed non-interest income and net trading income and a mild difference in market risk losses also have a negative contribution to CET1 capital but are not the main drivers of the result. Deteriorating credit quality would also drive an increase in RWA contributing to an additional CET1 depletion of 0.7 percentage points.

- The negative impact is only partially mitigated by reduced dividend distributions and the difference in the reduced tax payments because of projected losses.

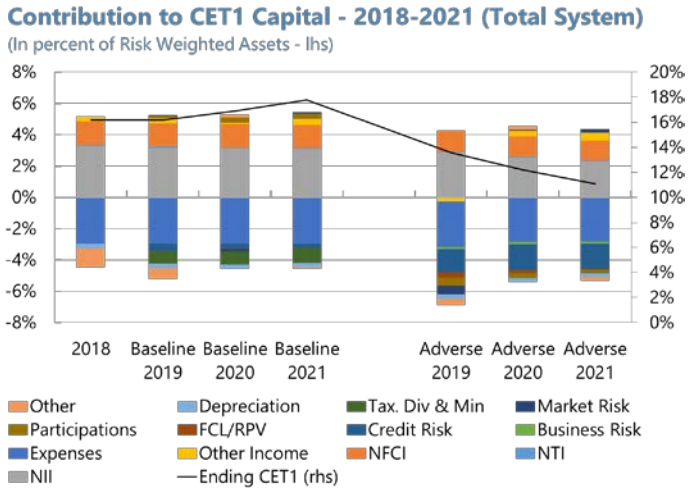
[46]Total capital shortfall under the adverse scenario is approximately EUR 5 million or 0.01 percent of the aggregate system CET1 capital.

Figure 7. Austria: Solvency Stress Test Results – System Wide Averages

The aggregate CET1 ratio increases by 2.3 ppt in the baseline but decreases by 4.4 ppt in the adverse scenario.

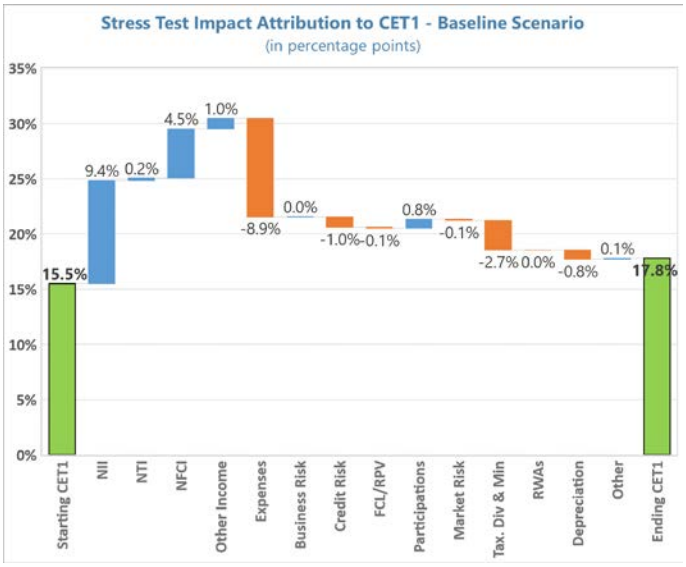


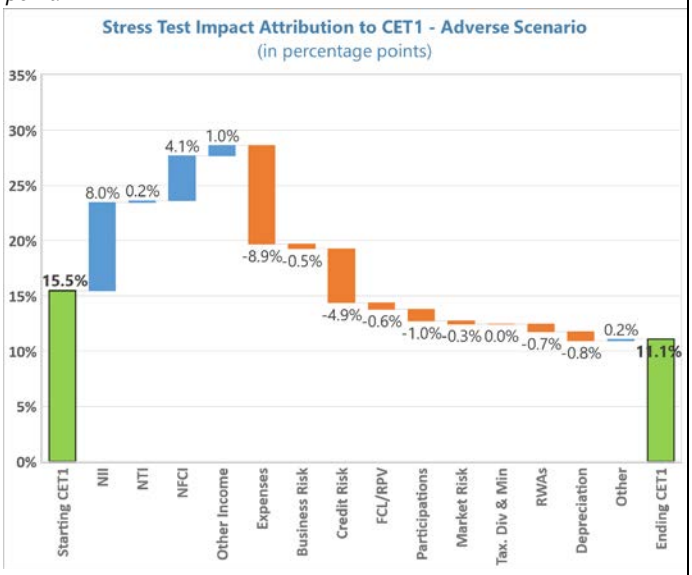
Credit impairments and lower net interest income are the major drivers of capital depletion in the adverse scenario.



The system has a moderate capital generation capacity, with the participation channel contributing 0.8 percentage points.

Credit losses account for an additional -3.9 percentage points compared to the baseline and RWA increase of -0.7 percentage point.

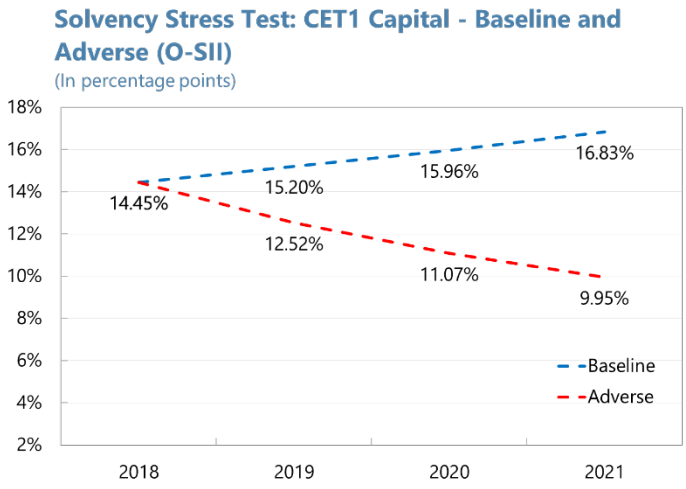




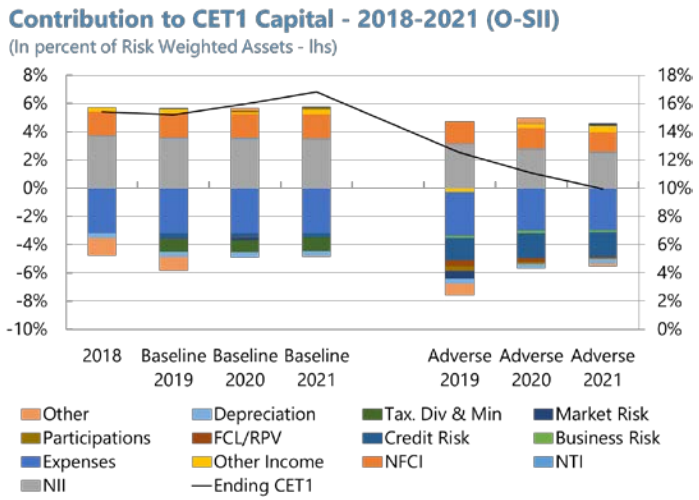
Source: OeNB; IMF staff calculations.

Figure 8. Austria: Solvency Stress Test Results – OSIIs

In the adverse scenario, the ending capital ratio is lower than the starting point by 4.5 ppt.

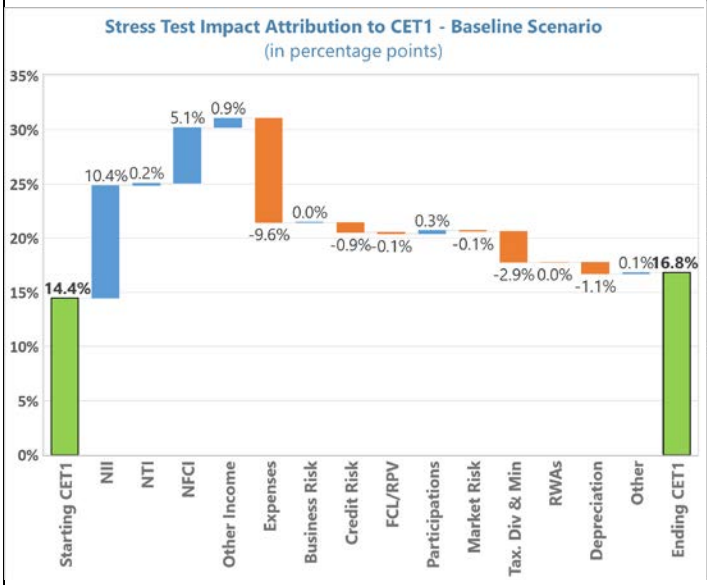


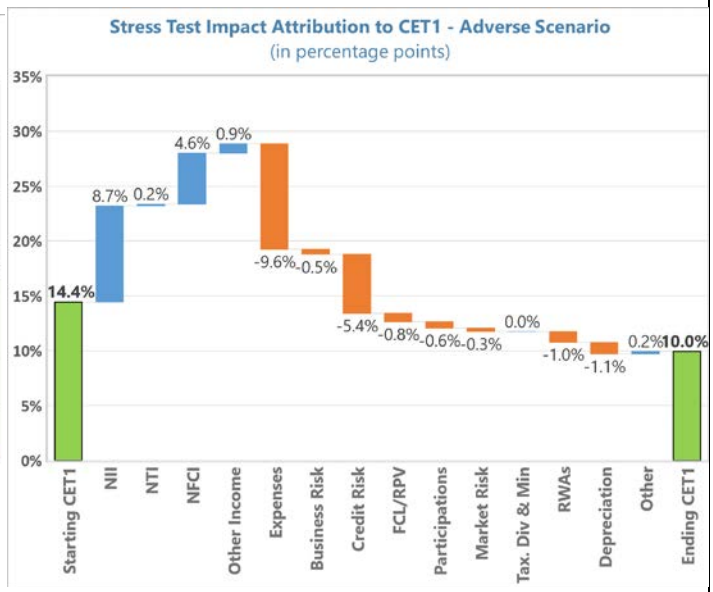
Credit losses are the main drivers of capital depletion in the adverse scenario.



Profitability is better for OSIIs though driven mainly by higher margins in the CESEE…

…with higher credit losses due to the higher risk levels.

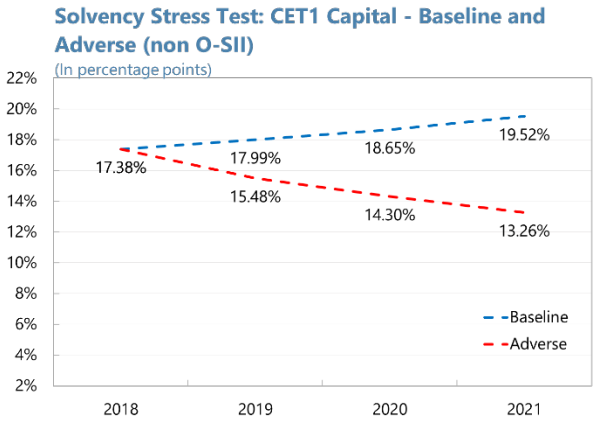




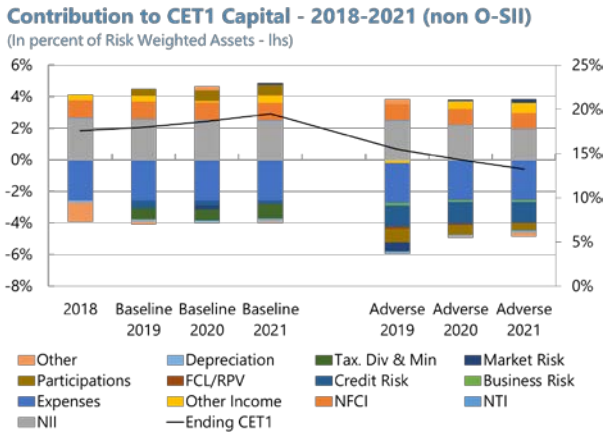
Source: OeNB, IMF staff calculations.

Figure 9. Austria: Solvency Stress Test Results – Non-OSIIs

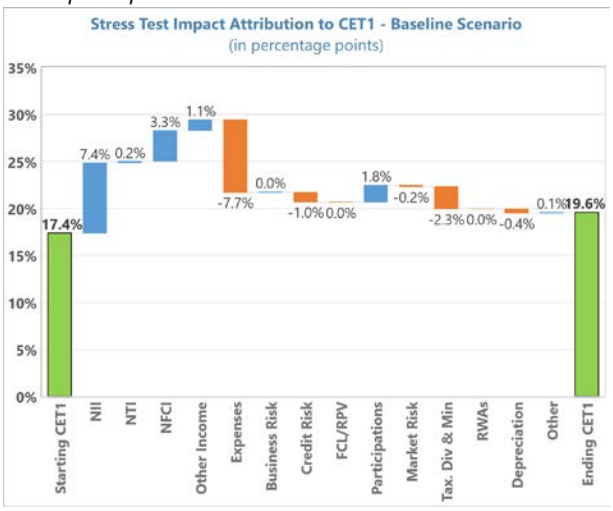
Profitability for non-OSIIs is better than in the baseline…



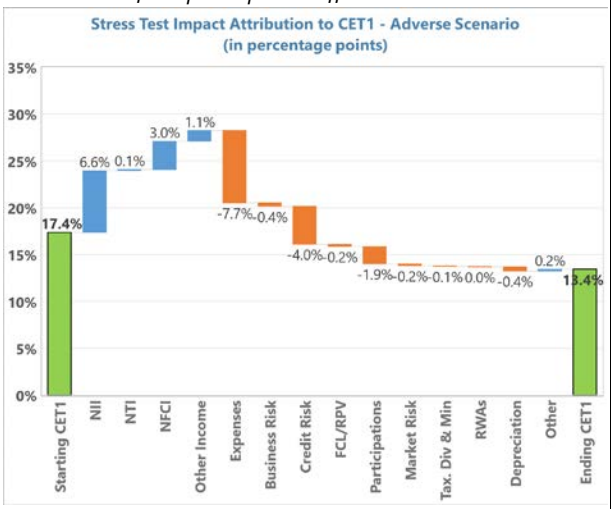
…as reflected in the lower net interest income and non-interest income compared to the system.



The positive result in the baseline can be partially attributed to the participation channel.



Non- OSIIs remain more vulnerable in a downturn due to the reversal of the participation effect.



Source: OeNB, IMF staff calculations.

45. While there is broad consistency of impact across OSII and non-OSII banks, results suggest heterogeneity in the drivers of capital depletion. During an economic downturn—as the one captured in the adverse macroeconomic scenario— the drivers negatively affecting the evolution of CET1 capital may be different between large international banks and smaller domestically-focused banks. This difference can be illustrated by looking at OSIIs and non-OSIIs separately (Figure 8 and Figure 9).

46. For the smaller banks belonging to the non-OSII group, the capital impact attributed to equity participation valuation is what drives the difference between the two scenarios. In the baseline, the positive valuations of participations are the main contributor to their internal capital generation capacity. Nevertheless, the same factor drives the negative result for non-OSIIs in the adverse scenario, where it has a negative contribution of 1.9 percentage points compared to a positive contribution of 1.8 percentage points in the baseline scenario. This is due to the fact that in the Raiffeisen sector in which smaller lower-tier banks hold stakes in larger higher-tier entities enabling them to participate in central entity's profits but acting as amplifier of inward spillovers in a downturn. Excluding the risk from equity participations—as is standard for other system-wide stress test—would significantly underestimate the total impact.

47. The inverse ownership scheme enables smaller regional banks to participate in the benefits of high interest margins and currently low credit risk costs stemming from CESEE region operations of the central entity. However, the scheme may act as a significant amplifier of inward spillovers in case of an economic downturn. In the hypothetical scenario of a significant economic downturn in the CESEE region a wider segment of Austrian banks would be affected (and not just the OSIIs with significant non-domestic exposures), because of the substantial propagation velocity of this inward spillover channel.

48. Credit losses are the main driver of the solvency stress test result. Credit losses stand at 4.9 percentage points of CET1 capital under the adverse scenario compared to a 1 percentage point decline in the baseline. Impairments in the adverse scenario are significant across all asset classes. An additional charge of 0.6 percentage points can be attributed—in the case of the adverse scenario—to the additional impairment for FC loans across all countries.

49. The increase in credit-linked RWAs for the system contributes to the depletion of CET1 by an additional 0.7 percentage points. This impact can be fully attributed to the OSII group (1 percentage point impact), since all portfolios of non-OSII are under the standardized regulatory approach and by assumption the core engine does not stress RWAs on those portfolios. [47] This impact for the OSIIs corresponds to an increase of total credit-linked RWAs at the end of the

[47] Given the high level of starting RWA densities of STA portfolios and the relatively conservative adjustment of IRB credit RWAs with respect to similar exercises for Austria banks the impact of the approach on the final result is not expected to be material. In any case, a single factor sensitivity analysis on the impact of STA RWAs change under the adverse scenario is straightforward.

scenario horizon of approximately 7.3 percentage points.[48] A negligible effect—also concentrated in O-SIIs can be attributed to their securitization portfolios.

50. NII experiences a substantial drop in the adverse scenario due to the imperfect interest rate pass-through. Under the adverse scenario, the rising interest rates in the domestic and CESEE countries and the inefficiency in achieving a full pass-through as prescribed by the methodology drive the reduction of the overall average NII by 18.9 percent relative to the observed net interest income during the year preceding the cut-off date (2018). The reduction is smaller under the baseline (4.7 percent) due to the milder interest rate fluctuations and the absence of idiosyncratic shocks to margins on the liability side (Figure 10, right panels).

51. OSII banks are more severely hit in terms of their aggregate NII reduction, mainly due to the sharper reference rate increases in some of the non-EU countries they are exposed to. Overall in the adverse scenario, the NII reduction for the OSII group is approximately 20.1 percent on average for the three years. The respective number for non-OSIIs stands at 6 percent. The difference is due to higher exposures of OSII banks to more volatile reference rates affecting interest income more pronouncedly.

52. Given the important influence of the methodology on the overall results, the NII impact should be interpreted with caution. While the methodology can produce conservative results under a wide spectrum of reference rate scenarios, a more realistic approach would incorporate country-specific calibration of interest rate shocks and margin overlays to reflect fragilities on the funding side as opposed to bank-specific spreads.[49] This may be particularly important for some of the Austrian OSIIs operating in the CESEE given that the post-stress net interest margins remain substantial even after the effect of price of risk under stress is deducted. It would be, therefore, advisable to derive an interest rate scenario including margin add-ons that would fully reflect the fragility of the market, rather than the vulnerability of the bank.

