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FINANCIAL SECTOR ASSESSMENT PROGRAM

TECHNICAL NOTE ON SYSTEMIC RISK ANALYSIS AND STRESS TESTING

This Technical Note on Systemic Risk Analysis and Stress Testing for the Japan FSAP was prepared by a staff team of the International Monetary Fund as background documentation for the periodic consultation with the member country. It is based on the information available at the time it was completed on April 16, 2024.

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TECHNICAL NOTE

SYSTEMIC RISK ANALYSIS AND STRESS TESTING

Prepared By
Monetary and Capital Markets Department, IMF

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

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AEs	Advanced Economies
AFS	Available-for-Sale
AUM	Assets Under Management
BMA	Bayesian Model Averaging
BOJ	Bank of Japan
BU	Bottom-up
CCoB	Capital Conservation Buffer
CCyB	Counter-Cyclical Capital Buffer
CDR	Cash/Short-Term Debt Ratio
CDS	Credit Default Swap
CET1	Common Equity Tier 1
CGE	Computational General Equilibrium
CLO	Collateralized Loan Obligation
COF	Cost of funding
CP	Current Policies
CRE	Commercial Real Estate
D-SIB	Domestic Systemically Important Bank
DSTI	Debt Service-to-Income ratio
DTI	Debt-to-Income ratio
EBIT	Earnings Before Interest and Taxes
ENV-FIBA	Environment-Firm and Bank
ES	Expected Shortfall
ESR	Economic Value-Based Solvency Ratio
FMC	Financial Monitoring Council
FSA	Financial Services Agency
FSB	Financial Stability Board
FSAP	Financial Sector Assessment Program
FW	Fragmented World
FX	Foreign Currency or Foreign Exchange
FY	Fiscal Year
GDP	Gross Domestic Product
GHG	Greenhouse Gas
G-SIB	Global Systemically Important Bank
GVA	Gross Value Added
HFT	Held-for-Trading
HH	Household
HQLA	High Quality Liquid Assets
HTM	Held-to-Maturity
ICE	Intercontinental Exchange
ICR	Interest Coverage Ratio
ICS	Insurance Capital Standard
IIR	Interest Income Rate

IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRB	Internal-Ratings Based Approach
IRS	Interest Rate Swaps
JGB	Japanese Government Bond
JPY	Japanese Yen
JSCC	Japan Securities Clearing Corporation
LCR	Liquidity Coverage Ratio
LGD	Loss Given Default
LGL	Loss Given Loss
LMTs	Liquidity Management Tools
LTI	Loan-to-Income
LTV	Loan-to-Value
MOF	Ministry of Finance
MtM	Mark-to-Market
NACE	Nomenclature of Economic Activities
NBFIs	Nonbank Financial Institutions
NFCs	Nonfinancial Corporates
NFCI	Net Fee and Commission Income
NGFS	Network for Greening the Financial System
NII	Net Interest Income
NPL	Nonperforming Loan
NSFR	Net Stable Funding Ratio
NZ	Net Zero
OCI	Other Comprehensive Income
OTC	Over-the-Counter
PCR	Provision Coverage Ratio
PD	Probability of Default
PiT	Point-in-Time
RAM	Risk Assessment Matrix
RCR	Redemption Coverage Ratio
REITs	Real Estate Investment Trusts
ROA	Return on Assets
RRE	Residential Real Estate
RWA	Risk Weighted Asset
SMEs	Small and Medium-Sized Enterprises
SMR	Solvency Margin Ratio
STD	Standard Deviation
STA	Standardized Approach
TD	Top-Down
VaR	Value-at-Risk
WEO	World Economic Outlook
WROR	Write-Off Rate
YCC	Yield Curve Control

EXECUTIVE SUMMARY[1]

The Japanese financial system has remained resilient through a series of shocks including the COVID-19 pandemic. Japan's large and globally well-integrated financial system withstood the pandemic shock, aided by strong capital and liquidity buffers and extensive policy support. Credit provision to the private sector has remained robust since the pandemic, supporting a steady economic recovery.

The Japanese financial system stands at a critical juncture amid an evolving macroeconomic environment, facing, in particular, market risk and foreign currency (FX) liquidity risk. After years of deflationary concerns and ultra-low interest rates, sustained inflationary pressures have emerged. This has led the Bank of Japan (BOJ) to end its negative interest rate policy and yield curve control framework, potentially allowing higher short and long-term domestic interest rates than those prevalent since 2016, when these exceptional policy measures were introduced. In this evolving macroeconomic environment, key risks to macrofinancial stability stem from a potential intensification of regional conflicts and geoeconomic fragmentation, global supply chain disruptions, and significant commodity price volatility, which could trigger an abrupt global economic slowdown and a surge in inflation, leading to an increase in foreign and domestic interest rates and tightening of global financial conditions. A materialization of these risks could translate into notable market risk for banks, given their sizable domestic and foreign securities holdings under mark-to-market accounting. Rising interest rates may also cause materializing credit risk for banks due to a high share of floating-rate loans in total loans, though in a scenario without economic disruptions, they may contribute positively to banks' net interest income. Insurers are also significantly exposed to market risk through their large security holdings. A tightening of global financial conditions and rising FX funding costs could imply FX liquidity risks for internationally active Japanese banks, given their elevated overseas exposure and strong reliance on unsecured wholesale funding and FX swaps. The challenges facing the banking system are further accentuated by several structural transformations occurring in the economy, including from climate change, digitalization, and an aging population.

The FSAP assessed the financial sector's resilience with a comprehensive scenario-based systemic risk analysis. The systemic risk analysis comprised a comprehensive set of stress testing exercises covering the financial and nonfinancial sectors. Solvency and liquidity stress tests were conducted for a sample of banks and insurance companies under a baseline and hypothetical adverse scenario, while liquidity stress tests were conducted for investment funds to assess their resilience to investor redemption shocks. For banks, the potential feedback from liquidity stress to solvency risks was also assessed. Risk analysis was also conducted for nonfinancial corporates and households, as well as for the real estate sector, which provided input to the bank solvency analysis. In addition, a climate risk analysis was conducted to assess the susceptibility of Japanese banks (for the same sample of banks that

[1] This note was prepared by Marco Gross (team lead for systemic risk analysis), jointly with Andrea Deghi, Salih Fendoglu, Rui Xu, Mustafa Yasin Yenice, and Jinhyuk Yoo (all at the IMF's Monetary and Capital Markets Department). Additional inputs were provided by Hugo Rojas-Romagosa (Research Department). The team thanks the authorities for the constructive dialogue and significant support with the provision of data and expertise throughout the FSAP.

is subject to the solvency stress test) to potential transition risks as the economy shifts to achieving the net zero greenhouse gas emissions target by 2050.

The FSAP's scenario-based risk analysis suggests that the financial system is broadly resilient to a range of macrofinancial shocks, though there are some areas of susceptibility.

- **Banks**: The solvency stress test indicates that the banking system would be able to maintain its solvency position under a hypothetical adverse scenario comprising high inflation and a sharp economic downturn. In the adverse scenario, the aggregate capital shortfall remains small, though some banks may be susceptible to the stress. Liquidity risks for banks were found to be contained at the system level due to a sufficiently strong liquidity position in Japanese Yen (JPY). However, some banks appear susceptible due to their sizeable FX exposures via large asset-side undrawn committed credit lines, and on the liability-side, via FX wholesale funding and FX swap dependence—the latter also implying a risk through possible adverse feedback to banks' profitability, and hence solvency, if FX funding costs were to rise.
- **Insurers***:* Insurers, especially life insurers, are sensitive to an increase in domestic and foreign interest rates, though in aggregate, their capital remains well above the regulatory capital requirements in the adverse stress testing scenario. A decline in equity prices, rising credit risk, and a potential default of counterparties remain relevant sources of risk under stress conditions. Insurers are not significantly exposed to liquidity risk, but some may face pressures under stress.
- **Investment funds**: The investment funds sector has been growing steadily and appears well positioned to accommodate plausibly sized investor redemption shocks under an adverse scenario. However, less liquid funds experience larger redemption shocks and could contribute to fragilities in domestic equity markets under more severe shocks.
- **Contagion**: The Japanese financial system is highly interconnected with globally and domestically systemically important banks (G-SIBs and D-SIBs, respectively) playing an important role in the network of financial institutions. While systemic domestic contagion risks based on bilateral exposures appear limited due to the strong capital positions of major financial institutions, broader changes in market sentiment or changes in valuation of common asset holdings could exacerbate such risks. Moreover, some selected banks and insurers with large claims on other financial institutions relative to their capital appear vulnerable to contagion risks. Cross-country inward and outward financial spillovers could be sizeable.
- **Nonfinancial corporates and households:** Nonfinancial firms experience an increase in their probability of default under the hypothetical adverse scenario due to a slowdown in economic activity and an increase in interest rates, with the impact being more pronounced for smaller firms. Under the adverse scenario, household default rates would rise, though starting from a very low level, due to the presumed rise in unemployment and interest rates. Mortgage loss-given-defaults (LGDs) would rise materially due to the assumed drop in house prices. Both default rates and LGDs could be lessened by the industry practice (5-year/125-percent rule) that could mitigate the impact of a sharp increase in interest rates on mortgage payments.

- **Climate risk**: The banking sector's exposure to emission intensive sectors is nonnegligible and constitutes, on average, about one-fifth of their assets. Notwithstanding the uncertainty around firms' emission intensities, banks generally appear resilient to a transition to net zero greenhouse gas emissions by 2050 relative to a "current policies" scenario, though the impact on capital positions varies across banks in the sample. In terms of physical risks, a high-level analysis shows that about one-third of physical assets are at risk of flooding in Japan, with significant variation across prefectures. The future damage rate from floods is expected to increase in some regions. Available climate adaptation indicators, however, suggest that Japan has a strong capacity to cope with extreme weather events.

The challenging risk environment underscores the need to strengthen the Japanese authorities' systemic risk monitoring and analysis. Systemic risk monitoring of the financial system needs further enhancement by leveraging on recent data collection efforts, filling remaining data gaps to enhance domestic and cross-border contagion analysis, introducing stress testing for investment funds, conducting comprehensive systemic JPY and FX liquidity risk analyses for banks and insurers, and performing more granular risk analysis for the household, nonfinancial corporate, and real estate sectors. The authorities should also continue to collect information on banks' securities holdings including interest rate hedging and FX positions, and to carefully monitor risks from sizable exposures of financial institutions to domestic and foreign securities and banks' FX liquidity needs.

Table 1. Japan: Main Recommendations

Recommendations	Timing[1]	Authorities
Further enhance the liquidity risk analysis for banks with, e.g., stress test tools and models for exposures in both JPY and foreign currencies and make it an integral part of systemic risk assessment.	ST	FSA, BOJ
Continue developing the bank solvency stress test model framework.	C	BOJ
Further enhance models to assess potential vulnerabilities, including price misalignments in real estate markets to complement indicator-based risk assessments.	C	BOJ
Develop and operate an investment fund stress test framework.	MT	FSA
Regularly conduct economic value-based solvency ratio (ESR) top-down stress test analysis for insurers and continue to closely monitor insurers liquidity risk.	MT	FSA
Develop models and fill data gaps to analyze contagion risks in the financial system among banks and nonbank financial institutions (NBFIs) as part of systemic risk monitoring.	MT	FSA
Further enhance the climate risk models and analysis for both physical and transition risks, possibly in collaboration with other governmental bodies and external research institutions.	MT	FSA, BOJ
Continue compiling data from banks related to securities holdings, including on hedging of interest rate risk and foreign currency risk.	C	FSA, BOJ
Continue to foster interagency collaboration for systemic risk analysis, ensuring that both the BOJ and FSA have necessary access to data.	C	FSA, BOJ
Continue to enrich the scope of the Common Data Platform in line with the evolving risk environment.	C	FSA, BOJ

[1] I Immediate (within 1 year); ST Short Term (within 1-2 years); MT Medium Term (within 3–5 years). C Continuous.

INTRODUCTION

A. Objectives and Scope

1. This note presents the findings and recommendations of the systemic risk analysis conducted for the Japanese financial system. The analysis is intended to help identify the key sources of vulnerabilities and systemic risk in major financial sectors to inform policy advice and strengthen the resilience of the system to absorb adverse shocks.

2. The analysis comprised a comprehensive set of stress testing exercises to assess the resilience of the financial system. The stress testing exercises cover the key components of the financial system (banks, insurance companies, and investment funds), as well as nonfinancial corporates and households, and simulate their financial health under a counterfactual adverse scenario and various sensitivity tests.[2] Risks were evaluated at the level of individual financial institutions on a stand-alone basis, and from a systemic risk perspective, using models for solvency (banks, insurers), liquidity (banks, insurers, investment funds), and solvency-liquidity feedback (banks). The risk analysis for nonfinancial corporates and households provided input to the banks' solvency analysis. Vulnerabilities and risks were also analyzed in the real estate sector to inform the stress testing exercises. In addition, climate risk analysis was conducted to assess the vulnerability of the domestic banking sector to potential transitions risks as the economy shifts to achieving the net zero greenhouse gas emissions target by 2050.

3. The analysis considers the high degree of interconnectedness of the domestic financial system. Contagion risks are analyzed among major banks, insurers and securities firms relying on bilateral exposures data. In addition, cross-border spillovers are also assessed from shocks to counterparties of banks in key foreign jurisdictions.

4. The stress tests placed strong emphasis on structural—instead of econometric—models, given Japan's specific historical macrofinancial dynamics. The decade-long ultra-low interest rates, and the associated specific macrofinancial dynamics (including, for example, very low default rates in most economic sectors) imply a challenge for econometric modeling methods. Structural model methodologies for various risk parameters, deeply rooted in micro data, were therefore prioritized for risk analysis of the nonfinancial corporate (NFC) and household segments, as explained in later sections. The market risk models are of a conventional, structural form as well, building on a modified duration-based valuation methodology, while accounting for hedging as a specific extension considered for the Japan FSAP application.

B. Macrofinancial Environment

5. The Japanese economy continues to grow after the COVID-19 pandemic, with broad-based price increases following three decades of low inflation. Real GDP growth has averaged

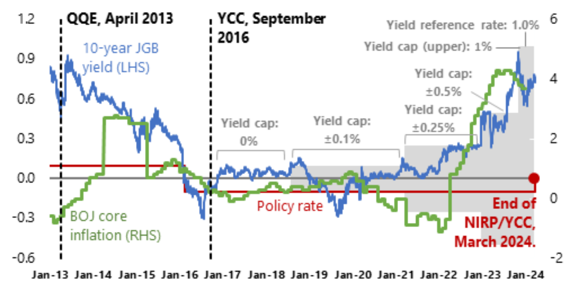
[2] The adverse scenario and sensitivity tests include global and domestic financial market stress (shocks to term and equity premiums and asset price corrections) and a sharp slowdown of economic activity. See the following sections for detailed information on the stress testing exercise.

about two percent per annum during 2021-2023, driven by a surge in inbound tourism, pent-up domestic demand, and aided by strong policy support (Figure 1; Table I.1). After years of deflationary concerns, inflation pressures have emerged, with both headline and core inflation (excluding fresh food) exceeding the Bank of Japan's (BOJ) 2 percent target since April 2022. The pickup in consumer prices has outpaced nominal wage growth, leading to a decline in real wages since the pandemic (Figure 1).[3]

6. The BOJ has ended its negative interest rate policy and yield curve control (YCC). Against a backdrop of persistent inflation, the BOJ incrementally relaxed its YCC framework over time, allowing for greater flexibility in 10-year Japanese government bond (JGB) yields (Text Figure).[4] With confidence taking hold that the inflation target can be sustainably achieved, it abolished the YCC and the Quantitative and Qualitative Easing (QQE) frameworks in March 2024, and ended the negative interest rate policy, while maintaining its gross JGB purchases broadly at the current pace.[5]

Japan: Inflation and Monetary Policy Shift

(Percent)



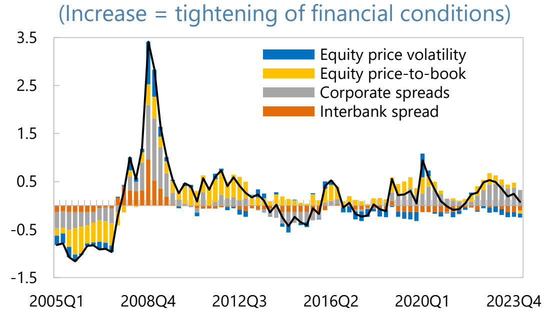
Sources: Tullett Prebon; Ministry of Internal Affairs and Communications; and IMF staff calculations.

Notes: The BOJ decided to guide overnight rate as primary policy tool, encouraging the rate to remain at around 0-0.1 pct. NIRP=negative interest rate policy. QQE=quantitative and qualitative easing. YCC=yield curve control.

7. Domestic financial conditions have remained generally easy in recent months on the back of an increase in equity prices, and a decline in corporate and interbank spreads (Text Chart).[6] Credit to the private sector has remained robust, driven by lending to NFCs and to the real estate sector (Figure 2). Gross debt of NFCs and households (relative to GDP) has increased since the pandemic, though they also hold sizable liquid assets. Sovereign debt to GDP has risen notably and, at 240 percent of GDP, is the highest among advanced economies (Figure 3).

Japan: Financial Conditions Index

(Increase = tightening of financial conditions)



Source: IMF staff calculations.

Notes: The index incorporates the corporate and interbank spreads, equity price-to-book ratio, and equity price volatility. Input variables are standardized and evaluated relative to the mean, with positive (negative) values indicating tighter (easier) financial conditions than the historical average. Values for 2024Q1 are based on data up to March 28, 2024.

[3] Nominal wage growth in Japan is significantly influenced by the annual spring wage negotiations, which gave workers a 2.1 percent rise in base pay in 2023 (a notable increase from the 0.6 percent rise in 2022). The first two rounds of wage negotiations in 2024 have resulted in a 5.3 percent increase in headline wages (3.6 percent in base pay), the highest increase in three decades, which may imply a further pick up in average nominal wage growth in FY2024.

[4] See the BOJ's Monetary Policy Releases for changes to the monetary policy framework over time.

[5] See https://www.boj.or.jp/en/mopo/mpmdeci/mpr_2024/k240319a.pdf for additional details and the announced changes to the monetary policy framework.

[6] Stock prices have reached multi-decade highs in Japan, with the TOPIX and Nikkei 225 rising by 25 percent and 28 percent in 2023 (y/y), respectively. This increase may be attributed to multiple factors including strong corporate

(continued)

8. Real estate prices have risen owing to strong demand amid low mortgage interest rates. Residential real estate (RRE) prices have increased by more than 11 percent in real terms since 2019 (Figure 4). The commercial real estate (CRE) sector has also seen steady price growth and remained resilient through the pandemic, though the momentum has slowed down since end-2022, especially in the retail and office sectors (Figure 5).[7]

9. Elevated interest rate differentials vis-à-vis other major economies have implied persistent depreciation pressures on the Japanese Yen (JPY). Low interest rates in Japan and aggressive monetary policy tightening in the U.S. and the euro area since 2022 have implied notable yield differentials, contributing to depreciation pressures on the JPY (Figure 6 and Figure 7). The higher prices of key imported goods (e.g., oil) may also have been a contributing factor to the JPY depreciation trend. Concurrently, the increase in U.S. interest rates has raised U.S. dollar funding costs for Japanese firms.

10. Liquidity in the JGB market has improved as the BOJ has allowed greater flexibility in the YCC framework. After a widening of the 10-year JGB yield target to ±50 bp by the BOJ in December 2022, volatility of interest rates increased and liquidity indicators (such as the bid-ask spread) in the JGB market deteriorated notably (Figure 8). In response, the BOJ made unscheduled purchases of JGBs, and the liquidity indicators improved. During 2023, the increased flexibility allowed by the BOJ in the conduct of YCC helped to smooth the JGB yield curve and improved the functioning of the JGB market. JGB trading volumes have risen amid higher yields.

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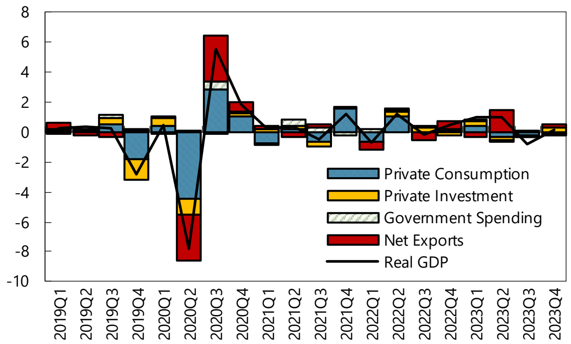
earnings, a weaker yen, inflation, and a conviction on structural changes such as progress in corporate governance reform, all of which have attracted investors, especially foreign investors, to the stock market.

[7] Price developments in the RRE market vary across regions, with a more pronounced increase in urban areas (IMF, 2020). CRE price developments also vary by region, as well as by segment with the retail sector remaining under pressure (Figure 5; MSCI Real Estate database).

Figure 1. Japan: Macroeconomic Developments

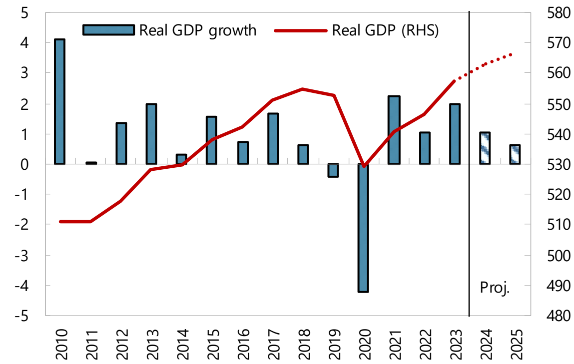
Real GDP has been recovering since the pandemic aided by strong domestic demand…

Contributions to Real GDP Growth
(Percent change, QoQ chained 2015 SAAR)



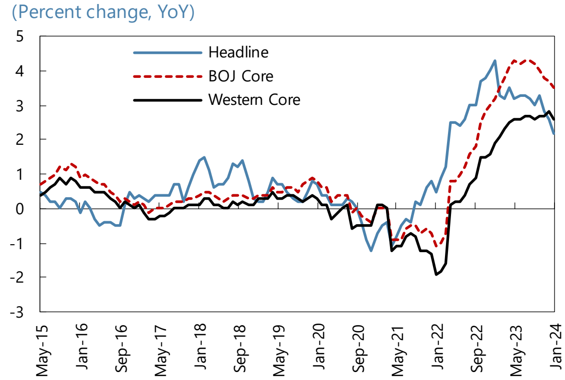
…and is above the pre-pandemic level.

Real GDP and Real GDP Growth
(Percent, LHS; in trillions of yen, RHS)



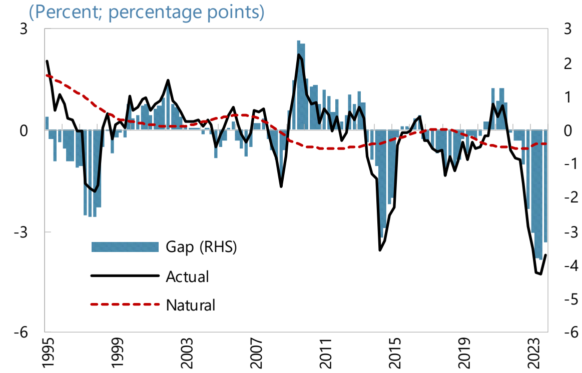
Headline and core inflation have risen above the BOJ's target of 2 percent since April 2022…

Price Inflation
(Percent change, YoY)



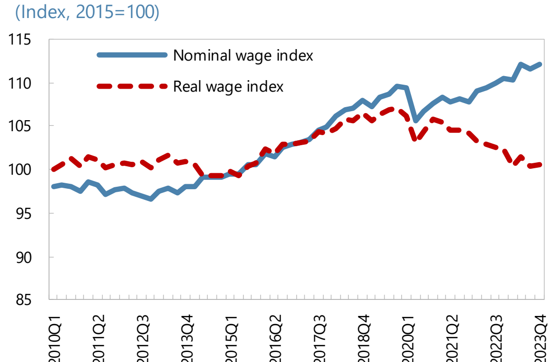
…while the monetary policy stance has remained accommodative.

Real Policy Interest Rate
(Percent; percentage points)



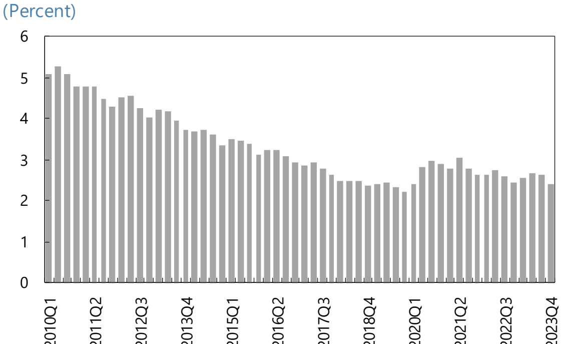
Real wages have declined since the pandemic…

Nominal and Real Wages
(Index, 2015=100)



…but the unemployment rate has remained stable.

Unemployment Rate
(Percent)

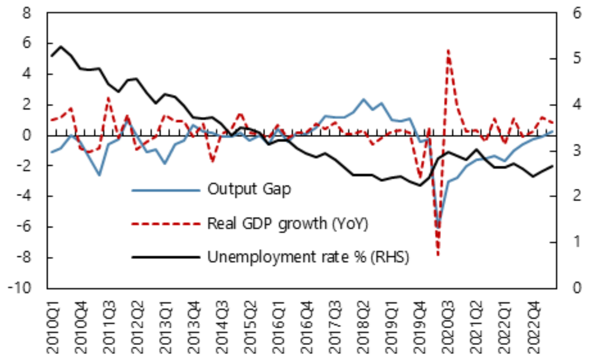


Sources: BOJ; Cabinet Office of Japan; Ministry of Health, Labor & Welfare; and IMF staff calculations.
Notes: BOJ core inflation excludes fresh food and energy. Western core excludes all food, non-alcoholic beverages, and energy. The gap in panel 4 refers to the difference between the actual and natural interest rate, with the latter estimated using the methodology in IMF WP/18/275.

Figure 1. Japan: Macroeconomic Developments (concluded)

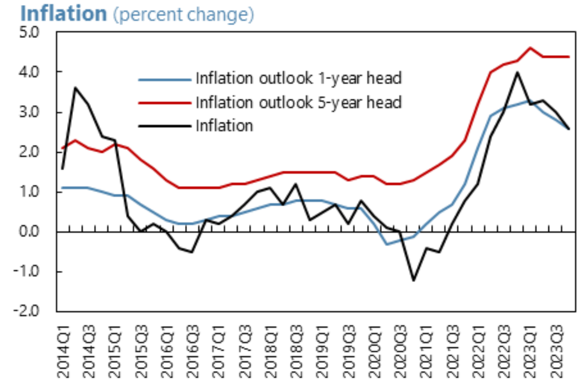
The output gap has closed amid a tight labor market…

Output Gap, Real GDP Growth, and Unemployment Rate (percent, percent change YoY)



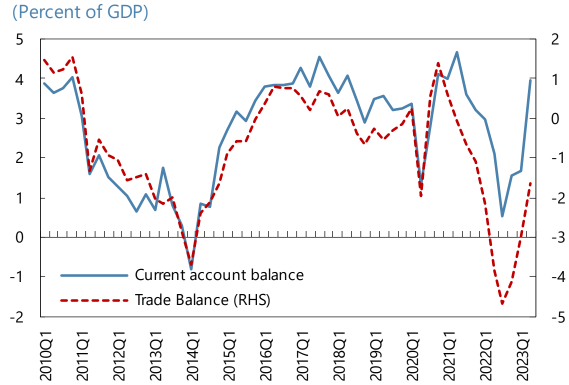
…and inflation expectations appear to be peaking at high levels.

Firms' Inflation Expectations (1Y-5Y) and Current Inflation (percent change)



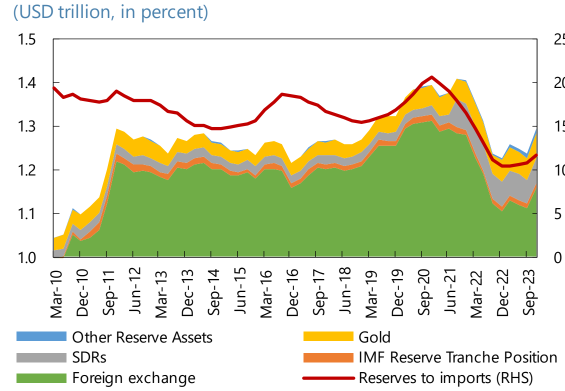
Trade balance has bounced back as the increase in oil prices has moderated.

Current Account Balance and Trade Balance (Percent of GDP)



FX reserves have declined since 2021 but remain at more than ten months of imports.

Japan: Official Reserve Assets (USD trillion, in percent)

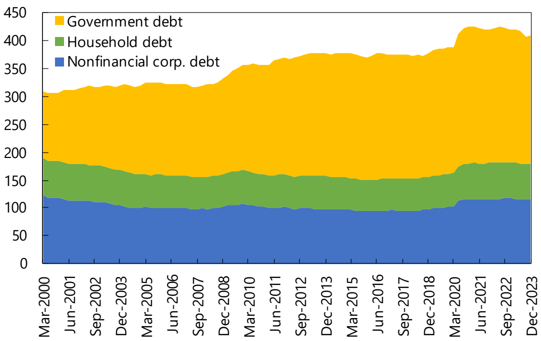


Sources: BOJ TANKAN survey; Cabinet Office of Japan; Ministry of Internal Affairs and Communications; Haver Analytics; Japan Tariff Association; OECD database; Trade Statistics of Japan Ministry of Finance; and IMF staff estimates.

Figure 2. Japan: Public and Private Sector Debt

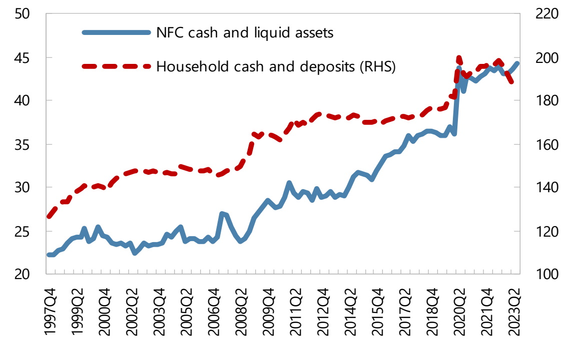
Public and private sector debt have increased notably since the pandemic…

Household, Nonfinancial Corp., and Government Debt
(Percent of GDP)



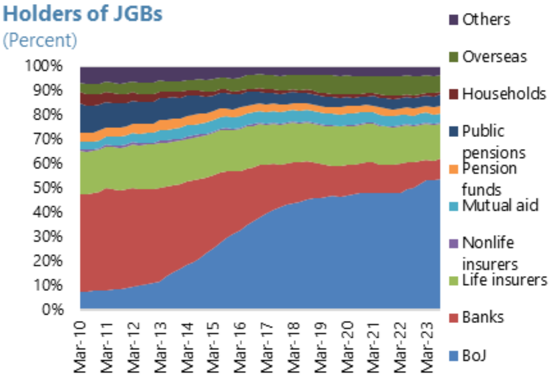
…although firms and households hold sizable liquid assets…

NFC Cash and Liquid Assets, and Household Cash and Deposits (Percent of GDP)



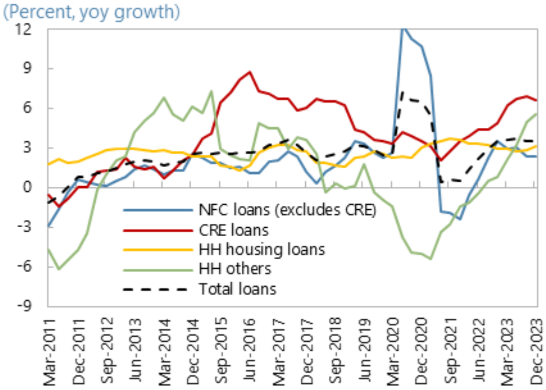
…and most of the public debt is held by the BOJ, which has purchased a record amount of JGBs since QQE.