53. In the adverse scenario the impact for non-interest income is moderate. Non-interest income projections are 10.1 percent lower for the system aggregate in the adverse scenario relative to the baseline (and the 2018 observed income). However, the overall impact is moderate, accounting for only 0.4 percentage points in terms of overall RWAs, due to the small relative weight of non-interest income in the Austrian banking sector's overall income generation capacity. The result is consistent across both OSIIs and non-OSIIs groups as illustrated in the waterfall of solvency stress test impact (Figures 8 and 9). The simplified methodology and the phased-in gradual introduction of the minimum haircut is another factor underpinning the moderate result.

[48] This result should also be interpreted with dome caution, since only part of the OSII credit exposures are under the IRB regulatory approach. For the residual (i.e. the exposures under STA), a zero-percentage point increase in RWAs is modeled.

[49] In other words, liquidity spreads (on top of sovereign spreads) might be country specific in terms of magnitude and/or persistence; high interest margin countries might experience higher liquidity shocks if one assumes that higher interest margins partially compensate for structural market and liquidity risks.

54. Market risk does not appear to have a substantial impact under the explored scenarios (Figure 10, left panels). The overall FVPL and FVOCI portfolios are relatively small and of good quality with the exception of some more material concentrations (noted mostly for non-OSIIs) on corporate bonds issued by banks and/or financials and some slightly above average equity exposures. The overall impact for the system stands at 1.2 EUR billion (or 0.3 percentage of RWAs), with the first year being the most severely impacted due to the shape of the interest rate shifts.[50]

55. FSAP team's solvency stress test results were benchmarked against OeNB's results by applying FSAP team's scenarios to OeNB's toolkit.[51] With respect to the initial differences in the starting point of this exercise, the two teams—FSAP team and OeNB—converged significantly in terms of methodological approaches and aspects of the modelling approach. The OeNB and FSAP teams collaborated on various aspects, including validation of the FSAP team's results.

Sensitivity Tests

56. An exploratory test of the resilience of the two-layered IPS (regional and federal IPSs) in the Raiffeisen sector was a key theme of the sensitivity analysis. The OeNB team conducted an exploratory analysis and shared the results as part of their financial stability monitoring. The FSAP stress test adverse scenario was used as the base case and additional losses of gradually increasing severity were introduced to stress the central institution of the Raiffeisen structure. As a result, for each additional loss case considered, the inward spillovers were measured using a full system simulation with ARNIE. Entities with capital shortfalls were also identified and the capital buffers of the IPSs were measured against projected shortfalls.[52] A range of support steps were considered which included: current ex-ante funding; future ex-ante funding (post phase-in period, as ex-ante funds are still in the set-up phase); contractually binding levels; and fully available excess capital above minimum requirements and regulatory buffers. The results shared with the FSAP team confirm the centrality and systemic importance of the central institution, the RBI, of the Raiffeisen structure. The results also illustrate how negative developments in material geographies[53] may be further exacerbated due to the inverse ownership structure and the elevated sensitivity of the overall sector to the performance of the central institution.[54]

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[50] In the adverse scenario, some of the interest rate shocks of the first year are easing due to the pass-through of accommodative policy during years 2 and 3. As a result, some of the Year 1 losses on the fixed income portfolio are partially reversed during Years 2 and 3.

[51] OeNB (2019) Financial Stability Report, December.

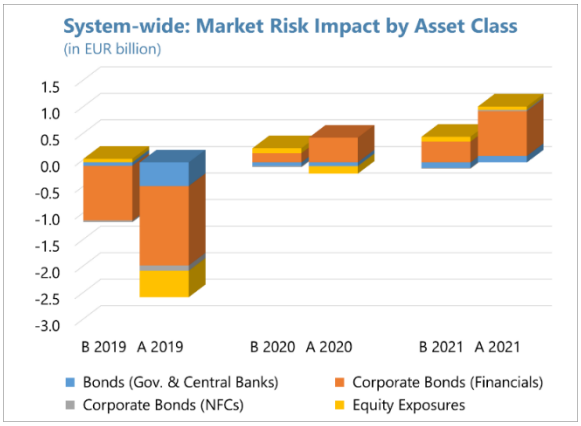
[52] The sequencing of support measures also considers the presence of overlapping regional and federal IPSs. It also identifies the sequencing of support actions to replicate contractual obligations.

[53] This is because RBI as the central institution consolidates all exposures in the CESEE countries. All other entities participate in the results via the equity participation channel.

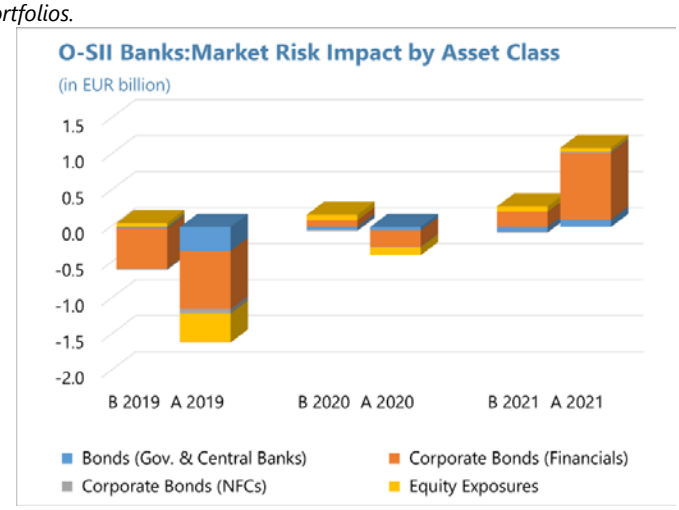
[54] The described approach is quite complex because it requires the initiation of repetitive runs for the entire banking system in an operating mode that resembles reverse stress-testing. Therefore, the results that the authorities shared with the FSAP team should be used with caution, as they only represent non-validated and non-quality assured preliminary results. Because of their sensitive nature (since they reflect IPS specific resiliency results), they are not be reported or published.

Figure 10. Austria: Solvency Stress Test Results – Market Risk and NII Impact

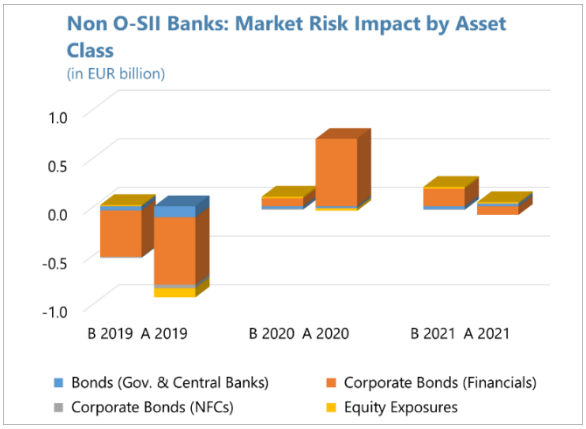
System-wide market risk impact is not material.



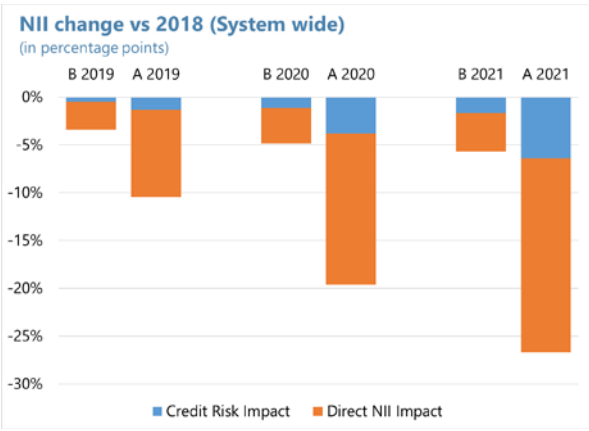
Most of the impact can be attributed to OSIIs due to their larger portfolios.



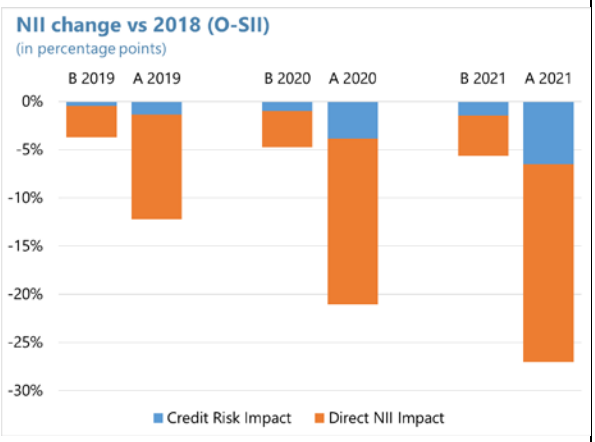
Non-OSII fair value portfolios have significant concentration in financials.



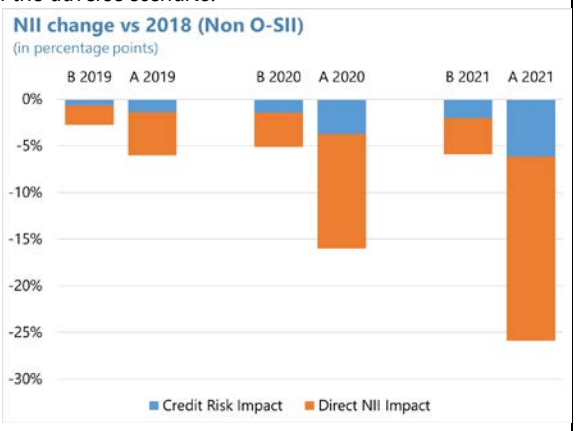
Net interest income is lower than the 2018 starting point in the adverse scenario.



OSIIs witness a more pronounced pattern due to the interest rate exposure to the CESEE countries.



The impact for non-OSIIs is relatively milder during the first two years in the adverse scenario.

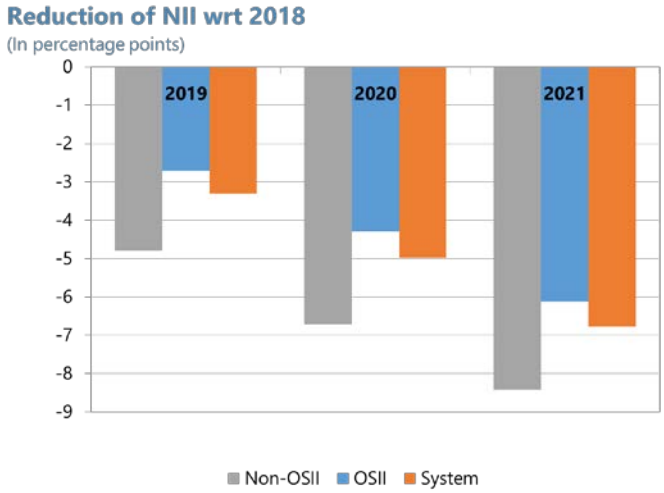


Source: OeNB, IMF staff calculations

57. The Raiffeisen IPS acts as a shock absorber for idiosyncratic shocks but may result in inward spillovers in case of a systemic event. In the case of idiosyncratic shocks, the IPSs provide additional capital and liquidity buffers which enhances the overall financial system's resilience. However, strong equity linkages between members create vulnerabilities when the stress occurs at the central institution. This participation structure may lead to increased "wrong-way" risk due to the positive correlation of risks factors between members, reduced resilience due to lower income-source diversification and reduced organic capital generation capacity. [55]

58. Low structural profitability in the domestic market was the second theme of the sensitivity analysis. The impact of a low-for-long interest rate environment could lead to a decline in margins from maturity transformation challenging banks' ability to generate profits on the domestic market.[56] This is especially relevant, given the fragmentation of the banking sector into smaller entities and the relatively modest progress made in reducing costs and improving operating efficiency.

Figure 11. Austria: Sensitivity Analysis – Impact of Low Interest Rate Environment on NII



Source: OeNB; IMF staff calculations

59. The scenario for this sensitivity analysis takes the more recent evolution of EU area interest rates (up to mid-September 2019) into consideration. Thus, the scenario assumes a decrease of the three months Euribor (10 years Government bond yield) with respect to end-2018 by 10 (80) basis points from 2018YE to mid-September 2019. After that, interest rates stay constant until end-2021. For non-EU CESEE currencies, the scenario assumes constant interest rates at their end-2018 level over the entire three years analysis horizon. To isolate the impact of the low interest

[55] The term "wrong-way" risk refers to the adverse correlation between the contingent liability of an IPS member and its capital generation.

[56] Given the upward sloping interest rate curves produced by the GFM model for the adverse scenario, a low-for-long interest rate scenario is expected to challenge banks' income generation capacity given that the typical maturity transformation function would not necessarily lead to higher profits.

rate environment, no increase in banks' credit spreads is assumed, in contrast to the methodological assumption of the main solvency stress test.

60. Under this scenario, system wide net interest income declines by 5 percent on average until end-2021 (Figure 11). This result is driven by the fact that legal floors on domestic customer deposits prevent interest expense from declining as it would without such floors. At the same time, in line with the methodology, maturing long-dated fixed rate assets, still paying higher interest, are replaced by identical assets but at lower reference rates, thus compressing interest income.

Concentration Analysis

61. An additional sensitivity test on credit concentration risk suggests concentration risks are, on average, contained (Figure 12). The test was performed simulating the default of the largest borrowers using the large exposure (LE) dataset before credit risk mitigations but after exemptions.[57] Exposures within the Raiffeisen were excluded because of the exemptions under the CRR. The results suggest that no defaults are triggered from losses on the largest exposure and capital losses would be moderate (2 percent of RWAs) upon default of three largest exposures. Banks would be able to meet their regulatory capital ratios comfortably following the default of their ten largest counterparties, an extreme event. Some caveats to the results are that the simulations do not consider credit risk mitigation measures in place—although on aggregate they are not actively used by Austrian banks—and that any potential netting arrangements in bilateral exposures were not considered.[58]

62. Results are highly sensitive to the network structure of the cooperative sector. Performing the test on gross exposures, 5 percent of aggregate capital would be depleted following the defaults of the largest counterparty (reflecting the Raiffeisen tiered structure).[59] However, on aggregate, the system's CET1 ratio would remain above the regulatory minimum even in the case of defaults on ten largest exposures. Results are conservative as the simulation does not take into account the support mechanism provided by the Raiffeisen IPS structure whereby in case of need, the regional IPS would step in, and if there is insufficient capacity at the regional level, the federal IPS would be required to provide support to failing banks to restore solvency.[60]

[57] Exposures include financial and non-financial counterparties but excludes the counterparties which are exempted under Article 400 of the CRR, such as the central bank, the central government, the regional governments, and cross-holdings under the IPS.

[58] All exposures were treated as unsecured with an LGD of 50 percent.

[59] In the sample of 440 banks, 395 banks belong to the Raiffeisen sector. At the same time, the Raiffeisen sector contributes to 35 percent of total system assets.

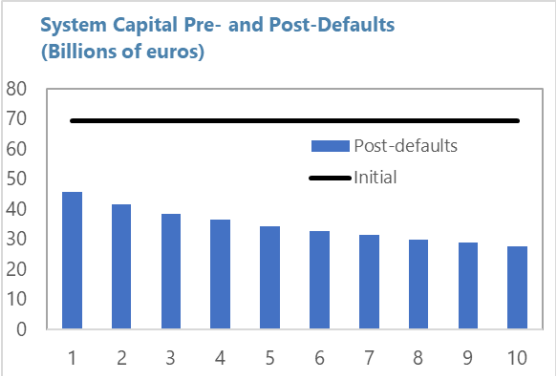
[60] While IPSs have considerable loss absorbing funds, their capital support is limited by the amount of ex-ante and ex-post funds, with the latter constrained by banks' own capital requirements.

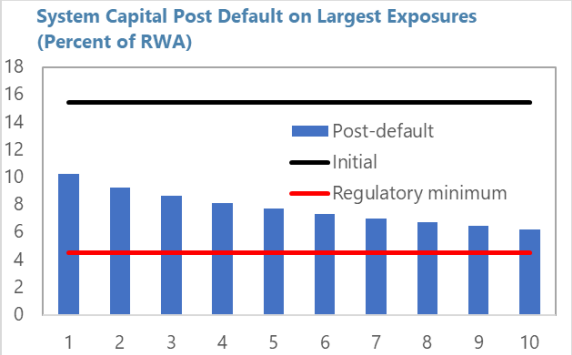
Figure 12. Austria: Concentration Risk [1/]

System capital is severely depleted, particularly in small banking institutions…

…though, on aggregate, system-wide capital remains above the regulatory minimum

Gross original exposures[2/]

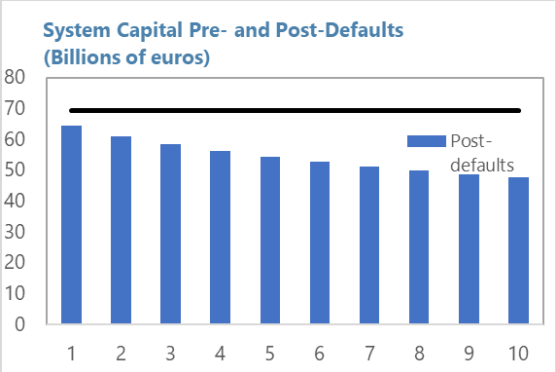


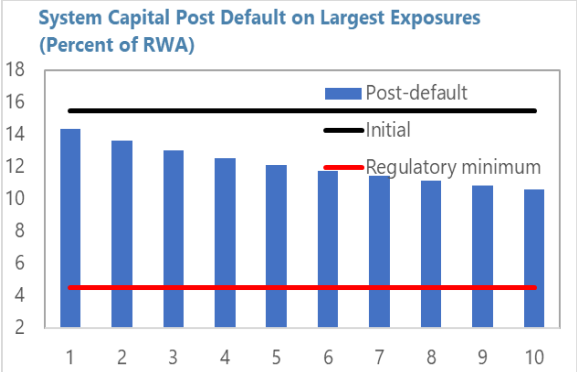


Gross original exposures net of exemptions and credit risk mitigation

System capital suffers moderate losses…

…and remains comfortably above the minimum.





Source OeNB and IMF staff calculations based on Large Exposure Data. Exposures to central banks, sovereigns, and sub-sovereigns are excluded.

1/ The analysis assumes loss given default of 50 percent. A default is triggered when capital falls below 4.5 percent CET1 regulatory minimum.

2/ The value of x-axis denotes *the number of largest exposurtes that is defaulted in the simulation.*

D. Policy Recommendations

63. The inward contagion amplification mechanism is an important feature of the Austrian banking system. Inward contagion risks warrant enhanced monitoring capacity and oversight by authorities, on the back of the significant implications for financial stability of the banking system. The authorities should ensure that participation risk is adequately measured in the supervisory process and, therefore, micro- and macroprudential buffers are properly calibrated to mitigate system-wide risks stemming from equity participations within the Raiffeisen sector.

64. Given the substantial footprint and complexity of the Austrian banking system, and the importance of stress testing in assessing this complexity, the stress testing function should be further strengthened. As noted, the solvency stress test was conducted using the permanent OeNB's ARNIE adjusted for the FSAP team's modelling approach. Running a granular stress test for all 440 consolidated Austrian banks would not have been possible without this infrastructure. This demonstrates the importance of a strong, versatile, and adaptable technical solution. It also provides evidence of the OeNB team's technical competence, efficiency, and dedication to develop, maintain, and manage this infrastructure. Stress testing appears to be a fundamental tool in assessing, evaluating, and informing the relevant authorities on the impact of policy decisions on the financial system. Stress tests are resource-intensive, requiring specialized staff, systems and IT infrastructure. Austrian authorities should ensure that resources and the organizational structure are adequate given the complexity of the exercise.[61]

65. The stress testing function should be further strengthened along multiple dimensions:

- fully integrate sensitivity, contagion, and interconnectedness analysis tools in the standard macroprudential stress testing toolkit;
- further develop the existing framework to capture second round effects, behavioral elements, dynamic balance sheet stress tests, separation of the prudential and accounting layers;
- increase the level of modelling granularity to fully capture the diversity of risks facing the Austrian banking system (for example, geographical dispersion);
- integrate under the same infrastructure a suite of satellite or core models that could be feasible alternatives to the ones used under the standard EBA approach, to enhance OeNB's capacity to execute fully-fledged macroprudential stress tests using a complete top-down perspective and a more targeted methodological approach; and
- enhance the capacity to calibrate scenarios that are comprehensively targeting the assessment of the Austrian banking sector cyclical and structural vulnerabilities and complementary to the ones used under the regular EBA exercises.

66. Establishing a concrete path to enhance the granularity of data is also imperative. While the granularity and quality of data on Austrian exposures is good, there seem to be significant gaps on CESEE exposures. Achieving the desired data coverage for financial stability purposes may involve interaction and cooperation with several authorities and entities. While not without challenges, this process needs to be strategically prioritized and tactically accelerated given the importance of those geographies for the financial system.

[61] This is in line with BIS (2018), "Stress Testing Principles".

LIQUIDITY STRESS TESTS

A. Overview

67. Top-down LCR-based and cash flow-based tests covered the entire banking system. The FSAP team conducted a Basel III LCR-based test over a period of 30 days (by aggregate currency position and by significant currency[62]), and a cash flow-based liquidity test over three months period. For both tests, the available infrastructure allowed the FSAP to consider a very broad set of scenarios reflecting a range of systemic liquidity stress episodes.[63] After the application of each scenario, liquidity conditions for all banks were estimated, and the relevant liquidity metrics calculated. An exploratory analysis based on a quasi-Net Stable Funding Ratio (NSFR) test was also conducted.[64] The system-wide coverage of banks also enabled the evaluation of additional liquidity protection offered by contractual liquidity support commitments of the two-layered IPS scheme in the decentralized Raiffeisen sector.

B. Current Liquidity Conditions and Banks' Liquidity Profiles

68. Austrian banks appear to be well diversified in terms of funding mix. Retail and corporate deposits account for almost 40 percent of banking system's liabilities. The repo segment does not play a significant role, but derivatives-related liabilities account for about 18 percent of total funding (Figure 13). The importance of the derivatives segment is due to the large presence of Austrian banks' in the CESEE region. If the asset side is also taken into account, there are no major mismatches.[65]

69. The FSAP liquidity stress tests used data available through consolidated regulatory reporting for liquidity monitoring. The regulatory bank-level reports provide a very granular and rich dataset on several liquidity metrics that facilitate monitoring and analysis of liquidity-related vulnerabilities. This dataset also includes information on contractual maturities for all funding segments, a granular picture of the asset side in terms of its counterbalancing capacity, and information on collateral encumbrance.

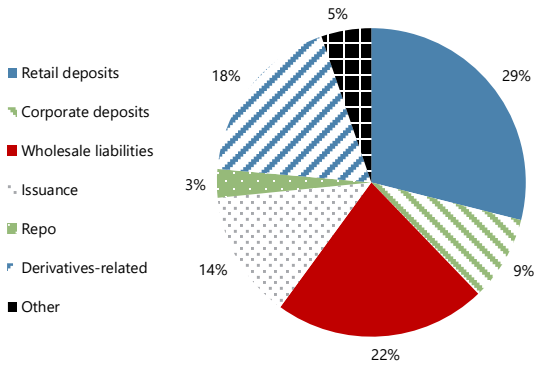
[62] The LCR requirement is binding at the aggregate level and not by significant currency in accordance with CRR.

[63] The FSAP team developed Matlab codes to carry out all liquidity stress tests. The coverage of the entire banking system and consideration of a broad range of stress scenarios was possible thanks to the advanced IT infrastructure at the OeNB.

[64] NSFR is still not binding from a prudential perspective but phased in for full implementation by June 2021. For monitoring purposes, banks are reporting NSFR calculations and authorities use EBA published proxy weights for the calculation of NSFR. Therefore, until the finalization of the relevant weighting scheme, a proxied metric is being monitored.

[65] Asset and liability derivative positions are mostly linked FX and cross-currency swaps and they seem to be balanced.

Figure 13. Austria: Funding Mix Profile of the Banking System
(In percent)



Sources: OeNB, IMF staff estimates.

C. LCR-Based Tests

70. The LCR metric measures the ability of banks to meet liquidity needs in a 30-day liquidity stress scenario by using a stock of unencumbered high-quality liquid assets (HQLA). With a regulatory standard of 100 percent, the FSAP calibrated three scenarios to measure banks' ability to withstand a 30-day stressed run-off rate against the run-off rate prescribed by the regulator for the standard LCR calculation. The first scenario considers stressed run-offs on retail deposits, due to an elevated level of retail withdrawals. The second scenario uses increased run-offs on wholesale sources of funding, especially on wholesale and corporate demand deposits. The third scenario combines the stressed run-off parameters of the first two tests and includes an additional decline in the price of liquid assets. This scenario is less likely, given that stress factors are applied in parallel for most funding segments across all banks. A summary of the assumptions underlying the three scenarios and their deviations from the regulatory LCR parameters can be found in the Annex VI.

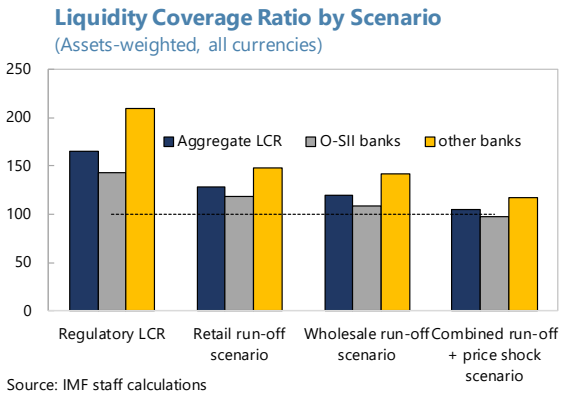
71. The results of the LCR-based stress tests show that the Austrian banking system is resilient to sizeable withdrawals of funding (Figure 14). The asset-weighted average LCR of 164.7 percent (and outflows-weighted average of 148 percent) is well above the regulatory minimum and remains above 100 percent for both retail and wholesale funding outflows scenarios (at 128 and 119.5 percent, respectively, when asset-weighted). Under the third ("severe") scenario which also includes a market price shock, the average LCR declines to 104.3 percent. The OSII banks have smaller liquidity buffers than the non-systemic institutions, with the average LCR for the OSII banks falling below the 100 percent threshold only in the third scenario. Nevertheless, even in this less plausible scenario, the weighted-average OSII LCR remains very close to the regulatory minimum.

72. The LCR-based tests were also performed for significant currencies. The EUR LCR declines from 145.8 percent under the regulatory definition to 96.9 percent under the severe

scenario. The system-wide U.S. dollar LCR average, at 56.6 percent, is already at the starting level below the 100 percent monitoring mark, and it decreases to 44.1 percent in the severe scenario. However, the U.S. dollar is not a significant currency for the Austrian banking system and the overall size of U.S. dollar outflows, amounting to 6.1 billion in the severe scenario, remains manageable from a systemic perspective. Overall, there appears to be ample space for banks to accommodate outflows under stress, given the stable deposit-based funding structure, ample security holdings, and significant short-term inflows from the loan book.

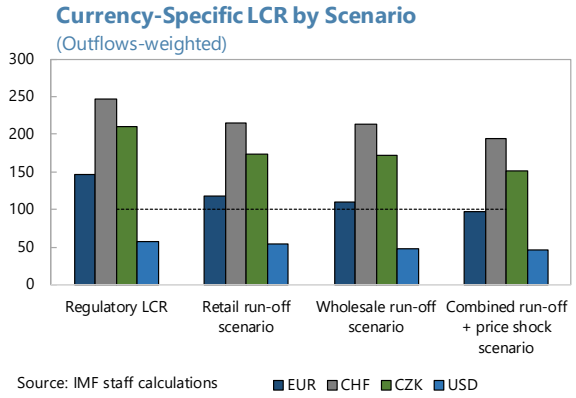
Figure 14. Austria: Liquidity Stress Test Results: LCR Analysis

The aggregate LCR stress tests suggest the banking system is resilient to sizable liquidity shocks.



Source: IMF staff calculations

USD LCR is below the 100 percent threshold, but dollar outflows are small relative to system's liquidity buffers.



Source: IMF staff calculations

D. Cash-Flow Analysis

73. The cash-flow analysis is based on the assessment of banks' ability to withstand liquidity outflows using their counterbalancing capacity. The analysis used information from the contractual maturity ladder for assets and liabilities and considered a longer duration of stressed liquidity conditions of 3 months. For that purpose, the highest levels of roll-over needs by liabilities segment during a forward-looking 3-month period were identified and applied in the stress test.

74. The FSAP considered a broad range of severity scenarios, each associated with a different set of run-off rates and haircuts on liquid asset. The severity of the scenario in the cash flow tests is defined by a set of run-off rates on the liability side and by a set of fair value and discount haircuts on the liquid assets side. With increasing severity, higher run-offs are applied to the respective estimates of roll-over needs, and an overall funding shortfall is estimated. Partial utilization of existing off-balance sheet credit or liquidity commitments is also accounted for. The counterbalancing capacity is then measured by estimating the ability to generate additional liquidity across all liquid asset classes after applying the scenario-specific fair value and collateral haircuts. In the final step, resulting counterbalancing capacity is compared to funding needs and a liquidity surplus or shortfall is established for the specific scenario. For each scenario a full collateral revaluation is performed, including also collateral that is used for repo and reverse repo

transactions. Detailed run-off rates, market and discount haircuts for liquid assets underlying three representative scenarios are presented in Annex VII**.**

75. The cash flow test assumes that banks continue to provide credit to the real economy. Under this approach (and contrary to what is commonly used in regulatory metrics focusing on bank-specific shocks such as the LCR) roll-over rates of maturing retail and corporate loans are assumed to be 100 percent, i.e. banks are not allowed to counterbalance outflows by not extending new credit to the real economy during the liquidity stress episode. This assumption increases severity of banks' liquidity needs and can be thought of as corresponding to the objective of the stress test which is to ensure that banks have enough balance sheet capacity to continue lending under stress. Additionally, the cash flow test accounts for second-order effects from reduced asset valuations, which can lead to margin calls for existing collateralized funding positions.[66]

76. Results of the cash flow-based test confirm the system's resilience to large liquidity shocks. Figure 15 presents results for three stress scenarios, representative of the severity range applied in the cash-flow analysis. The cash-flow analysis identifies small liquidity shortfalls for some small banks under the severe scenario (which considers very large, albeit extreme, wholesale funding outflows and declines in prices of some asset classes). However, even in this extreme case, the combined liquidity shortfall of EUR 1.5 billion is of a manageable magnitude given OeNB's ability to provide liquidity to the system either through standard facilities or through extraordinary measures. The aggregate net liquidity position, defined as the counterbalancing capacity minus net outflows (inflows minus outflows) during the stress horizon, of the banking system remains positive across scenarios: it declines from the initial 21 percent of system assets to a sound level of 8.8 percent in the severe scenario. Overall, banks' ability to withstand liquidity shocks can be attributed to the elevated level of high-quality securities holdings and the stable funding mix, which is dominated by customer deposits.

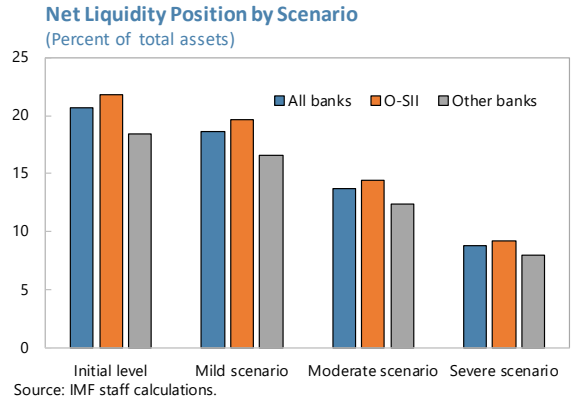
E. Liquidity Support in the IPS Scheme

77. The cash flow-based test was used to evaluate the role of the IPS scheme in providing liquidity support in the Raiffeisen sector and its resilience. This additional exercise was possible thanks to the system-wide coverage of liquidity stress tests. The cash flow-based test was repeated in a scenario that assumes no additional IPS liquidity protection. Under this scenario, individual Raiffeisen banks withdraw contributions from the IPS network and all contractual obligations to support other institutions in the Raiffeisen system are assumed to be terminated. In this scenario, banks can only rely on their own liquidity buffers.

[66] This does not account for a full repricing of derivatives positions due to underlying price adjustments. The latter task would require far more granular data on the derivatives positions and their sensitivities and was not within the scope of the FSAP liquidity stress test. Finally, for collateral eligible for central bank operations, collateral haircuts are anchored to standing liquidity facilities haircuts of the ECB and it is assumed that these haircuts will be maintained at a constant level during the entire liquidity stress period.

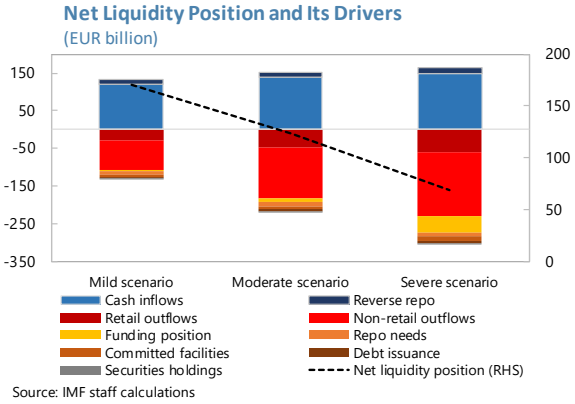
Figure 15. Austria: Liquidity Stress Test Results: Cash Flow Analysis

The cash-flow stress tests also point to ample liquidity buffers…



Source: IMF staff calculations.

…with non-retail funding the key driver of total outflows in the scenarios considered.



Source: IMF staff calculations

78. The IPS structure can resist severe liquidity shocks and enhances the banking system's resilience to liquidity risks. In the severe scenario, some regional IPSs have a liquidity shortfall. However, the additional liquidity buffers at the federal IPS layer are adequate to support all liquidity shortfalls of the regional IPSs (Figure 16). The results of the additional exercise show that in the absence of IPS support, the combined liquidity shortfall in the banking system increases to EUR 1.7 billion (compared to 1.5 billion with support arrangements in place) but remains small relative to the size of the system. In other words, although the IPS increases the overall resilience to liquidity shocks, the banking system can withstand a prolonged period of adverse liquidity conditions even without it.

F. Exploratory NSFR Stress Test

79. As part of the exploratory analysis, the FSAP team also performed a NSFR stress test. During the first stage of this analysis, an proxy metric for the NSFR metric was computed based on the figures reported by banks in the NSFR monitoring templates and using the EBA weights that are commonly used for such monitoring exercises.[67] At a second stage of the exploratory analysis, a simple stress was applied by assuming the funding market remains dysfunctional for a year, during which banks could not effectively roll-over long-term liabilities providing Available Stable Funding (ASF). As a result, ASF liabilities maturing during the next four quarters were assumed to be rolled-over as short-term liabilities. Furthermore, some migration of outstanding balances of ASF segments with maturities above one year into the Q1, Q2, Q3 and Q4 maturity buckets was assumed to mimic historical volumes.[68] The stressed NSFR is then calculated using the original set of volumes for items

[67] Up to this stage the approach (and the results) were identical with the results produced by OeNB as part of their standard NSFR monitoring exercise.

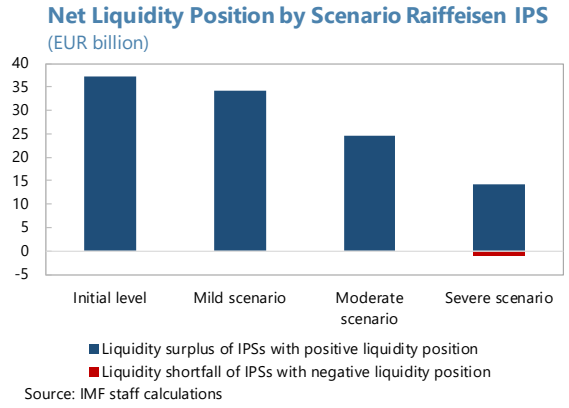
[68] And to the extent that the available over one-year balances were sufficient to enable such redistribution.

Required Stable Funding (RSF) and original proxy weights, but stressed values for items providing ASF.

80. The asset-weighted aggregate NSFR[69] stands at 122 percent and remains well above the 100 percent target under stress (Figure 16). While only a small proportion of the system (2.2 percent of system assets) has an NSFR below 100 percent, this relative share increases substantially (to over 28 percent of system assets) under stress. Importantly, however, the system-wide NSFR, at 112 percent, remains well above the 100 percent target. Overall, the asset-weighted stressed NSFR remains comfortably above the target under the stress scenario, even as the NSFR will only come into force in 2021Q2.