Holders of JGBs
(Percent)



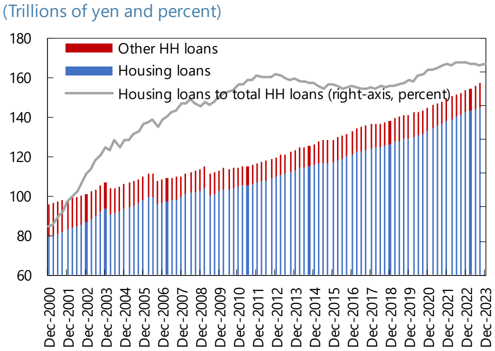
Domestic private sector credit growth has remained robust…

NFC, CRE, and Household loans
(Percent, yoy growth)



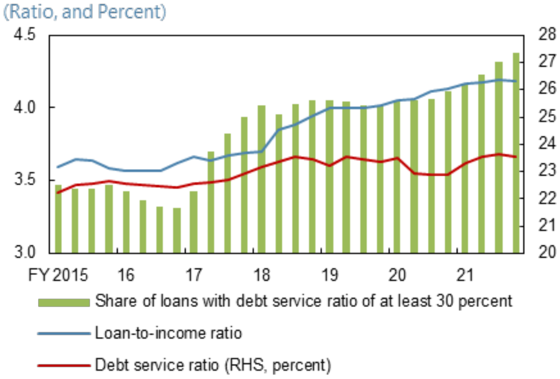
…and housing loans have increased notably since the pandemic…

Household Loans
(Trillions of yen and percent)



…while debt-service-to-income and loan-to-income ratios have also been rising.

Household Loan-to-Income and Debt Service Ratio
(Ratio, and Percent)

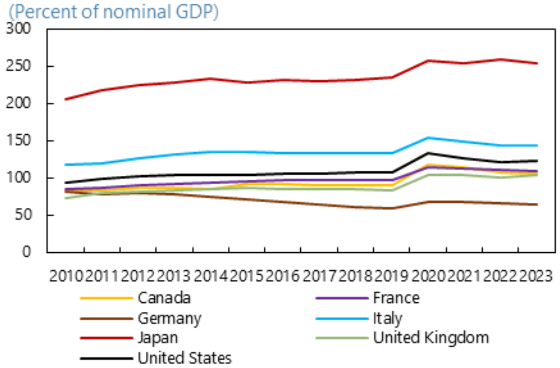


Sources: BOJ; IMF WEO; Institute of International Finance; Ministry of Finance (MOF); and IMF staff calculations.
Notes: Japan fiscal year ("FY") starts in April and ends in March of the following year (e.g., FY2021 stands for April 2021-March 2022). Loan-to-income ratio is ratio of loan (at origination) to the borrowers' income. Debt service ratio represents annual debt service (at origination) to annual borrowers' income. NFC=nonfinancial corporate, CRE=commercial real estate, HH=household, QQE=Quantitative and qualitative monetary easing.

Figure 3. Japan: Sovereign Debt, BOJ Balance Sheet, and Banking System Reserves

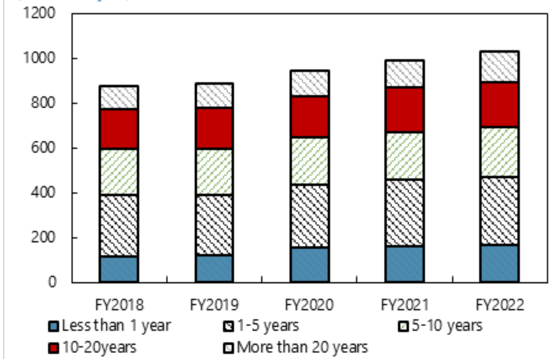
Sovereign debt in Japan is the highest among G7 economies.

General Government Debt
(Percent of nominal GDP)



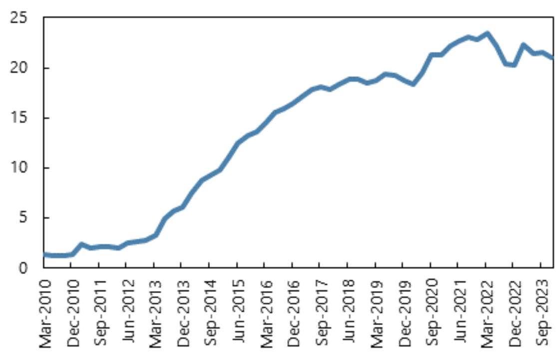
Most outstanding government bonds are of a longer maturity.

Outstanding Amount of Gov. Bonds, Years to Maturity
(In trillion yen)



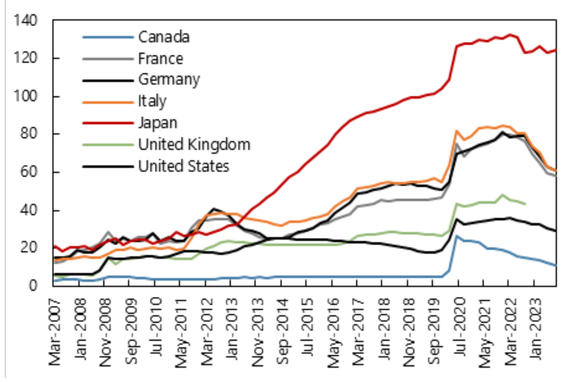
The size of banks' reserves relative to their assets has grown consistently over the past decade...

Japan Banking System Reserves at BoJ
(In percent of total banking system assets)



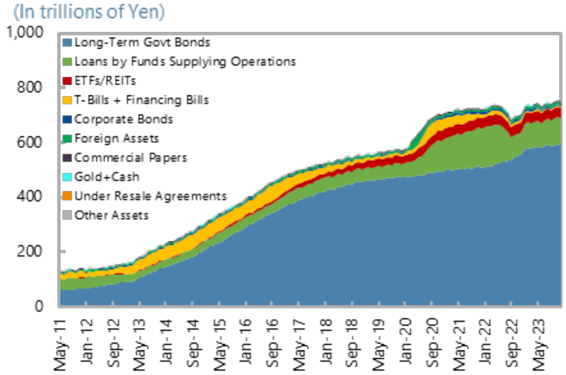
...as the BOJ's balance sheet has expanded...

G7: Central Bank Balance Sheet to GDP
(Percent of GDP)



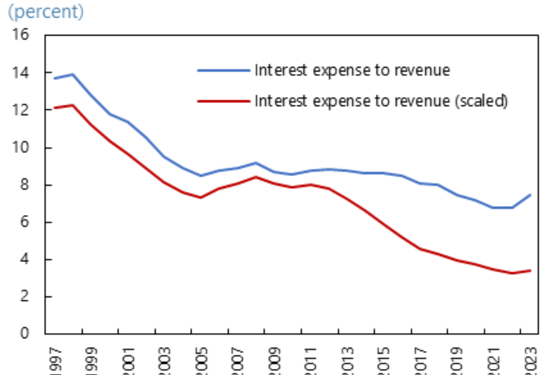
... with a large share of JGB holdings.

Bank of Japan Balance Sheet (Asset-Side)
(In trillions of Yen)



The sovereign's interest expense has declined gradually over the years due to low interest rates.

Sovereign Interest Expense for Public Debt to Revenue
(percent)

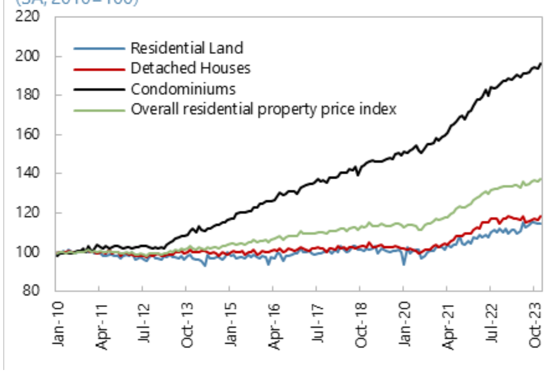


Sources: BIS Locational Banking Statistic; BOJ; MOF; Haver Analytics; IMF Balance Sheet Approach Matrix; and IMF WEO database.
Note: The "scaled" interest expense to revenue ratio in the lower right chart is computed by multiplying the initial interest expense by one minus the share of JGBs held by the BOJ to account for profit distribution from the BOJ to the government.

Figure 4. Japan: Trends in Housing Markets

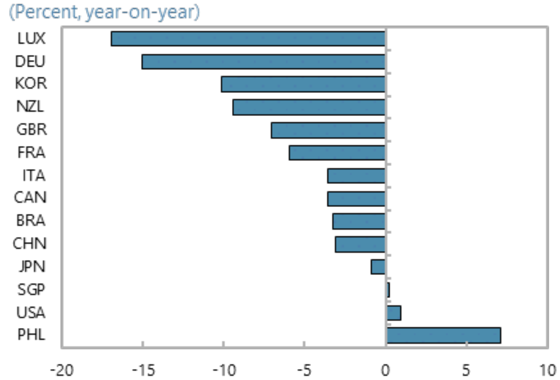
Residential real estate prices in Japan have increased sharply since the pandemic…

Residential Property Prices
(SA, 2010=100)



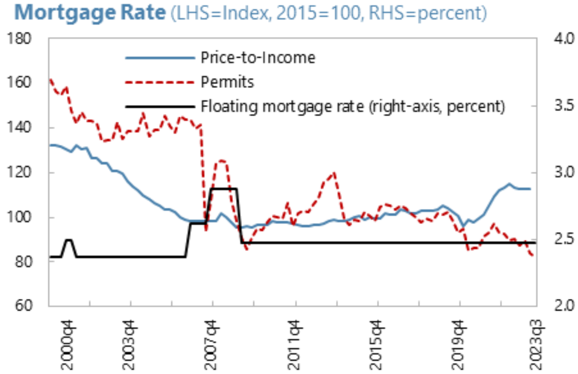
… while most of the countries have faced large price declines

Change in Real House Prices, 2023:Q3
(Percent, year-on-year)



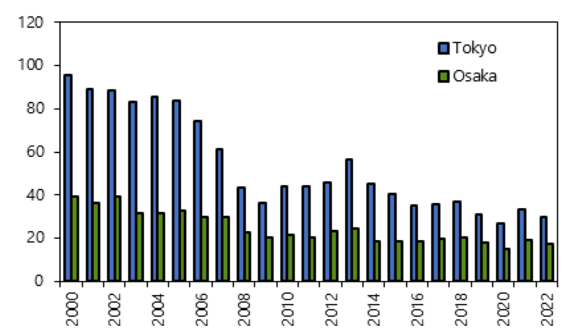
Strong demand for residential property amid low mortgage rates and tight supply have been contributing to price pressures…

House Price to Income, Issued Permits and Mortgage Rate (LHS=Index, 2015=100, RHS=percent)



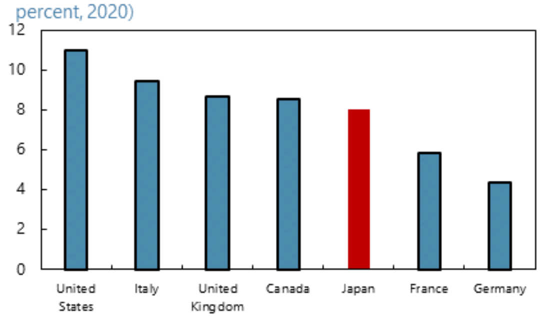
…especially in large metro areas.

Number of Dwellings Put on Market
(Thousands)



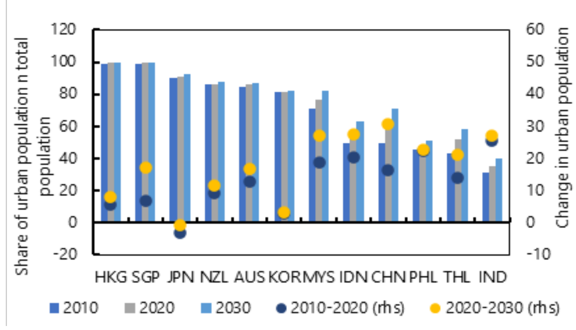
About one-tenth of the population spends over 40 percent of their disposable income on housing.

Overburden Rate
(Share of population spending more than 40 percent on housing, percent, 2020)



In the longer term, shrinking population could dampen pressures on house demand.

Urban Population
(left axis, percentage; right axis, percent)



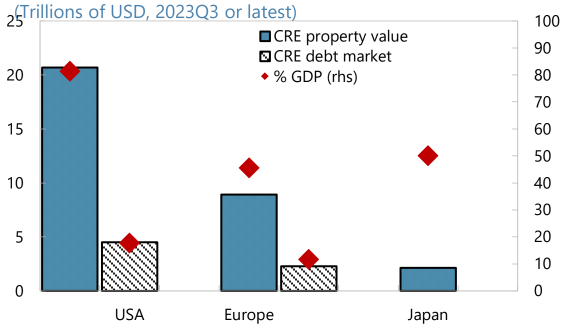
Sources: BIS; BOJ; Ministry of Land, Infrastructure, and Transport and Tourism; MSCI Real Estate; OECD; and IMF staff calculations.
Notes: The top right panel indicates year-on-year change in real house prices computed in 2023Q3. In the bottom left panel, cost overburden rate corresponds to the share of the population spending more than 40 percent of their disposable income (including social transfers) on housing (mortgage or rental expenses, excluding utilities or regular maintenance costs).

Figure 5. Japan: Trends in Commercial Real Estate Markets

CRE exposures represent a significant share of GDP.

Estimated Size of the CRE Market

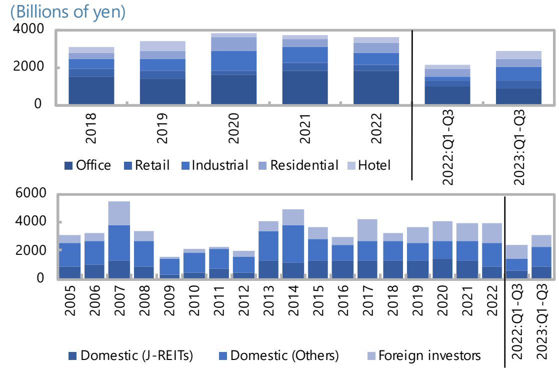
(Trillions of USD, 2023Q3 or latest)



While globally CRE transactions have fallen in 2023, they have remained largely stable in Japan.

Transaction Volumes by CRE Sector and Investor

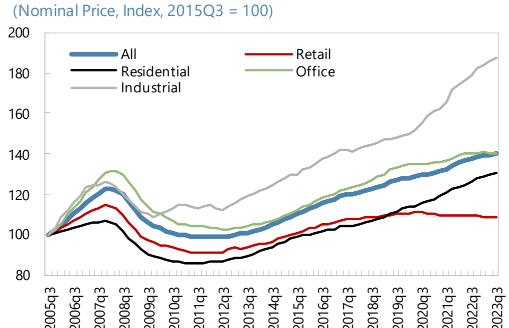
(Billions of yen)



Overall CRE prices have increased steadily…

Japan: CRE Price by Segment

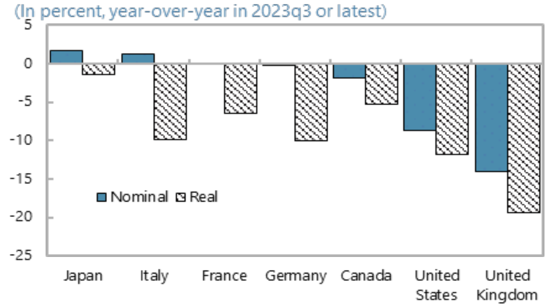
(Nominal Price, Index, 2015Q3 = 100)



…though the momentum seems to have slowed down in recent months.

Nominal and Real Commercial Prroperty Price Growth

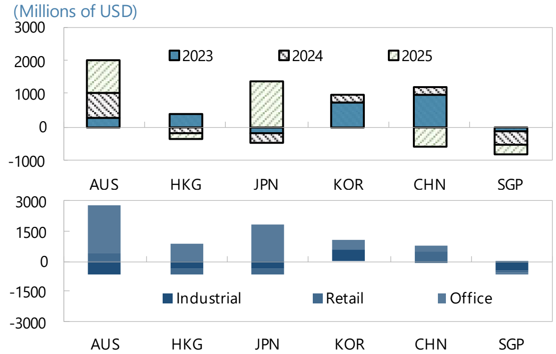
(In percent, year-over-year in 2023q3 or latest)



Refinancing risks may become relevant in 2025 especially, in the office sector.

APAC: Debt Funding Gap by Maturity

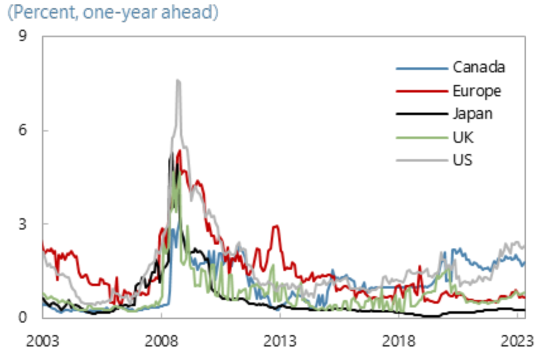
(Millions of USD)



REITs implied default probability has risen, but remains low relative to peer countries

REITs Expected Default Frequency

(Percent, one-year ahead)



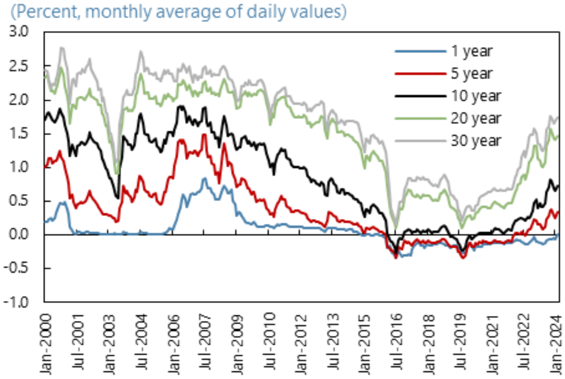
Sources: BIS Statistics; Haver, MSCI Real Estate; OECD; and IMF staff calculations.

Notes: In the bottom left panel, debt funding gap refers to the lack of new debt available to meet existing loan requirements. To measure the debt funding gap for each origination year and sector, the fraction of loans due within five years ("maturing debt") is identified, which is then divided by the average loan-to-value ratio in the origination year to calculate the total value of CRE properties with upcoming debt expirations. The value is then adjusted to reflect an expected price correction. Based on this new value and agencies' forecasted loan-to-value ratio, the debt funding gap is then calculated against the original loan amount. In the bottom right panel, the expected default frequency is calculated as the average of the indicator across REITs in each country area. CRE = commercial real estate. APAC=Asia Pacific. REIT = Real Estate Investment Trust.

Figure 6. Japan: Interest Rates

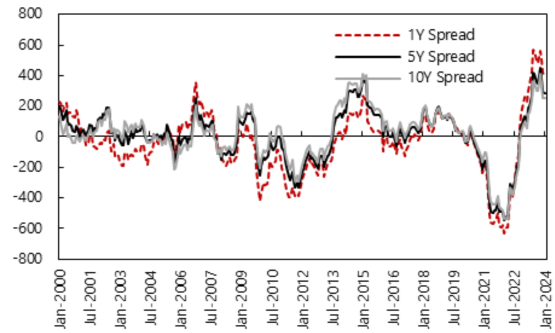
Long-run JGB yields have been rising recently as the YCC framework has been relaxed…

Japanese Government Bond Yields
(Percent, monthly average of daily values)



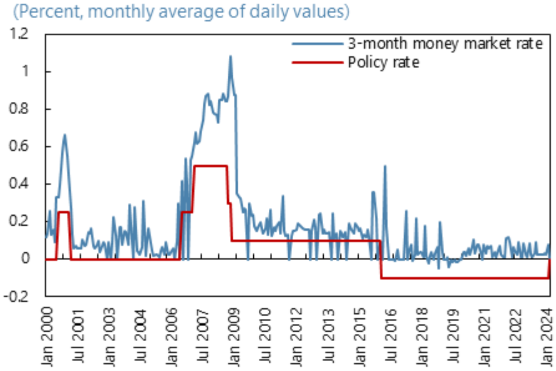
…yet yield differentials with U.S. Treasury bonds remain significant.

United States-Japan Government Real Bond Yield Spread
(Basis points, monthly average of daily values)



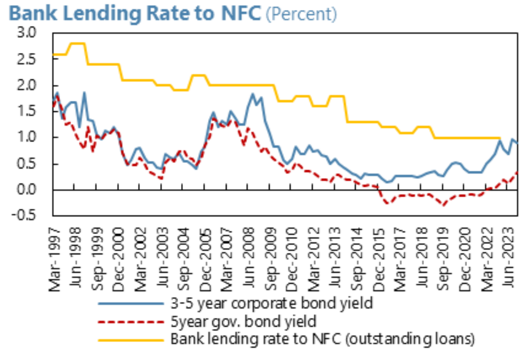
Policy and money market rates have remained at historical lows…

Policy Rate and 3-Month Money Market Rate
(Percent, monthly average of daily values)



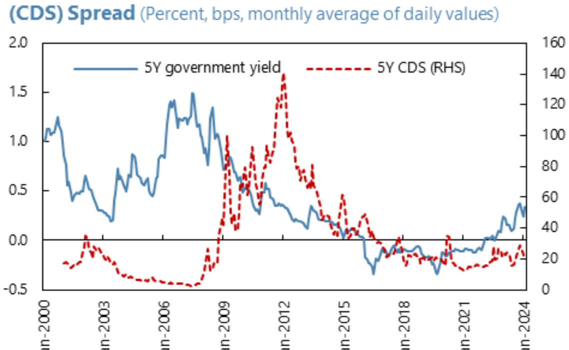
…and bank lending rates for NFCs have trended down, though yields on NFC bonds have risen since 2021.

Corporate Bond 3Y-5Y yield, Government 5Y yield, and Bank Lending Rate to NFC (Percent)



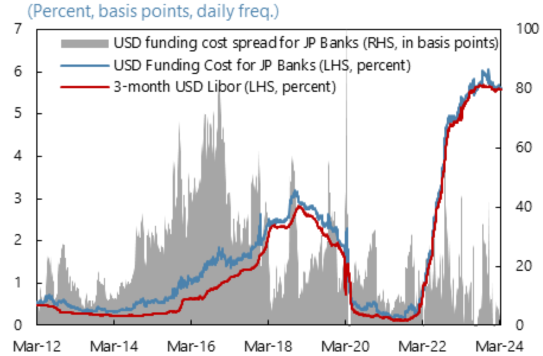
Sovereign CDS swap spreads have also remained low.

JGB 5-Year Yield and Sovereign 5-Year Credit Default Swap (CDS) Spread (Percent, bps, monthly average of daily values)



U.S. dollar funding costs have risen sharply since the Fed's tightening of monetary policy in early 2022.

Cost of Short-Term USD Funding for Japanese Banks
(Percent, basis points, daily freq.)

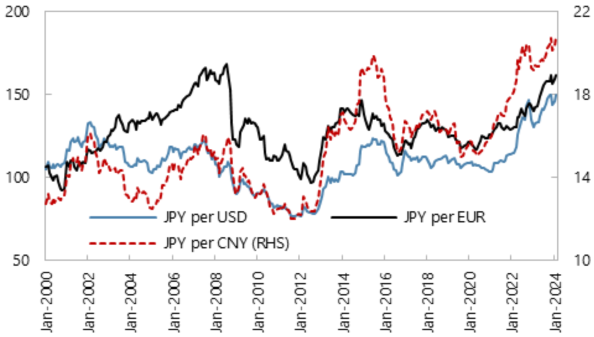


Sources: Bloomberg LLP; BOJ; MOF; S&P Markit CDS price; and IMF staff calculations.
Notes: Spreads are calculated as (US Yields - Japan Yields) × 100 (In Basis Points). NFC=nonfinancial corporate; JGB=Japanese government bonds; CDS=credit default swap; YCC=yield curve control. The USD funding cost estimate for JP banks in the lower right involves the JPY-USD currency basis swap (3-month).

Figure 7. Japan: Exchange Rates

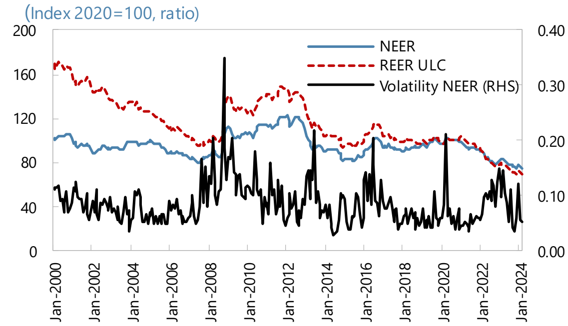
The JPY has been facing depreciation pressures…

Selected Bilateral Exchange Rates to the Japanese Yen (JPY)
(Units, monthly average of daily values)



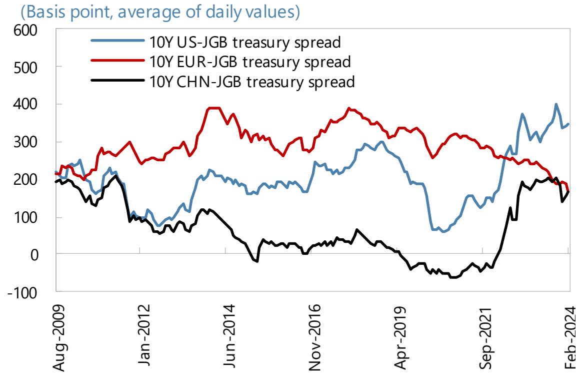
…and somewhat increased exchange rate volatility…

JPY Nominal Effective Exchange Rate (NEER), Real Effective Exchange Rate ULC (REER), and NEER Volatility
(Index 2020=100, ratio)



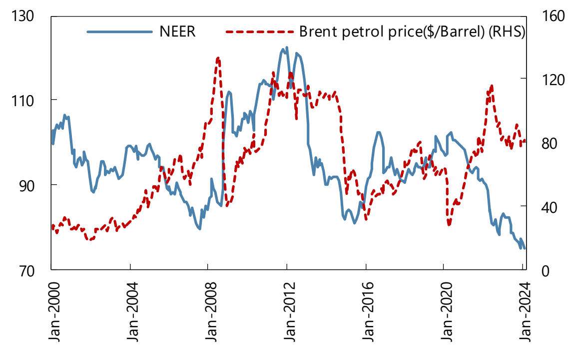
…partly because of notable interest rate differentials with major economies…

10-Year US-JGB, EUR-JGB, CHN-JGB Treasury Spread
(Basis point, average of daily values)



…and the higher cost of key imports such as oil.

JPY Nominal Effective Exchange Rate (NEER) and Brent Crude Oil Prices (Index, 2020=100, $/Barrel)

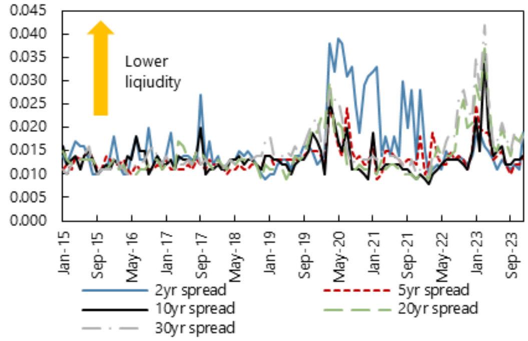


Sources: BIS; Bloomberg LLP; BOJ; Cabinet Office of Japan; and IMF staff calculations.

Figure 8. Japan: Market Liquidity

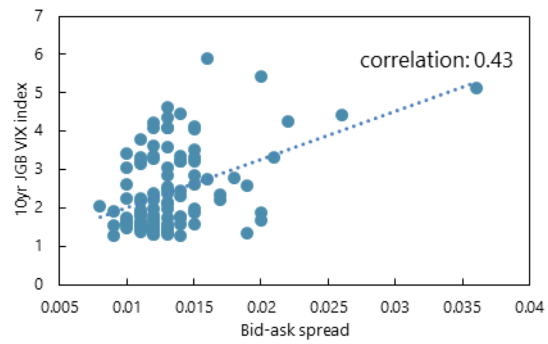
The bid-ask spreads were volatile in January 2023 following greater flexibility in the YCC framework in December 2022.

JGB Bid-Ask Spread
(Percentage points)



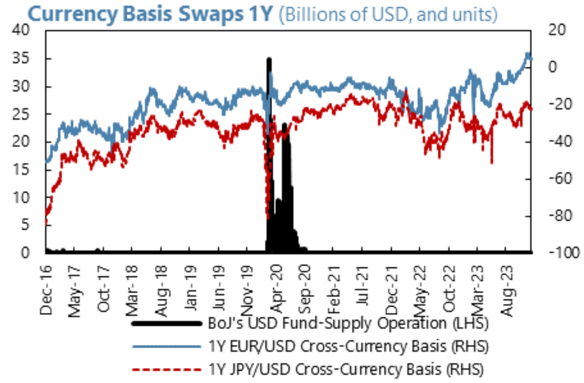
Historically, a deterioration in JGB market liquidity has been associated with higher market volatility.

Implied Volatility and Market Liquitidy of JGB
(Index and spread)



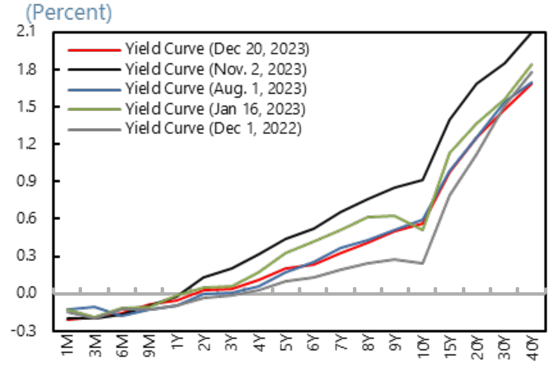
The BOJ provided USD funding amid strains in offshore USD funding markets in March 2020.

BoJ Lending-USD Funds-Supplying Operation and Currency Basis Swaps 1Y (Billions of USD, and units)



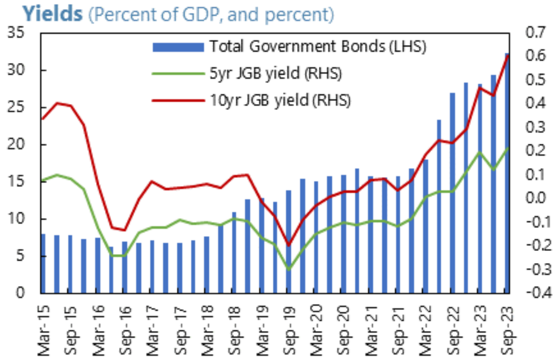
Distortions in the yield curve have declined with greater flexibility in the YCC framework.

JGB Yield Curve
(Percent)



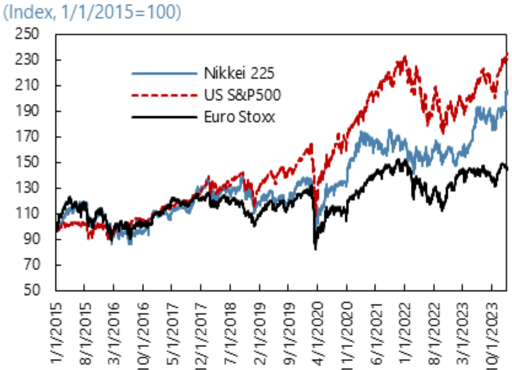
JGB trading volumes have risen in tandem with higher yields.

OTC Daily Transactions: Government Bond and JGB Yields (Percent of GDP, and percent)



The Japanese stock market has boomed in 2023.

Stock Market Index
(Index, 1/1/2015=100)



Sources: BOJ; MOF; Bloomberg LLP; Cabinet Office of Japan; Eikon Refinitiv; Haver Analytics; Japan Securities Dealers Association; and IMF staff calculation.
Note: Bid-ask spread is the difference between the bid and ask yield of JGB.

C. Financial System Structure

11. Japan has a large and globally well-integrated financial system. Japan has one of the largest financial systems in the world with total assets nearly seven times GDP at end-2023 (Figure 9). Financial groups have a significant presence in the financial system and comprise banks, trust banks, insurers, and securities firms. The four largest financial groups make up about one-fifth of total financial assets amounting to about 170 percent of GDP. Among financial institutions, the banking sector accounts for almost 60 percent of the financial system, with one-third of its assets held by three Global Systemically Important Banks (G-SIBs). Japan's insurance sector—dominated by life insurers—accounts for 12 percent of the financial system and ranks fourth in the world by total written premiums (in U.S. dollar terms). Investment funds have grown in importance over the years, and account for 8 percent of the financial system compared to 6 percent in 2016, amid conscious efforts by the authorities. The pension sector is dominated by the Government Pension Investment Fund (GPIF) and amounts to 8 percent of the financial system. [8]

12. Banks play a dominant role in Japan's financial system. The banking sector consists of city banks (including G-SIBs), trust banks, regional banks, Shinkin banks (credit unions), credit associations, credit cooperatives, and other banks (e.g., Japan Post Bank) (Table I.2).[9] As of March 2023, city banks account for about 22 percent of the sector's assets, while regional banks and Shinkin banks make up 11 percent and 4 percent, respectively. City banks and other large banks have nationwide networks and overseas operations, but regional and Shinkin banks have a primarily domestic client base. Credit cooperatives serve mainly farmers in agriculture, forestry, and fisheries. Foreign banks have a small market share (3 percent) and are mostly involved in investment and private banking.