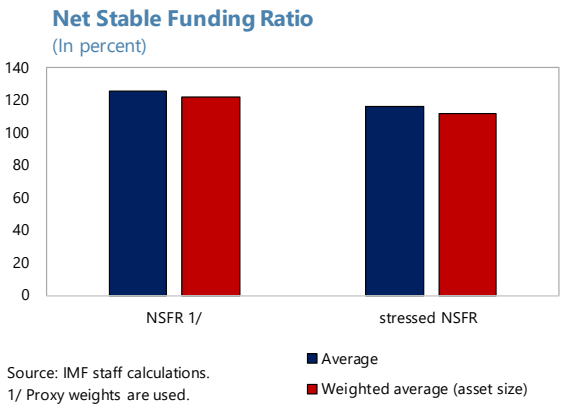
Figure 16. Austria: Liquidity Stress Test Results: IPS Scheme and NSFR-proxy Analyses

The Raiffeisen IPS scheme can satisfy its members liquidity needs also in the most adverse scenario.



Source: IMF staff calculations

The NSFR remains high under stressed conditions, thanks to the stable funding structure of the banking system.



Source: IMF staff calculations.
1/ Proxy weights are used.

G. Policy Recommendations

81. The rich liquidity stress testing toolkit can be further enhanced along the following dimensions:

- Further develop systemic liquidity components end enhance the macroprudential angle. This could include development of approaches or calibration of parameters that deviate significantly from the microprudential angle (where risks are idiosyncratic) as appropriate assumptions on run-offs and haircuts for a systemic liquidity episode may be different from the ones currently used in the microprudential approach.

- Enhance the forward-looking aspects of the cash-flow analysis toolkit by carefully assessing cliff effects over time bands. Using the last reporting date as a snapshot of the contractual

[69] As the calibration is not yet finalized, a proxy was used for this analysis.

liquidity profiles might lead to accepting blind spots that can be critically impairing the assessment of overall resilience.

- Enhance the granularity of the data on the asset side, as regards encumbrance, eligibility for central bank liquidity facilities and fair value quality characteristics (duration, issuer credit quality, present haircuts etc.). This would further facilitate the development of a layer dealing with second round effects (fire sales, realistic modelling of market haircuts, simulation of policy decisions of the LoLR etc.).

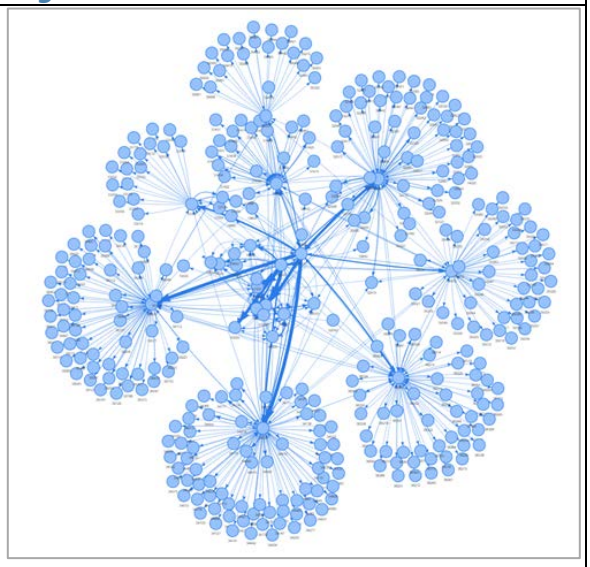
- Fully integrate the analysis on the liquidity support buffers due to the IPS structures in the standard liquidity analysis by defining and quantifying the impact of IPSs on systemic liquidity for a distinct set of support scenarios for failing IPS members.

CONTAGION ANALYSIS

A. Overview

82. The Austrian banking system is heavily tiered and clustered (Figure 17).[70] There are a few important central nodes and many smaller banks. This reflects the tiered structure of the banking system which reflects the importance of the cooperative banking sector. Network density is relatively moderate given limited inter-cluster connectivity. The focal nodes in the network are identified as the central institution of the liquidity associations within the decentralized sectors. Affiliated members are required to hold a liquidity reserve at the central institution which is distributed to the banks when they require liquidity. The liquidity reserves are bankruptcy remote under resolution. This poses challenges for the network analysis as liquidity reserves cannot be netted out from counterparties' gross exposure in the cooperative sector based on the central credit registry data.

Figure 17. Austria: Interbank Network 1/



Source: OeNB, FSR Dec. 2019.
1/ The edges are shown for interbank exposures above EUR 25 million on a consolidated level. Therefore, intragroup exposures in the savings sectors are netted out.

B. Domestic Interconnectedness

[70] See Puhr et al (2012) for a description of the topology of the Austrian banking system using unconsolidated interbank data from the Austrian credit registry.

83. A network analysis module is used to assess direct contagion in the banking sector arising from individual hypothetical defaults. A bank's induced failure leads to the default on all its interbank obligations. A failing bank can also cause liquidity strains to its borrowing counterparties from forced fire sales needed to replace lost funding. This increases the potential for indirect defaults to cascade through the interbank market. The subsequent defaults are assumed to materialize when a bank breaches its minimum capital requirement. Based on the Austrian regulatory framework, this occurs when a bank's total capital adequacy ratio drops below 4.5 percent of total risk-weighted assets. The model assumes two channels of distress (Annex VIII):

- If the default of any given bank leads to the default of at least one other bank in the system, a subsequent contagion round is simulated and impact of the second bank's default on all other banks is assessed, and so on (i.e., "cascade effects").

- In addition to the direct loss of capital stemming from a second bank's exposure to the failing institution, the affected bank can suffer further losses if it needs to replace a fraction of funding lost due to the failure of the first bank by selling assets at a discount. A caveat of this analysis is that it does not consider interbank netting arrangements which could soften the impact from contagion.

84. The analysis is conducted on consolidated gross exposures based on central credit registry data. The dataset covers all credit instruments with a volume above EUR 350,000, including outstanding volume of loans, guarantees and commitments but excludes equity instruments. Exposures to affiliated banks within the cooperative sector were deducted for the purpose of the exercise, as a significant amount of credit exposures are linked to the liquidity reserve held at the central institution. The analysis assumes a 30 percent discount in the fire sale of assets, a 65 percent roll-over ratio of interbank liabilities, a 80 percent recovery rate for secured interbank lending, and a 50 percent recovery rate for unsecured lending (Table 3). A sensitivity analysis was performed to capture the role played by the network structure of the Raiffeisen sector by including all exposures among affiliated banks. A caveat of the analysis is that it does not include equity exposures which would amplify interbank losses.

Table 3. Austria: Network Analysis Parameters Calibration

Parameter/Variable	Description
λ1=0.5	50 percent LGD on unsecured lending
λ2=0.2	20 percent LGD on secured lending
ρ=0.35	Share of lost funding that is non-replaceable
δ=0.3	30 percent discount on asset sales
capital	CET1 capital under Basel III
bank default	CET1 capital falls below 4.5 percent

85. Results are very sensitive to the treatment of exposures in the cooperative sector. When the network structure is based on gross bilateral exposures (including exposures across affiliated entities), both the contagion and vulnerability indices are considerably higher, as expected.[71] The maximum contagion index for the group of OSII banks calculated on gross exposures amounts to 41 percent of total capital (unweighted), with the median bank contagion OSII being 1.1 percent (Figure 18). Excluding exposures across affiliated entities, maximum contagion falls to 1.2 percent of system capital, while median contagion decreases to 0.5 percent. The effects are highly skewed pointing at the key role played by the central institution in the decentralized Raiffeisen sector.

C. Cross-Border Interconnectedness

86. The FSAP team examined interbank cross-border contagion of Austrian banks using the CoMap methodology.[72] The analysis studied the impact from counterparty default risk and liquidity pressures from linkages to domestic and international banks. In contrast to the standardized parameters used in the domestic contagion analysis, bank specific calibrated parameters were used to measure banks' systemic importance and their degree of fragility (for example, banks' funding rollover needs and liquidity buffers).

87. Results suggest that outward and inward spillovers between Austrian banks' and foreign banks in the CESEE and EA are limited. This is partly driven by the exemptions in the LE regulatory reporting template which eliminate most exposures among affiliated parties in the decentralized sectors, as well as cross-border intragroup exposures. The results indicate also that liquidity buffers held by Austrian banks limit the extent of contagion from the default of a funding counterparty in Austria. Specifically, the median contagion index from Austrian OSII banks to the Austrian banking system is estimated at 0.83 percent, though with a wide distribution, as the contagion at the 10th and 90th percentile is 0.5 and 2.1 percent, respectively. The non-OSII sample shows negligible contagion effects. Looking at cross-border interbank contagion effects, results suggest that outward spillovers to the CESEE are limited to a few Austrian banks, whereas the median contagion from Austrian OSIIs to the EA is low at 0.12 percent capital depletion. Inward spillovers to Austrian banks from hypothetical outright bank defaults in the CESEE and Italy are negligible.[73]

[71] The index of contagion shows the percent of total capital impairment in the banking system due to the failure of each bank. The index of vulnerability is the average percent capital impairment for a bank due to the failure of other banks.

[72] The analysis was based on Gorpe et al (2019).

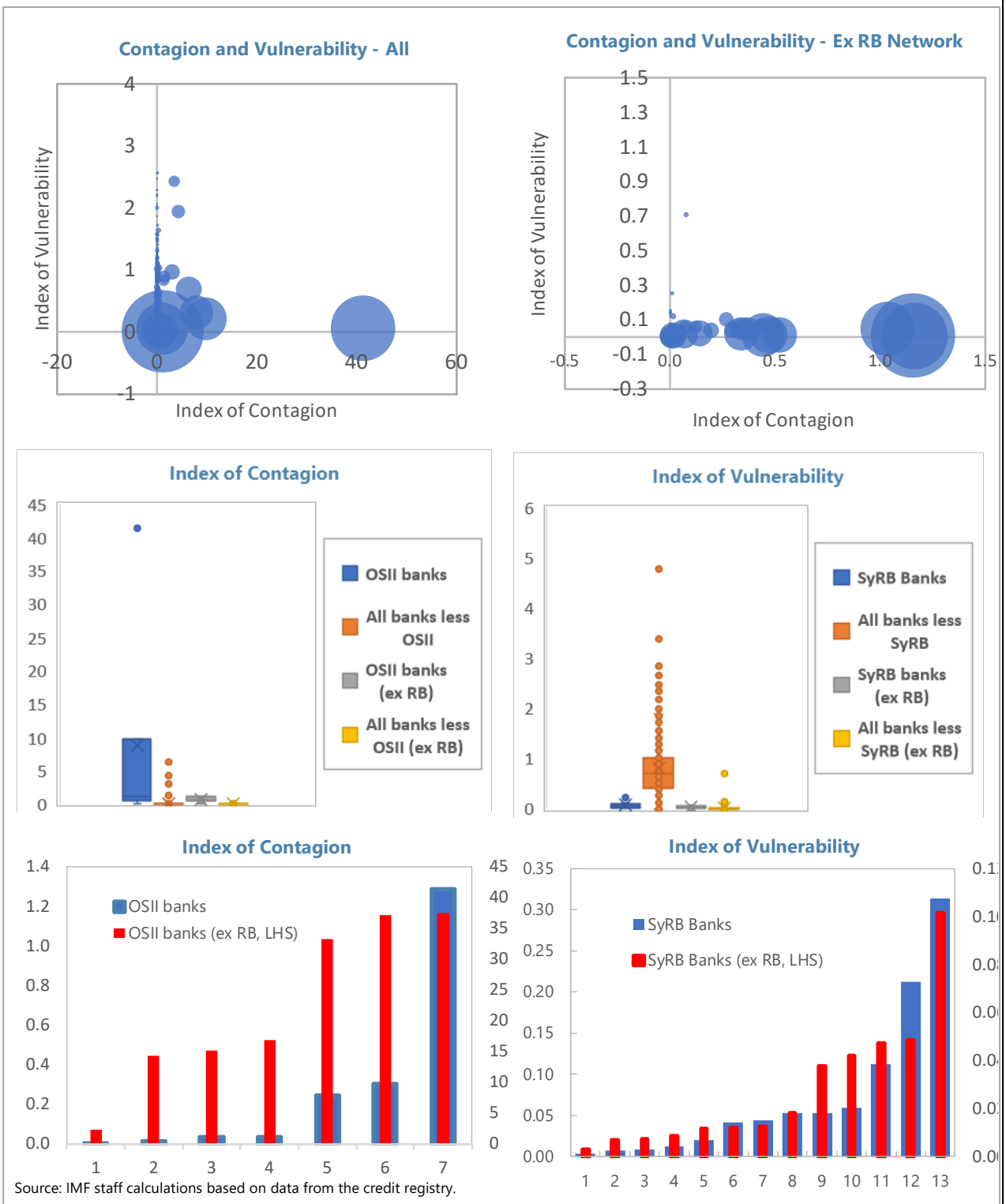
[73] Results should be interpreted with caution as the CoMap approach was applied at the consolidated level, and hence excludes intragroup contagion.

D. Policy Recommendations

88. A more precise picture of contagion and vulnerability inherent in the system could be obtained by conducting network analysis on a detailed breakdown of exposures by instrument. The two scenarios elaborated above provide results based on two extreme assumptions: one in which all exposures within the Raiffeisen sector are subject to default, and one in which no exposures are lost within the Raiffeisen network. In an exercise closer to reality, only liquidity reserves would be excluded from counterparty credit risk, i.e. those held at the central institution. At the same time, equity exposures should be included in the exercise. The value of these augmented "net" exposures should be monitored closely over time, possibly on a quarterly basis, and should feed into the network analysis to monitor changes in contagion and vulnerability over time.

Figure 18. Austria: Network Analysis 1/

(Percent)



Source: IMF staff calculations based on data from the credit registry.

1/ The size of bubbles is proportional to the individual banks' capital. "Ex-RB" in panels denotes results calculated based on exposures net of bilateral exposures in the Raiffeisen network. OSII refers to "Other systemically important institutions" whereas SyRB denotes banks subject to the "Systemic risk buffer". The acronym "RB" denotes exposures among IPS members in the Raiffeisen sector.

Annex I. Austria: Risk Assessment Matrix

Nature (Source) of Main Threats	Overall Level of Concern	
	Likelihood of Realization of Threat in the Next 1–3 Years *(high, medium or low)*	**Expected Impact on Financial Stability if Threat is Realized** *Risk assessment: high, medium, or low)* *Supervisory assessment: amplifying (A), neutral (N), or mitigating (M)*
1. Contagion from CESEE countries (Regional)	**Medium** • CESEE countries are subject to boom-bust cycles. They are vulnerable to a deterioration in investor sentiment, asset volatility, capital outflows, FX swings, and geopolitical risk. • Some countries are exposed to a sharp decline in commodity prices and waves of international sanctions. • Concerns over the adequacy of AML controls on foreign branches and subsidiaries within CESEE countries exposes Austrian banks to operational and reputational risk.	**Risk Assessment: High** • Austrian banks' exposure to the CESEE region reached 24 percent in 2018. Foreign currency loans represent 25 percent of exposures (80 percent EUR, 10 percent in CHF, 9 percent in USD). Austrian banks source 42 percent of profits from CESEE. • A sharp slowdown in CESEE countries, and FX depreciation would lead to higher NPLs and lower profitability. • Breaches of AML obligations can lead to fines and sanctions increasing operational risk expenses, lower equity market valuations, and a spike in funding costs. **Supervisory assessment: Neutral** • Banking sector oversight: Weak requirements on transactions with related parties, major acquisition, and financial integrity add risks from CESEE exposures. (**A**) • Macroprudential: SyRB for CESEE cluster risk increases capital resilience. (**M**) • Crisis management: MPE for two large international banks reduces the potential to spread contagion. (**M**)
2. Sharp rise in risk premia (Global)	**High** • An abrupt deterioration in market sentiment (e.g., prompted by policy surprises, renewed stresses in emerging markets, or a disorderly Brexit) could trigger risk-off events such as recognition of underpriced risk. • Higher risk premia would cause higher debt service and refinancing risks; stress on leveraged firms, households, and vulnerable sovereigns; disruptive corrections to stretched asset valuations; and capital account pressures—all depressing growth.	**Risk Assessment: Medium** • Higher interest rates would increase borrowers' income gearing and refinancing risks particularly for high-leveraged firms and households. The effect would be larger for borrowers with variable-rate loans: 80 percent (44 percent) of new loans for corporates (households). • Significant asset price changes would impact the fair valuation of banks' financial investments. **Supervisory assessment: Neutral** • Banking sector oversight: Oversight of NPLs and foreborne exposures has strengthened but a look-back approach to default risk could hinder timely supervisory action. (**A**) • Macroprudential: the timely activation of the CCyB would help increase bank resilience through the cycle. (**M**) • Crisis management: Banks' recovery plans are mature and tested. (**M**)
3. A sudden correction in the Austrian real estate market (Domestic)	**Medium** • Real estate prices have increased rapidly in Austria over the last 5–6 years and are estimated to be overvalued by around 10-15 percent. • The share of foreign currency housing loans is high compared to Austria's peers.	**Risk Assessment: Medium** • A drop in real estate prices, would result in higher impairment charges for banks, caused by defaults or delayed loan repayments by highly leveraged households and construction firms. • Lower house prices could depress domestic demand through reduced consumption, hitting banks' profits further.