13. The nonbank financial segment is dominated by the insurance sector, in particular life insurers. Life insurance accounts for over 90 percent of the sector, with total assets of about 72 percent of GDP. The insurance sector is highly concentrated—five of the largest life insurers (three of which are mutual in structure) account for more than 60 percent of the total assets of life insurers, while the four largest non-life insurers represent nearly 90 percent of the non-life insurance sector's assets.

14. The Japanese securities markets are among the largest in the world. The stock market capitalization of the Tokyo Stock Exchange stood at more than USD 6.2 trillion (146 percent of GDP) at end-2023, making it the fifth largest stock exchange in the world. The nonfinancial corporate bond market is the fourth largest in the world and has a capitalization of 16 percent of GDP in 2023 compared to 29 percent of GDP in the U.S. and 25 percent of GDP in China and France. The largest

[8] The GPIF and corporate pension funds constitute 5 percent and 3 percent of the financial system, respectively.

[9] The three G-SIBs are Mitsubishi UFJ Financial Group (MUFG), Mizuho Financial Group (MHFG), and Sumitomo Mitsui Financial Group (SMFG). Japan also has four domestic systemically important banks (D-SIBs) (Sumitomo Mitsui Trust Holdings, Norinchukin Bank, Daiwa Securities Group, and Nomura Holdings). The Japan Post Group plays an important role in both the banking and life insurance sectors, accounting for about 12 percent and 22 percent of the sectors, respectively.

Japanese securities firms—three of which are subsidiaries of the G-SIBs—are major players in global capital markets, investment banking, and asset management.

15. The investment funds sector is small but growing steadily. As of end-2022, the total assets under management (AUM) of investment funds in Japan stood at slightly more than USD 3 trillion. Of the total AUM, 81 percent was held by publicly offered and privately placed investment trust funds, about 7 percent in real estate-related corporation-type investment funds, and 12 percent in privately placed investment funds (partnerships). Most of the assets held by publicly offered investment funds are invested in equity and bonds. The industry is dominated by Investment Management Business Operators (IMBOs) that are part of major financial groups led by securities firms and major banks.

16. There are three domestic central counterparties (CCPs) in Japan, including one of the top-10 CCPs worldwide. These are the Japan Securities Clearing Corporation (JSCC), Japan Securities Depository Center DVP Clearing Corporation, and Tokyo Financial Exchange. The average daily cleared value from all JSCC products—exchange cash and derivatives, over the counter (OTC) swaps, and JGB repos—exceeded JPY 100 trillion (about 18 percent of GDP) between April 2022 and March 2023.

17. Fintech-based financial services constitute a small base but have been growing rapidly, especially in the digital payments sphere. Technology-based innovation in financial services in Japan is most relevant for payment services, banking, and crypto assets. While the level of fintech penetration is still relatively modest, the pace has been picking up, particularly in digital payments, owing to several government initiatives. As a result, the ratio of cashless payments to total payments reached 36 percent in 2022, up from 21 percent five years earlier. The usage rate of online financial services (i.e., banking, investment, insurance websites or apps) among those aged 16-64 is 20 percent, well below other G7 countries for which the average is almost double, but the rapid growth in the accounts of some digital banks and penetration of open banking suggest steady changes in this area.

18. The financial system is characterized by a high degree of interdependence between the financial and real sectors. Both banks and nonbank financial institutions (NBFIs) have large exposures to each other and to corporate and household sectors (Figure 10). Banks and NBFIs hold a notable share of JGBs, though their exposure has declined considerably by about 15 and 10 percentage points, respectively, in the last decade.

19. Amid ultra-low domestic interest rates and subdued economic growth during the last decade, financial institutions have expanded their overseas exposures in search of higher returns. The share of foreign assets in the total assets of banks and NBFIs is notable, at 14 and 20 percent, respectively, with the latter increasing by 6 percentage points over the last decade (Figure 10). Most of the foreign assets held by banks are in the form of loans and debt securities, while insurers hold sizable foreign debt and equities. To obtain foreign currency (FX) funding, banks mostly rely on unsecured wholesale funding and FX swaps, which makes them highly sensitive to an increase in foreign interest rates. In this context, the overseas exposure of Japanese financial institutions has declined since 2022 due to the sharp rise in U.S. interest rates and FX funding and hedging costs (Figure 11).

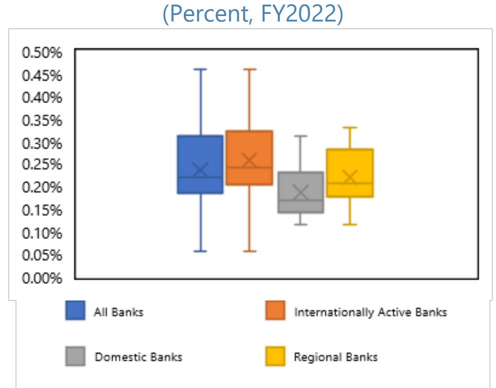
D. Financial Sector Soundness

20. The financial system withstood the pandemic shock, aided by strong policy support. Banks entered the pandemic crisis with generally strong capital and liquidity positions, which deteriorated only modestly in the aftermath of the pandemic owing to massive fiscal and monetary stimulus and supportive financial sector measures (Table I.3).[10]

21. Banks' capital ratios remain well above the regulatory minimum, and liquidity buffers remain high. Banks are generally well capitalized but have seen some recent decline in capital ratios due to valuation losses from overseas securities holdings as foreign interest rates have risen (Figure 11). Nonperforming loan (NPL) ratios have remained low and fairly stable since the pandemic. Although corporate bankruptcies—particularly for small firms—have been rising in 2023, they remain at a low level (BOJ, 2023). Banks have maintained sizeable JPY liquidity buffers, with about one-third of total assets being liquid assets (Table I.4).

22. Profitability of the banking sector has remained structurally weak in a low interest rate, subdued growth environment. The decline in interest rates since 2016 has put downward pressure on banks' net interest margins as lending rates have fallen while deposit rates have remained close to zero, constrained by the effective zero lower bound. The low interest rate environment has posed a challenge in particular for domestic banks and regional banks, whose profitability, on average, falls short of the other bank clusters (Text Chart). Profitability of internationally active banks, particularly G-SIBs, has been aided in 2022 by a rise in foreign interest rates lifting net interest margins in foreign lending and by the depreciation of the JPY.[11] Looking forward, an increase in domestic interest rates may also positively contribute to bank profitability through an increase in banks' net interest income, and thereby to their capitalization.

Japan: Banks' Return on Assets
(Percent, FY2022)



Sources: FSA; and IMF staff calculations.
Note: The return on assets for the underlying banks is computed as net income after tax over annual average total assets.

[10] See Table I.4 for information on financial sector policy support measures during the pandemic, and their phaseout timing.

[11] From a business model perspective, banks operating in specific regions are called regional banks. Banks with one or more foreign branches or subsidiaries are termed as internationally active banks, while those without are classified as domestic banks. This classification into internationally active or domestic banks is mainly used for capital adequacy ratio regulation purposes. Hereinafter, the categories internationally active, domestic and regional are used to describe banks' characteristics but it should be noted that there is a considerable overlap between regional banks and internationally active/domestic banks given the definition.

23. The Financial Services Agency (FSA) has initiated measures to support the consolidation of regional banks to enhance their efficiency and preserve viability. As part of a broader drive to improve banking sector efficiency, the act on special measures for the anti-monopoly act provides a 10-year window for a merger or other integration between regional banks. This would exempt the merger from the application of the anti-monopoly act on the condition that the new merged bank is judged to better serve its local communities by leveraging the capacity generated by the merger.

24. Liquidity conditions have been mostly stable among banks. As of December 2022, the share of retail deposits and insured deposits is 58 and 60 percent, respectively, in the Japanese banking sector. According to the BOJ's October 2023 Financial System Report (FSR), about 30 percent of banks have core deposits with a maximum maturity of 10 years or more, while about 20 percent of banks have core deposits with an average maturity of 5 years or more. In addition, nearly 40 percent of core deposits have a remaining maturity of over 5 years.[12]

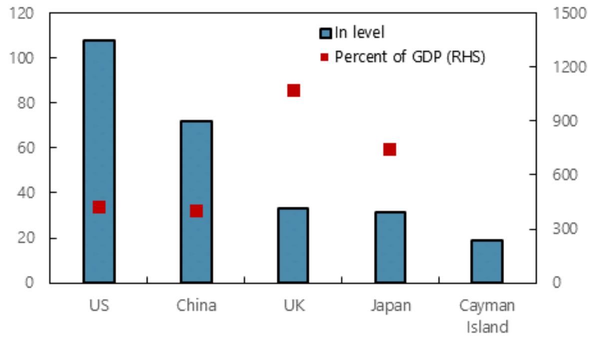
25. Insurance companies have strong capital buffers. The average solvency margin ratio (SMR) of major life insurers and non-life insurers in the stress test sample stood at 956 percent and 840 percent, respectively, in March 2023, while the economic value-based solvency ratio (ESR) was 226 percent and 212 percent, respectively. In recent years, the insurance sector has confronted higher FX hedging costs, a decrease in unrealized gains on securities and, for non-life insurers, higher expenses related to natural disasters that impacted profitability, the annualized premiums for new businesses have also risen and returned to levels seen before the COVID-19 pandemic. Furthermore, the ongoing reduction of insurance policies with legacy high guaranteed interest rates has contributed to internal capital generation, positively influencing the overall financial strength of insurers.

[12] The October 2023 FSR defines core deposits as those that remain at a bank for an extended period of time without being withdrawn. For the exact definition used, see Box 2 of the aforementioned FSR.

Figure 9. Japan: Financial System Structure

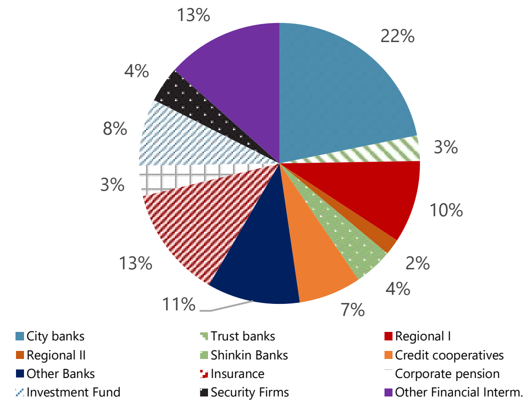
The Japanese financial system is one of the largest in the world…

Top Five Countries by Financial System Assets
(Trillions of dollar, and percent of GDP)



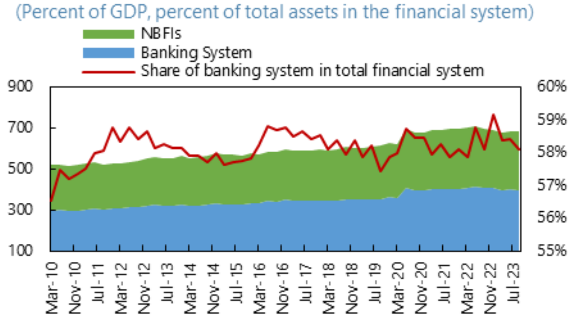
…and is dominated by banks.

Total Financial Assets of Financial Institutions, March 2023 (Percent)



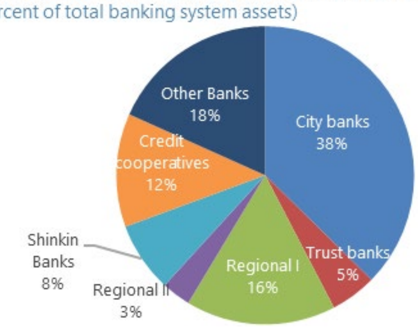
The banking system's share in total financial sector assets has stayed stable at about 60 percent…

Banking System and NBFI
(Percent of GDP, percent of total assets in the financial system)



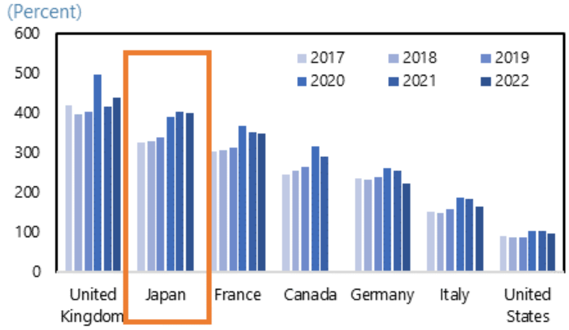
…with city banks constituting the dominant group.

Financial Assets by Types of Banks, March 2023
(Percent of total banking system assets)



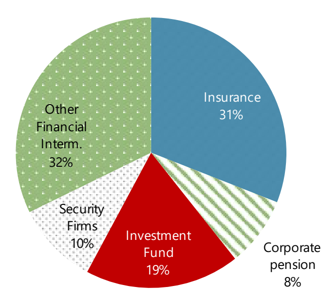
The Japanese banking system is sizeable in cross-country comparison.

Banking System Total Assets to GDP
(Percent)



The NBFI segment is dominated by insurers, followed by investment funds.

NBFI Total Assets, March 2023
(In percent of total NBFI assets)



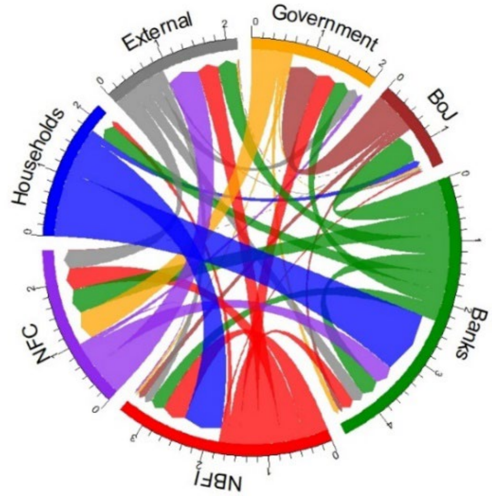
Sources: Financial Stability Board; BOJ; Japanese Bankers Association; Shinkin Central Bank; and IMF staff calculations.
Notes: Japan Post Bank is included in the category of "other banks." Other financial intermediaries consist of miscellaneous non-banking institutions, public financial entities, and financial dealers and brokers (not securities firms). Regional Bank I, typically established within the main city of a prefecture, concentrate most of their operations within the prefecture, and maintain significant relationships with local enterprises and local governments. Regional Banks II focus on servicing the financial needs of both smaller companies and individuals situated within their immediate geographical localities. The list of Regional I and Regional II banks is available here: https://www.fsa.go.jp/en/regulated/licensed/index.html. Shinkin banks are cooperative regional financial institutions serving small-and-medium enterprises and individuals, operating under the Shinkin Bank Law.

Figure 10. Japan: Financial System Interconnectedness

NBFIs are notably interconnected with banks, NFCs, and households.

Cross-Sectoral Interlinkages, 2022

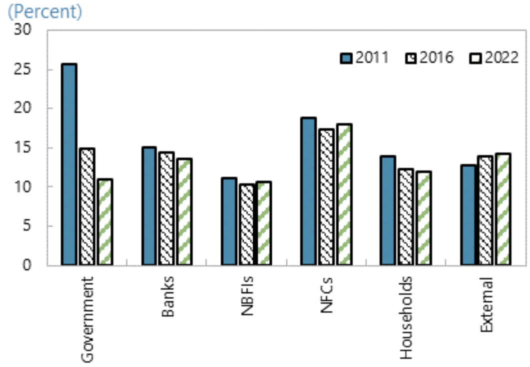
(Asset claims in JPY quadrillions)



Banks and NBFIs have reduced their holdings of government securities, while increasing their cross-border exposures.

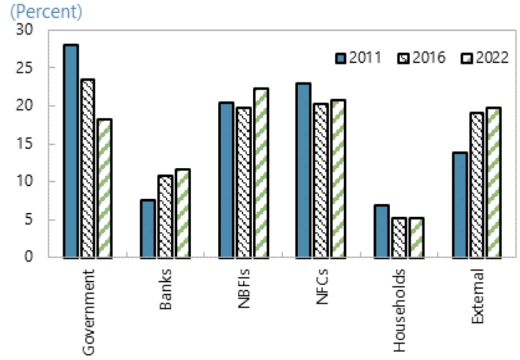
Banks' Asset-Side Exposure

(Percent)



NBFIs' Asset-Side Exposure

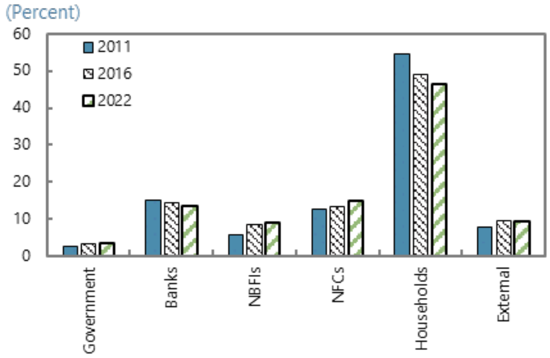
(Percent)



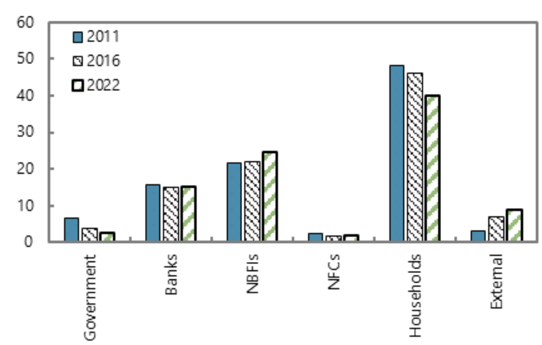
A large share of bank and NBFI liabilities is to households…

Banks' Liabilities to Selected Sectors

(Percent)



NBFIs' Liabilities to Selected Sectors

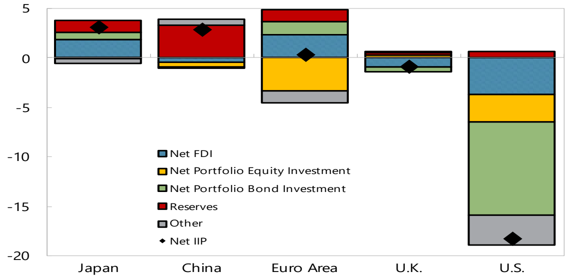


Sources: IMF Balance Sheet Approach Matrix; and IMF staff calculations.
Notes: The size of the link reflects the relative significance of claims, and the direction of the arrow indicates exposures of a creditor to the borrower. Information regarding NFC claims on NFCs is unavailable. NFCs=nonfinancial corporates. NBFI=nonbank financial institutions.

Figure 11. Japan: Cross-Border Exposures and Capital Flows

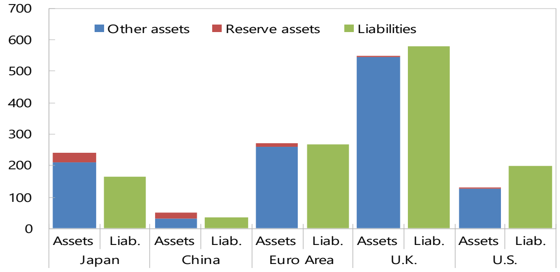
Japan has the largest net foreign assets globally …

Net Foreign Asset (Trillions of USD, 2023Q3)



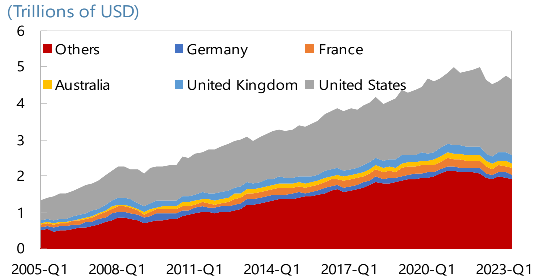
…with sizable gross foreign assets.

Gross Foreign Assets and Liabilities Positions
(In percent of GDP, end of 2023Q3)



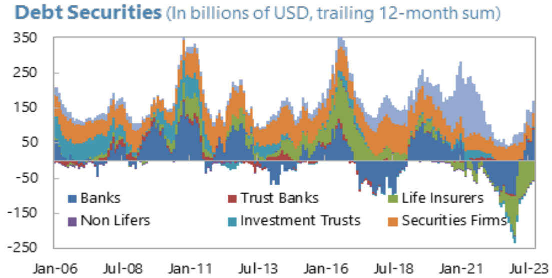
…including bank claims on major economies…

Japanese Banks' Cross-Border Claims
(Trillions of USD)



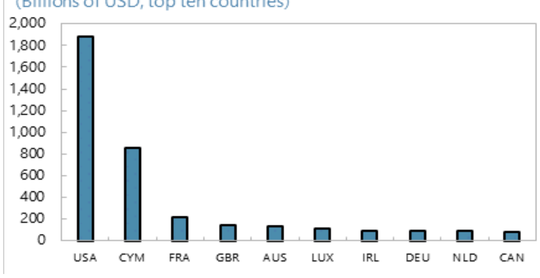
…though amid rising foreign interest rates, domestic investors have reduced their foreign exposure since 2022.

Japanese Residents' Net Purchases of Long-term Debt Securities (In billions of USD, trailing 12-month sum)



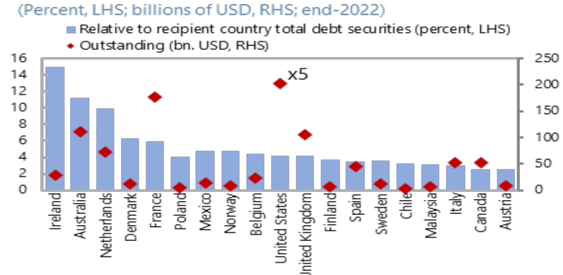
Portfolio investments are mostly tilted towards the U.S., Europe, and offshore centers…

Japan Portfolio Investment assets, June 2023
(Billions of USD, top ten countries)



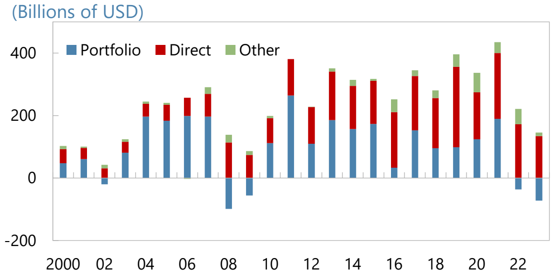
… and appear meaningfully large relative to the size of some of the destination markets.

Japanese Portfolio Debt Investment in Foreign Markets
(Percent, LHS; billions of USD, RHS; end-2022)



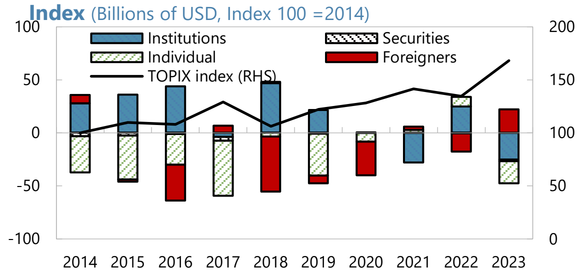
Nonresident investments into Japan have stayed strong.

Cross-Border Liability Flows
(Billions of USD)



Portfolio equity inflows have risen in 2023, contributing to a surge in stock prices.

Net Purchase of Stocks by Investor Type, and TOPIX Index (Billions of USD, Index 100 =2014)

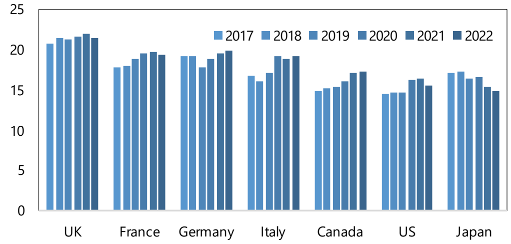


Sources: BIS; Bloomberg; IMF, Balance of Payments; IMF, Coordinated Portfolio Investment June 2022 Survey; IMF International Investment Position; MOF; and IMF staff calculations.
Notes: In bottom left panel, values for 2023 are total up to Q3 only. The bottom right panel shows the net purchases of stocks in Tokyo and Nagoya stock markets.

Figure 12. Japan: Bank Financial Soundness Indicators in Cross-Country Comparison

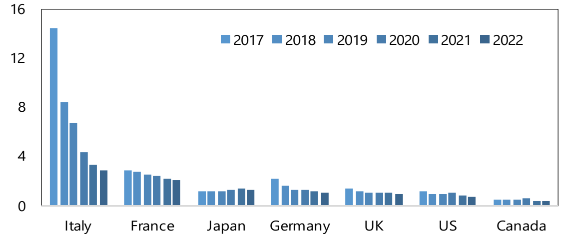
The Japanese banking sector is generally well capitalized...

Regulatory Capital to Risk-Weighted Assets
(Percent)



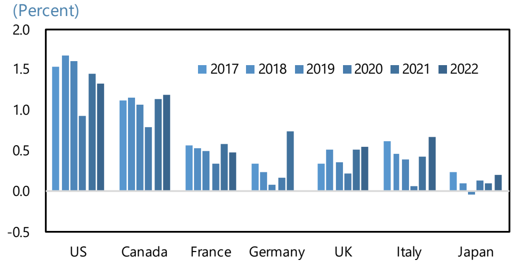
...with a low level of NPL ratios...

Nonperforming Loans to Total Gross Loans
(percent)



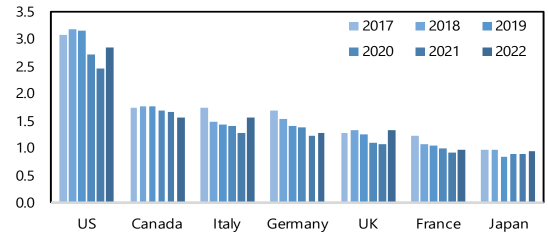
...but is characterized by low profitability ...

Return on Assets
(Percent)



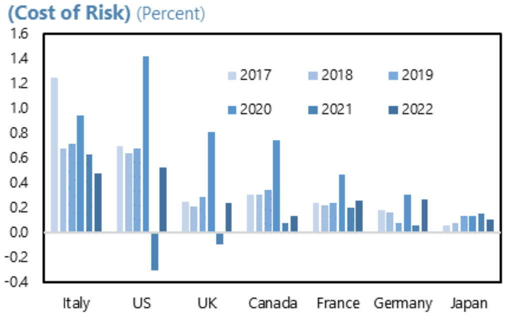
...partly driven by low net interest margins.

Net Interest Margin
(Percent)



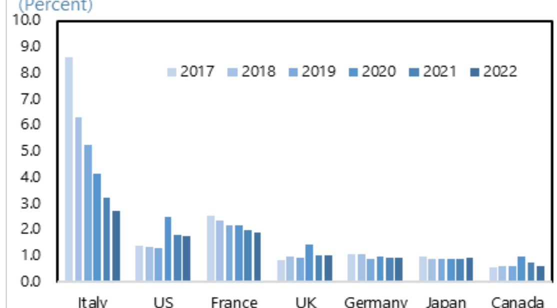
Low NPLs and credit costs have implied ...

Net Loan Loss Provision Flow Relative to Gross Loan (Cost of Risk) (Percent)



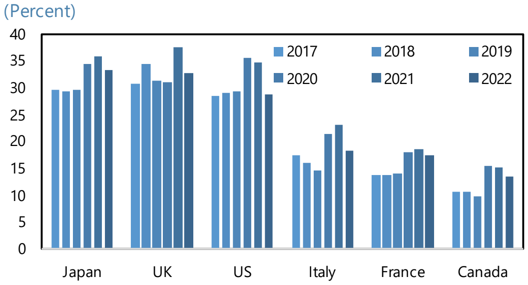
...that loan loss reserves have been low.

Loan Loss Reserves to Gross Loans
(Percent)



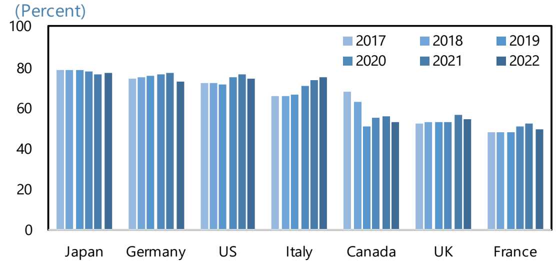
Japanese banks hold a large share of liquid assets in total assets...

Liquid Asset Ratio
(Percent)



...with a high share of deposits in total liabilities.

Share of Deposits in Total Liabilities
(Percent)



Sources: IMF, Financial Soundness Indicators; Fitch Connect; and IMF staff calculations.

SYSTEMIC RISK ANALYSIS

A. Key Vulnerabilities and Risks

26. Three key sources of vulnerabilities underlie the Japanese financial system:

- **Financial institutions have a significant exposure to domestic and foreign securities that are held under mark-to-market accounting.** On average, about one-fifth of banks' assets constitute securities but the share is larger for domestic banks (Figure 13). Insurance companies, especially life insurers, also hold a sizable share of securities in total assets (Figure 14).

- **The banking system has a notable FX exposure.** Liabilities of banks in USD terms alone amount to 30 percent of total liabilities. USD liabilities mostly take the form of FX swaps and unsecured wholesale funding, which implies a susceptibility to rising USD funding costs and rollover/run-off risk (Figures 15 and 16). Banks' liquidity coverage ratio (LCR) in USD terms rests well below 100 percent, while there is no minimum requirement for it in place, at present. Moreover, banks also have a sizeable share of undrawn FX commitments through credit and liquidity lines (67 percent of total commitments at end-September 2023, Figure 15).[13] On the foreign asset side, in addition to securities, loans constitute a sizable share of banks' assets. For the ten banks categorized as "major banks" by BOJ (2023), foreign loans constitute about one-third of total loans, significantly exposing them to macroeconomic conditions in foreign economies.

- **Real estate markets appear to be overvalued in some areas.** RRE prices have recorded above trend growth in recent years, and the price-to-income ratio has been at historical highs (Figure 17). In the CRE market, prices have appreciated notably (in real terms) for the industrial and multifamily residential segments, while the retail sector has been under pressure. According to estimates derived from formal models, both the residential and commercial real estate markets are overvalued by, on average, 17 and 30 percent, respectively.[14] Possible vulnerabilities in real estate markets could pose a challenge. About 11 percent and 15 percent of banks' total outstanding credit constitutes CRE and retail mortgage loans, respectively. Of the latter, more than three-fourth constitutes floating-rate mortgages (BOJ, 2023). While households' debt-service-to-income (DSTI) ratios have remained broadly stable, the share of housing loans with DSTIs exceeding 30 percent has increased (27 percent in March 2022).[15]

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[13] Details regarding the differential characteristics of different banking clusters in Japan will be discussed in Section IV.

[14] RRE prices used in the analysis are at an aggregate level, with a larger weight attached to more densely populated urban areas. Given the heterogeneous RRE price trends across regions, as noted in footnote 11, the estimated price overvaluation may thus be more pertinent to these areas.

[15] Loan-to-income (LTI) ratio also points to rising risks associated with housing loans. LTI ratio at origination has been increasing steadily since 2015, reaching 4.2 as of end-March 2022 (compared to 3.6 in 2015), driven primarily by young-age borrowers (BOJ, 2022).

27. In view of these vulnerabilities, macrofinancial instability could be triggered by various factors. The Japanese financial system is operating amid an evolving macroeconomic environment. Key risks to macrofinancial stability at the current juncture stem from a potential intensification of regional conflicts and geoeconomic fragmentation, global supply chain disruptions, and significant commodity price volatility that could lead to an abrupt and synchronized global economic slowdown and generate inflationary pressures, implying a sharp increase in foreign and domestic interest rates.[16] Higher interest rates could, in turn, tighten global financial conditions, triggering volatility in global financial markets and exacerbating the global economic downturn.

28. An adverse, global downturn scenario implies market and credit risk for Japanese financial institutions. An increase in domestic and foreign interest rates would imply valuation losses on debt securities held under mark-to-market accounting. A rise in interest rates would also raise the risk of default among already leveraged firms and highly indebted households and could trigger significant price corrections in real estate markets commensurate to the size of the overvaluation (see Appendix II). Combined with a notable share of floating rate loans in total loans—55 and 75 percent for corporate and housing loans, respectively, according to BOJ (2023)—these factors could imply that interest rate risk, as one form of market risk, could morph into material default risk (Figure 17).[17] A sharp global economic slowdown could also raise overseas credit risks for banks.[18, 19] Furthermore, through notable FX liabilities, including the sizeable, yet undrawn off-balance sheet commitments, the banking sector would also be exposed to liquidity risk if foreign funding costs increase.

29. Japan further confronts several ongoing structural transformations. Climate-related transition risks are highly relevant for Japan as it is among the largest carbon emitters globally and

---

[16] In such an adverse scenario, the rise in domestic interest rates could partly occur because of an increase in sovereign risk premia, given the high level of sovereign debt in Japan.

[17] Amid a sharp rise in foreign interest rates since 2022, Japanese banks have registered record valuation losses from foreign bonds, amounting to nearly JPY 3 trillion as of end-March 2023, although overall valuation net gains on securities holdings remained positive given the positive contribution from rising stock prices. In case of a further increase in overseas interest rates, valuation losses could weigh on banks' balance sheets, especially of those banks with limited or no interest rate hedging.

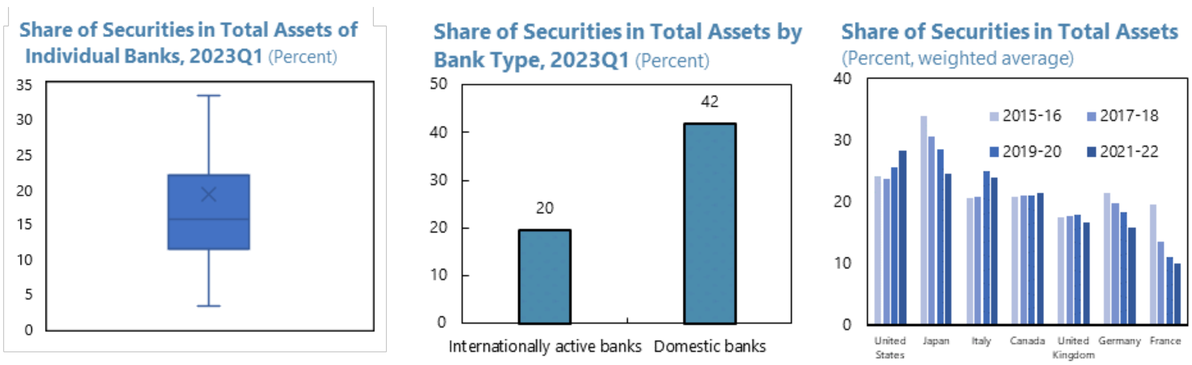
[18] The share of foreign loans in major banks' total loans has nearly doubled over the last decade and is up by about 5 ppt since the last FSAP. The majority of overseas loans are investment grade (about 60 percent). Major banks have also increased their overseas collateralized loan obligation (CLO) investment since 2016, with over 99 percent concentrated in AAA-rate tranches. As of 2019, CLO holdings amounted to about JPY 20 trillion, less than one-tenth of the size of banks' overseas loans and credit products, of which most (almost three-fourths) are held to maturity (see, e.g., https://www.boj.or.jp/en/research/wps_rev/rev_2020/data/rev20e02.pdf).

[19] The direct exposure of Japanese major banks to overseas CRE market via loans or securities holdings appears limited in aggregate—less than 2 percent of their total assets, or less than 5.3 percent of total loans (BOJ, 2023)—though some institutions could be more exposed. Indirect risks from overseas CRE markets could also arise through possible price spillovers to domestic CRE markets (for example, in case of a potential abrupt tightening of global financial conditions), which could be relevant for Japanese financial institutions given their more material exposure to domestic CRE markets.

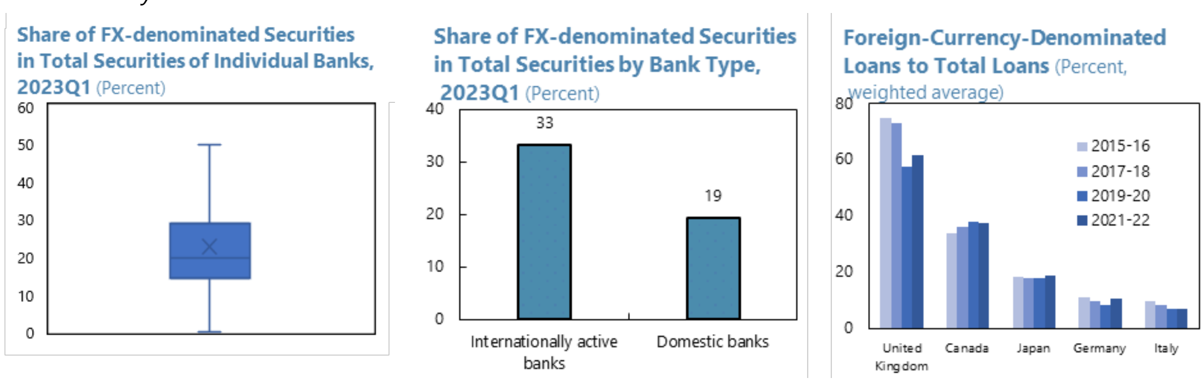
has pledged to reduce GHG emissions significantly over the next decade (Figure 18).[20] A digital transformation of the financial sector is also occurring rapidly (Figure 19), offering opportunities to the sector to enhance efficiency, but also raising potential competitiveness challenges for incumbent financial institutions and increasing cybersecurity risks.[21] An aging population poses a long-standing challenge to financial stability, particularly through its potentially adverse impact on regional banks' profitability, as discussed in the 2017 FSAP. This confluence of challenges facing the Japanese financial system is summarized in Figure 20.

Figure 13. Japan: Banking System Security Holdings and Foreign Exposures

The share of securities in banking sector assets is high, particularly for domestic banks but has been trending down.



The share of FX-denominated securities in total securities averages about 30 percent but is generally higher for internationally active banks.



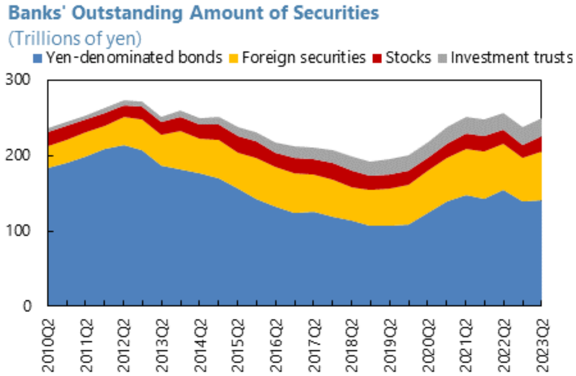
Sources: FSA; Fitch Connect; and IMF staff calculations.
Notes: The 23 banks covered in these charts constitute over 80 percent of the banking system assets and are included in the solvency and liquidity risk analysis of the FSAP. In the box plots, lines in the middle of the box are medians, the boxes are the interquartile range, the whiskers mark the top/bottom one percentiles, and the cross (x) indicates the mean value.

[20] Under the United Nations Climate Change Convention, Japan has set an interim target to reduce GHG emissions by 46 percent from 2013 levels by 2030, and to achieve net zero GHG emissions by 2050. While policies to support the green transition offer new investment opportunities, they could also affect the financial soundness of carbon-intensive firms and generate credit risks for financial institutions exposed to these firms.

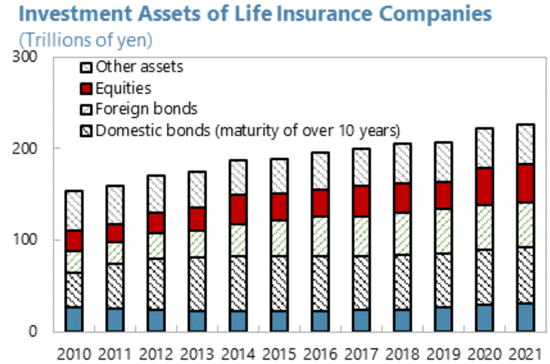
[21] More than 200 cyberattacks against critical infrastructure occurred in 2021, the highest level in the past five years (BOJ, 2022). There has also been a sharp increase in cyberattacks against Japanese businesses since Russia's invasion of Ukraine, according to a survey by Teikoku Databank.

Figure 14. Japan: Vulnerability of the Financial Sector to Changes in Yields

Banks have a high exposure to domestic and foreign bonds…



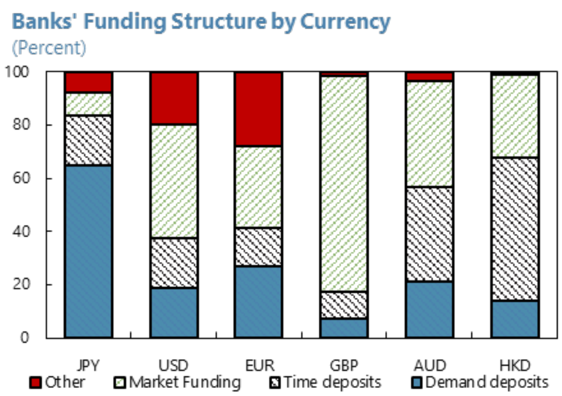
…as do insurance companies.



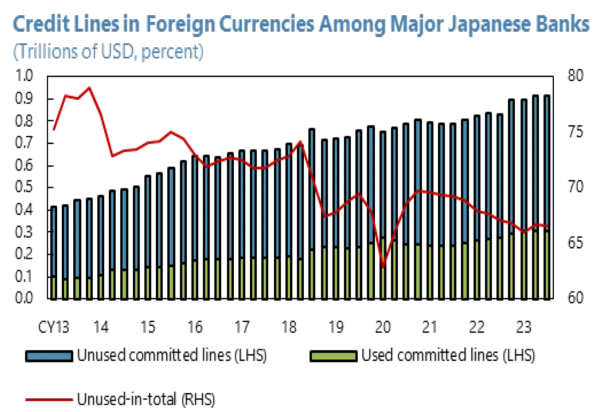
Sources: Bloomberg L.P.; BOJ, Financial System Report; and IMF staff calculations.

Figure 15. Japan: Banks' Funding Structure by Currency and Credit Lines in Foreign Currencies

USD liabilities are dominated by market funding (i.e., non-deposit funding).



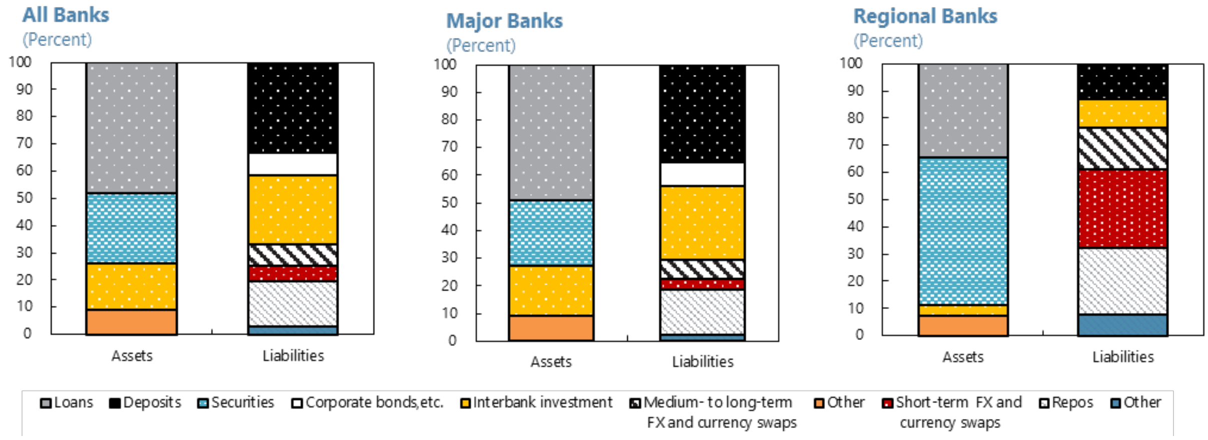
Japanese banks' unused off-balance sheet commitments in foreign currency have trended down, but remain sizeable relative to total credit lines.



Sources: BOJ; FSA; and IMF staff calculations.
Note: Data as of end-September 2023. Major banks here contain ten banks, including six internationally active banks and four domestic banks.

Figure 16. Japan: Banks' Asset and Liability-Side Foreign Currency Exposure

The banks' asset-side FX exposures are dominated by loans and securities. Regional banks hold a higher share of their FX assets in securities (rather than loans) than major banks. It exposes them to higher market risk but is beneficial from a liquidity perspective. Regional banks make more material use of FX swaps than major banks.

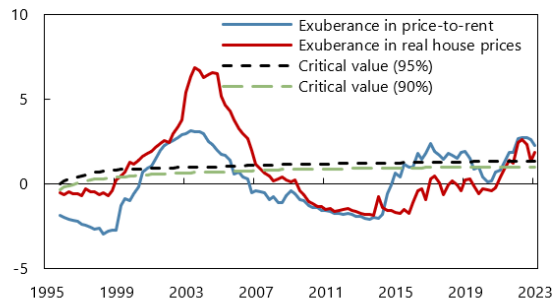


Sources: BOJ; FSA; and IMF staff calculations.
Note: Data as of end-September 2023. Major banks here contain ten banks; including six internationally active banks and four domestic banks.

Figure 17. Japan: Vulnerabilities in Real Estate Markets

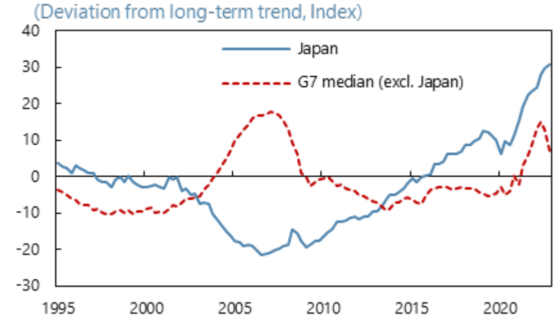
House prices have been rising above trend in recent years…

Indicators of Rapid Price Appreciations
(Index)



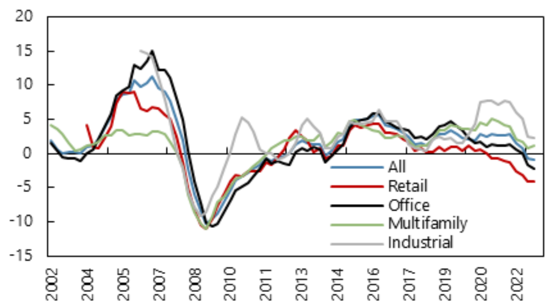
…while affordability has declined.

Price-to-Income ratio Misaligment
(Deviation from long-term trend, Index)



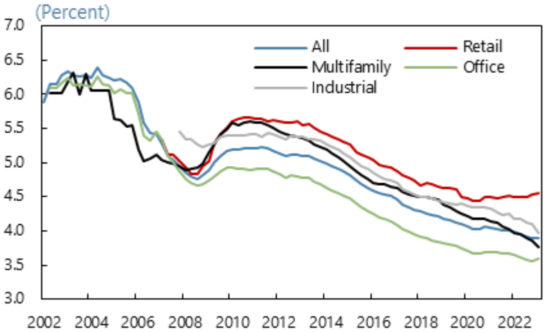
In CRE, the industrial and residential segments have been booming…

Real Commercial Real Estate Price Growth by Segments
(Percent, year-over-year)



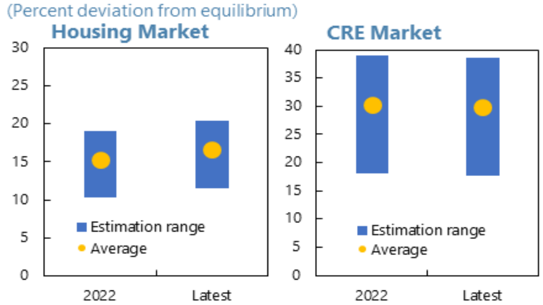
… and capitalization rates have remained compressed.

Capitalization Rate by Segments
(Percent)



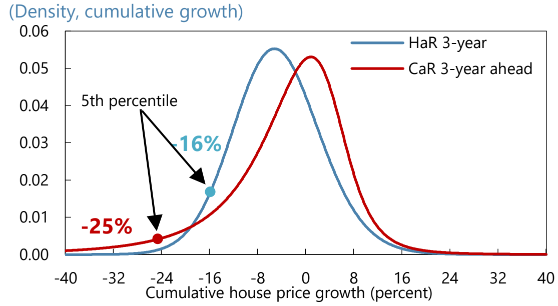
Real estate markets appear to be moderately-to-highly overvalued…

Overvaluation Measures
(Percent deviation from equilibrium)



…increasing the likelihood of sizeable corrections.

House-Price-at-Risk and CRE-Price-at-Risk
(Density, cumulative growth)

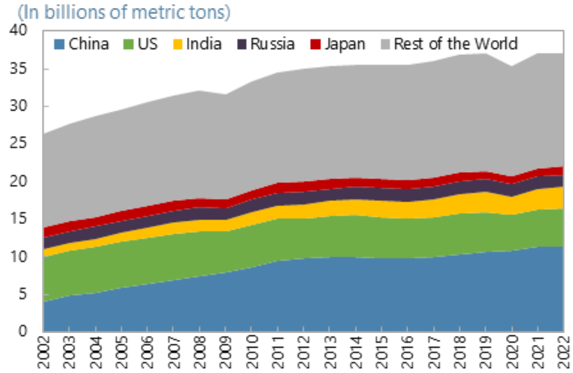


Sources: BIS Statistics; Haver, MSCI Real Estate; OECD; and IMF staff calculations.
Notes: In the top left panel, indicators of rapid price appreciation are based on recursive (right-tailed) unit root tests to detect periods of rapid price appreciations. These correspond to periods during which the estimated backward sup augmented Dickey-Fuller statistics exceed the corresponding 90/95th percentile critical value from their limit distribution, implying that prices are overshooting their underlying trend. In the top right panel, misalignment is computed as the deviation from the estimated historical trend. In the bottom left panel, overvaluation measures are estimated using an error correction model controlling for demand-and supply-side factors including changes in income per capita, short and long-term interest rates, credit growth, equity price growth, change in the fraction of working age population, and change in issued permits. The estimated range (blue bar) is computed from different levels of base prices (for years 2000-15) that are used to obtain changes in fitted valuations and to derive estimates of price misalignments relative to fair values. The average misalignment is the mean over different base years (yellow marker). In the bottom right panel, probability densities are estimated for the three-year-ahead (cumulative) house and CRE price growth distributions following an approach similar to Adrian and others (2020) and Deghi, Mok, and Tsuruga (2021), respectively. Forecast density estimates assume the 3-year ahead GDP growth path projected by the WEO. Filled circles indicate the price decline with a 5 percent probability (5th percentile) in an adverse scenario. More' details are provided in Appendix II.

Figure 18. Japan: Climate-Related Transition and Physical Risks

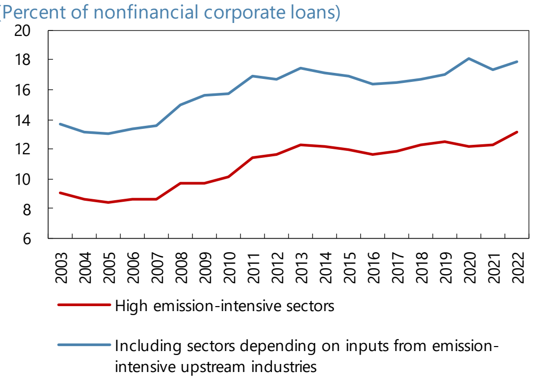
Japan is one of the largest carbon emitters in the world …

Global CO2 Emissions
(In billions of metric tons)



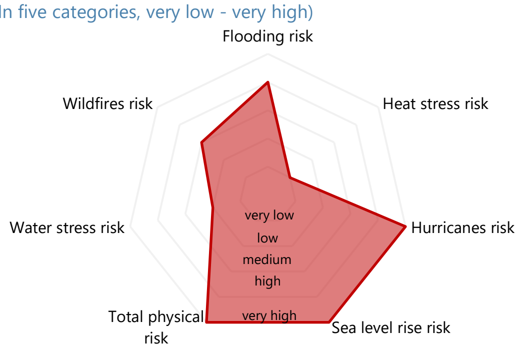
…with almost one-fifth of bank loans to emission intensive sectors, exposing the sector to transition risks.

Bank Loans to Emission Intensive Sectors
(Percent of nonfinancial corporate loans)



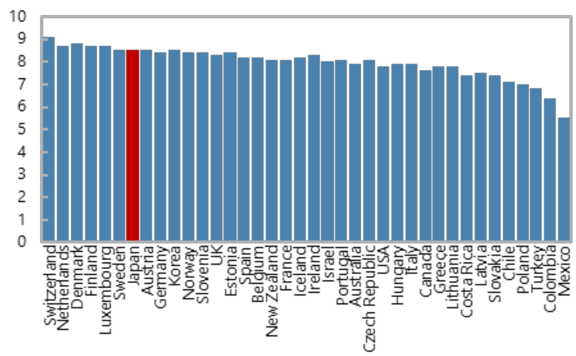
Japan also has a high degree of exposure to physical risk…

Exposure to Physical Risk Scores
(In five categories, very low - very high)



…though is considered to have a strong adaptive capacity to handle such risks.

Climate Change Coping Capacity, 2023
(In index, 0-10)



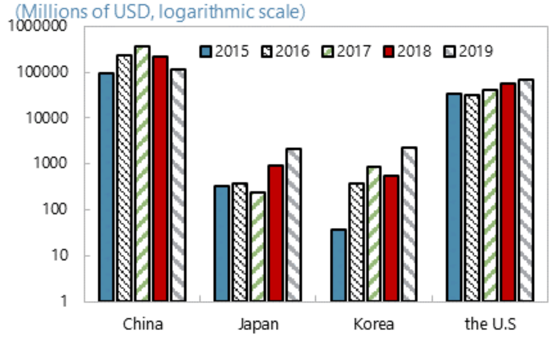
Sources: BOJ; German Watch; Global Carbon Atlas; Haver Analytics; Index for Risk Management (INFORM); U.S Energy Information Administration (EIA); OECD; and IMF staff calculations.
Note: In the lower right chart, higher score indicates greater capacity to cope with climate physical change risk, and vice versa.

Figure 19. Japan: Fintech Developments and Demographic Shift

Fintech credit has been growing…

Fintech Credit

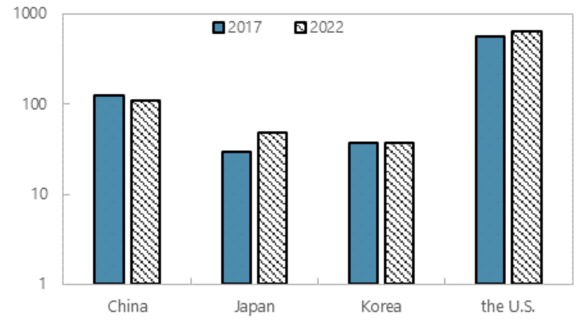
(Millions of USD, logarithmic scale)



…and the number of fintech companies has been rising.

Active Fintech Entities by Incorporation Coutnry

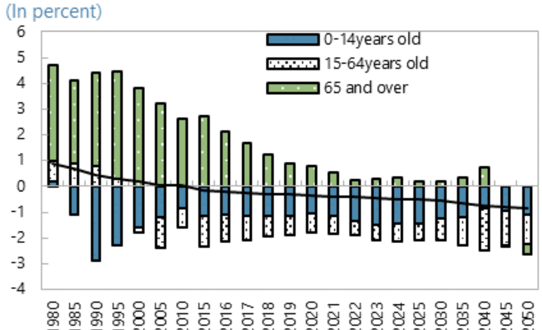
(Number of entities, logarithmic scale)



Japan's population is aging and shrinking, posing a challenge to the economy and the financial system.

Projected Population by Age and Growth Rates

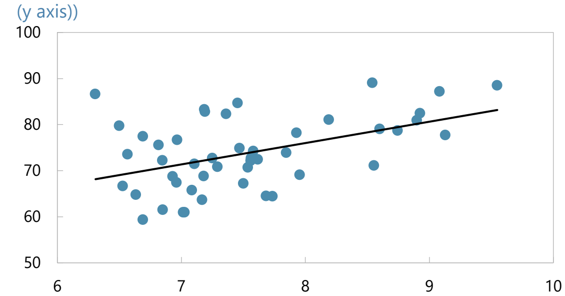
(In percent)



Regional banks in less-populated prefectures have on average limited business opportunities.

Loans-to-Deposit Ratio of Regional Banks

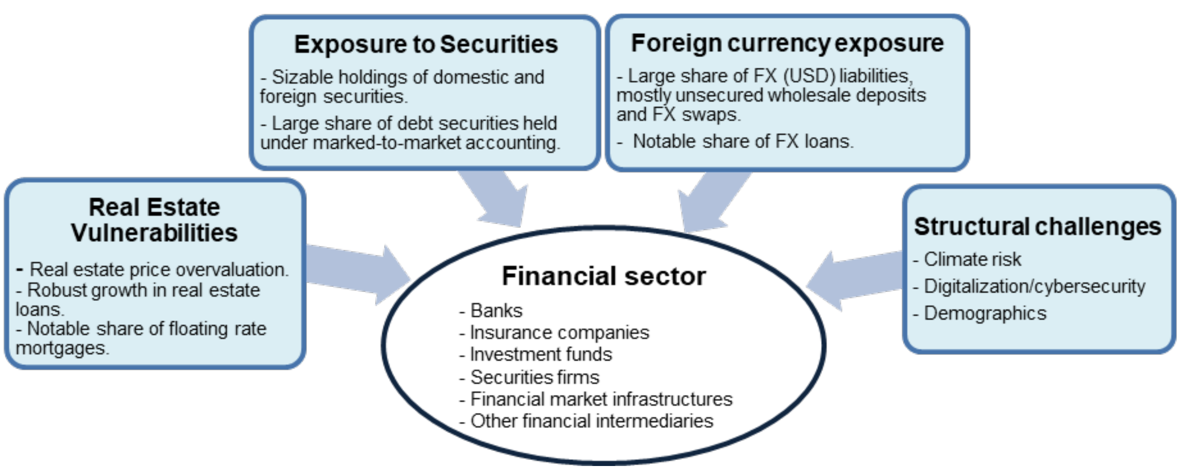
(log population (x axis) and loans in percent of deposit in FY2021 (y axis))



Sources: "Fintech and big tech credit: a new database," BIS Working Paper No. 887, September; Cambridge Fintech Ecosystem Atlas database; Regional Bank Association; Ministry of Health, Labor, and Welfare; National Institute of Population and Social Security Research; OECD statistics; Population Census of Japan; and IMF staff calculations.

Notes: In the top right panel, financial entities are defined as those that use digital technology to provide or to enable the provision of financial services. In Japan, these entities predominantly operate in sectors such as crypto asset exchange, digital capital raising, digital identity, digital payments, WealthTech, etc.

Figure 20. Japan: A Snapshot of Key Challenges Facing the Japanese Financial System



Source: IMF staff.

B. Macrofinancial Scenarios

30. To assess the resilience of Japan's financial sector, a baseline and an adverse scenario spanning a three-year horizon from 2024-2026 underpin the systemic risk analysis. The baseline scenario is aligned with the IMF's October 2023 World Economic Outlook (WEO). The adverse scenario (Figure 21) represents a global downturn scenario, accompanied by a global financial market downturn, combining various risks defined in the Risk Assessment Matrix (RAM, Table I.5) that are relevant for Japan.

31. The adverse scenario originates from a global commodity price shock alongside equity market and term premia shocks and implies some appreciation of the JPY. It is assumed to provoke a sharp increase in inflation and a large negative output gap—the latter comparable in magnitude to that observed in Japan during the COVID-19 pandemic (Table I.6).[22] Domestic interest rates are assumed to initially react to the rise in inflation, but any further increase is contained by the wide output gap and a gradual decline in inflation. Weaker aggregate demand and higher interest rates, in turn, raise the NFC sector's default probability by putting downward pressure on profitability and raising their interest payment burden. The economic slowdown and higher inflation imply a fall in real wages, which combined with the increase in interest rates, exacerbates the default risk of indebted private sector borrowers, resulting in a decline in real estate demand and triggering a notable correction in real estate prices. The scenario trajectories for countries other than Japan are summarized in Table I.7.

32. The adverse scenario meets the severe yet plausible criterion. The standard deviation (STD) multiple for the adverse scenario regarding real GDP growth amounts to 1.8x, when measuring it based on 2-year cumulative GDP growth under the adverse scenario relative to the historical mean and STD of GDP growth in Japan. Relative to the growth rate of 2023 (instead of to historical mean growth), the adverse STD multiple amounts to 2.2x.[23]

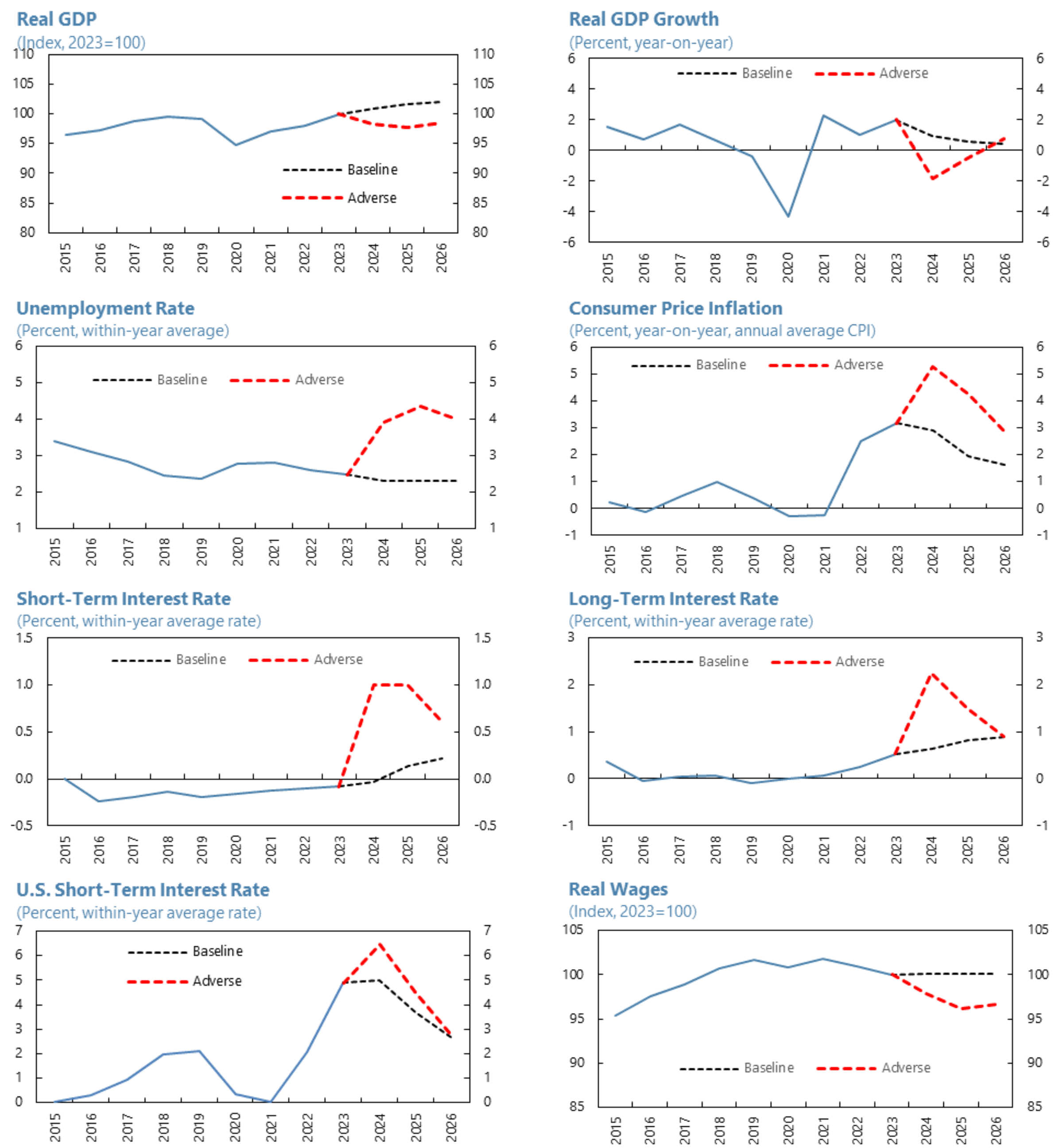
33. Numerous sensitivity analyses are conducted on top of the initial adverse scenario. These include yet more pronounced shocks to Japanese short- and long-term interest rates, GDP growth, and FX valuation shocks (Table I.8). The interest rate sensitivity analysis assumes that short-term rates (1Y sovereign bond yields) move to 1.5 percent (instead of 1 percent in year 1 under the initial adverse scenario); while 10Y JGB yields move to 3 percent in (2.25 percent in year 1 under the initial adverse scenario). Real GDP growth is assumed to drop further to -3.2 percent and -1 percent

[22] While both the USD and JPY are safe-haven currencies, the small appreciation for the JPY vis-à-vis the USD in the adverse scenario reflects the observed historical pattern where in times of higher global uncertainty, the JPY appreciated vis-à-vis the USD. In addition, the assumed decline in economic growth in Japan is somewhat smaller than in the U.S. in the adverse scenario, implying some diversion of portfolio equity inflows that could imply appreciation pressures (Table I.7).

[23] The standard deviation multiple relative to historical mean is a more relevant metric, and that shall, as a convention, not deviate too much from 2x. The multiple vis-à-vis current growth should be larger than 2x when setting off in an initial strong growth (boom) regime, and less than 2x when starting from a weak/recessionary regime.