Nature (Source) of Main Threats	Overall Level of Concern	
	Likelihood of Realization of Threat in the Next 1–3 Years *(high, medium or low)*	**Expected Impact on Financial Stability if Threat is Realized** *Risk assessment: high, medium, or low)* *Supervisory assessment: amplifying (A), neutral (N), or mitigating (M)*
	• There have also been signs of easing in banks' lending standards in household loans with an increase in high risk mortgages (high LTV and DTI ratios).	• The impact is lessened by the low exposure of Austrian banks to housing loans in Austria at 16 percent of assets. **Supervisory assessment: Mitigating** • Banking sector oversight: FMA minimum standards of the granting of FX and RPV loans (2013), revised in 2017, helped decrease default risk in mortgage loans. (M) • Macroprudential: 2018 FMA's guidance on sustainable lending standards in real estate financing has strengthened bank supervisory dialogue to prevent a deterioration in underwriting standards. (M) • Crisis management: A synchronized decline in regional real estate prices could spread contagion through the DGS system. (A)
4. Weaker-than-expected global growth (Global)	**Medium** • Idiosyncratic factors in the U.S., Europe, China, and stressed emerging markets feed off each other to result in a synchronized and prolonged growth slowdown: • U.S.: Confidence wanes against a backdrop of a long expansion with stretched asset valuations, rising leverage, and policy uncertainty, leading to weaker investment and a more abrupt closure of the output gap. • Europe: Weak foreign demand, Brexit, or concerns about some high-debt countries makes some EA businesses delay investment, while faltering confidence reduces private consumption. Inflation expectations drift lower, and the region enters a prolonged period of anemic growth and low inflation. • China: In the near term, further escalation in trade tensions not only reduce external demand, disrupt supply chains, and depresses confidence and investment, but potentially also trigger tighter financial conditions, a sharp downturn in the property market, renewed PPI deflation, and a drop in commodity prices. In the medium term, weaker external demand, the potential reversal of globalization, and the increasing role of the state could weigh on growth prospects. Moreover, excessive policy easing—reversing progress in deleveraging and rebalancing—increases risks over time of a disruptive adjustment or a marked growth slowdown. • Large stressed emerging economies: Policy missteps, idiosyncratic shocks, and/or contagion prevent expected stabilization or recovery in stressed economies from materializing, generating negative spillovers and reducing global growth.	**Risk Assessment: Low** • A widening in Italian spreads would depress asset valuations of Italian government bonds, even though Austrian banks' exposure to Italy is limited (1.3 percent of total foreign claims). Another channel of contagion is through funding markets as the third largest Austrian banks is a subsidiary of an Italian G-SIB. Adverse developments in Italy could lead to financial distress through higher funding costs. • Austria is a very open economy, with exports comprising more than 50 percent of GDP. Therefore, any retreat from cross-border integration, trade dispute or a deepening of geopolitical uncertainties, can pose material downside risks to Austrian output. A balance-sheet recession in Austria would depress disposable income, increase affordability risk (particularly for export-driven corporates), and lead to higher default rates. • Persistent low interest rates would erode bank margins and become a major threat for life insurance companies, given their rate-sensitive products and investments. **Supervisory assessment: Amplifying** • Insurance sector oversight: Implementation of risk rating and stress testing methodologies need clear steer. (A) • Macroprudential: SyRB for systemic vulnerability and O-SII buffer increase capital resilience. (M) • Crisis management: A unified, single resolution process for a major Austrian bank with an Italian parent (SPE) could lead to a downgrade in its credit profile. (A) • Banking sector oversight: A weak framework for country risk and transfer risk could add losses from events in foreign countries. (A)

Bank Solvency Stress Testing

Domain		Assumptions
		Top-down by FSAP team
1. Institutional perimeter	Institutions included	• All Austrian credit institutions both directly supervised by the ECB (six SIs) plus one subsidiary of a foreign SI) and directly supervised by the Austrian authorities (433 LSIs).
	Market share	• For the 7 SIs, about 60 percent of banking sector assets • For the entire 440 institutions, above 95 percent of total assets of deposit-taking institutions in Austria
	Data and baseline date	• European and Austrian regulatory returns and supervisory data (e.g. FINREP and COREP) • OeNB's statistical data warehouse • Austrian Central Credit Register (CCR) and external data sources (Kreditschutzverband, KSV) • Moody's Analytics: CreditEdge data on corporate default probabilities • Data as of December 2018 • Scope of financial consolidation: group-wide
2. Channels of risk propagation	Methodology	• Balance sheet approach • Projections of key balance sheet, income statement and capital account items • Static balance sheet assumption • The exercise will not provide separate accounting projection layers for impairments. Only 19 entities from the sample report under IFRS 9 with the remaining reporting under national GAAP • Credit risk, market risk, net interest income and non-interest income projections will be produced for all banks for two scenarios: baseline and macro adverse • Indirect credit risk emanating from foreign currency loans and repayment vehicles is stressed for CHF, JPY, USD and EUR (for countries where the EUR is a foreign currency but also for domestic RV loans). • Participation risk also accounted for, based on OeNB's internal entity equity participation matrix • Granular projections of credit risk parameters are performed, including exposures at default (EADs), probabilities of default (PDs) losses given default (LGDs) for each asset class and geography

Domain		Assumptions
		Top-down by FSAP team
		• Different asset class segmentation was used for SIs and LSIs. SIs segments were based on COREP segmentation and LSI segments were mapped to a CCR relevant segmentation that also included a more granular breakdown of corporate exposures based on NACE classification. Satellite models were mapped in accordance with the dual segmentation approach (a generic corporate satellite model can be used to drive PD paths for multiple NACE segments with different starting points). • Net interest income is projected based on its sensitivity to macrofinancial conditions for both reference rates and effective spread margins across all interest rate sensitive asset and liability segments and all material exposure geographies. The approach is similar to the one used in the EBA exercise and is considered to be conservative for the interest rate scenario, however, some additional assumptions on repricing profiles are needed given the absence of bottom up data. • Net trading income, net fee and commission income will be stressed based on its historical volatility in combination with haircuts based on the EBA methodology. • Operational expenses are kept at the starting point level through all scenario years (an exponentially smoothed historical average, validated by line supervisors). • The impact on P&L and OCI due to FVTPL and FVOCI positions is also estimated as part of the market risk impact. Debt securities at Amortized Cost portfolios are not stressed. • The mark-to-market approach is used to assess the impact of equity prices and commodity prices on net open positions. • Risk weighted assets are adjusted to reflect changes in the quality of credit exposures.
	Satellite models for macrofinancial linkages	• In the absence of reliable historical default data, a structural model approach, partially relying on DSR/LTV exposure joint distributions and Monte Carlo simulations for house price developments, is used to estimate PDs and LGDs for mortgage exposures across geographies. • Bayesian Model Averaging (BMA) techniques are used to produce satellite projections for the corporate sector across geographies. Cross-sector or cross-country proxies are also used for the projection of parameters where a direct calibration is not feasible due to data constraints or for sectors of very low materiality.

Domain		Assumptions
		Top-down by FSAP team
3. Tail shocks	Stress test horizon	• Three years (2018 Q4 – 2021 Q4).
	Scenario analysis	• Based on two common macroeconomic and financial scenarios (baseline and macro adverse). • The scenarios specify key macrofinancial variables (e.g., real GDP growth, inflation rate, unemployment rates, exchange rates, equity prices, house prices, interest rates and credit growth) for Austria and important geographies/countries, as well as global variables (e.g. commodity prices). • The baseline scenario is based on July 2019 World Economic Outlook (WEO) projections. • The macro adverse scenario is calibrated using the Global Macrofinancial Model (GFM) model assumes the materialization of the systemic risks highlighted in the RAM. Financial instability can materialize from a confluence of risk triggers including contagion from CESEE countries; a sudden sharp tightening in global financial conditions; a correction in real estate prices in Austria; and a slump in global growth. The scenario features a financial cycle downturn with FX market disruptions, and sovereign stress generating a balance-sheet recession in Austria and the CESEE region. In terms of severity, it implies a deviation of Austria real GDP from its baseline of 6.9 percent by 2021, with a 2.3 Standard Deviation move in two-year cumulative real GDP growth rate, and a 20 percent peak-to-trough decline in real estate prices. Output shocks in the CESEE region range between 8.1 and 12.6 percent deviation from baseline.
	Sensitivity analysis	• A Low-for-Long interest rate scenario was used as the adverse interest scenario in a sensitivity analysis focusing on low structural profitability concerns. • A series of reverse stress tests are performed in to evaluate and asses the relative resiliency of IPSs and to identify the tipping point for each one of them. • Complementary simulation analysis of the Raiffeisen bank inverse ownership structure will be used to measure the impact of participation risk and to identify the levels of stress that could cause sever inward spillovers.
4. Risks and buffers	Risks/factors assessed (how each element is derived, assumptions)	• Credit risk captures all on-balance/off-balance sheet exposures at amortized cost by regulatory exposure sector and geography. Different paths are produced for different sector/geography combinations. • The starting point of credit parameters is also used to project scenario dependent forward paths.

Domain		Assumptions
		Top-down by FSAP team
		• Market risk is reflected in valuation effects of FVTPL and FVOCI positions, as well as net open financial positions (i.e., equities, and commodities). Interest rate curves based on the two scenarios are used to infer interest rate changes by country. The adverse macro scenario is further augmented to include financial variables that are needed to produce accurate projections for fair value positions.
		• Net interest income is affected by projecting effective interest rates by asset/liability class and geography. A time to repricing approach, based on fixed/variable rate break-down
		• and using the point in time repricing ladder informs further the velocity of passthrough rates. • Shocks to non-interest income are simulated to capture varying degrees of market-sensitive components of non-interest income. • Credit exposure concentration risk is also assessed, taking into account market structure specificities.
	Behavioral adjustments	• Under the static balance sheet assumption exposures remain constant and do not evolve in accordance with credit growth assumptions of scenarios. This is an assumption imposed by infrastructure driven constraints. • For NII, maturing assets/liabilities are assumed to be replaced by instruments of the same type, maturity but at current rates. • If banks' capital falls below regulatory requirements, no prompt corrective action is assumed. • Banks are assumed to pay a fixed share of 30% of their profits, if positive, in taxes and another 30% as dividends to shareholders. • One-off adjustments made by OeNB line supervisors as part of the OeNB's annual stress testing exercise will be accepted to warrant a uniform starting point at T0.
5. Regulatory and market-based standards and parameters	Calibration of risk parameters	• Scenario dependent forward paths for PiT PDs and LGDs are estimated for each asset class and geography. • It is assumed that prudential expected losses will coincide with accounting impairments, therefore, the accounting layer is ignored.
		• Given the limited availability of PiT LGD data, some very basic proxies are used.

Domain		Assumptions
		Top-down by FSAP team
		• For internal ratings-based (IRB) exposures, risk-weight assets are projected based on updated regulatory TTC PDs and downturn LGDs, using appropriate scaling multipliers from the PiT parameters. • For standardized approach (STA) exposures, risk-weight assets are assumed to remain constant.
	Regulatory/accounting and market-based standards	• In the baseline, hurdle rates include the regulatory minimum and all applicable buffers. • In the adverse scenario, the regulatory minimum is assumed to be the hurdle rate, i.e. all buffers can be drawn-down. • Hurdle rates are based on the common equity tier-1 ratios.
6. Reporting format for results	Output presentation	• System-wide evolution of CET1 capital ratios. • Distribution of banks' capital positions • Contribution to key drivers to system-wide net income and capital position, including differences between the baseline scenario and the adverse scenario. • Share of institutions with capital below the hurdle rates. •
7. Infrastructure used	Output presentation	• OeNB's ARNIE infrastructure is used to account for the extended bank sample and the cross-entity equity participations (inverse ownership). • IMF team's satellite model projections are imported as an external overlay into ARNIE. • Banks' credit and interest rate starting point parameters were validated using IMF staff estimates and in some cases a scaling factor was applied to the satellite model to anchor projections better with regulatory or historically observed parameters. • Starting point translation into scenario dependent forward paths for individual banks and segments follows the IMF guidelines (absolute shift, distance to defaults or similar type of translation).

Bank Liquidity Stress Testing

Domain		Assumptions
		Top-down by FSAP team
1. Institutional perimeter	Institutions included	• Seven SIs, and 433 Austrian LSIs
	Market share	• For seven SIs, about 60 percent of banking sector assets • For all 440 entities (including the 7 Sis), above 95 percent of total assets of deposit-taking institutions
	Data and baseline date	• ECB/SSM and OeNB: regulatory returns based on the Liquidity Coverage Ratio and the Net Stable Funding Ratio and Additional Liquidity Metrics from the FINREP/COREP data repository • Data as of December 2018 • Scope of financial consolidation: group-wide
2. Channels of risk propagation	Methodology	• The exercise is based on three types of tests—LCR test, cash-flow analysis and NSFR test. • The LCR test is in line with the standard Basel monitoring tool, featuring total liquidity and liquidity in all significant currencies (Euro, Swiss Franc, US dollar and CESEE currencies). • The cash-flow analysis analyzes the net cash balance, accounting for available unencumbered assets, contractual cash inflows and outflows, and behavioral flows. • For the cash-flow analysis, relevant second-round effects could be considered, including margin calls for existing collateral positions, central bank's liquidity provision, additional asset haircuts due to fire sales, additional repo haircuts due to limited collateral supply, and wholesale funding market freezes because of banks' solvency and liquidity concerns. • NSFR reporting is still used for monitoring purposes (non-binding). The analysis reports recent NSFR statistics but also introduces standard parameters for the calculation of stressed NSFR. • The IPS structure was taken into account -to the extent possible- when assessing liquidity under stress. Regulatory liquidity waivers were considered, and the mandatory interbank deposits of Article 27(a) of the Banking Act were reallocated to the depositing entities, increasing their counterbalancing capacity.
	Satellite models for macrofinancial linkages	• For the cash-flow analysis, asset haircuts reflect two components: (i) shocks to interest rates and asset prices as captured the macrofinancial scenarios; and (ii) additional haircuts required by counterparties to accept specific assets as collateral for secured funding transactions.
	Stress test horizon	• For the LCR test, the stress test horizon is 30 days. • For the cash-flow analysis, the horizon of stress events would normally be 3 months. Nonetheless, a longer period of stress events (up to 1 year) may be considered as sensitivity analysis.
3. Tail shocks	Scenario analysis	• For the LCR test, twelve scenarios are considered as a combination of: (i) three scenarios on liquid assets shock (regulatory, mild and severe), and ii) four scenarios on liability outflows; regulatory, one reflecting retail outflows, one reflecting higher wholesale outflows, and one combining the retail and wholesale outflows.

Domain		Assumptions
		Top-down by FSAP team
		• For the cash-flow analysis, a series of scenarios are considered, with a range from mild to severely adverse liquidity conditions. The cash-flow analysis considers both funding and market liquidity risks. • For the NSFR analysis, only one stress scenario featuring inability of banks to roll=-over longer-term funding positions for a period of a year. (still of exploratory nature, given the smaller experience on stressed NSFR).
	Sensitivity analysis	N/A
4. Risks and buffers	Risks/factors assessed (how each element is derived, assumptions)	• Funding liquidity risk is reflected in funding run-off rates and asset roll-over rates, the latter providing cash inflows related to non-renewal of maturing assets. • Market liquidity risk is reflected in asset haircuts, which could be influenced by market movements, potential fire sales and collateral supply considerations.
	Behavioral adjustments	• Liquidity from the central bank's emergency lending assistance (ELA) is not considered. • The cash-flow analysis may consider some behavioral assumptions about a counterparty's ability or willingness to transact based on banks' solvency and liquidity conditions.
5. Regulatory and market-based standards and parameters	Calibration of risk parameters	• The LCR tests are based on regulatory and stress parameters. • The cash-flow analysis may incorporate relevant second-round effects. • Stress funding run-off rates, asset roll-over rates, and asset haircuts are calibrated based on empirical evidence and relevant international experiences.
	Regulatory/accounting and market-based standards	• LCR per Basel III; the hurdle at 100 percent (at the aggregate currency level). • Net cash balance for the cash-flow analysis; to pass, a non-negative net cash balance is required, where the balance reflects net funding outflows and counterbalancing capacity. • NSFR is not yet applicable but a targeted post-introduction limit of 100 percent was assumed.
6. Reporting format for results	Output presentation	• Changes in the system-wide liquidity position, including important drivers for cash outflows, cash inflows and counterbalancing capacity. • Distribution of banks' liquidity positions. • Number of institutions with LCR/NSFR below 100 percent and/or negative net cash balance • Amount of liquidity shortfalls, including by currencies
7. Infrastructure		• Fully comprehensive infrastructure developed my IMF staff with a FINREP/COREP data repository integrated backbone.

Network Analysis

Domain		Assumptions
		Top-down by FSAP team
1. Institutional perimeter	Institutions included	• Seven SIs, and 433 Austrian LSIs
	Market share	• For seven SIs, about 60 percent of banking sector assets • For all 440 entities (including the 7 Sis), above 95 percent of total assets of deposit-taking institutions
	Data and baseline date	• Austrian central credit registry data • Data as of December 2018 • Scope of financial consolidation: group-wide w.r.t. to Austrian subsidiaries
2. Channels of risk propagation	Methodology	• Network analysis using Furfine algorithm and Espinosa-Sole tool • Includes contagion channels from funding concentration and foreign counterparties • Cascading effects from individual defaults through credit and funding counterparties
	Linkages with solvency and liquidity stress tests	• The transmission of funding shocks is linked to liquidity stress test results by allowing banks to draw down their liquid buffers to replace funding from defaulting funding counterparties
	Buffers	• Tier 1 capital • Counterbalancing capacity
3. Tail shocks	Size of the shock	• Outright defaults
4. Sensitivity test	Factors	• Performance of collateral (for secured exposures) • Loss given default (for unsecured exposures) • Role of netting arrangements • Elimination of exposures within the decentralized Raiffeisen sector • Use of CoMap tool to account for Austrian banks' idiosyncratic calibrations and spillover risks to/from foreign counterparties using the large exposure database, gross exposure net of exemptions
5. Reporting format for results	Output presentation	• Failed capital in percent of total capital • Contagion index • Vulnerability index • Grouping of banks by OSII (for contagion index), and SyRB (for vulnerability index)

Annex III. Credit Risk Satellite Models

Probabilities of Default Modelling (PD PiTs)

1. A series of econometric models were estimated to produce scenario-dependent forward paths for point-in-time (PiT) probabilities of default (PDs) for the different exposure segments. The selection of the modelling approach was largely driven by the loans and advances segmentation and the availability of corresponding historical time series for calibration purposes. Given the very limited availability of exposure segment specific historical data and the need to ensure robustness, the calibration of PD models for the corporate and financials segments were based on historical data from a third-party provider.[1]

2. The lack of reliable historical data on mortgage and unsecured retail credit exposures was the reason for deploying a structural model for the calculation of mortgage loss rates across all material geographies. The methodological approach and the resulting models are described in Annex IV.

3. The Austrian banking is also characterized by significant levels of geographical dispersion. Banks belonging to the OSII group tend to have significant credit exposures portfolios outside Austria, as illustrated in Table III.1. This requires estimating satellite models for most segments across a large number of material geographies or countries in order to capture a substantial part of the total exposures. For the purposes of the solvency stress test, the FSAP team estimated satellite PD models for a total of 18 material geographies, which accounted to approximately a model coverage exceeding 90 percent of the exposures.