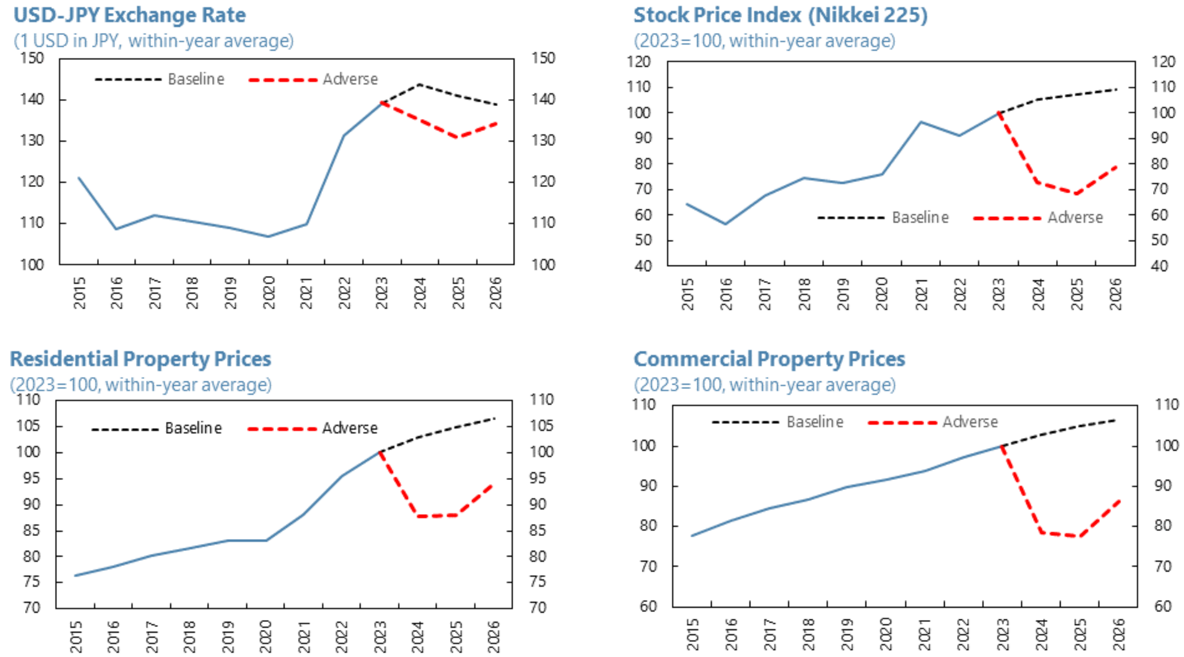
in the first two years (compared to -1.8 percent and -0.5 percent under the initial adverse scenario, respectively).

Figure 21. Japan: Macrofinancial Scenarios for Stress Testing



Sources: BOJ; IMF WEO; and IMF staff calculations.
Notes: Short-term interest rates are 1-year JGB bond yields. Long-term interest rates are 10-year JGB bond yields.

Figure 21. Japan: Macrofinancial Scenarios for Stress Testing (concluded)



Sources: BOJ; IMF WEO; and IMF staff calculations.
Notes: Short-term interest rates are 1-year JGB bond yields. Long-term interest rates are 10-year JGB bond yields.

BANKING SECTOR STRESS TESTING

A. Bank Solvency Stress Test

Methodology

34. The FSAP conducted a top-down solvency stress test for internationally active and domestic banks, including regional banks. Twenty-three banks, including thirteen regional banks, were covered in the stress test exercise, which represent 82 percent of the banking system's total assets as of 2023Q1.[24] The solvency stress test model captured all relevant transmission channels for banks to be affected by their operating environment (credit risk, market risk, the latter including interest rate risk, and other profit and loss drivers). The model allowed for dynamic balance sheets. It further took explicit account of interest rate risk hedging and FX risk hedging by sourcing detailed data from banks and using a fine-grained set of portfolio types by investment category and numerous economic sectors. Tax credit (deferred tax assets), which can be applied under the Japanese capital regulation, were not accounted for in the bank solvency stress test, following common FSAP practice. This means that the adverse scenario impacts on banks' solvency ratios as

[24] The data for the stress testing exercise captures the foreign exposure of banks, which is primarily through lending via foreign branches, direct cross-border lending, as well as foreign security holdings.

presented later in this note would be to an extent less adverse if the tax credit mechanism was accounted for.

35. The credit risk module as employed for the Japanese banks had a "model-flows-imply-stocks-philosophy." This means that various sub-models provided default rate and implied default flow projections, based on which NPL stocks and other metrics were calculated. Additional required parameters included cure rates, write-off rates, and gross loan growth assumptions. The latter were informed by the macrofinancial scenario. Box 1 summarizes the main formulas that are involved for obtaining the loan loss impacts. Write-off rates were held constant at the bank-portfolio specific initial values. Cure rates were also held constant at initially observed values in the baseline scenario and stressed under the adverse scenario.

36. Structural models for loss given defaults (LGDs) were employed. For the household segment, the LGD module embedded in the micro-macro simulation was used to project the bank-level mortgage LGDs, primarily as a function of residential house prices as defined in the scenarios. For the corporate segment and the consumer credit segment, the Frye-Jacobs methodology was employed, which let LGDs move as a function of PDs.

37. The dynamics of credit risk weighted assets (RWAs) were driven by the evolution of default rates, implied default migration effects, downturn LGDs, and general loan growth. Twenty-two of the twenty-three banks in the stress test sample follow the internal ratings-based (IRB) approach (either A- or F-IRB), and one bank the standardized approach. For the performing IRB bank-portfolios, the Basel risk weight formulas were employed. Probability of default (PD) through-the-cycle (TTC) inputs were used as a smooth function of the bank-portfolio-specific default rate paths, with the smoothing factor being judgmentally set to 0.2. Downturn LGDs were kept at the initially observed levels under both the baseline and the adverse scenarios. The RW formulas were used to imply "pseudo-T0" risk weights to imply "pseudo RWA" levels at the outset as well, where the terminology "pseudo" signals that these risk weights are model implied and not necessarily equal to the banks' reported risk weights. The changes from those pseudo starting points to the RWAs conditional on the scenario were attached to banks' observed T0 RWA starting points. This attachment scheme was used to obtain well behaved RWA paths at bank-portfolio level.[25] Risk weights for nonperforming IRB exposure were held constant at the initially observed values from the relevant bank portfolios. For the standardized approach (STA) bank, the risk weights were held constant for performing and nonperforming exposures respectively, so that overall RWA effects could arise from general loan growth and default migration from performing to nonperforming.

[25] The Basel formulas are nonlinear, which implies that RWs obtained by applying them at loan level (as banks do) versus at bank-portfolio level (as done in the IMF FSAP stress test) are not necessarily equal. They correlate notably in the bank-portfolio cross-section, as was analyzed in detail and confirmed for the Japanese banks' data.

Box 1. Japan: Loan Loss Calculations and Credit RWAs—Summary of Relevant Formulas

The schematic on the right side summarizes the relevant objects and their dependencies pertaining to the loan loss and related capital impact, as explained in the following.

Gross exposures, L_t, were subject to the CR methodology and were projected at the bank-portfolio level using a gross loan growth trajectory (g_t), defined under the macrofinancial scenarios. A non-zero (zero) g_t implies a dynamic (static) balance sheet from a specific bank-portfolio perspective.

$$L_{t+1} = L_t(1 + g_{t+1}) .$$

An indexation to denote banks, portfolios, and scenarios has been omitted for the sake of notational brevity. The exposures and various related metrics were projected at quarterly frequency (g_t, for example, refers to mean quarterly growth rate). Default rates as projected from the various structural and selected econometric models were used to imply the nonperforming exposure stocks along the scenario horizon:

$$NPL_{t+1} = NPL_t(1 - WROR_{t+1} - CURER_{t+1}) + PD_{t+1}(L_t - NPL_t) ,$$

where $WROR_t$ is an NPL write-off rate pertaining to a quarterly flow window, $CURER_t$ a quarterly cure rate, denoting the percentage of NPLs moving back to performing status, and PD_t a quarterly default rate.[1] The performing exposure stock was implied as a residual:

$$PL_{t+1} = L_{t+1} - NPL_{t+1} .$$

The provision stocks for performing exposures can be expressed as:

$$PS_{t+1}^{PL} = PCR_{t+1}^{PL} \times PL_{t+1} .$$

The provision coverage ratio (PCR) for performing exposures (PCR-P) was informed by the banks' portfolio level initial coverage ratios. These PCR-PL's were assumed to move as a function of projected point-in-time (PiT) loss rates with a smoothing parameter at 0.2. That is,

$$PCR_{t+1}^{PL} = PCR_t^{PL} + 0.2(PD_{t+1} \times LGD_{t+1} - PD_t \times LGD_t) .$$

This smoothing was to reflect that not all, but a number of, Japanese banks, moved from a time invariant to a more forward looking, time varying provision scheme for performing exposures, based on expected losses. The provision stocks for nonperforming exposures were computed as:

$$PS_{t+1}^{NPL} = PCR_{t+1}^{NPL} \times NPL_{t+1} .$$

The PCRs for NPLs were floored at the LGDs from Year 1 forward and moved in line with the PiT LGD trajectories for the bank-portfolios. That is,

$$PCR_{t+1}^{NPL} = \max(PCR_{t=0}^{NPL}, LGD_{t+1}),$$

which means that any potential under-provisioning for NPLs would be "corrected" in year 1 (i.e., resulting in an additional one-off loss and capital impact), and reflected as such under both the baseline and adverse scenarios. It further means that the provisioning dynamics forward in time reflect the LGD.

The capital impact resulting from performing exposures amounted to:

$$LL_{t+1}^{PL} = PS_{t+1}^{PL} - PS_t^{PL} ,$$

and that from nonperforming exposures to:

$$LL_{t+1}^{NPL} = PS_{t+1}^{NPL} - PS_t^{NPL} + WRO_{t+1} \times LGL_{t+1} \times NPL_t .$$

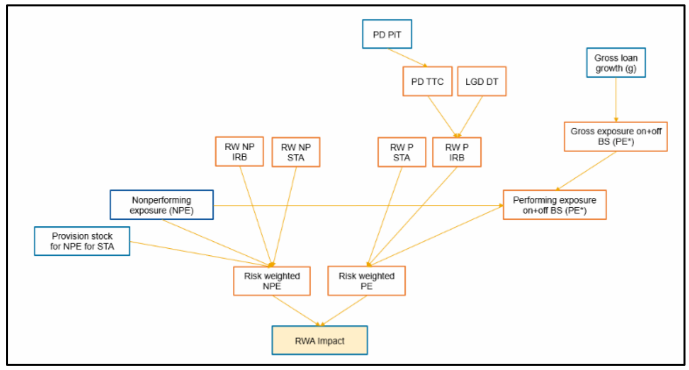
---

[1] Given that the historical data for NPL cure rates for the bank-portfolios were very limited, judgmental stress assumptions were employed instead of modeling them. For first and second years, cure rates fall to 0.75x and 0.85x, respectively, the level of the baseline at bank-portfolio level and equal the baseline cure rates in the third year.

Box 1. Japan: Loan Loss Calculations and Credit RWAs—Summary of Relevant Formulas (concluded)

The total capital impact amounted to $LL_{t+1} = LL_{t+1}^{PL} + LL_{t+1}^{NPL}$, that is, the periodic capital contribution from just the loan losses for bank b was $\Delta CAR_{b,t+1} = \sum_{p=1}^{P} LL_{p,t+1}$, where the various underlying bank portfolio $p = 1 \ldots P$ were made explicit here. For performing exposures, the capital impact was driven by the change in risk parameters and the change in performing exposure balances, as both reflected in the change in the provision stock. For nonperforming exposures, the formula shows the dependence on change in volume and risk parameters (the LGD in particular) for outstanding nonperforming stocks, as well as the additional impact from write-offs. Such additional impact would only arise if the loss-given-loss (LGL) was different from the provision coverage at the time of the write-off. To see this, an expanded version of the formula shows the

$$LL_{t+1}^{NPL} = PS_{t+1}^{NPL} - PS_{t}^{NPL} + \underbrace{WRO_{t+1} \times PCR_{t+1}^{NPL} \times NPL_t}_{A} + \underbrace{WRO_{t+1} \times (LGL_{t+1} - PCR_{t+1}^{NPL}) \times NPL_t}_{B}.$$



The term A in the equation makes sure that a fall in the provision stock that is due to a write-off is not mistakenly interpreted as a release of provisions (and hence a profit). The term B in the equation accounts for the additional gain or loss resulting from a possible gap between the LGD at time of write-off (i.e., the LGL) and a provision coverage, informed by the LGD, just before the write-off. The terms A and B reduce to the shorter version in the previous equation above, as PCR_{t+1}^{NPL} cancels out. It was assumed that the LGL stands to an extent above the LGD and the associated NPL provision coverage ratio, using the bank-portfolio specific and scenario conditional cure rate for transforming the LGD into an LGL:

$$LGL_{t+1} = \frac{LGD_{t+1}}{1 - \alpha \times CureRate}$$

The α in this equation was set to 0.5. It is not set to 1 because a portion of the NPL stock is already closer to the time of write-off, and hence its LGD and provision coverage already closer to the LGL.

With regard to credit risk RWAs, the schematic on the right side depicts the relevant objects, dependencies, and the link to the parameters that inform the loan losses. RWs for performing IRB exposures were projected using the IRB RW formulas. RWs for nonperforming exposures were held constant. STA risk weights for performing and nonperforming exposures were held constant, too; all as summarized in the table below.

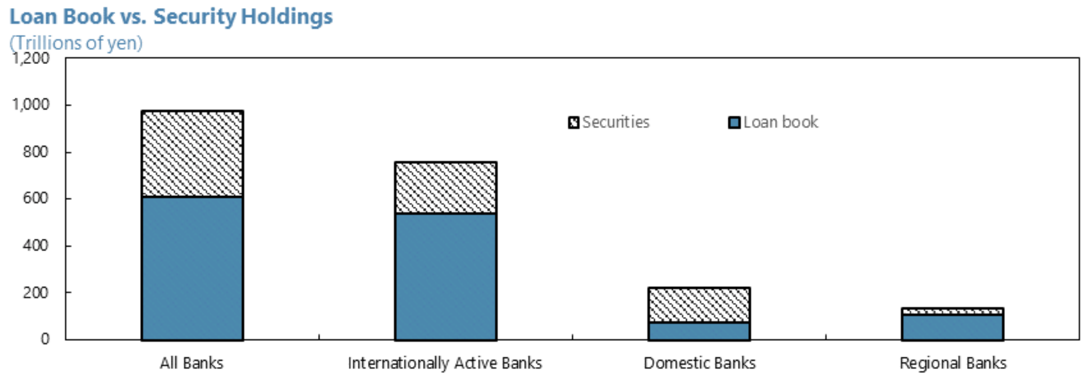
	IRB	STA
Performing	Endogenous through RW calculations, with PD TTC and LGD DT as input	Constant
Nonperforming	Constant	Constant, net of provisions

Gross loan growth under a dynamic balance sheet, the IRB performing RW changes, and migration effects were therefore the three sources for changes in credit risk RWAs for a bank.

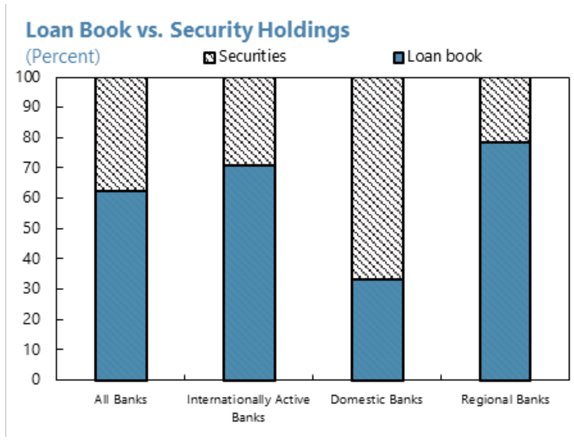
The initial risk parameter distributions across individual banks and portfolios are depicted in Figures 22-31.

Figure 22. Japan: Balance Sheet Structure of Banks

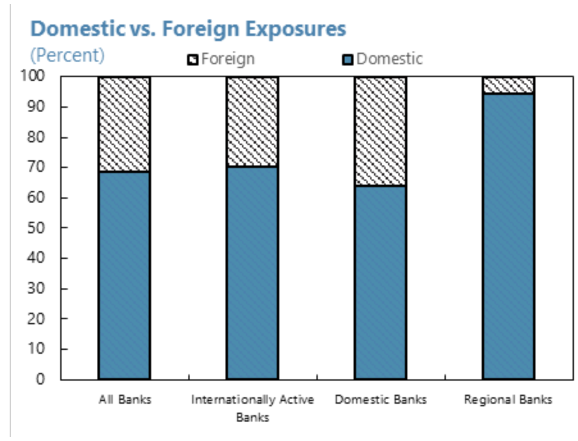
Japanese banks' security holdings are significant, both for internationally active banks and domestic banks, and less so for the regional bank cluster.



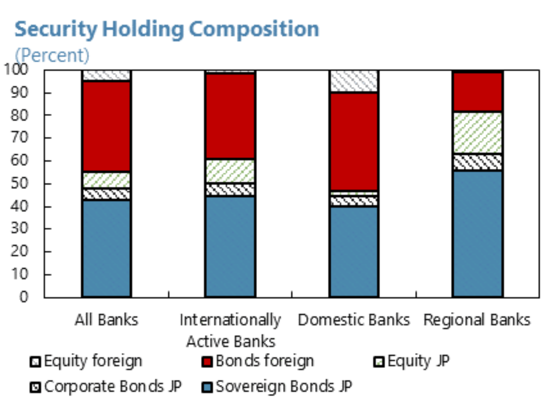
Security investment shares for domestic banks are particularly sizeable.



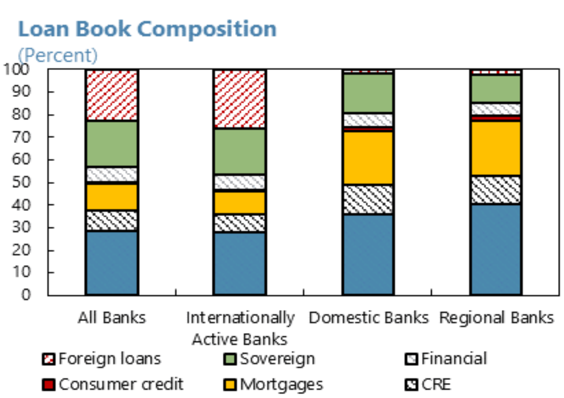
All bank clusters, but to a lesser extent regional banks, are exposed to foreign borrowers.



Domestic sovereign and foreign bonds represent the largest share of overall security holdings.

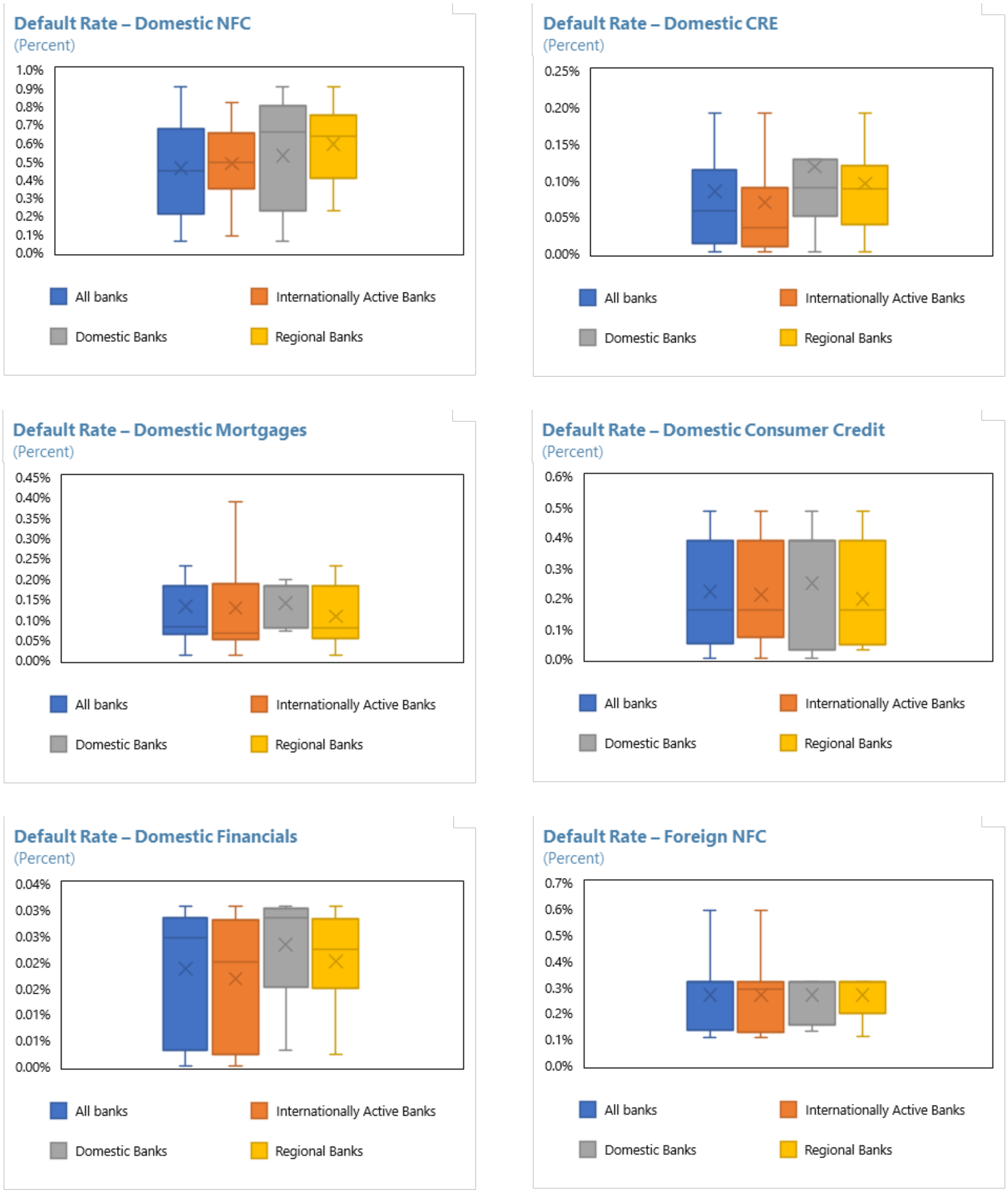


Foreign lending in the form of loans is more significant for international banks than for other bank clusters.



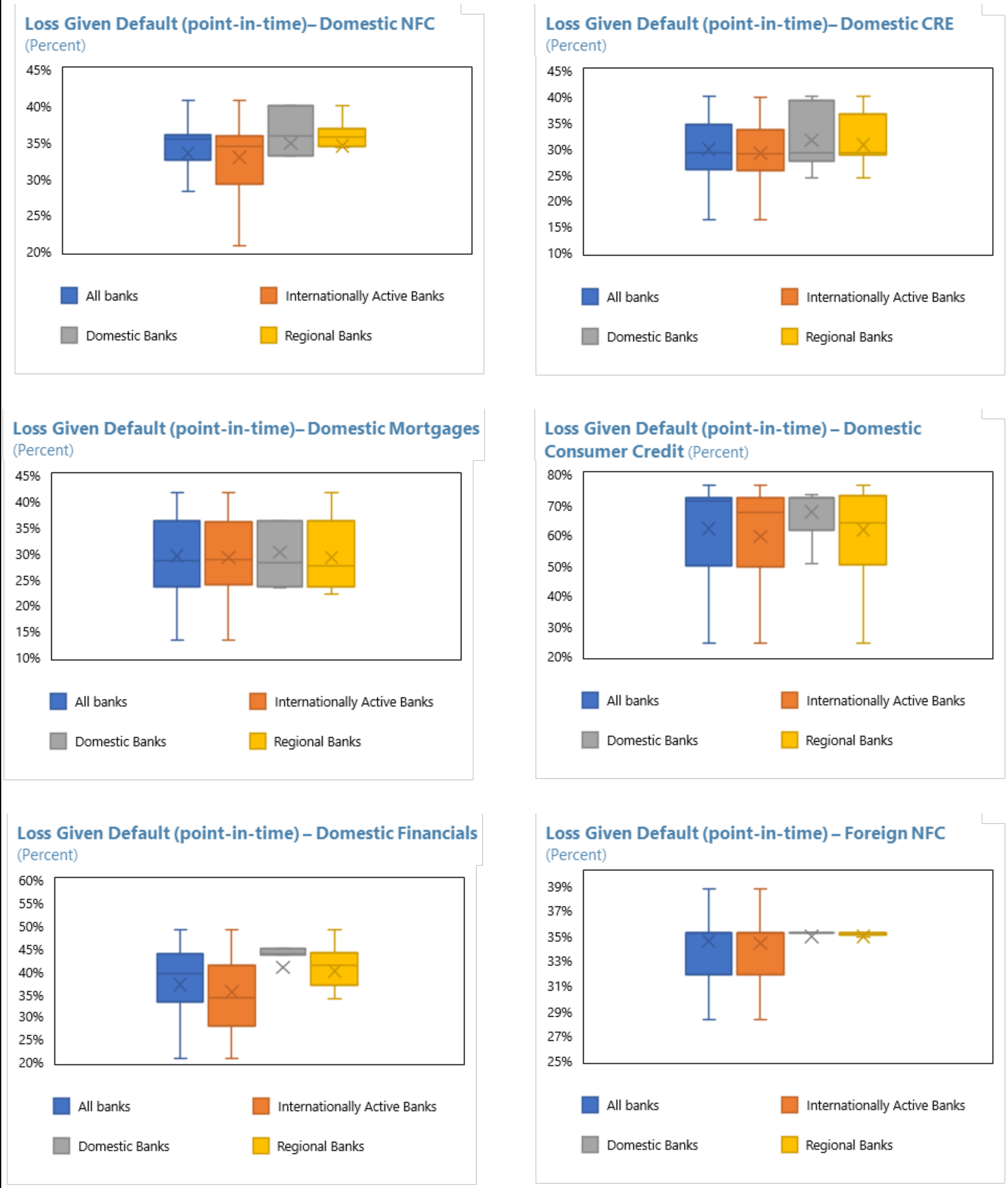
Sources: FSA; and IMF staff calculations.
Notes: All data as of end-March 2023. The security holdings shown in these charts comprise—beyond direct bond and equity investments—also their investments in bond funds, equity funds, and REITs. The data underlying these charts is for the sample of 23 banks that were subject to the solvency and liquidity stress test in the FSAP.

Figure 23. Japan: Default Rates at the Outset (FY2022)



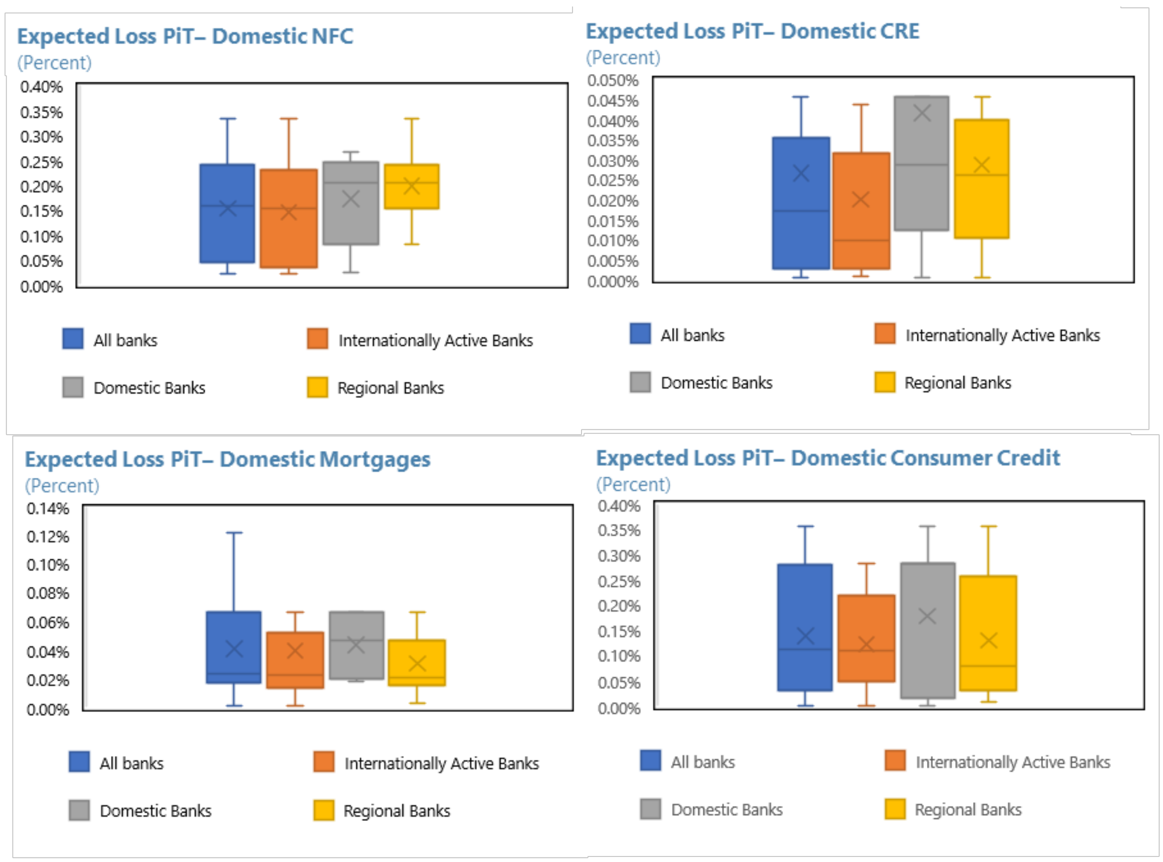
Sources: FSA; and IMF staff calculations.
Notes: The chart collection shows the distribution of point-in-time annual default rates across banks, for different bank clusters, and by portfolio segments. In the box plots, lines (crosses, x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles. CRE=commercial real estate. NFC=nonfinancial corporate.

Figure 24. Japan: LGDs at the Outset (end-FY2022)



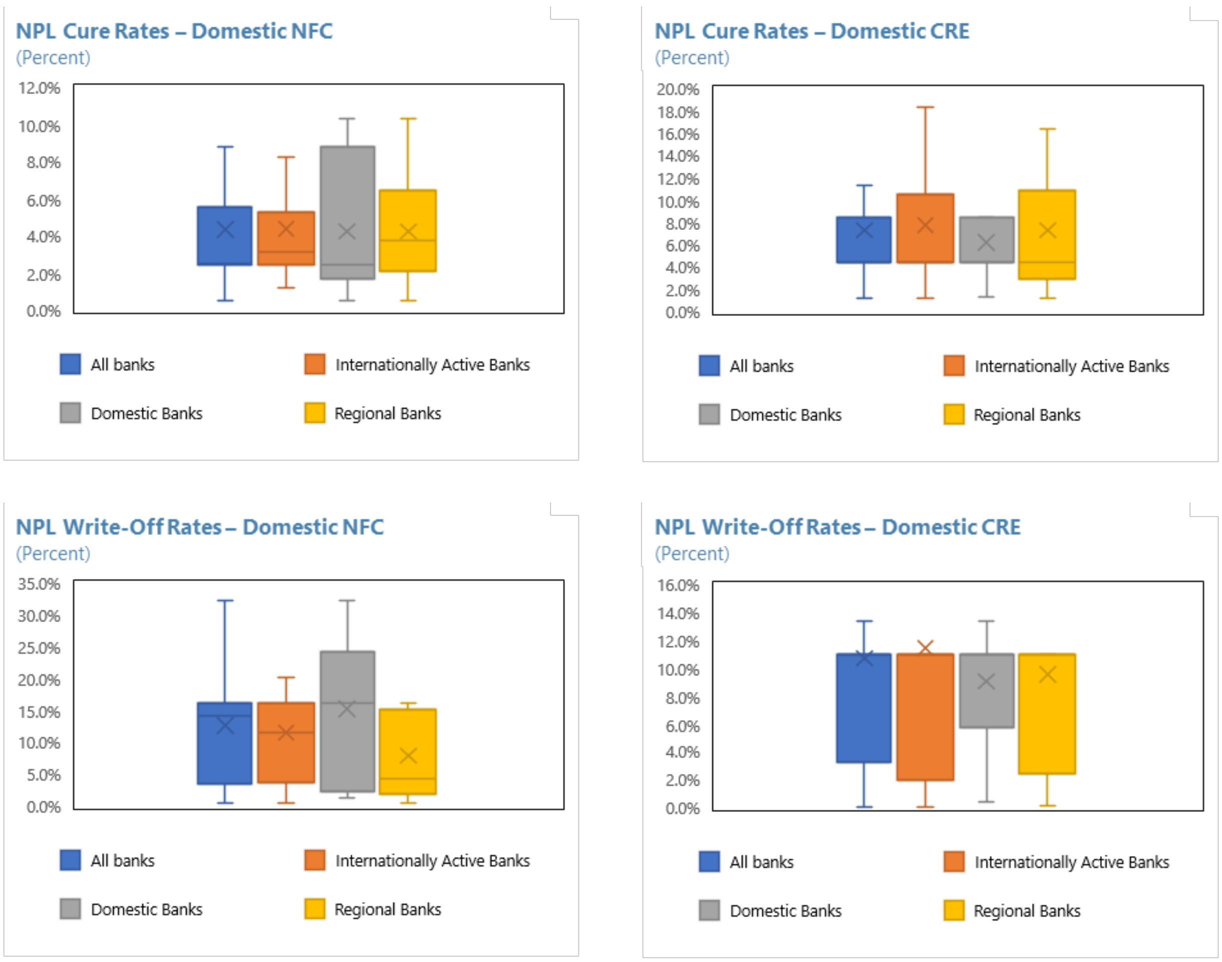
Sources: FSA; and IMF staff calculations.
Notes: The chart collection shows the distribution of point-in-time LGDs across banks, for different bank clusters, and by portfolio segments. In the box plots, lines (crosses, x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentile.