Corporate and Financials segments

4. A Bayesian Model Averaging (BMA) econometric technique was employed for modelling and projecting the default rate at the individual geography and portfolio segment levels. The BMA approach operates with a pool of equations (several hundreds or thousands) used to estimate the default rates. Weights are assigned to each equation that reflect their predictive power. This results in a "posterior model" equation.[2] The pool of equations contains equations for every single credit risk indicator (per portfolio segment and geography), by considering all possible combinations of predictors from a pool of potential predictor variables, including variables such as real GDP, investment, consumption, exports, price inflation, and short- and long-term interest rates.

[1] Historical default rates from Moody's Analytics Creditedge were used to obtain historical series for the corporate and financials segments across all material geographies considered.

[2] See Gross and Población (2017). The methodology is known as Bayesian Averaging of Classical Estimates (BACE) method; see Sala-I-Martin, Doppelhofer, and Miller (2004).

Table III.1. Austria: Geographies for Which a Model is Estimated		
1	AT	Austria
2	CZ	Czech Republic
3	SK	Slovakia
4	HU	Hungary
5	RO	Romania
6	BG	Bulgaria
7	SI	Slovenia
8	HR	Croatia
9	PL	Poland
10	RU	Russia
11	UA	Ukraine
12	DE	Germany
13	UK	UK
14	ES	Spain
15	FR	France
16	US	US
17	TR	Turkey
18	ROW	Rest of the World

5. Various techniques were used to capture PD dynamics. 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:

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

6. To estimate the impact of shocks of macrofinancial variables on PDs, the logit-transformed PDs were modeled as a linear function of the aforementioned exogenous macroeconomic and financial factors (regressors). The model specification also allows inclusion of the autoregressive lags as well as lags of the explanatory variables, to account for the backward-looking nature of credit risks.

7. The estimated conditional PD PiT forecasts for each segment estimated by the BMA models were further anchored to the aggregate (system-wide) starting point PDs to eliminate any potential overshooting attributable to the market-based nature of the historical default

rate time series.[3] Bank-specific conditional forward paths were then produced using a translation of the system-wide forward path model using an absolute shift in the PD space.

8. A wide set of explanatory variables were used for the estimation of credit risk satellite models. For both domestic and foreign credit exposures, similar set of input variables were used to explain and project PD PiTs for all segments, such as real GDP, exchange rate, inflation, unemployment rate, output gap, stock market price indices as well as outstanding private credit. Inputs other than unemployment rates are subject to quarterly growth transformation, and unemployment rate were taken as percentage point changes between periods. The sample period used for calibration ranges between 2000 and 2018, and a quarterly frequency was used in accordance with the standard method.

9. The model selection for the BMA follows several criteria. A unique benefit of the BMA approach is for the users to select different model specifications, such as the number of autoregressive lags, number of explanatory variables under permutation, and number of lags for each explanatory variable. Staff used the following five information criteria to determine the best specification for each model: R-square, the Durbin Watson statistics, number of significant variables with high posterior inclusion probability, the quality of in-sample forecast, and ultimately, the size of the impact in the forecasting period. The ideal candidate would have a relatively high R-square, a Durbin Watson statistic between 1.5 to 2.5, a small root-mean-square-error, and a historically consistent size of impact under stress.

10. The scenario dependent PD projections are broadly in line with historical stress episodes for the corporate and the financial segment. This is reflected in the forward-looking PD paths for all countries included in the sample, in which the size of impact is broadly in line with past stress episodes (in particular during the GFC). Nonetheless, the results display salient idiosyncrasies among segments, with corporate segment generally displaying higher PDs, for both in-sample realizations and out-of-sample forecast, across all countries.

11. Output, unemployment rate, equity returns, and credit-related measures play significant roles in the determination of underlying credit risks. This is reflected in the high posterior inclusion probability and sizable long run multiplier estimate (i.e., coefficients for both the contemporaneous and lagged terms for the independent variables) for both segments as well as for most geographies. (Table III.1)

12. Separate models were estimated for all material geographies of the all material geographies (Table III.1). Either because the calibration of a model was not possible or because the historical time series was limited or unavailable for some countries, some satellite proxies were also used. SK and SI were proxied using the CZ satellite forward path and BG and HR used the RO

[3] This was performed by running a small model adjusting the historical (realized) starting point as provided by the series provider with the system-wide starting point (as provided by OeNB). Regulatory PDs and historical evidence from the observed defaults during past downturns have also been used for cross-checking purposes.

path. [4] ROW was mapped to a time series corresponding to EA, as most of the residual exposures for most domestic banks were cross-country exposures in the EA. In total 13 separate models corresponding to 13 different countries were estimated for corporates and financials. The PD path trajectories under both scenarios considered are illustrated in Figure III.1 and Figure III.2 for the corporate and financials segments respectively. Table III.2 summarizes the equation estimates and key statistics for all models estimated using the BMA methodology.

[4] For CZ historical data series were available for a single corporate segment; therefore, the same forward path was applied for corporates and financials.

Figure III.1. PD PiT Models for Corporates by Material Geography

(Percent)

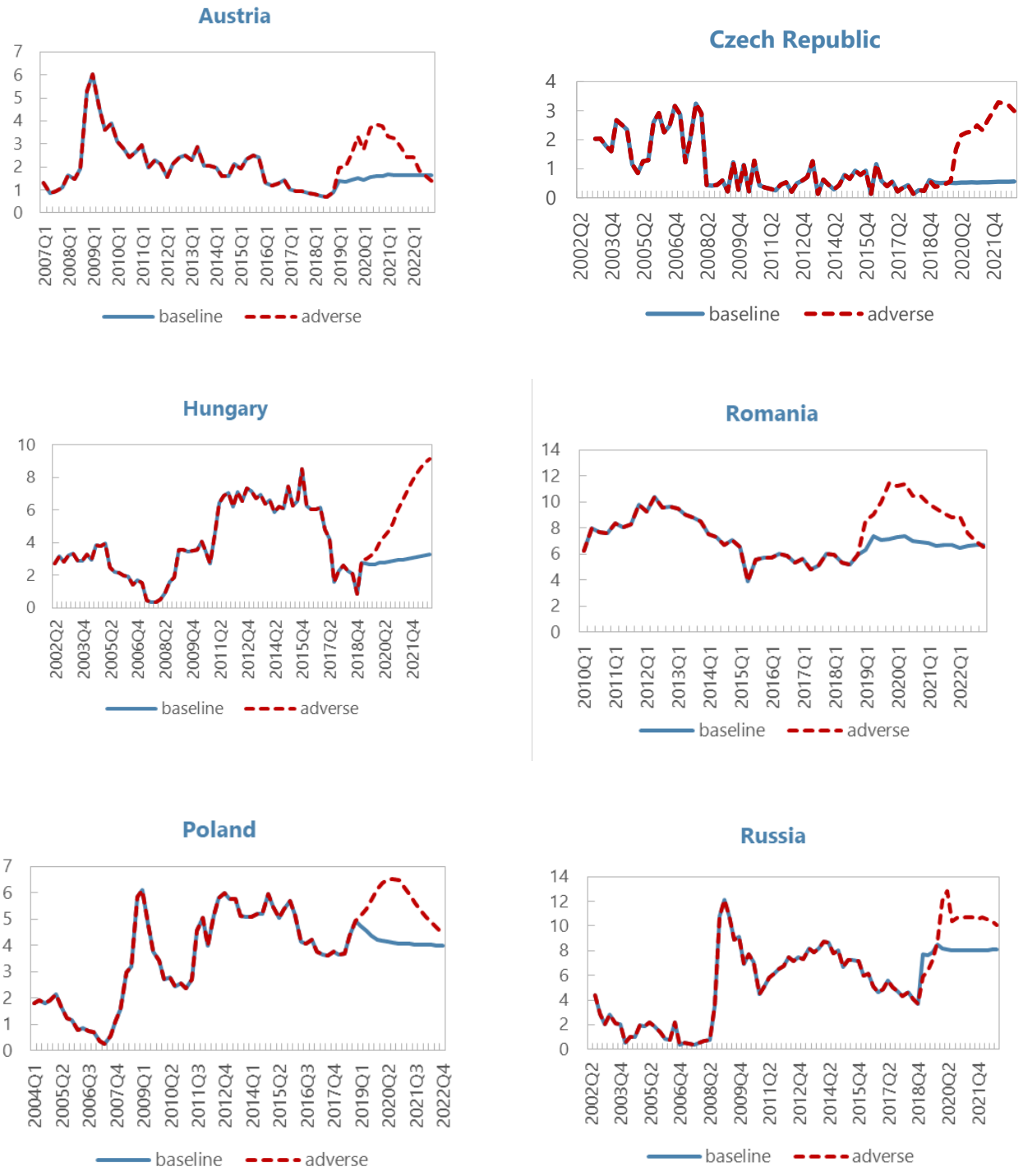
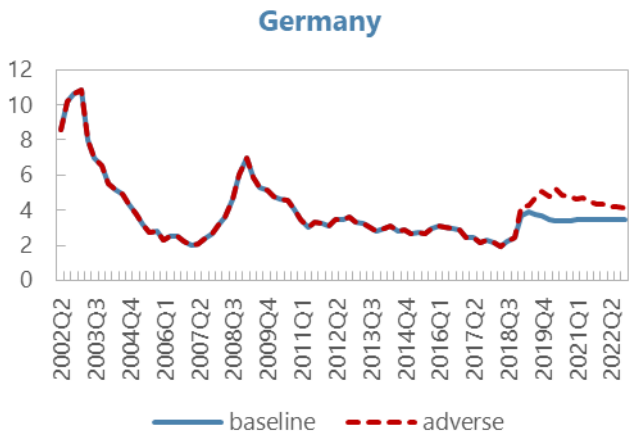
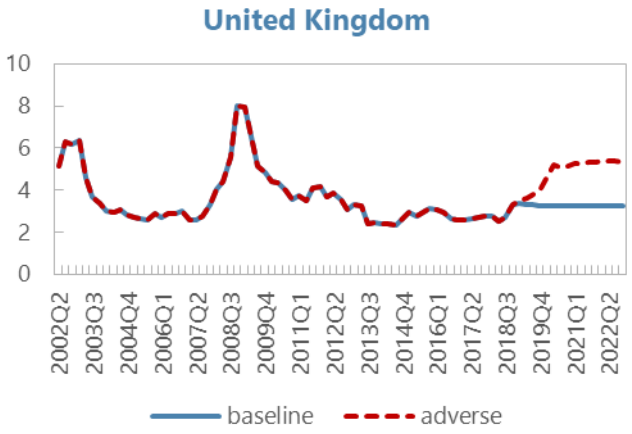
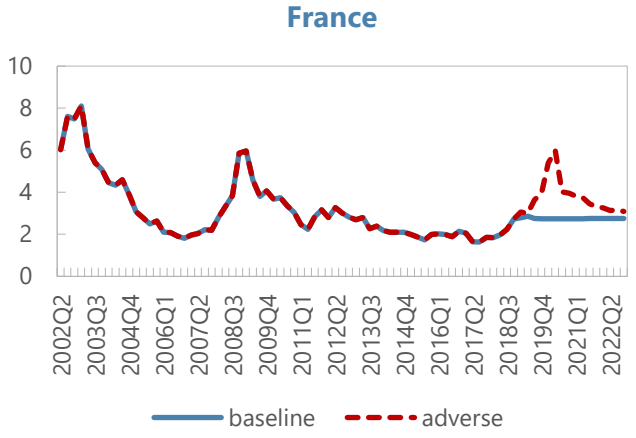
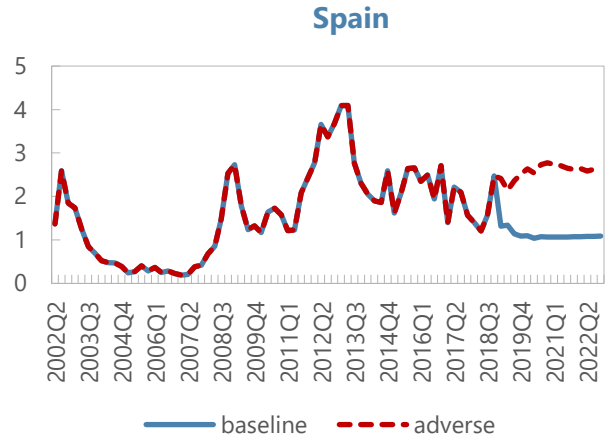


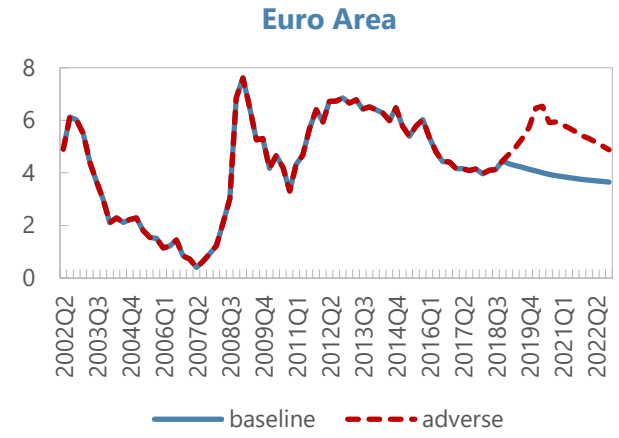
Figure III.1. PD PiT Models for Corporates by Material Geography (continued)











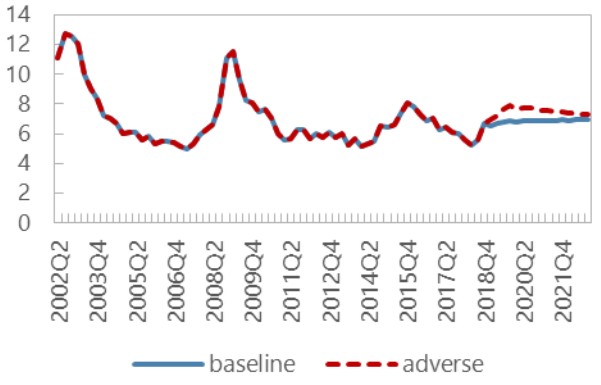


Figure III.1. PD PiT Models for Corporates by Material Geography (concluded)

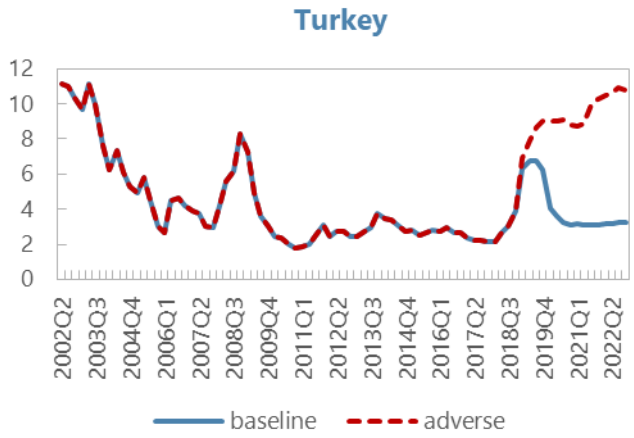


Figure III.2. Austria: PD PiT Models for Financials by Material Geography

(Percent)

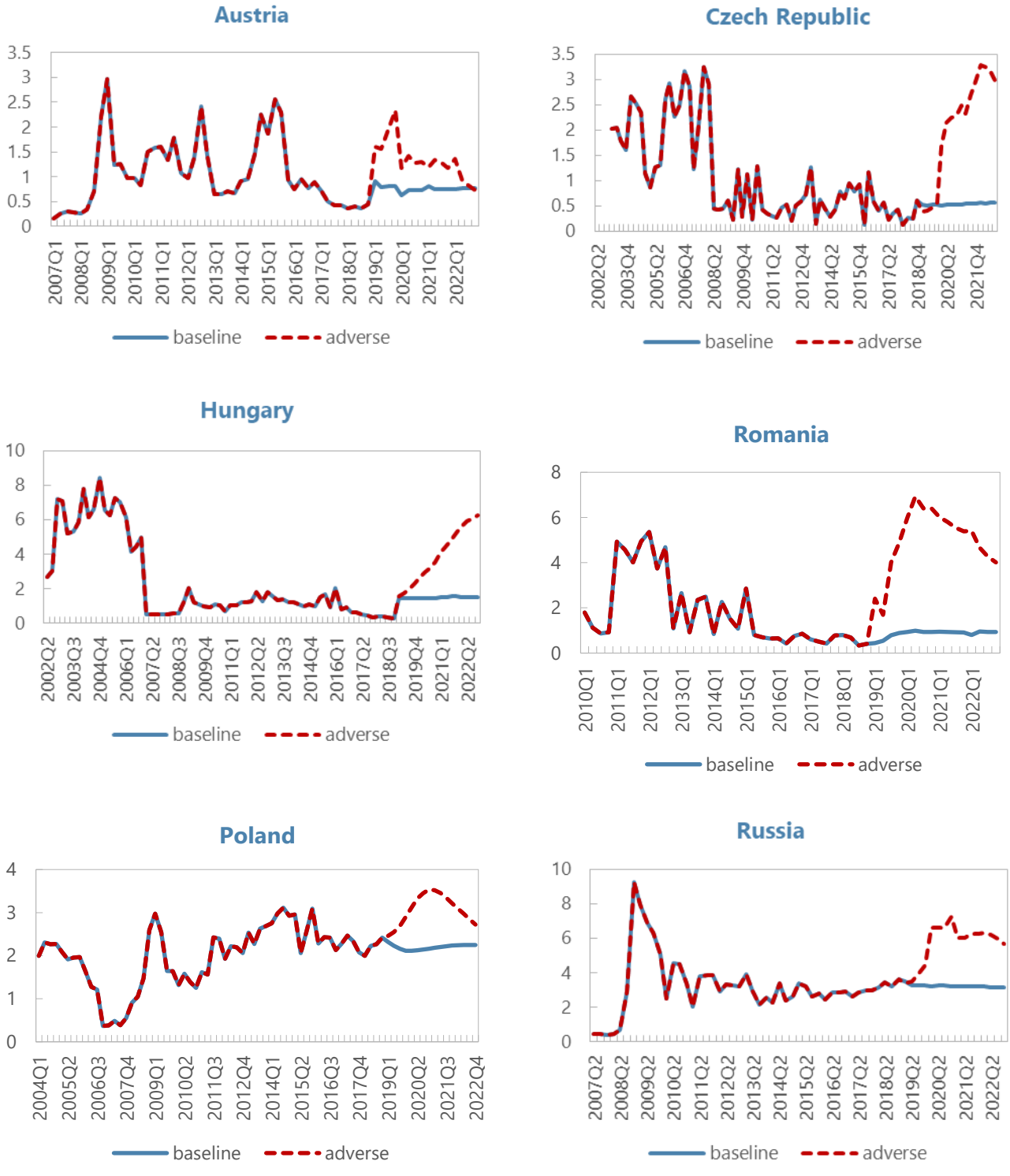


Figure III.2. Austria: PD PiT Models for Financials by Material Geography (continued)

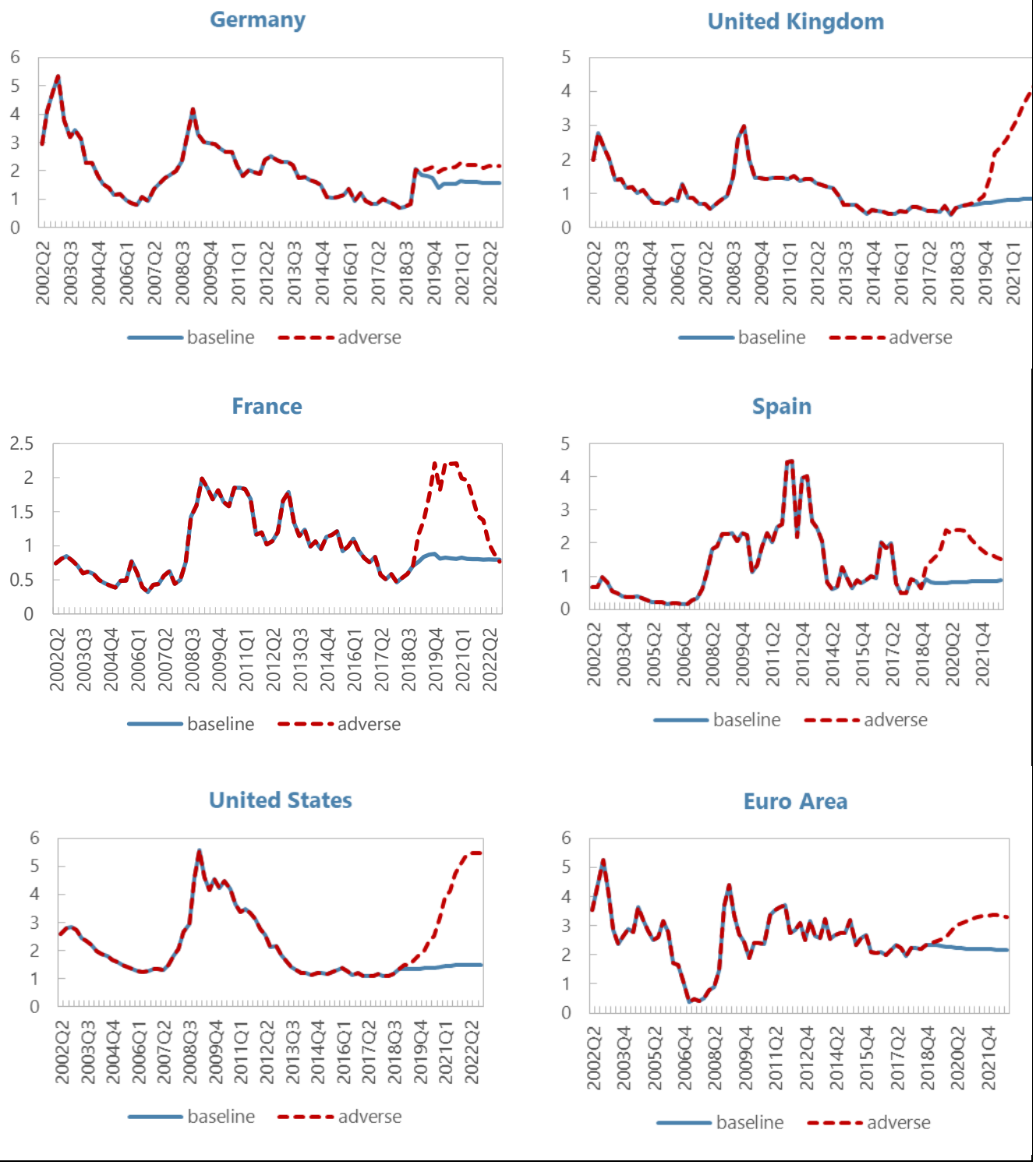


Figure III.2. Austria: PD PiT Models for Financials by Material Geography (concluded)

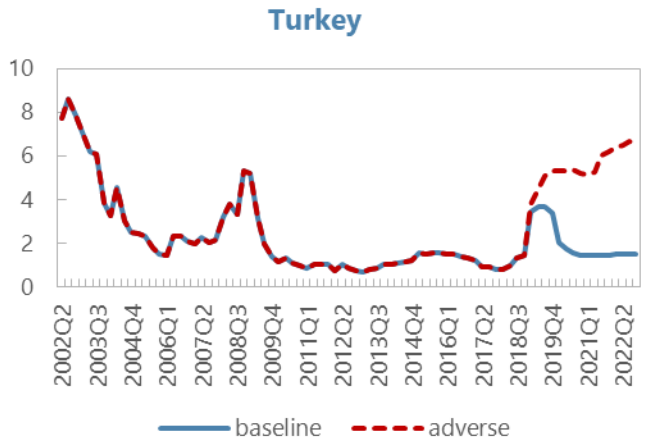


Table III.2. Austria: Estimation of the Credit Risk Satellite Model
Equation estimates for default rates by portfolio (normalized long-run multipliers)
(Dependent variable: Moody's EDF)

	Austria		
	Corporate group	Financials group	All
GDP growth, yoy	-0.83*	-0.41*	-0.78*
Exchange rate against USD, yoy	0.01	0.42*	0.03
Inflation, yoy	-0.01	-0.01	-0.01
Unemployment rate, yoy	0.01	0.01	0.01
Output gap, percent	-0.01	-0.02	-0.01
Stock price index, yoy	-0.42*	-0.48*	-0.54*
Private credit, yoy	-0.01	-0.01	-0.01
R square	0.66	0.7	0.7
Number of lags of independent variables	2	2	2
Number of observations	48	48	48
	Czech Republic		
	Corporate group	Financials group	All
GDP growth, yoy	0.05		0.04
Exchange rate against USD, yoy	-0.08		0.04
Inflation, yoy	-0.09		-0.14*
Unemployment rate, yoy	0.15		0.41*
Output gap, percent	-0.09		-0.04
Stock price index, yoy	0.02		0.01
Private credit, yoy	0.91*		0.87*
R square	0.83		0.82
Number of lags of independent variables	2		2
Number of observations	64		64
	Hungary		
	Corporate group	Financials group	All
GDP growth, yoy	-0.01	0	-0.01
Exchange rate against USD, yoy	0.02	0	0.03
Inflation, yoy	-0.33*	-0.01	-0.27*
Unemployment rate, yoy	0.01	0.29*	0.04
Output gap, percent	-0.65*	0	-0.55*
Stock price index, yoy	-0.01	0	-0.01
Private credit, yoy	-0.01	0	-0.01
R square	0.71	0.09	0.52

Table III.2. Austria: Estimation of the Credit Risk Satellite Model
Equation estimates for default rates by portfolio (normalized long-run multipliers)
(Dependent variable: Moody's EDF)

Number of lags of independent variables	2	2	2
Number of observations	67	67	67
	Romania		
	Corporate group	Financials group	All
GDP growth, yoy	-0.55*	-0.43*	-0.6*
Exchange rate against USD, yoy	0	0.01	0
Inflation, yoy	0	0	0
Unemployment rate, yoy	0.05*	0.27*	0.03*
Output gap, percent	-0.01	-0.16	-0.01
Stock price index, yoy	-0.01	-0.25*	-0.01
Private credit, yoy	-0.27*	-0.16*	-0.25*
R square	0.89	0.83	0.88
Number of lags of independent variables	2	2	2
Number of observations	36	36	36
	Poland		
	Corporate group	Financials group	All
GDP growth, yoy	0	-0.13	0
Exchange rate against USD, yoy	0	0	0
Inflation, yoy	0	-0.01	0
Unemployment rate, yoy	0.02	0.06	0.03
Output gap, percent	0	-0.01	0
Stock price index, yoy	-1.19*	-0.91*	-1.25*
Private credit, yoy	0	-0.15	0
R square	0.92	0.83	0.93
Number of lags of independent variables	2	2	2
Number of observations	60	60	60
	Russia		
	Corporate group	Financials group	All
GDP growth, yoy	-0.07	-0.01	-0.07
Exchange rate against USD, yoy	0.01	0.01	0.01
Inflation, yoy	-0.01	-0.19*	-0.01
Unemployment rate, yoy	0.06	0.03	0.06
Output gap, percent	-0.02	-0.56*	-0.02
Stock price index, yoy	-0.36*	-0.2*	-0.36*

Table III.2. Austria: Estimation of the Credit Risk Satellite Model
Equation estimates for default rates by portfolio (normalized long-run multipliers)
(Dependent variable: Moody's EDF)

Private credit, yoy	-0.64*	-0.03	-0.64*
R square	0.76	0.64	0.76
Number of lags of independent variables	2	2	2
Number of observations	66	47	66
	Germany		
	Corporate group	Financials group	All
GDP growth, yoy	-0.01	-0.01	-0.01
Exchange rate against USD, yoy	0	0	0
Inflation, yoy	-0.01	-0.01	-0.01
Unemployment rate, yoy	0.01	0.01	0.01
Output gap, percent	-0.01	-0.01	-0.01
Stock price index, yoy	-0.67*	-0.19*	-0.65*
Private credit, yoy	-0.48*	-0.58*	-0.49*
R square	0.78	0.59	0.76
Number of lags of independent variables	2	2	2
Number of observations	67	67	67
	Euro Area		
	Corporate group	Financials group	All
GDP growth, yoy	-0.03	-0.02	-0.02
Exchange rate against USD, yoy	0.07	0.01	0.06
Inflation, yoy	0	0	0
Unemployment rate, yoy	0.01	0.04	0.01
Output gap, percent	0	-0.14	0
Stock price index, yoy	-0.82*	-0.24	-0.84*
Private credit, yoy	-0.4	-0.34*	-0.42
R square	0.93	0.8	0.92
Number of lags of independent variables	2	2	2
Number of observations	67	67	67
	United Kingdom		
	Corporate group	Financials group	All
GDP growth, yoy	-0.03	-0.04	-0.02
Exchange rate against USD, yoy	0.04	0.04	0.06
Inflation, yoy	0	0	0
Unemployment rate, yoy	0.28*	0.64*	0.41*

Table III.2. Austria: Estimation of the Credit Risk Satellite Model
Equation estimates for default rates by portfolio (normalized long-run multipliers)
(Dependent variable: Moody's EDF)

Output gap, percent	0	0	0
Stock price index, yoy	-0.67*	-0.2	-0.52*
Private credit, yoy	0	0	0
R square	0.88	0.86	0.89
Number of lags of independent variables	2	2	2
Number of observations	67	67	67
	Spain		
	Corporate group	Financials group	All
GDP growth, yoy	-0.01	-0.17*	-0.01
Exchange rate against USD, yoy	0.01	0.01	0.01
Inflation, yoy	-0.01	-0.01	-0.01
Unemployment rate, yoy	0.01	0.08*	0.01
Output gap, percent	-0.39*	-0.02	-0.31*
Stock price index, yoy	-0.42*	-0.22*	-0.38*
Private credit, yoy	-0.43*	-0.61*	-0.52*
R square	0.91	0.9	0.94
Number of lags of independent variables	2	2	2
Number of observations	67	67	67
	France		
	Corporate group	Financials group	All
GDP growth, yoy	-0.01	-0.66*	-0.01
Exchange rate against USD, yoy	0	0.28*	0
Inflation, yoy	0	-0.01	0
Unemployment rate, yoy	0.05	0.01	0.09*
Output gap, percent	-0.01	-0.03	-0.01
Stock price index, yoy	-0.78*	-0.31*	-0.77*
Private credit, yoy	-0.01	-0.01	-0.01
R square	0.58	0.65	0.59
Number of lags of independent variables	2	2	2
Number of observations	67	67	67
	United States		
	Corporate group	Financials group	All
GDP growth, yoy	-0.01	-0.01	-0.06*
Exchange rate against USD, yoy	0	0	0

Table III.2. Austria: Estimation of the Credit Risk Satellite Model
Equation estimates for default rates by portfolio (normalized long-run multipliers)
(Dependent variable: Moody's EDF)

Inflation, yoy	-0.02	-0.01	-0.01
Unemployment rate, yoy	0.01	0.5*	0.02
Output gap, percent	-0.01	-0.51*	-0.01
Stock price index, yoy	-0.44*	-0.04	-0.64*
Private credit, yoy	-0.44*	-0.02	-0.32*
R square	0.63	0.77	0.74
Number of lags of independent variables	2	2	2
Number of observations	67	67	67

	Turkey		
	Corporate group	Financials group	All
GDP growth, yoy	-0.01	-0.01	-0.01
Exchange rate against USD, yoy	0	0	0
Inflation, yoy	0	0	0
Unemployment rate, yoy	0.4*	0.35*	0.38*
Output gap, percent	-0.02	-0.03	-0.02
Stock price index, yoy	-0.01	-0.01	-0.01
Private credit, yoy	0	0	0
R square	0.17	0.16	0.16
Number of lags of independent variables	2	2	2
Number of observations	67	67	67

Notes: 1: * Denotes a higher posterior inclusion probability than the prior inclusion probability, which indicates variable statistical significance.
2: For various portfolio segments presented here, the equations do contain lags of either the dependent variable or the exogenous right-hand-side variables (beyond their contemporaneous inclusion), or both.
3: A long-run multiplier is defined as the sum of all coefficients of a given right-hand-side variable on its contemporaneous and lagged terms. The long-run multiplier is normalized, moreover, by multiplying it by the ratio of the standard deviation of the left-hand-side and the respective right-hand-side variable that is concerned.
4: The normalized long-run multiplier is interpreted as follows: a one-standard-deviation change in the concerned right-hand-side variable induces the normalized multiplier times the historical standard deviation of the left-hand-side variable. Note that the default rates on the left-hand side have been included in the equation in logit format. The normalized multipliers can be compared across variables and equations.

Source: IMF staff calculations.

Loss Given Default Modelling (LGD PiTs)

13. The LGD PiT modelling followed OeNB's internal approach for stressing LGDs. According to this approach, an effective LGD is used in expected loss/impairments calculations for each asset segment. The effective LGD is calculated from an LGD used for unsecured exposure (the *LGD unsec*), factoring in available collateral by multiplying it with (1 - collateral ratio), with collateral ratio expressing the ratio of collateral to total exposure. This approach assumes an LGD of zero for the collateralized part. To be conservative, only collateral also eligible under the Basel credit risk mitigation regime is recognized. The collateral is shocked by applying a haircut based on the type of the collateral and the scenario shock that is most relevant for this type of collateral, increasing the effective LGD under stress.

14. **For Austrian exposures the *LGD unsec* is calibrated based on data from the central credit register.** For other countries, the *LGD unsec* is based on the World Bank's Doing Business database, using the Austrian LGD as an anchor. In the adverse scenario, *LGD unsec* is also shocked using scaling factors anchored to the applied macro scenario.

Annex IV. A Structural Model for Mortgage Defaults

1. In the absence of reliable historical default time series on mortgage exposures for all countries, a structural model was used as a satellite to project forward loss rates. While much of the infrastructure is advanced and sophisticated, there are significant data gaps in the historical data layer that impose constraints on the estimation of satellite models for mortgages at a granular level. The existence of such gaps can be partially attributed to the fact that the Austrian credit register does not capture in detail smaller retail exposures.[1] In addition, less data is available on the CESEE countries, since the number of banks with significant operations in those countries is small.

2. An additional constraint was the lack of information on DSR/LTV distributions for the existing stock of mortgages. While a data collection exercise is in place to monitor credit characteristics for recent vintages, relatively less information is available for the existing stock of mortgages. In terms of geographical coverage data is even more scarce since borrower-based credit affordability metrics are not systematically monitored by country of origination. Therefore, and in order to deploy the structural model for estimating scenario projections for mortgage default rate, the following assumptions were made:

- A DSR/LTV joint distribution for the stock of existing mortgage exposures was constructed assuming an average maturity of individual loans of 25 years at origination and an unchanged distribution for the years prior to 2011[2]. These assumptions are consistent with the small contribution of older vintages in the default rate due to the maturation/amortization impact.

- DSR and LTV ratios across all vintage distributions were adjusted using household income and house price historical time series as proxies for the impact on DSR and LTV respectively. The exercise did not allow using existing liquid wealth buffers to avoid default under stress.

- The same joint DSR/LTV distribution was assumed for all material geographies. The different model outcomes by geography were the result of applying different scenarios on interest rate, unemployment and house price shocks which are defined by country in the scenario.

3. The model takes into account the evolution of household affordability in accordance with the scenario path. House price shocks and household behavioral assumptions are also used to estimate scenario-dependent default rates and loss rates. The approach is described in the TUI model first introduced by the Reserve Bank of New Zealand and has been used, with some

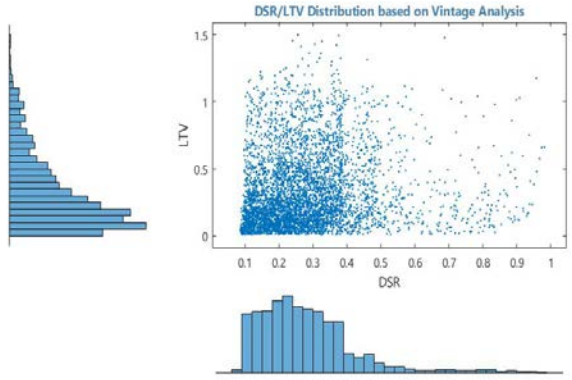
[1] All exposures below EUR 350k are captured as a pooled bucket under the name "KK" with no apparent distinction between mortgages or other retail credit.

[2] Due to lack of the relevant data, for vintage years prior to 2011 the 2011 vintage DSR/LTV distribution was assumed to be the actual one.