Figure 25. Japan: Expected Loss at the Outset (FY2022)



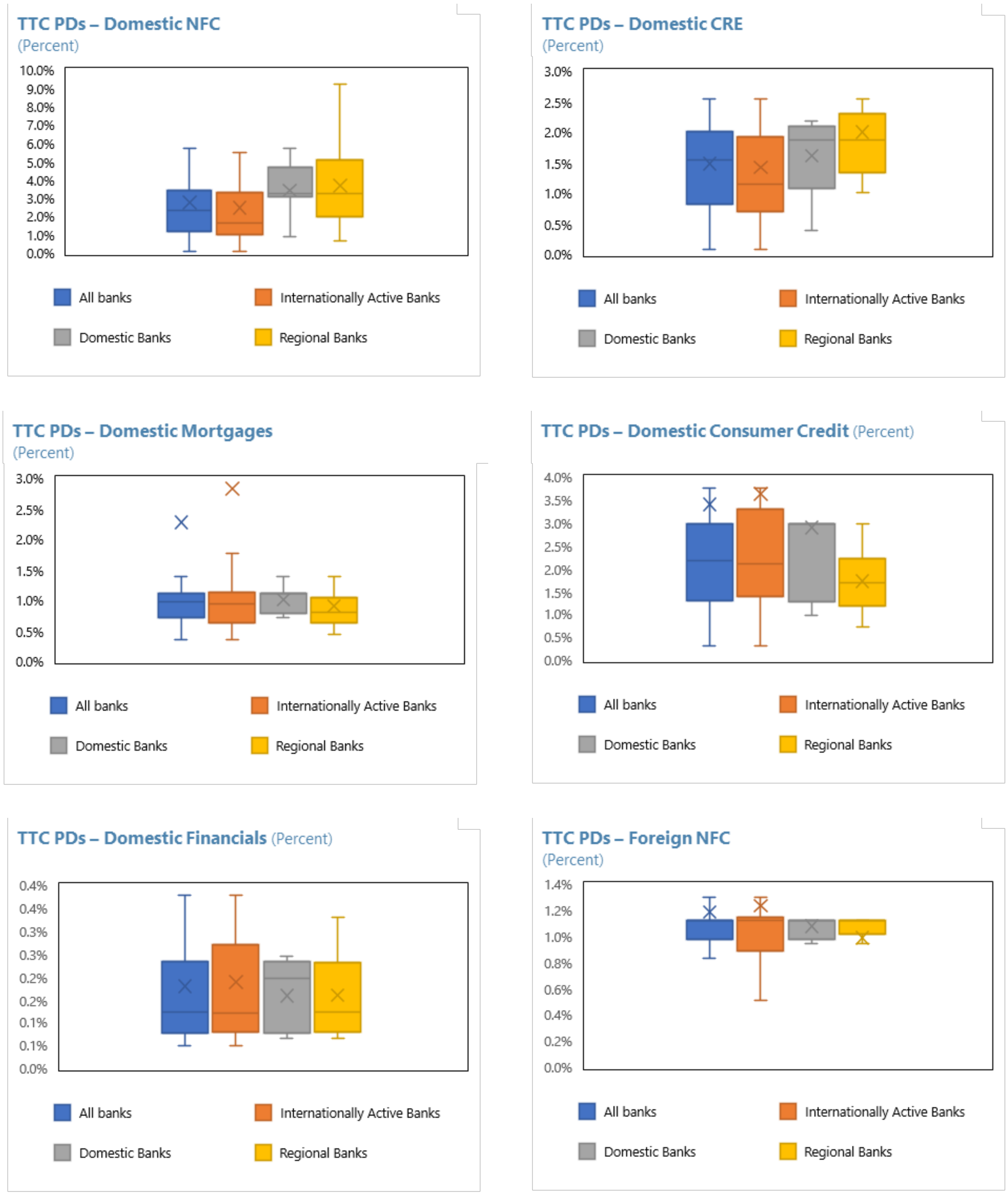
Sources: FSA; and IMF staff calculations.
Notes: The expected loss metrics for the underlying bank portfolios were computed as the product of observed annual default rates and PiT LGDs. In the box plots, lines (crosses, x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentile. CRE=commercial real estate. NFC=nonfinancial corporate. PiT=point-in-time.

Figure 26. Japan: Cure Rates and Write-Off Rates at the Outset (FY2022)



Sources: FSA; and IMF staff calculations.
Notes: The chart collection shows the distribution of point-in-time annual cure rates across banks, for different bank clusters, and by portfolio segments. In the box plots, lines (crosses x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles. The distributions for cure rates and write-off rates are shown here only for the domestic NFC and domestic CRE portfolios of the banks because for the other portfolios, the distributions are rather "tight," due to some missing data in the cross-section of banks for the other portfolios.

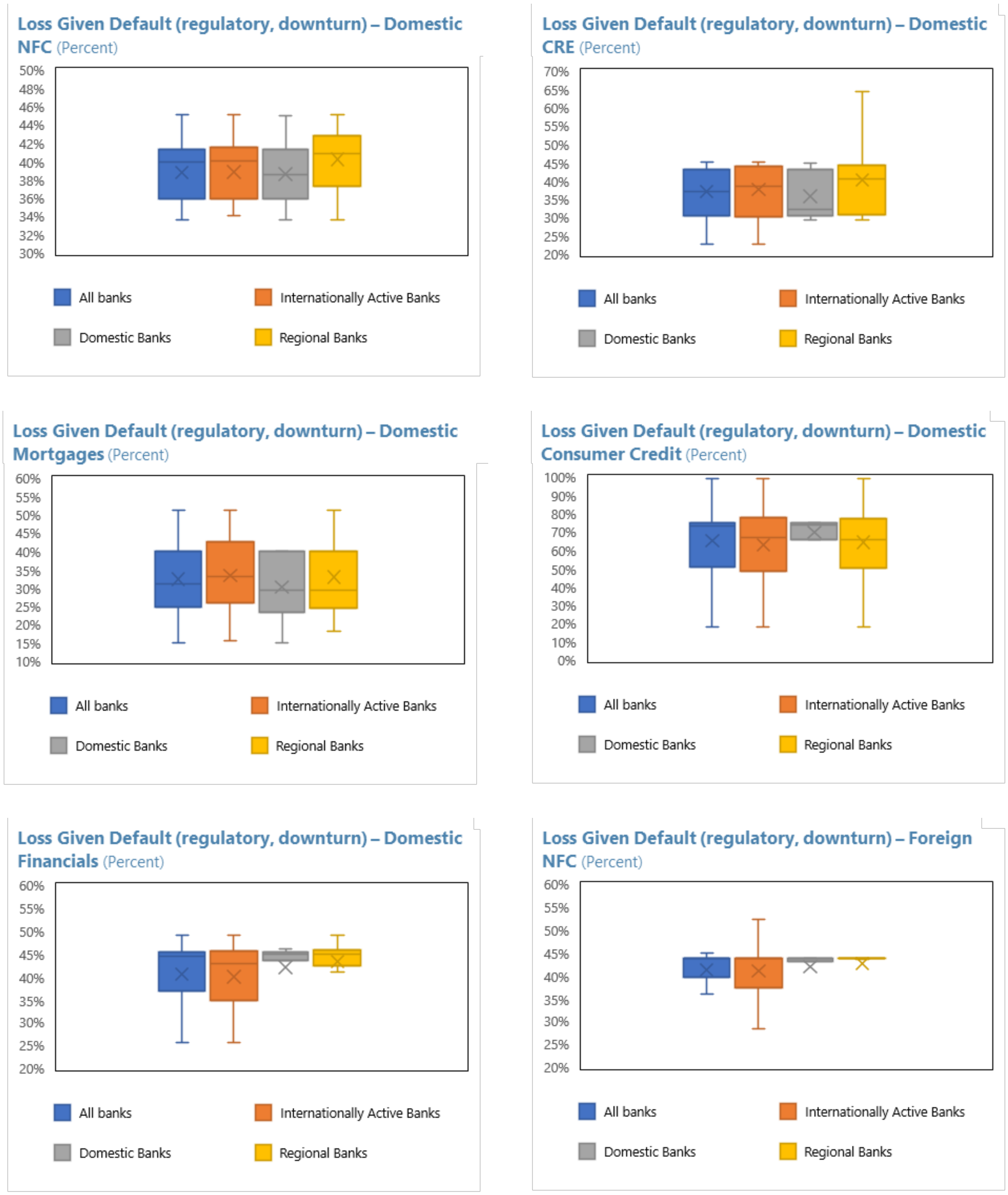
Figure 27. Japan: TTC PDs at the Outset (FY2022)



Sources: FSA; and IMF staff calculations.

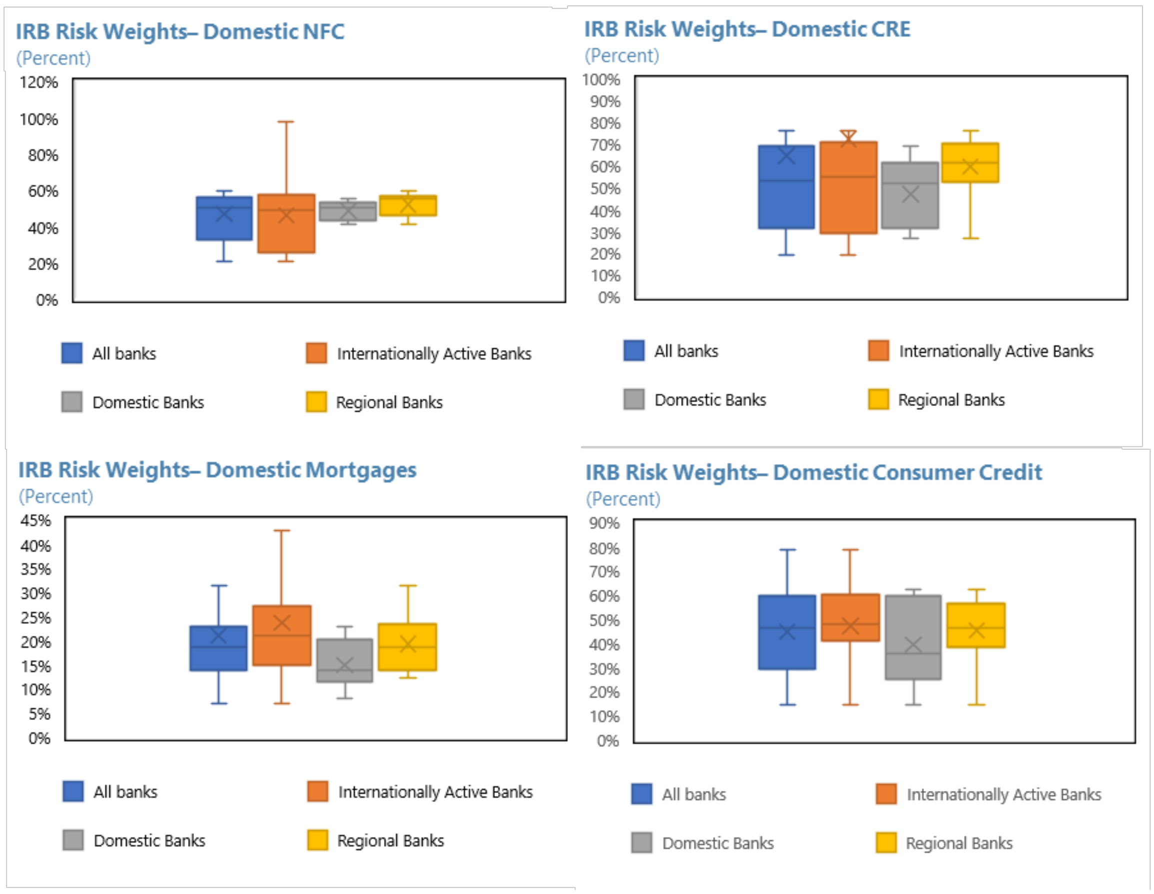
Notes: The chart collection shows the distribution of through-the-cycle annual PDs across banks, for different bank clusters, and by portfolio segments. In the box plots, lines (crosses x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles

Figure 28. Japan: Regulatory LGDs at the Outset (end-FY2022)



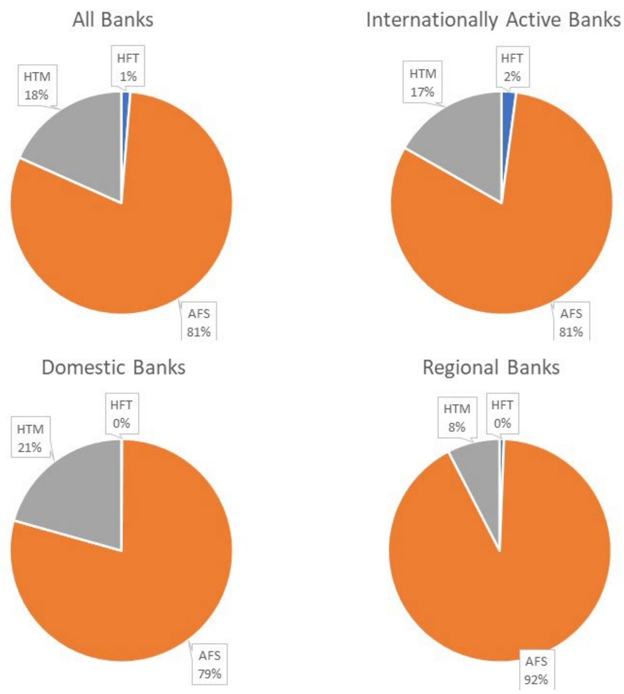
Sources: FSA; and IMF staff calculations.
Notes: The chart collection shows the distribution of regulatory (i.e., downturn) LGDs across banks, for different bank clusters, and by portfolio segments. In the box plots, lines (crosses x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles.

Figure 29. Japan: IRB Risk Weights for Performing Exposures (end-2022)



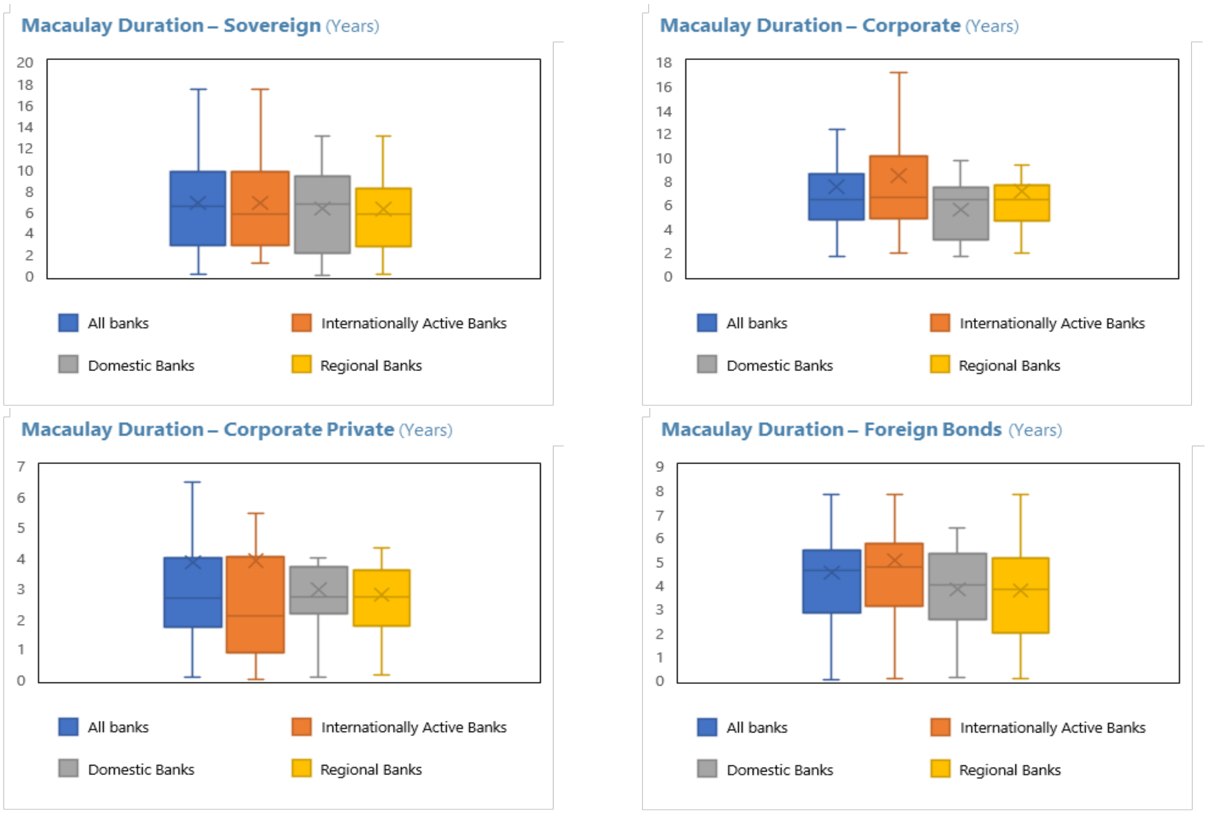
Sources: FSA; and IMF staff calculations.
Notes: The chart collection shows the distribution of IRB risk weights for performing exposures across banks, for different bank clusters, and for selected portfolio segments. In the box plots, lines (crosses x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles.

Figure 30. Japan: Banks' Holding Shares of Bonds and Equity in Held-for-Trading (HFT), Held-to-Maturity (HTM), and Available-for-Sale (AFS), by Types of Banks



Sources: FSA; and IMF staff calculations.
Note: The underlying data from all banks are for 2023Q1 (end-FY2022).

Figure 31. Japan: Duration Distribution for Japanese Banks' Bond Holdings



Sources: FSA; and IMF staff calculations.
Notes: The chart collection shows the distribution of Macaulay bond durations in the cross-section of banks. Sovereign, corporate and corporate private refer to domestic bonds. The foreign bonds category comprises bonds of all counterparty types in foreign jurisdictions. The underlying durations are measured at the portfolio level, which themselves are individual bond-level exposure weighted aggregates computed by the banks. In the box plots, lines (crosses x) in the middle of the box are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles. The durations are for the bonds from all investment categories (AFS, HTM, HFT); producing them for only the AFS and HFT portfolios would not change the visual appearance of the charts in any notable way.

38. Net interest income projections were obtained based on structurally informed models for the banks' interest income and cost of funding, while accounting for solvency to funding cost feedback. Econometric pass-through equations were estimated for all banks individually; that is, 23 models were obtained for the interest income rates (IIRs), and 23 cost-of-funding (CoF) models, based on data spanning the period 2002Q1-2023Q1. The cost-of-funding variable was defined as the four-quarter trailing sum of quarterly interest expense flows divided by the four-quarter average of liabilities. The predictor variables included in the CoF models comprised five core variables: (1) short-term market/policy rates (including the 1Y sovereign yield that is a primary, focal variable in the scenario), as the primary pass-through channel from bank-external interest rates to the banks [+]; (2) the 1Y US treasury bond yield, to account for a notable portion of Japanese banks' funding being in USD [+]; (3) a realized volatility metric for the Japanese stock market, to capture market price of risk effects that can drive the banks' CoF beyond what is implied by their "fundamental" own risk dynamics [+]; (4) BOJ's total asset growth, to account for the impact of BOJ's monetary policy through means other than by interest rate-based policy [-]; and (5) the banks' individual regulatory capital ratio, to account for solvency-funding cost feedback [-]. The signs of all estimated coefficients were as expected (as indicated in brackets above); see Figure 32. The solvency-funding cost feedback was found to be economically significant, and further to correlate positively with the banks' wholesale funding shares in the cross-section of Japanese banks.

39. The IIR model estimates suggest that interest income of Japanese banks is driven by domestic and foreign interest rate conditions alike, as expected given their notable cross-border exposure. The IIR at bank level was defined as the four-quarter trailing sum of quarterly interest income flows divided by the four-quarter trailing average of interest-bearing assets. The predictor variables in the pass-through equations included (1) the banks' own bank-specific cost of funding spread (spread to 1Y JGB); (2) the 1Y JGB yield; (3) 10Y JGB yield; (4) a 10Y US treasury spread to 10Y JGB; and (5) a 10Y euro area yield benchmark spread to 10Y JGB. The factor loadings on these five variables were found to be generally positive for all banks (Figure 32). The domestic JGB yields and the banks' own CoF are economically the more relevant drivers; but the rate dynamics in the U.S. and the euro area do also play a significant role. Separately, in the solvency stress test model, it is assumed that nonperforming exposures do not generate interest income. This spillover from materializing default risk to diminished interest income is important.

40. A modified duration-based valuation formula for bonds lies at the center of the market risk module, which was made to account for interest rate risk hedging for the Japanese banks. Detailed data were collected at the bank-portfolio level for Macaulay durations, current yields, and interest rate sensitivities while accounting vs. not accounting for hedges.[26] The information related to interest rate hedging that was sourced from banks and incorporated in the stress test model was partial to an extent, because it does not represent the use of broader forms of hedging beyond instrument-specific interest rate swaps. The extent to which interest rate hedges are effective in containing interest rate stress will be explored later in this section. Beyond bond valuation, equity investments of the banks were revalued in line with the equity price index paths under the scenarios. Valuation changes from FX open positions were computed based on the FX rate assumptions in the scenarios.

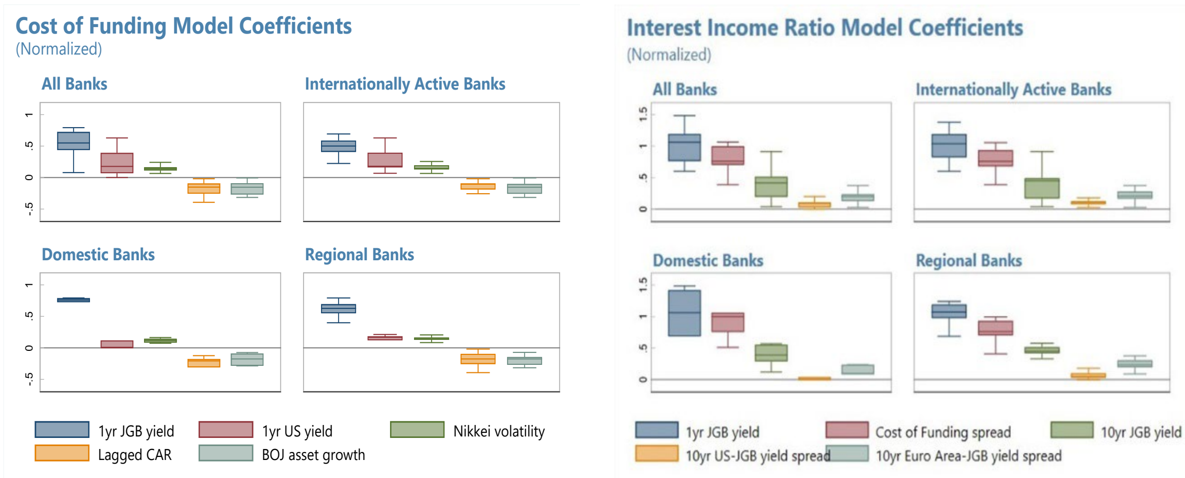
41. Security holdings of domestic banks held in the AFS category are marked to market, i.e., the "AFS filter" is not accounted for. The AFS filter for domestic banks was assumed to not be present, to thereby reflect the economic valuation effects of the domestic banks' bond holdings. Their stating point capital ratios were adjusted to reflect the unrealized gains at the onset of the stress test scenario horizon.

42. Other P&L items included net fee and commission income (NFCI) and a sizeable "other operating expense" item. A panel Bayesian Model Averaging (BMA) model was set up for the NFCI component, relating the NFCI to total asset (TA) ratios of banks to a set of macrofinancial indicators, including short- and long-term market interest rates, GDP, employment, and others. The "other operating expense," comprising mostly salary expenses, was held constant as a ratio to total assets

[26] Japanese banks manage their interest rate risks typically through interest rate derivatives, including interest rate swaps, futures, and fixed-income bear funds.

gross of provisions. This means that under a dynamic balance sheet, when the balance sheets of banks grow (grow less/shrink), this expense item would grow (grow less/shrink) accordingly.

Figure 32. Japan: Interest Income and Cost of Funding—Sensitivities



Sources: FSA; and IMF staff calculations.
Notes: The pass-through coefficients were estimated at the bank-level, in multivariate pass-through regressions which had the cost of funding and interest income ratio variable on their left hand-side, and on their right hand-side the independent variables as listed in the legend of the charts. The pass-through coefficients were normalized here by multiplying them with the ratio of the standard deviation of the left and right hand-side variables. They are therefore comparable across right hand-side variables and across models. Their interpretation is: a 1 STD move in the right hand-side variable induces a normalized coefficient times a standard deviation of the left hand-side variable.

Results

43. **The aggregate Common Equity Tier 1 (CET1) ratio of the Japanese banking system falls by 510 basis points in the first year of the adverse scenario but remains well above the regulatory minimum**.[27] The decline is more pronounced for domestic banks than for internationally active banks, and for regional banks considered as a separate group compared to the system-wide aggregate (Figure 33 and Figure 34). The low point of the capital ratio path is in the first year, which is compatible with the design of the adverse scenario, with its trough being in the first year and a subsequent slow recovery.[28]

44. **The results are driven mainly by sizeable valuation losses from security holdings and rising loan losses that are partially offset by an increase in interest income due to rising interest rates**. Valuation losses are the most dominant driver of changes to banks' capital ratio,

[27] The banks, defined as "domestic," have a so-called AFS filter in place. It means that valuation gains and losses stemming from their bond and equity investments in the AFS category do not affect their regulatory capital metrics (or only with a delay). In the solvency stress test, the AFS filter for domestic banks was ignored, however, and their starting point capital ratios adjusted to reflect the unrealized valuations gains/losses reported at end-FY2022. The rationale for accounting for the valuation changes of AFS securities lies in revealing the economic valuation effects and to ensure a level playing field and comparability of the impacts vis-à-vis the international banks in the stress test sample.

[28] As mentioned before, the AFS filter was switched off for the domestic bank sample and tax credit effects not accounted for, with both of these features implying that the adverse scenario impacts on the banks' capital ratios would be to some extent less pronounced.

contributing to a decline in the banking system capital ratio by 6.3 percentage points in the first year of the adverse scenario (see Other Comprehensive Income (OCI) in Figure 35). Loan losses grow three-fold under the adverse scenario relative the baseline scenario, albeit they remain at a manageable level due to initial default rates for most of the banks and portfolios resting at low levels. Net interest income (NII) contributes positively under the adverse scenario, despite rising funding costs and defaults that put downward pressure on NII. The contribution from securities' valuation losses is more pronounced for regional banks and domestic banks, compared to the total banking system, which reflects their above-average security holding shares, while assuming that the AFS filter is not active.

45. Overall losses are dominated by valuation losses from bonds and equity, and a sizeable portion of those in turn stem from foreign investments. Despite the loan book as a share of loan book and bond and equity investments amounting to 60 percent, the loss contribution to the combined loan losses and valuation losses amounts to only 10 percent, while the combined contribution from bond and equity investments amounts to 90 percent. Regarding the loan book, the loss contributions from domestic vs. foreign exposures amount to 79 percent and 21 percent, respectively. For bond and equity investments, the loss contributions from domestic vs. foreign exposures amount to about 50 percent each. For bonds, these shares exclude the HTM portfolios of banks, which amount to about 20 percent of total bonds (Figure 30).

46. NPL ratios at the aggregate loan book level rise from 0.8 percent to a sizeable 2.5 percent for the banking system. The rising default flow rates (in conjunction with assumptions for cure rates and write-off rates in the solvency stress test model) imply for NPL stocks and associated ratios to rise notably (Figure 36). For the system aggregate, the initial NPL ratio at 0.8 percent rises to 2.5 percent in the third year. For domestic banks and regional banks, the initial NPL ratio at 1.5 percent rises to 3.6-3.8 percent in the third year. The NPL ratios grow in a sluggish manner, peaking only in the third year, because defaults accumulate and outflows from the NPL stock due to write-offs do not outweigh the inflow to NPLs from defaulting exposures over the stress test horizon.

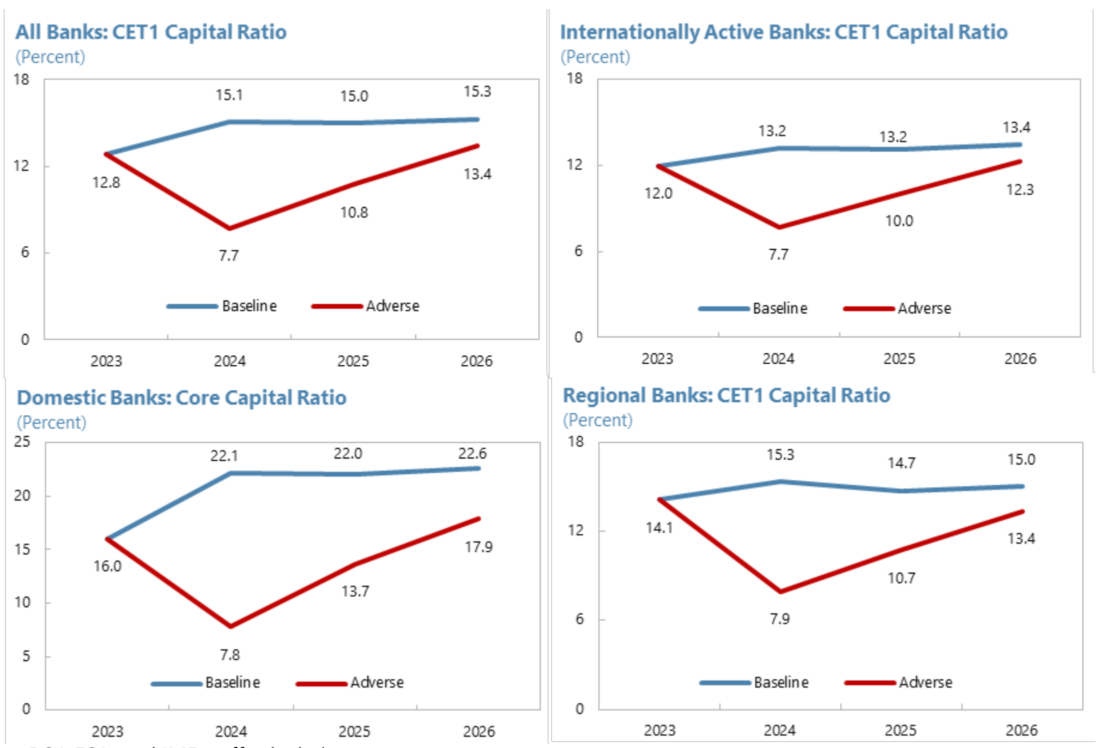
47. Loan loss rates (the "cost of risk") rise six-fold at the system level, and by more for domestic banks and regional banks. The aggregate loan loss rate for all banks increases from 0.1 percent in the initial year to 0.6 percent in the first year of the adverse scenario (Figure 37). For domestic banks and regional banks, the increase in loan loss rates is more pronounced and it reaches 1.0-1.1 percent in the first year of the shock. However, the rise in loan losses does not materially contribute to changes in the capital ratio, due to the initial favorable levels of the risk parameters involved. The portfolio level contributions to loan losses are about proportional to the loan book shares, for example, ranging around 35-40 percent for domestic nonfinancial corporate lending, 16-20 percent for domestic mortgages, and less than 5 percent for domestic consumer credit (Figure 38).[29]

[29] The 5-year/125 percent rule was not accounted for (this aspect will be discussed later in this note). Mortgage PDs could be lessened by the industry practice (5-year/125-percent rule) that could mitigate a sharp increase in mortgage payments. According to the authorities, mortgage PDs in Japan have been low historically.