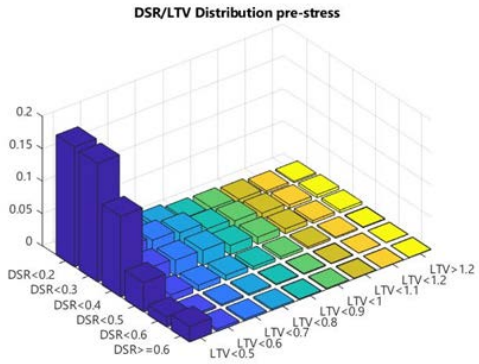
additional adaptations for each specific case, in several FSAP missions. [3,4] A slightly different version of this model has been applied to calibrate macroprudential policies under stress.[5] The original model can be further enhanced with the use of household survey microdata to account for behavioral reactions from borrowers.[6]

Figure IV.1 Austria: The Structural Model for Mortgage Defaults

The DSR distribution appears contained on the DSR axis, despite the fact that recent vintages appear to have tails at risky KTV levels.

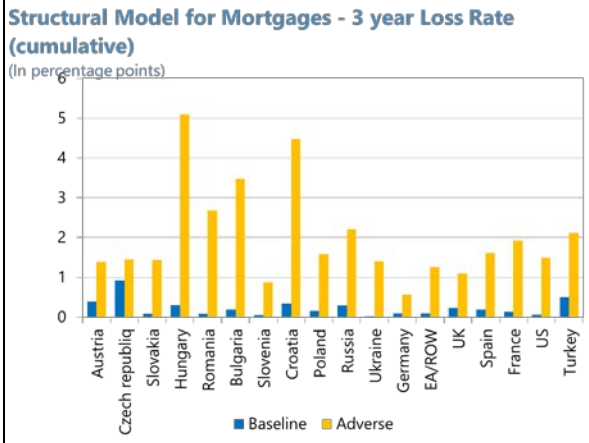


The initial system-wide distribution appears to be concentrated on the safe partitions, …



These characteristics results in moderate losses for both scenarios for most countries…

…under a scenario that is quite severe for both mortgage insurers and banks.



Sources: IMF staff estimates.

[3] See Harrison and Mathew (2008).

[4] See IMF (2017b), and IMF (2019a) and IMF (2019b)

[5] Gornicka L., and Valderrama L. (2020).

[6] This is done along the general principles described in Laliotis et al. (2019), Laliotis and Población (2016) and Gross and Población (2017), where the micro data repository is used to calibrate distributions and simulate borrower behavioral reaction elements under the application of LTV/DTI limits following the application of a macroprudential borrower-based measure.

4. The structural component of the model defines the probability of a household being under stress. This probability is a function of the change in the Debt Service Ratio (DSR) due to an interest rate change and the change in the unemployment rate in the scenario. Under the general form, this distress probability is given by the structural function:

$$PSS_t = a_0 \cdot D + a_1 \cdot DSR_t^{\beta 1} + \alpha_1 \cdot \Delta DSR_t^{\beta 2} + \alpha_3 \cdot \left(\alpha_4 \cdot u_t + \alpha_5 \cdot (\Delta u_t)^{\beta 3}\right) \qquad \text{(Eq.1)}$$

with D denoting a demographic distress contribution component, DSR_t denoting the borrower's DSR post stress, ΔDSR_t the delta in DSR vs the cut-off date, u_t the unemployment rate, and Δu_t the change in unemployment rate from the cut-off date. The equation (above) captures the borrower affordability component and how this is affected by the macro-scenario shock.[7]

5. Additional conditions need to be met in order to assume that a mortgage exposure reaches default. At a second stage, default occurs only when the household is in distress (post-first stage), the household's liquid wealth is not enough to cover servicing needs, and the value of the loan is higher than the value of the collateral (negative equity condition is a prerequisite for default). [8] Therefore, default occurs only if the post-stress LTV is higher than 1 and if any wealth buffers are not enough to cover the servicing needs after a distress event. Hence, under a positive house price assumption the model captures any potential masking of defaults due to price appreciation. In this positive house price scenario, an outright sale would be triggered by a borrower's distress as opposed to a default event.

Default probability is given by formula

$$PD_t = PSS_t \cdot \frac{\{\#|\tilde{V}_t - C < L \text{ and } B^t(LW_0) = 0\}}{(\#iterations)}, \qquad \text{(Eq.2)}$$

where the first term within the brackets denotes the probability that the property value after stress $\tilde{P}_T$ minus some liquidation discount C is lower than the outstanding loan notional L, and the second term denotes that the stochastic behavioral rule $B^t(x)$—which accounts for the use of Liquid Wealth LW_0 at the cut-off—has failed to save the loan from default.[9] The $\#iterations$ suggest that this outcome is the result of a significant number of Monte Carlo simulations in which any type of

[7] The original TUI model (Harrison and Mathew, 2008) was slightly adapted with the introduction of a DSR ending-level term (second term of Eq 1) to also account for potential defaults of high-risk borrowers (households with high DSRs should go through the default test).

[8] The fact that this only comes at a second stage and after the control for a household being distress explains why negative equity would not drive default rates; none of the non-distressed households (which are substantially more as a percentage of the overall population of borrowers) would ever default, even in the event of negative equity. Therefore, negative equity is just a trigger of default event vs outright sale. The type of recourse (full recourse vs nonrecourse) also does not play a major role in the structural approach, since borrowers' default under distress and when available wealth either in the form of property value or liquid wealth alternatives might be used to avoid default.

[9] In the actual calibration for the solvency ST a linear survival rule was implemented as the behavioral rule: the survival probability is linear between a wealth buffer of 8 and 36 months. Buffers below 8 months will not be sufficient to weather a default event and borrowers with wealth buffers exceeding 36 months would survive the distress event with probability 1.

behavioral rules can be incorporated and any type of house price shock distributions can be modelled.

6. The conditional LGD is driven by the discounted sale price of the house. The sale occurs at time t+s (where s denotes the average time to realize the collateral); the sale proceeds are net of transaction costs (discounted at a rate reflecting the scenario interest rate premium) and assume an additional foreclosure liquidation discount δ:

$$LGD_t = 1 - \frac{(1-\delta)P_{t+s}}{L*(1+r_t+cs_t)^s} \qquad \text{(Eq.3)}$$

7. The joint distribution is partitioned along the DSR and LTV dimensions. Using LTV partitioning values of 1.2, 1.1, 1. 0.9, 08, 0.7, 0.6, and 0.5, and DSR partitioning values of 0.2, 0.3, 0.4, 0.5 and 0.6, the first two dimensions of the household data are mapped to a 5 by 8 partitioned space. For each DSR/LTV partition a Monte Carlo simulation (on house price changes anchored to a central house price shock) is used to produce model-based projections on 3-year loss rates. A portfolio average 3-year loss rate would correspond to the weighted average of the projected loss rates per DSR/LTV density partition. This means the portfolio distribution along the two dimensions (DSR and LTV) can be used to produce an overall portfolio estimate.

Table IV.1. Austria: Loss Rates Estimated for Material Geographies Pre-Starting Point Adjustments

Loss Rates ($\boldsymbol{PD} * \boldsymbol{LGD}$) (in percentage points)

	Baseline				Adverse			
	2019	2020	2021	Total 3 Year	2019	2020	2021	Total 3 Year
Austria	0.13	0.13	0.13	0.39	0.36	0.46	0.57	1.38
Czech Republic	0.31	0.22	0.39	0.92	0.48	0.48	0.48	1.44
Slovakia	0.03	0.03	0.03	0.08	0.37	0.38	0.69	1.43
Hungary	0.10	0.10	0.10	0.30	0.98	1.70	2.42	5.10
Romania	0.03	0.03	0.03	0.08	0.56	0.89	1.22	2.67
Bulgaria	0.06	0.06	0.06	0.19	0.76	1.16	1.56	3.48
Slovenia	0.02	0.02	0.02	0.05	0.29	0.29	0.29	0.87
Croatia	0.11	0.11	0.11	0.34	0.95	1.49	2.04	4.47
Poland	0.05	0.05	0.05	0.16	0.53	0.53	0.53	1.58
Russia	0.10	0.08	0.11	0.29	0.74	0.74	0.74	2.21
Ukraine	0.01	(0.00)	0.01	0.02	0.47	0.47	0.47	1.40
Germany	0.03	0.03	0.03	0.09	0.14	0.19	0.24	0.57
EA/ROW	0.03	0.03	0.03	0.09	0.35	0.42	0.50	1.26
UK	0.08	0.08	0.08	0.23	0.23	0.37	0.50	1.10
Spain	0.06	0.06	0.06	0.19	0.41	0.54	0.66	1.61
France	0.05	0.05	0.05	0.14	0.40	0.64	0.88	1.92
US	0.02	0.02	0.02	0.06	0.18	0.50	0.81	1.49
Turkey	0.17	0.05	0.29	0.51	0.70	0.70	0.70	2.11

8. The structural model produces 3-year scenario-dependent loss rates. In order to produce yearly projections, the model is sequentially run using the 1-year, 2-year and 3-year scenario loss rate projection. Each run uses the 1-year loss rate projected by the previous run to infer the annual loss rate that would correspond to a cumulative loss rate as projected by the model for the total number of years and the scenario corresponding to this point in time. In this way, 3-year loss rate projections are translated into yearly projections, with the cumulative impact being anchored to the original 3-year loss rate projection and end-horizon scenario. This is presented in Table IV.1 for all material geographies considered.

9. Model projections for both baseline and adverse are consequently translated into bank- specific projections using the bank mortgage exposure starting points. This translation is performed using an absolute shift in the PD space to ensure that the demographic component of the model is correctly captured in the baseline scenario projection.10 As a result, this starting point adjustment brings the baseline scenario projections closer to the idiosyncratic default rates actually observed in the market under current conditions. Adverse scenario loss rates are projected as an additional delta impact versus the baseline one.

10. Overall the loss rates projected by the model are relatively moderate for most countries (Table IV.1). This result is the combined effect of a very contained population in terms of starting DSR and the moderate house price shocks for most countries in the adverse scenario. The overall stock of mortgage exposures is heavily concentrated in the safer partitions of the DSR/LTV space, i.e. the partition segments with low starting current DSR and relatively low LTVs. In this context, to result in more pronounced loss rates the adverse scenario would require a combination of much higher [positive] interest shocks and negative house price developments.[11]

[10] First term of the structural equation (Eq. 1).

[11] This is partially illustrated in the third panel of Figure IV.1 where countries with high 3-year cumulative loss rates in the adverse scenario are the ones associated with a strong positive interest rate shock (Hungary, Romani, Bulgaria, and Croatia).

Annex V. Foreign Currency (FC) and Repayment Vehicle (RV) Loans

1. ARNIE's FC/RV loan module quantifies the loss potential arising from appreciations of FC loans denomination currencies and/or underperformances of repayment vehicles attached to bullet loans. It covers the indirect credit risk triggered by an increase in (home currency) debt and/or a decrease of funds set aside to repay debt at maturity. This indirect credit risk is an add-on to the common macro-economic credit risk covered in the credit risk module of the solvency stress test.

2. A different methodology is applied to Austria and CESEE exposures for two reasons. First, loan characteristics are different: whereas domestic FCLs are mainly arranged as bullet loans, virtually all FCLs in CESEE are installment loans. Second, the data sources are different.

3. The analysis follows OeNB's methodological approach and covers all material portfolios, i.e., in Austria: RV loans in EUR, CHF and JPY; and in CESEE: CHF, EUR (in non-EUR countries) and USD loans. It includes private household and corporate exposures.

Scenarios

4. The baseline and adverse FX paths from the IMF's macro-economic scenario are used. While in the baseline scenario the appreciation of the relevant FCs is limited, the adverse scenario implies rather severe appreciations in most cases: the CHF appreciates versus the EUR by around 50 percent, while at the same time, the EUR appreciates versus local CESEE currencies in the range of 10 to 30 percent.

5. As concerns the performance of RVs, 2 percent p.a. (nominal) are assumed in the baseline and 0 in the adverse scenario.

Domestic FC and RV Loans

6. All domestic RV loans (most of which are FC) are considered. As these loans are bullet loans, they hardly show default events. In addition, troubled FC loans usually are converted to Euro in which case they disappear from the radar. For these reasons, the method for the domestic case is not based directly on credit risk measures such as NPLs or loan loss provisions (LLPs). Instead, an indirect method is applied, which was developed in former FSAPs for FC loans and has meanwhile been adapted to include RV loans as well.

7. The central idea of the extension to RV loans is that at maturity it makes no difference to the debtor whether a shortfall in the RV has been triggered by an appreciation of the FC or by an underperformance of the RV. Thus, RV underperformance can be translated into an equivalent FC appreciation which can be handled within the existing model. The RV extension draws on data from the "Repayment Vehicle Survey", conducted by the OeNB. In the survey, the top 26

players [1] in FC/RV loans report–among others–a coverage gap (difference between the expected repayment amount needed at maturity and the expected final value of the RV), actual market values of RVs and contractual annual savings into the RVs.

8. The basic model for FC loans assumes that an individual debtor has a FC debt of D EUR p.a. and a disposable income (after debt) of I EUR p.a. An appreciation of the loan currency will increase D by a certain amount and will lower I by the same amount. Therefore, an appreciation of the FC by ΔFX implies a relative change ΔI of disposable income by

$$\Delta I = - D/I * \Delta FX. \quad (1)$$

The central question is how credit quality deteriorates given a change in disposable income (ΔI). To that end, a relationship between yearly changes of LLP ratios of loans denominated in euros and yearly changes of real GDP (which is then used to proxy ΔI) is established:

$$\Delta LLPR = f(\Delta GDP). \quad (2)$$

With a linear function f (.) and an estimated slope $\beta = -2.5$, this yields:

$$\Delta LLPR = 2.5 * D/I * \Delta FX. \quad (3)$$

9. This methodology is applied to the data of the financial stability reporting of domestically operating entities (OeNB's integrated reporting framework) conducted by the OeNB, which contains information on remaining maturities of FC loans.

10. Additional impairments resulting from (3) are distributed equally over the loan's remaining maturity. The share of additional impairments allotted to the first 3 years represents the scenario loss. Thus, the loss represents an impairment need during the stress horizon from an economic point of view rather than from a regulatory point of view (as no actual defaults necessarily occur during the stress horizon).

11. In (3) the ratio D/I represents a debtor's "leverage". Based on supervisory minimum standards regarding buffers that debtors must hold to cover FX appreciations the ratio is set to 2.5. ΔFX in (3) denotes the FC appreciation in the scenario. It is not set with respect to the

[1] Other banks receive the sample average.

starting point of the stress test, but with respect to the starting point of the loan, thus also accounting for hidden liabilities accumulated in the past.

FC loans in CESEE

12. For CESEE historical data on stocks of loan loss provisions (LLPs) broken down by currencies are available. The excess growth of LLP ratios in FC over the growth of LLP ratios in LCs (the "boost-factor") is related to historically observed FC appreciations. Data are available per banking group, per country, and per sector (private households and corporates) since 2007.

13. The relationship between FC appreciations and the additional FC credit risk (as measured by the boost factor) is assumed to be non-linear. Instead, exponential and quadratic functions are used with different estimation criteria for data fitting (quadratic, absolute, Huber-type). This leads to 15 different models over which the average is taken. The resulting models for the CHF are also used for EUR and USD because they show a better fit. The additional credit risk costs are calculated as the difference of the increase of loan loss provisions with and without the boost factor.

Annex VI. LCR Scenarios

Table VI.1. Austria: LCR Test Scenarios: Key Assumptions

Parameter	Position	Scenario			
		Regulatory LCR	Retail run-off scenario	Wholesale run-off scenario	Combined run-off + price shock scenario
run-off rates	stable retail deposits	5%	10.0%	5.0%	10%
	other retail deposits	10%	20.0%	10.0%	20%
	operational deposits	5-25%	10-35%	15-35%	15-35%
	non-operational deposits	20-40%	20-40%	40-60%	40-60%
change in liquid assets weights	level 1 assets	no	no	no	-5/0%
	level 1 covered bonds	no	no	no	-20/-3%
	level 2A assets	no	no	no	-15/-5%
	level 2B assets	no	no	no	-25/-5%

Annex VII. Cash Flow-based Stress Test: Haircuts and Run-Off Rates

Table VII.1. Austria: Cash-Flow Test Scenarios: Key Assumptions

Parameter	Position	Scenario		
		Mild	Moderate	Severe
run-off rates	stable retail deposits	4.9%	8.0%	10%
	other retail deposits	9.7%	16.1%	20%
	deposits from credit institutions	48.7%	80.3%	100%
	deposits from corporates	14.5%	27.1%	35%
roll-off rates	retail and corporate customers	0.0%	0.0%	0%
	credit intitutions	48.7%	80.3%	100%
haircuts	level 1 assets	2.2-3.3%	2.4-4.3%	2.5-5%
	level 2A assets	8.2-16.3%	12.4-24.7%	15-30%
	level 2B assets	8.2-29.5%	12.4-29.7%	15-50%
market price shock	level 1 assets	-0.2%	-0.9%	-5%
	level 2A assets	-0.2/-0.6%	-0.9/-2.8%	-5/-15%
	level 2B assets	-1%	-5%	-25%

Annex VIII. The Network Model

This annex summarizes the methodology presented in Espinosa-Vega and Solé (2010). A simple version of balance sheet identity for a bank i in a network of N banks can be simplified as equation (1),

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

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

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

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

A bank fails if its total capital adequacy ratio is below a threshold (4.5 percent), which starts chain reactions to other banks in the banking system. A parameter (loss given default ratio, λ) controls for severity of credit losses and capital impairment upon failure (i.e., 100 percent of the loss given default (LGD) ratio for unsecured loans implies that all the claims vis-à-vis "A" are lost completely).

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

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

Let F_t be the set of failed banks through multiple rounds of contagion. A bank fails the event if:

$(k_i - \sum_{h\in F_t} \lambda x_{hi}) * \frac{1}{RWA_i} < 4.5\ percent$ for the simulation with credit shock and

$(k_i - \sum_{h\in F_t} (\lambda x_{hi} + \delta\rho x_{ih}))* \frac{1}{RWA_i} < 4.5\ percent)$ for the simulation with credit-funding shock.

A simulation continues until there are no more failures of other banks.

There are three parameters that need to be set in the model: loss given default ratio (λ), loss of funding ratio (ρ), and the discount rate (δ). In this analysis, we set λ =0.5 for unsecured interbank exposure, λ =0.2 for secured interbank exposure, ρ=0.35, and δ=0.3.

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