48. Three (four) banks face capital shortfalls under the adverse scenario when considering CET1 (total capital) as the reference metric. The three and four banks whose capital ratios fall below the hurdle rate of 4.5 percent for CET1 and 8 percent for total capital ratio (and 4 percent for domestic banks' core capital ratio metric) amount to a mere 0.04 percent and 0.05 percent of 2022 nominal GDP, respectively.[30] Three of the four banks with total capital ratio below the hurdle rate belong to the regional bank cluster. Together, the four banks represent five percent of total assets of the 23 banks in scope of the stress test.

49. Under the adverse scenario, the capital ratios of several banks would fall into the range of the Capital Conservation Buffer (CCoB). For CET1 and total capital ratios, eight and twelve banks, respectively, would consume their CCoB buffer, which would thereby serve its intended role during a downturn scenario. The aforementioned three and four banks with a capital shortfall under the adverse scenario would fully deplete their CCoB as they fall further below the hurdle rate.

Figure 33. Japan: Bank Solvency Stress Test Results—CET1 Capital Ratios

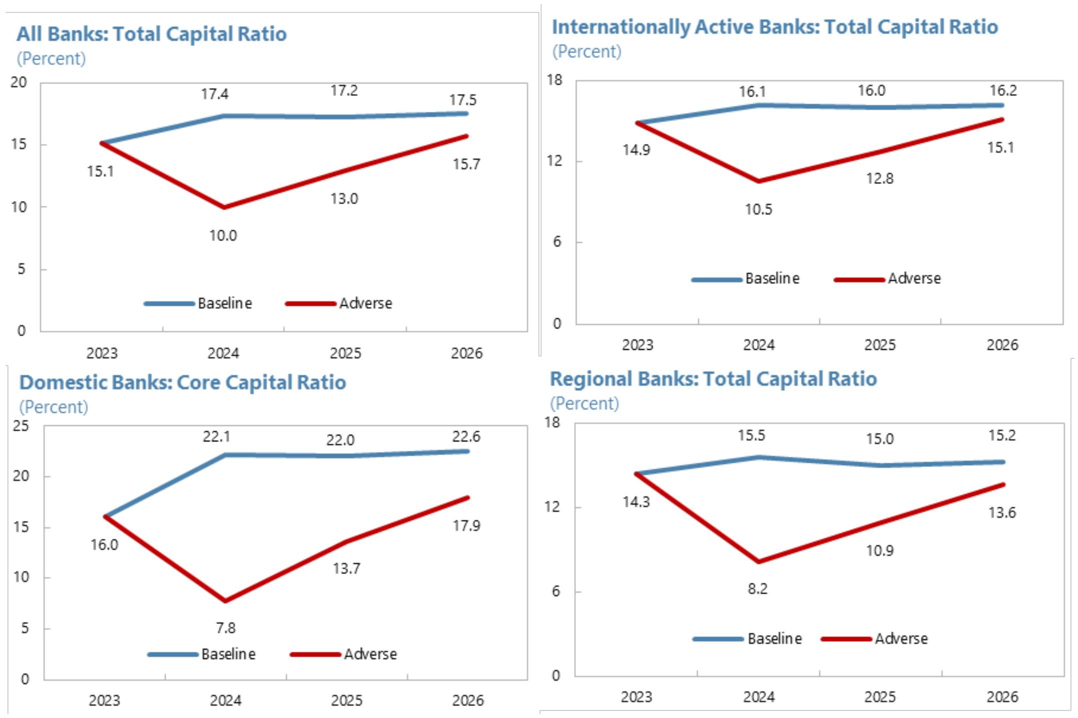


Sources: BOJ; FSA; and IMF staff calculations.

Note: For the domestic bank cluster, their core capital ratio is used, which differs from CET1 and total capital ratios as employed for international banks. The starting point for the domestic banks' core capital was adjusted to take unrealized gains/losses at the onset into account. The AFS filter was "switched off" for domestic banks, to thereby assess the economic valuation effects on their core capital ratios and to facilitate the comparison with the international banks for which no AFS filter is in place. The regional banks cluster considers both internationally active and domestic regional banks. Deferred tax credit effects were not accounted for; their inclusion would reduce the impact of the adverse scenario to an extent.

[30] Additional surcharges on capital requirements for G-SIBs and D-SIBs in the sample were included in the hurdle rates.

Figure 34. Japan: Bank Solvency Stress Test Results—Total Capital Ratios

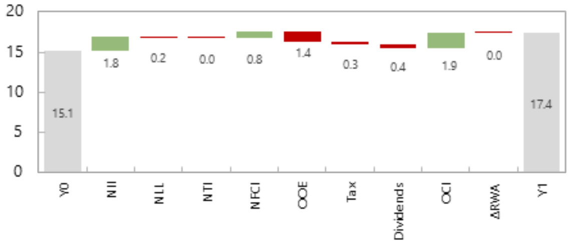


Sources: BOJ; FSA; and IMF staff calculations.

Figure 35. Japan: Bank Solvency Stress Test Results—Contribution Analysis—Up to Year 1

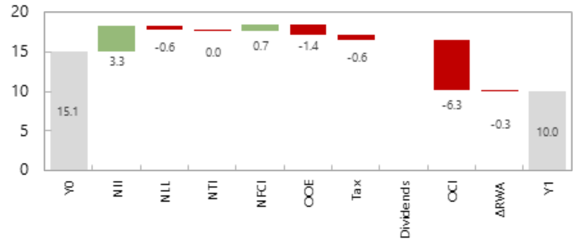
All Banks: Baseline, up to Y1

(Starting and end-point capital ratios in percent, contributions in pp)



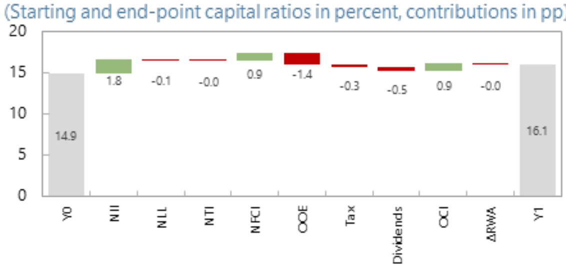
All Banks: Adverse, up to Y1

(Starting and end-point capital ratios in percent, contributions in pp)



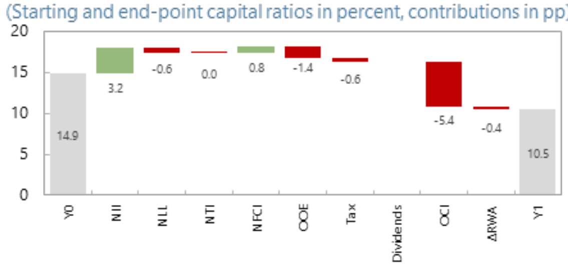
Internationally Active Banks: Baseline, up to Y1

(Starting and end-point capital ratios in percent, contributions in pp)



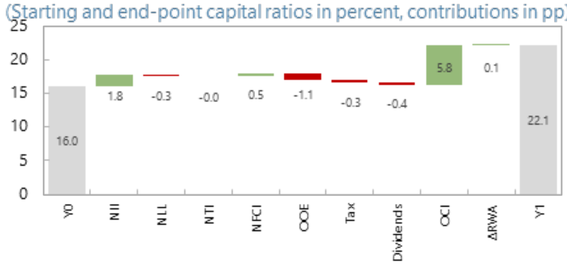
Internationally Active Banks: Adverse, up to Y1

(Starting and end-point capital ratios in percent, contributions in pp)



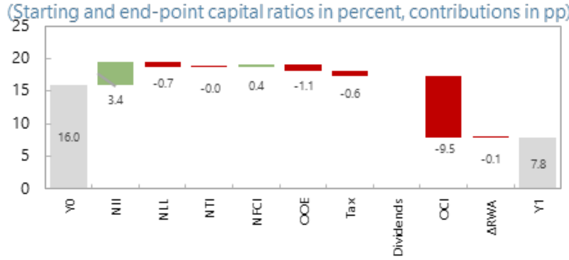
Domestic Banks: Baseline, up to Y1

(Starting and end-point capital ratios in percent, contributions in pp)



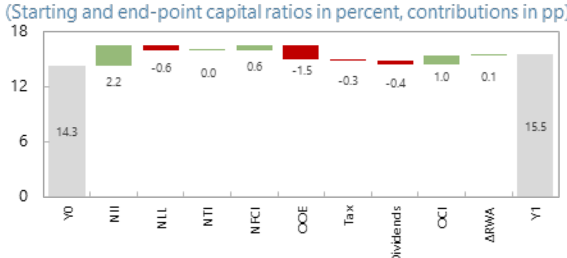
Domestic Banks: Adverse, up to Y1

(Starting and end-point capital ratios in percent, contributions in pp)



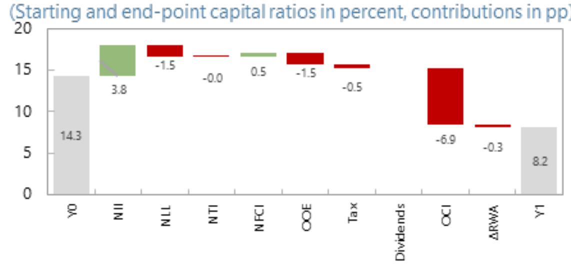
Regional Banks: Baseline, up to Y1

(Starting and end-point capital ratios in percent, contributions in pp)



Regional Banks: Adverse, up to Y1

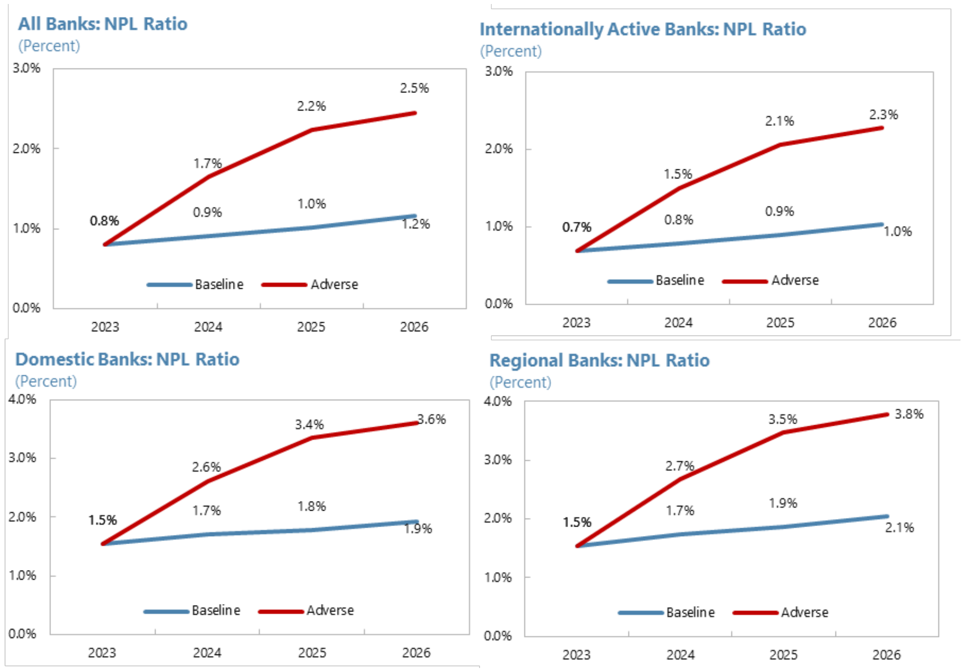
(Starting and end-point capital ratios in percent, contributions in pp)



Sources: BOJ; FSA; and IMF staff calculations.

Notes: The contribution analysis as shown here pertains to total capital ratios for international banks and core capital ratios for domestic banks. The capital ratios at the initial position in Year 0 and Year 1 are driven by the percentage point contributions arising from NII (net interest income), NLL (net loan losses), NTI (net trading income), NFCI (net fee and commission income), OOE (other operating expenses), taxes, dividends, and valuation gains or losses recorded under OCI (other comprehensive income). The delta RWA term captures the effects of dynamically moving risk weights for IRB exposures, performing-to-nonperforming migration effects for STA portfolios, and general loan growth as assumed under the scenarios.

Figure 36. Japan: Bank Solvency Stress Test Results—NPL Ratios

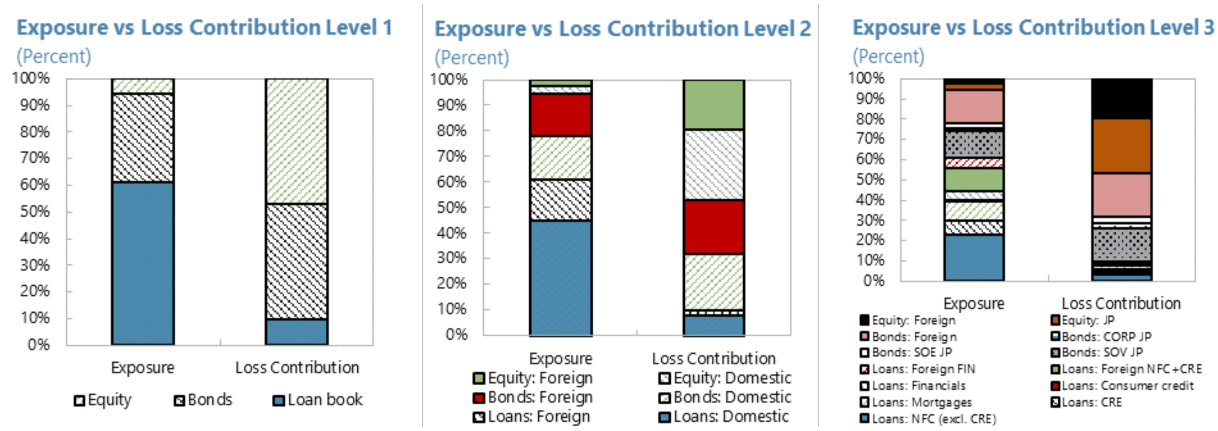


Sources: BOJ; FSA; and IMF staff calculations.
Notes: The NPL ratios pertain to the overall loan book of the banks, summing all underlying portfolios. The NPL stocks are driven by default flows, cure outflows, write-offs, and influenced by gross loan growth as defined in the scenario.

Figure 37. Japan: Bank Solvency Stress Test Results—Net Loan Loss Ratios

Sources: BOJ; FSA; and IMF staff calculations.
Notes: The loan loss rates are defined as annual loan losses divided by 2-year moving average balances of gross loans (all portfolios combined). Loan losses in the numerator are driven by provision flows for nonperforming and performing exposures (driven in turn by fore- and backflows, including cures), and loss differentials between realized losses and provision coverage for nonperforming exposures that are written off along the scenario horizon.

Figure 38. Japan: Exposure Shares Vs. Loss Contributions



Sources: BOJ; FSA; and IMF staff calculations.

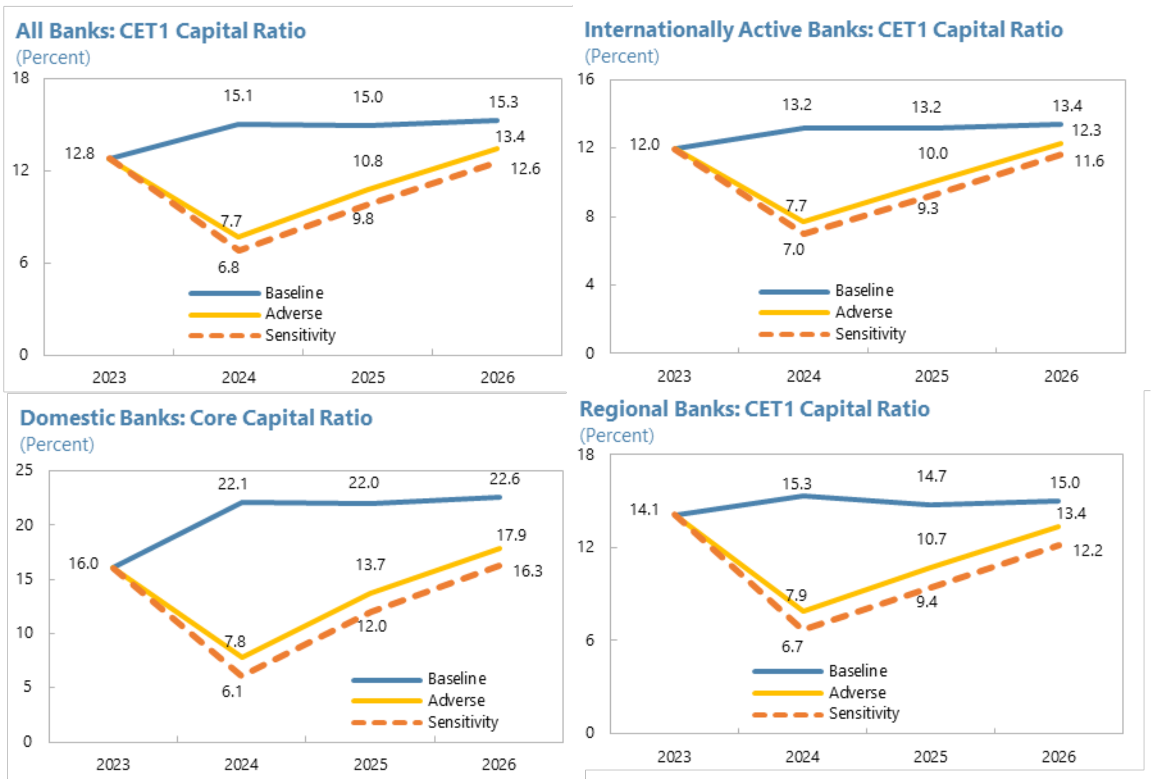
Sensitivity Analysis

50. **The sensitivity analysis implies additional capitalization pressure for banks compared to the initial adverse scenario.** Considering the interest rate sensitivity analysis, the banking system aggregate capital ratio drops by an additional 1.1 percentage points from the initial adverse scenario to reach 8.9 percent (Figure 39). The additional decline in capital is driven primarily by larger valuation losses on securities through higher interest rates, and to an extent by further rising loan losses. The latter is the result mainly of interest rate risk morphing further into default risk of corporates and households.[31] Domestic banks and regional banks are more sensitive to additional rate shifts than other banks due to their higher share of security holdings. The count of banks with total capital falling below the hurdle rate in this case doubles to eight, of which five belong to the regional bank cluster. The system-wide total capital shortfall rises from 0.05 percent of GDP to 0.3 percent of GDP.[32]

[31] The GDP growth sensitivity analysis implies modest additional bank capital impacts, due to the prominent use of structural models for credit and market risk, which establish the relationships of relevant metrics with the underlying drivers, such as the unemployment rate for mortgage default rates. Moreover, bond and equity valuation effects were found to dominate for Japanese banks, which are primarily a function of changes in interest rates and equity prices.

[32] A notable share of the regional bank cluster is classified as "internationally active" banks.

Figure 39. Japan: Bank Solvency Stress Test Results—Interest Rate Sensitivity Analysis



Sources: BOJ; FSA; and IMF staff calculations.
Notes: For the domestic bank cluster, their core capital ratio is used, which differs from CET1 and total capital ratios as employed for international banks. The starting point for the domestic banks' core capital was adjusted to take unrealized gains/losses at the onset into account. The AFS filter was "switched off" for domestic banks, to thereby assess the economic valuation effects on their core capital ratios and to facilitate the comparison with the international banks for whom no AFS filter is in place.

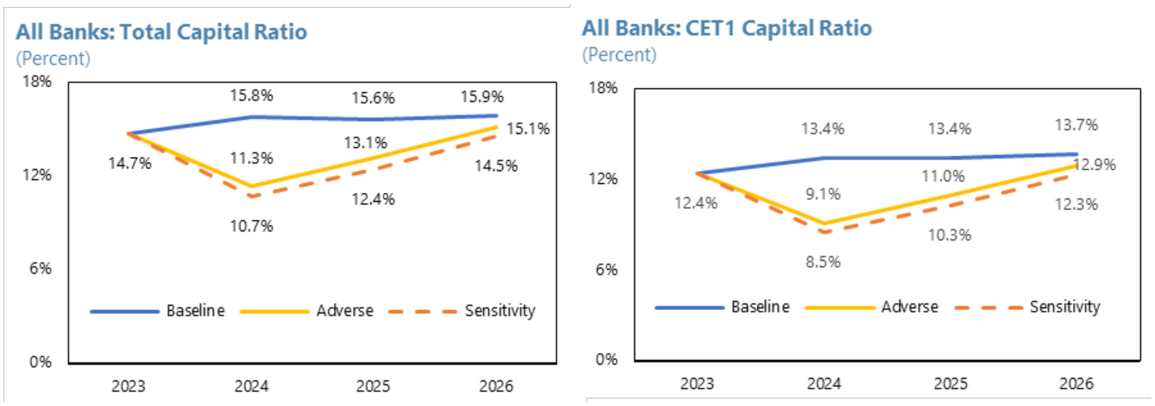
51. Interest rate hedging helps to shield the Japanese banks against interest rate risk. The impact on bank capital ratios as presented up to now take interest rate hedges of the Japanese banks into account. A counterfactual of switching this hedging off would make the aggregate banking system capital ratio fall by an additional 130 basis points in the first year compared to the initial adverse scenario to reach an overall shift in capital ratios of 640 basis points. In this case, ten banks would see their total capital ratios fall below the hurdle rates. This finding suggests that interest rate hedging can play a beneficial role to mitigate interest rate-related market risk.[33]

52. When activating the AFS filter for the domestic bank sample, the adverse scenario impacts become less pronounced at the banking system level (Figure 40). The starting point for the banking system, i.e., also including the banks for which the AFS filter is not relevant, moves from 15.1 percent to 14.7 percent, reflecting the difference in the valuation gains for domestic banks at the outset. The capital ratio drops then by 340 basis points, compared to 510 basis points under the

[33] As mentioned earlier, the hedging-related data may be to an extent be incomplete.

initial setting with the AFS filter deactivated. For the underlying domestic banks sample, the adverse scenario results are notably more benign.

Figure 40. Japan: Bank Solvency Stress Test Results—AFS Filter On for Domestic Banks



Sources: BOJ; FSA; and IMF staff calculations.
Notes: For the domestic bank cluster, their core capital ratio is used, which differs from CET1 and total capital ratios as employed for international banks. The starting point for the domestic banks' core capital was adjusted to take unrealized gains/losses at the onset into account. The AFS filter was "switched off" for domestic banks, to thereby assess the economic valuation effects on their core capital ratios and to facilitate the comparison with the international banks for whom no AFS filter is in place.

53. **Net open FX positions for a majority of banks in the sample are small relative to their capital.** Only two banks have sizeable net open FX positions, which size-wise belong to the largest and smallest quarter of the bank sample. At end-FY2022, they face net open FX positions relative to capital of about 40 percent, which is largely driven by the mismatch between their USD assets and liabilities. These banks are either not or only partially FX hedged. Given that most other banks do not appear to be characterized by sizeable FX mismatches, the banking system was judged to be well balanced in terms of currency mismatches at the aggregate level. This assessment, however, does not negate the relevance of FX asset-side market risk and FX liability-induced liquidity risks.

54. **An additional counterfactual analysis, assuming that the USD funding cost for Japanese banks rises materially, suggests that for only a small number of large banks this may imply notable capitalization pressure**. The U.S. dollar funding cost shock was informed by the historical distribution of JPY-USD currency basis swap spreads. It was set to +70 bps, which was last observed in 2017 (Figure 8). The shock was assumed to prevail over the rising "base" interest rates for the U.S. in the adverse scenario.[34] The solvency model and its funding cost component were customized to take the bank-specific U.S. dollar funding dependence in volume terms into account. The capital ratios for some selected banks of the 23 banks in the stress test sample would fall by more than 0.5 ppt (and in very selected cases more than 1 ppt) relative to the initial adverse scenario.

[34] The combined shock from the U.S. short-term (1Y sovereign) rate shift in the adverse scenario (+150 bps from year 0 to year 1) coupled with the additional 70 bps spread shock implies a combined +220 bps funding cost shock for Japanese banks' USD funding.

B. Bank Liquidity Stress Test

Methodology

55. A cash flow-based bank liquidity stress test was conducted, accounting for solvency-liquidity interactions. The test, anchored in hypothetical, severe liquidity outflow assumptions, captures the availability of liquid assets and potential need for banks to sell securities in different investment categories, involving a sales hierarchy.[35] Importantly, securities under fair value accounting are assumed to be sold first (if necessary), before those under amortized cost accounting are considered, i.e., those under held to maturity, or in the available-for-sale (AFS) category for domestic Japanese banks.[36] The horizon of the liquidity stress test extends to six months and operates in weekly time steps (i.e., 24 weeks). It was conducted based on data that combines all JPY and foreign currency exposures. Liquid asset buffers—which are at the banks' disposal to cover the liability-driven outflows of reserves—are defined as banks' reserve holdings at the central bank, cash in own vaults, interbank placements in the form of loans and deposits from the asset side of a bank, equity investments, derivative-related inflows, and bonds.

56. The liquidity stress test model was fed with detailed supervisory data. The data included detailed maturity profile for the asset and liability sides, the asset-side bond exposures' duration, and interest rate hedging-related information; the same that feeds the market risk module of the bank solvency stress test. Among the important model parameters are the assumed run-off rates for liabilities, alongside the equity and interest rate shocks. The run-off rates were informed by the Liquidity Coverage Ratio (LCR) run-off calibration, as applicable to Japanese banks, for a "base case" stress calibration (Table 2).[37] The equity price shock and interest rate shifts were aligned with those used for the bank solvency stress test and other components of the systemic risk analysis. The shocks pertaining to the first year under the solvency stress test were assumed to instantaneously apply at the onset of the liquidity stress simulation.

57. The dominant sources of liability-driven outflows of assets are unsecured wholesale funding and derivatives (including FX swaps). Conditional on the maturity profile of the banks,

[35] Trading and available-for-sale securities are sold first if reserves at banks and the BOJ do not suffice to service the liability-driven outflows of assets. These are followed by the sale of held-to-maturity assets (and AFS securities for domestic banks in Japan), if needed. The latter can imply adverse feedback to banks' solvency through the realization of previously unrealized losses, and additional valuation losses under the adverse scenario. In addition, the feedback from rising funding costs due to a worsening solvency position of banks, especially for those with a higher share of non-deposit funding, are considered. The liquidity stress test model does not take account of banks' management actions, such as by raising additional private/public funding. The stress calibration is severe overall, in some respects more severe than implied by an LCR parameterization.

[36] The AFS filter "shields" the domestic banks' regulatory capital metrics from valuation changes of securities (bonds and equity investment) held under the AFS investment category.

[37] The LCR-type run-off rates were modified to account for the fact that their meaning in the liquidity stress test is different than under the LCR. That is, under the LCR, they apply to initial outstanding balances, while in the liquidity stress test model they apply to only the portion of the liability balance that contractually matures in a given period (here week). Hence, the run-off rates for the liquidity stress test need to be higher than under the LCR, to be economically equivalent. This calculation was done by taking the maturity profile of liabilities of the Japanese banks into account.

the run-off rate calibration (Table 2) implies that—at the banking system level—about 50 percent of total liability-driven outflows of assets over the first 30 days of the liquidity stress test are driven by a run-off of unsecured wholesale funding, following by 30 percent from liability-side derivatives (which include FX swaps, with about half of the derivatives pertaining to U.S. dollar-related FX swaps), 10 percent from retail unsecured funding, and a residual of about 10 percent for secured wholesale funding and drawdowns from credit and liquidity lines. For domestic banks and regional banks, the contribution from derivatives does not exceed 5 percent; the contribution from unsecured retail funding is, instead, more sizeable, at 35 percent and 20 percent, for domestic banks and regional banks, respectively.

Table 2. Japan: Stressed Run-Off Rate Calibration (Base Setting)

Liability Side			Run-Off Rates						
			1 to 7 days	8 to 15 days	16 to 30 days	31 to 60 days	61 to 90 days	90 to 180 days	More than 180 days
1	Retail unsecured	Stable deposits	3%	3%	3%	2%	2%	1%	0%
2		Less stable deposits	5%	5%	5%	4%	3%	1%	0%
3		Stable term deposits	5%	5%	5%	4%	3%	1%	0%
4	Wholesale unsecured	Debt securities and CDs	100%	100%	100%	75%	50%	25%	0%
5		Wholesale deposits by CORP, SOV,	15%	15%	15%	11%	8%	4%	0%
6		Residual	100%	100%	100%	75%	50%	25%	0%
7	Wholesale secured	Funding from BoJ	0%	0%	0%	0%	0%	0%	0%
8		Backed by Level 1 assets	3%	3%	3%	2%	2%	1%	0%
9		Backed by Level 2A assets	7%	7%	7%	5%	4%	2%	0%
10		Backed by Level 2B assets	20%	20%	20%	15%	10%	5%	0%
11		Residual	40%	40%	40%	30%	20%	10%	0%
12	Derivatives	Derivatives	100%	100%	100%	75%	50%	25%	0%

Source: IMF staff.

Results

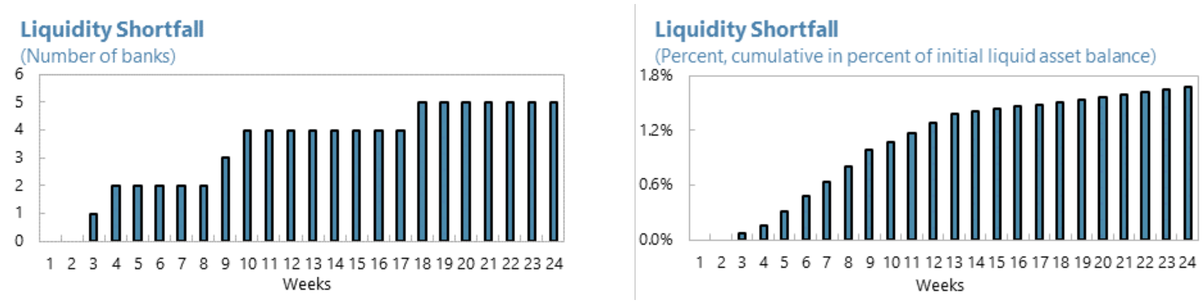
58. The liquidity stress test results suggest that Japanese banks are generally resilient against a hypothetical, severe liquidity stress event. This assessment is based on the all-currency liquidity stress test results (Figure 41). Five banks would face a liquidity shortfall, which would accumulate to 1.7 percent of initial liquid asset buffers among the 23 banks. The five banks represent 7 percent of total assets of the 23 banks in scope of the stress test. They include three regional banks. Various types of liquid asset buffers are depleted to a significant extent in aggregate over the banking system. Held-for-trading securities are generally small for all Japanese banks, and are ranked first in the sales hierarchy under stress, hence they are depleted fully at the system level (Figure 42).

59. The feedback to solvency—from selling mark-to-market securities to honor liability-driven outflows of cash—is confined to only a small number of banks, though may be material for those selected banks. For two out of 23 banks, the feedback to capital ratios implies a decline of more than 2 percentage points. For one additional bank, the impact amounts to a decline of 1.2 percentage points. One of the more sizeable impacts (larger than a decline of 2 percentage points) is for a bank that does not face a liquidity shortfall, but for which the sale of the securities suffices to avert its liquidity shortfall. Mirror-wise, two of the banks with a liquidity shortfall do not face feedback to capital, because the bonds they sell are under fair value accounting already.

Figure 41. Japan: Bank Liquidity Stress Test Results

Five banks fail the liquidity stress test. The first (fifth) bank faces a liquidity shortfall after three (18) weeks.

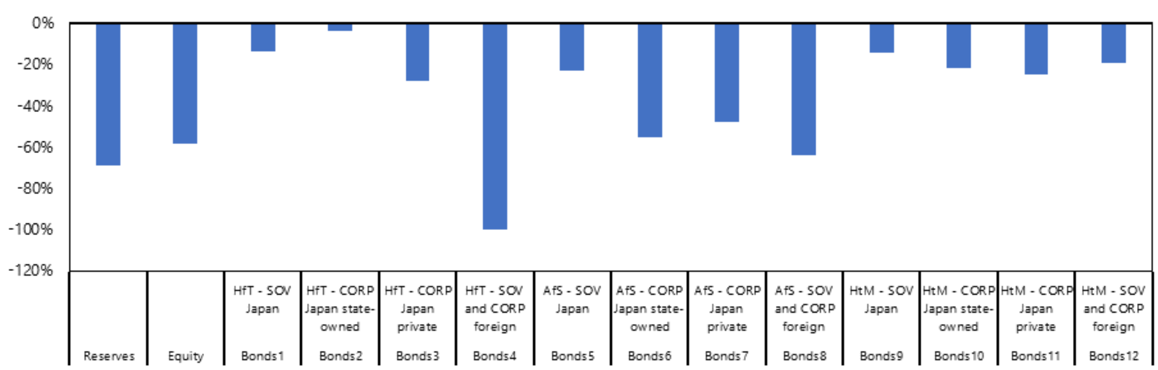
The liquidity shortfall accumulates to 1.7 percent of initial liquid asset stocks by the end of the 6-month horizon.



Sources: BOJ; FSA; and IMF staff calculations.

Figure 42. Japan: Bank Liquidity Stress Test—Buffer Depletion

Various liquid asset buffer types are depleted to a significant extent in aggregate over the banking system. HFT exposures are generally small for all Japanese banks, and they are ranked first in the sales hierarchy under stress, and hence they are depleted fully at system level.



Sources: BOJ; FSA; and IMF staff calculations.
Notes: Reserves here include reserves at central bank, cash in vaults, sight and term deposits at other banks, repo backflows, and backflows from derivatives. For domestic banks, their AFS bond holdings are subsumed here by the HTM bond categories. The impacts pertain to the banking system sum over banks, so that the use of reserves and equity, which are sorted before bonds in the sales hierarchy, do not need to reach 100 percent before other liquid asset buffers (bonds) are used. This reflects the underlying bank heterogeneity.

Sensitivity Analysis

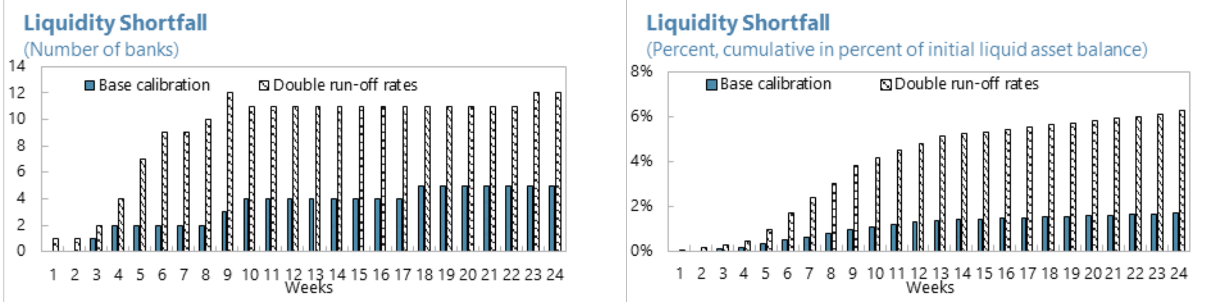
60. A bank liquidity risk-related sensitivity analysis considers a hypothetical case whereby the run-off rates for liabilities would double, compared to the initial stress calibration. In this case, the number of banks with a liquidity shortfall rises to twelve, most of which are internationally active banks. The liquidity shortfall accumulates here to about 6 percent of initial liquid asset stocks.

The value in considering such more severe run-off scenarios lies in better revealing the relative liquidity risk of the banks, while abstracting to an extent from the more severe impacts in absolute terms (Figure 43).

Figure 43. Japan: Bank Liquidity Stress Test Results—Double Run-Off Rate Severity

The number of banks with a liquidity shortfall rises to twelve.

The liquidity shortfall accumulates to about 6 percent of initial liquid asset stocks.



Sources: BOJ; FSA; and IMF staff calculations.

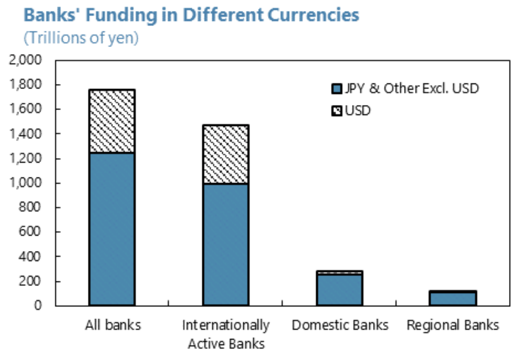
Focal Analysis: FX Liquidity Risk for Banks

61. Japanese banks' foreign currency exposure is sizeable, exposing it to market risk (FX assets) and liquidity risk (FX liabilities). Liabilities in USD alone represent 30 percent of total liabilities (Figure 44). USD funding is obtained largely through FX swaps and unsecured wholesale funding, making banks susceptible to rollover risks and the risk of rising USD funding cost. The cost of USD funding for Japanese banks has been rising in line with rising U.S. policy and market interest rates since March 2022, but the spread for Japanese banks remains particularly compressed since the pandemic, after only an occasional, short-lived shock for about a week in March 2020.

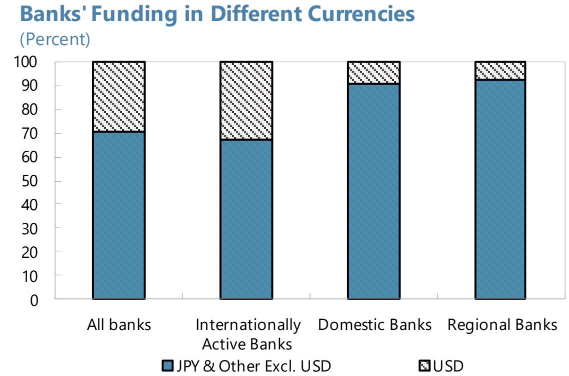
62. Regional banks appear to face more pronounced liquidity risks in some dimensions, including through FX exposure, albeit they benefit from lower FX off-balance sheet commitments. Regional banks face a lower liquid asset ratio than other banks, smaller reserve ratios than other bank clusters (Figure 46), and they appear to make yet more use of FX swaps than major banks. On the positive side, they have a higher share of stable (rather than unstable) retail deposits, use more secured borrowing from the BOJ than other banks, and their FX off-balance sheet exposures are smaller than for other banks.

Figure 44. Japan: Banks' Foreign Currency Funding

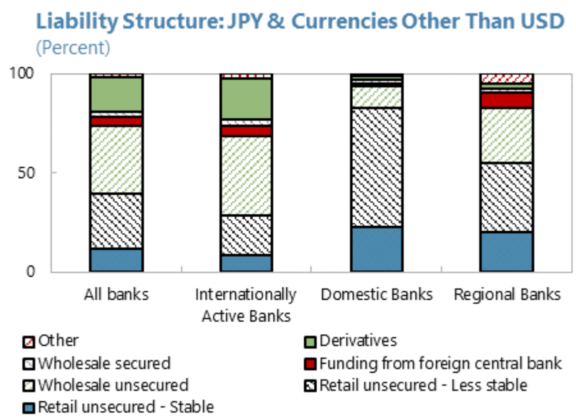
Foreign currency funding is sizeable in particular for internationally active banks.



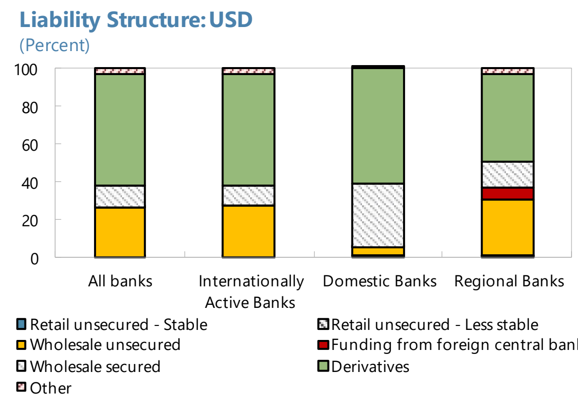
It represents about 30 percent of their total liabilities, while for domestic and regional banks it amounts to a rounded 10 percent.



Retail and wholesale unsecured funding dominates the liabilities in JPY and currencies other than the USD. Retail unsecured is dominant for domestic banks.



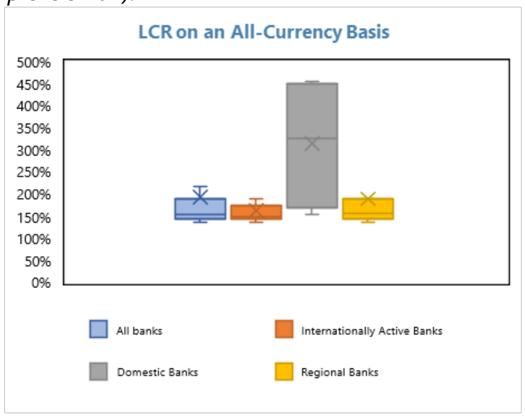
Regarding USD funding, derivatives (largely FX swaps) and unsecured wholesale funding dominate at banking system level. For domestic banks, secured wholesale funding weighs more strongly than unsecured wholesale funding.



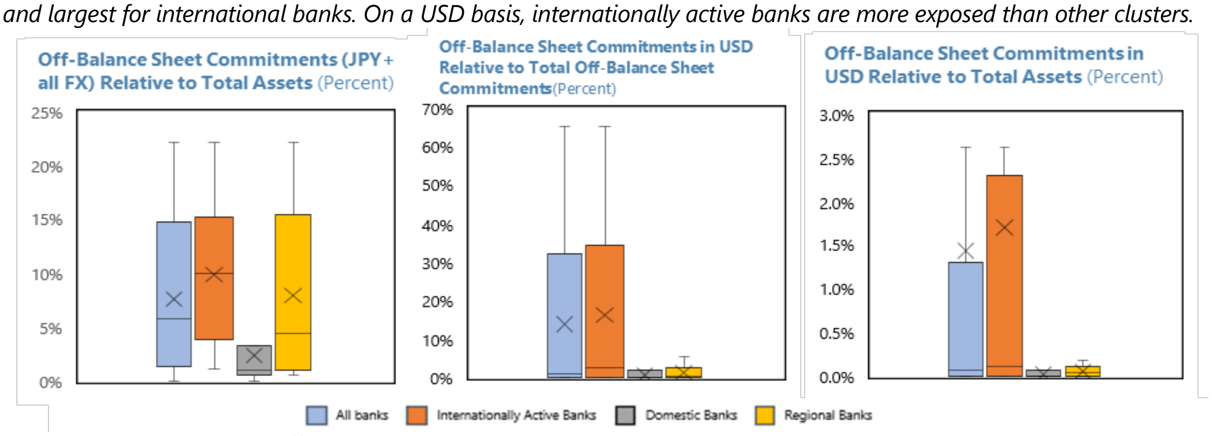
Sources: BOJ; FSA; and IMF staff calculations.
Note: Data as of end-March 2023.

Figure 45. Japan: Banks' LCR and Off-Balance Sheet Commitments—All-Currency

All-currency LCRs generally rest well above the 100 percent reference value. Domestic banks are somewhat better placed in terms of median LCRs, with a larger cross-bank heterogeneity surrounding it (a caveat to mind: the number of domestic banks here in the sample is small).



Off-balance sheet exposure arising from credit and liquidity lines are low for domestic banks (smaller drawdown risk) and largest for international banks. On a USD basis, internationally active banks are more exposed than other clusters.

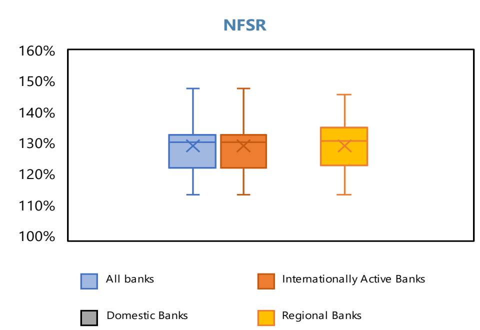


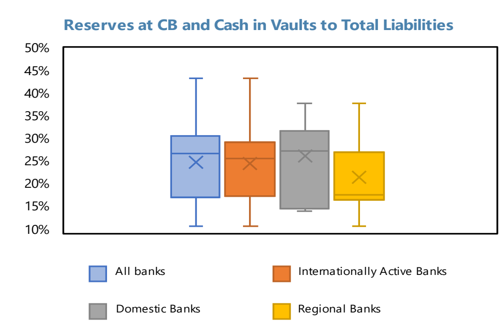
Sources: BOJ; FSA; and IMF staff calculations.
Notes: Underlying individual bank data as of end-March 2023. In the box plots, lines in the middle of the box are medians, box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles

Figure 46. Japan: Other Selected Liquidity Risk Metrics

The distribution of NSFRs is comparable for regional banks and that of all banks combined. The NSFR is not available for domestic banks.

The median ratio of banks' reserves and cash relative to total liabilities is smaller for the regional bank cluster than for other clusters.





Sources: BOJ; FSA; and IMF staff calculations.
Notes: Underlying individual bank data as of end-March 2023. In the box plots, lines in the middle of the box are medians, box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles

63. A counterfactual analysis, assuming an outflow of yet undrawn USD committed credit lines, suggests that some Japanese banks would see their liquidity position weakened substantially, while their all-currency LCRs would remain above 100 percent. The liquidity pressure under such a scenario would be generally confined to the banks with large committed, yet undrawn credit and liquidity lines—which tend to be large for internationally active banks, mostly G-SIBs. Their all-currency LCRs would remain above 100 percent, falling from 150 percent at the outset to 120 percent on average under the counterfactual. The U.S. dollar LCRs of these banks rest below 100 percent at the outset and would fall between 30-40 percentage points under the counterfactual drawdown scenario.

INSURANCE SECTOR STRESS TESTING

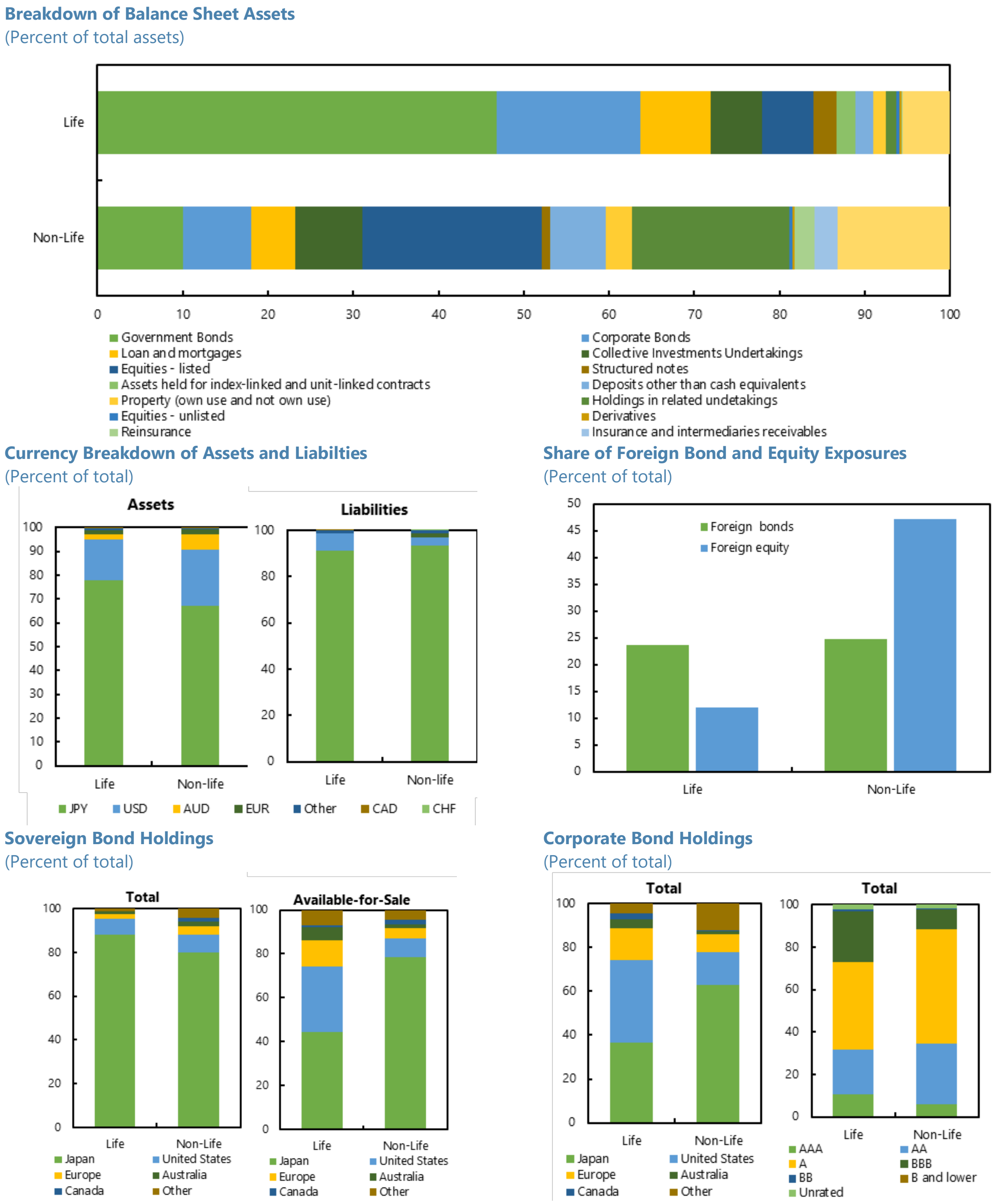
A. Insurance Firms' Balance Sheet Structure

64. Japanese life insurers hold a sizable share of their assets in government bonds, while non-life insurers are more exposed to equities. As of March 2023, major life insurers invested about 45 percent of their assets in JGBs and bonds of municipalities and public sector entities, with another 17 percent invested in corporate bonds. Non-life insurers had a smaller exposure to government bonds at 20 percent (Figure 47), but a notable exposure to equities that comprised 40 percent of their total assets (half of which toward foreign equities). While foreign bonds account in aggregate for 15 percent of the insurers' portfolio, large variation exists across insurers. For instance, for some life insurers, foreign bonds are more than 60 percent of their total fixed-income investments. A large part of insurers' corporate bonds comprises investment grade assets, with 97 percent of the securities being rated at BBB or above.

65. Life insurers substantially hedge their foreign asset portfolios against currency risk, but nonlife insures less so. In recent years, as insurers have increased their investments in overseas markets to seek higher returns, there has been a rise in the share of their assets denominated in FX. As of March 2023, the total share of FX-denominated assets stood at 22 percent for life insurers and 33 percent for nonlife insurers, while their respective shares for FX-denominated liabilities were 8 percent and 7 percent, respectively (Figure 47). To manage currency risk, insurers employ currency forwards and swaps, engaging with both domestic and foreign banks as counterparties. The extent of FX hedging varies among insurers, but the hedge ratio remains at a relatively high level for life insurers (at about 45 percent of the total foreign asset position), compared to 23 percent for non-life insurers.[38] In response to a rise in FX hedging costs in recent years due to a tightening of monetary policy in other major advanced economies, life insurers reduced their foreign bond holdings and shifted to domestic long-term bonds and foreign stocks (Figure 48).

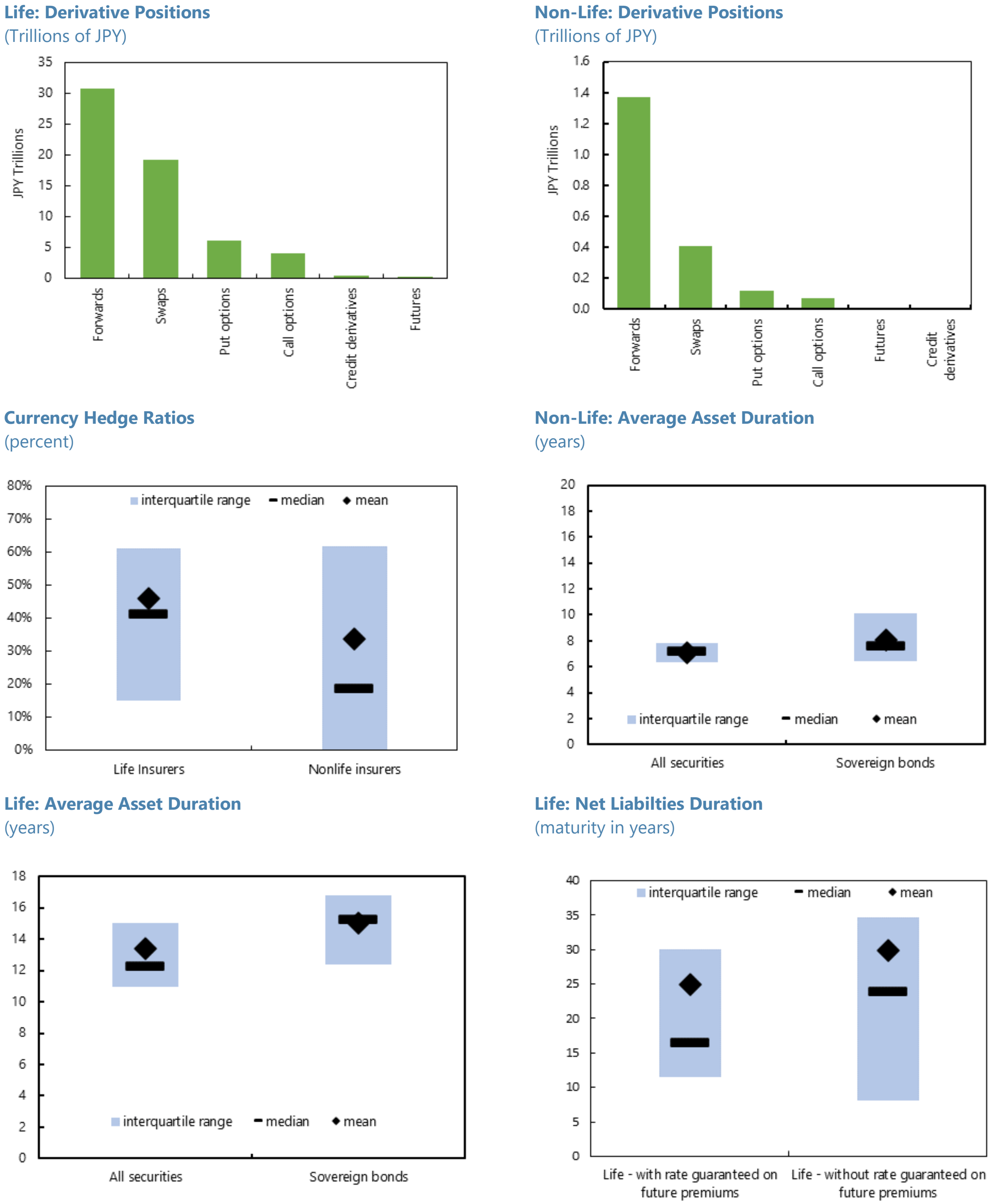
[38] A high currency hedge ratio is not unique to Japanese insurers, but rather is the norm among large non-U.S. institutional investors such as pensions and insurers.

Figure 47. Japan: Balance Sheet Structure of Insurers, March 2023



Source: IMF staff calculations based on FSA data and company submissions.

Figure 48. Japan: Insurers' Derivatives Use and Asset Duration, March 2023



Sources: FSA; insurance firms' data submissions; and IMF staff calculations.
Notes: In panel 4, the hedge ratios are calculated as the net notional amount of foreign currency forward and swap contracts (sold minus bought) by the foreign currency denominated. In panels 5 and 6, asset duration refers to Macaulay duration of the securities portfolio of insurers and is computed as the weighted average time until maturity (years) across holdings.

66. Life insurers have long-term insurance liabilities and invest mainly in longer term JGBs to match the durations of their assets and liabilities. The median asset duration is 12 years for major life insurers, while their median net liabilities duration is 17 years. An increase in long-term interest rates makes it attractive for insurers to increase their holdings of very long-term JGB instruments to extend their asset duration and reduce interest-rate risk, a credit positive.

67. Japanese non-life insurers cover wind and water damage in their property insurance. Wind damage accounts for almost 100 percent of property insurance and water damage accounts for around 70 percent. Climate change poses a significant risk to non-life insurers due to potential increased severity and frequency of such damage. Despite the long-term nature of climate risks, which unfold over decades, property insurance is typically renewed annually and hence premiums can, in principle, be adjusted more frequently.[39]

B. Insurance Solvency Stress Test

Methodology

68. The stress test exercise relied on detailed supervisory data submitted by the individual institutions to the regulatory authorities. The data, at the solo-level of consolidation, is supplemented by additional submissions that were requested by the authorities from the insurance firms. The information is current as of March 31, 2023. Stress tests were conducted on twelve of the largest life insurance companies and ten of the largest nonlife insurance companies, collectively representing 72 percent and 93 percent of premiums in the respective sectors. The stress tests, conducted based on a balance sheet-based approach, evaluate the solvency of individual insurers by analyzing the dynamics of available and required capital conditional on various adverse scenarios. These scenarios include the revaluation of portfolio holdings and specific shocks related to the insurance industry.

69. The stress tests assessed credit and market risks for insurers under the current solvency margin ratio (SMR) as well as under a market-consistent valuation using the Economic value-based solvency Ratio (ESR). Top-down solvency stress tests were conducted by the FSAP team under the SMR and by the authorities under the ESR. In addition, bottom-up (BU) stress tests were conducted by insurers under the SMR with the same scenarios adopted for the top-own stress test exercise. The calibration of the market stress scenarios affecting various asset classes is aligned with the narrative for the bank stress test, but the shocks are assumed to occur instantaneously at the reference date, i.e., applied to the insurers' balance sheets as of March 31, 2023. Two shocks were added to the insurance sector exercise that were not part of the macrofinancial scenarios used for the banking sector stress test. First, the insurance solvency stress test includes the simultaneous default of the largest banking counterparty and of the largest nonfinancial corporate counterparties. Second, lapse risk is included in the form of a (non-

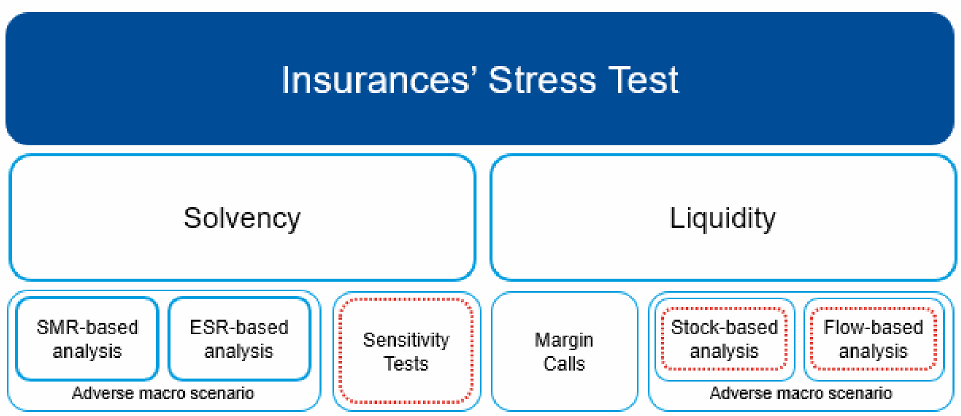
[39] Nonlife insurers experienced a three percent increase in total direct premiums in FY2022, while the annualized premium (average annual premium income of the contract term) for life insurers declined for the fourth consecutive year.

permanent) mass lapse event leading to 20 percent of insurance policies being discontinued in the bottom-up (BU) stress test exercise.

70. In addition, sensitivity analyses were carried out to complement the adverse scenario analysis (Figure 49). Sensitivity analysis tested the effect of single shocks on capital positions due to changes in interest rates, currency shocks and catastrophic events. Natural disaster risks were calibrated based on past events that could plausibly occur again. Further details are provided below.

71. The aggregate assets of insurance firms in the sample amount to JPY 360 trillion, of which the majority can be attributed to life insurers. While the participating firms' aggregate initial solvency ratio stands above the regulatory threshold of 200 percent, the levels of individual insurers differ widely. The average SMR for life insurer is about 955 percent, while for nonlife insurers it equals 840 percent. The average (median) ESR is 225 percent for life insurers and 211 percent for nonlife insurers. In the computation of the capital requirement, market risks dominate, contributing to 70 percent of capital requirements and 81 percent for life and non-life insurers, respectively. Among the market risk components, equity risk contributes the most across insurers, followed by currency risk. Life insurance risk is the second largest contributing factor to capital requirement in life insurers.

Figure 49. Japan: Components of Insurance Stress Test



Source: IMF staff.
Notes: SMR-based analysis refers to the solvency risk analysis based on the current solvency margin regime; ESR-based analysis refers to the Economic value-based Solvency Ratio (ESR) that will be introduced in fiscal year 2025.

72. The macrofinancial scenario specified by the FSAP for the banking sector stress test is adjusted for the purpose of the insurance stress test. For the insurance stress test, all shocks were assumed to occur at the beginning of the first year (instantaneous shock). The calibration of the instantaneous market stress scenarios affecting various asset classes are aligned with the narrative of the macrofinancial scenario for banks. Market shocks, such as declines in equity and property prices, have therefore been front-loaded. In so doing, the maximum drawdown during the projection horizon of the macrofinancial scenario is realized immediately after the reference date (March 31, 2023).[40]

Table 3. Japan: Macrofinancial Shocks for Insurers' Stress Tests (Solvency & Liquidity Risks)

Equity	**Scenario**	**Currencies**	**Scenario**
Japan	-27%	JPY effective exchange rate	+3.4%
United States, Euro area	-32%	JPY-USD: Nominal	+6.5%
Other advanced economies	-25%	JPY-EUR: Nominal	+2.8%
Emerging economies	-35%	JPY-AUD: Nominal	+1.5%
Holdings in related undertakings	-15%		
Real estate	**Scenario**	**Corporate bond spreads**	**Scenario**
Residential, domestic	-12.1%	Non-financials, AAA	+50bp
Commercial, domestic	-22.6%	Non-financials, AA	+60bp
Residential, other countries	-15.0%	Non-financials, A	+90bp
Commercial, other countries	-25.0%	Non-financials, BBB	+140bp
Investment funds	**Scenario**	Non-financials, BB or lower	+220bp
Alternative funds	-8.0%	Non-financials, unrated	+200bp
Private equity funds	-10.0%	Financials, AAA	+80bp
Infrastructure funds	-5.0%	Financials, AA	+100bp
Risk-free interest rates	**Scenario**	Financials, A	+140bp
JPN, 1 year	+1.1 p.p.	Financials, BBB	+200bp
JPN, 10 years	+1.75 p.p.	Financials, BB or lower	+250bp
USD, 1 year	+1.5 p.p.	Financials, unrated	+210bp
USD, 10 years	+2.5 p.p.	**Other investments**	**Scenario**
Other, 1 year	+1.5 p.p.	Structured notes and collateralized securities	-5%
Other, 10 years	+1.5 p.p.	Other investments, not classified elsewhere	-5%

Source: IMF staff.
Note: A positive value of JPY-USD implies an appreciation of JPY relative to USD. Input variables that are not included in the macrofinancial scenario specified by the FSAP, are calibrated using a non-parametric methodology that simulates forward in time the variables while conditioning on risk factors assumed in the adverse scenario (Gross, Henry and Rancoita, 2022).

[40] To cover the most relevant risk factors for insurers' balance sheets, specifically market risk, shocks to asset prices have been defined more granularly. The scenario includes shocks to the risk-free interest rate, equity and property prices, as well as credit spreads of corporate bonds (Table 3). Additional breakdowns of the input variables are calibrated using a non-parametric methodology that jointly simulates forward in time the variables up to a self-defined horizon (i.e., 180 business days) by bootstrapping historical data at high frequency (Gross, Henry and Rancoita, 2022). The simulated data conditions on the value of the main risk factors assumed in the macrofinancial scenario specified by the FSAP.

73. Two further shocks are added in the insurance sector exercise, which are not part of the macrofinancial scenarios used for the banking sector stress tests:

- Lapse risks: a mass lapse event, assumed to imply that 20 percent of insurance policies for which discontinuance would result in an increase in insurance liabilities are discontinued. No permanent shock is assumed.[41]

- Simultaneous default of the largest banking counterparty and of the largest nonfinancial corporate counterparties.
    - 100 percent write-off for equity exposures, guarantees for liabilities;
    - 50 percent write-down for bonds and loans;
    - 15 percent write-down for deposits, loaned securities, and lease assets.

74. To complement the short-term perspective of an instantaneous shock, insurance firms were requested to provide a three-year projection of specific business developments under the baseline and the adverse scenarios. The items to be reported included gross written premiums, investment returns, average guaranteed interest rate and net surplus. Projections were made in line with the macrofinancial scenarios (e.g., with regard to the assumptions on GDP and interest rates), while the market prices of asset-side investments were assumed to remain constant after the shocks have occurred at the beginning of the first year of the projection horizon. Interest payments received, dividends, and rental incomes would therefore be the only items contributing to investment returns.

Assumptions Regarding Capital Standards

75. The resilience of the insurance sector is tested under the SMR and the ESR. The SMR is one of the indicators that the supervisory authority utilizes to judge the management soundness of an insurance company. It is understood that problems concerning the management soundness of a general insurance company requiring potential remedial actions will not arise if the ratio is 200 percent or more.[42] The formula for the SMR is as follows:

$$\text{Solvency margin ratio} = \frac{\text{Total Amount of Solvency Margin}}{\text{Total amount of risks x 1/2}} \text{ x } 100$$

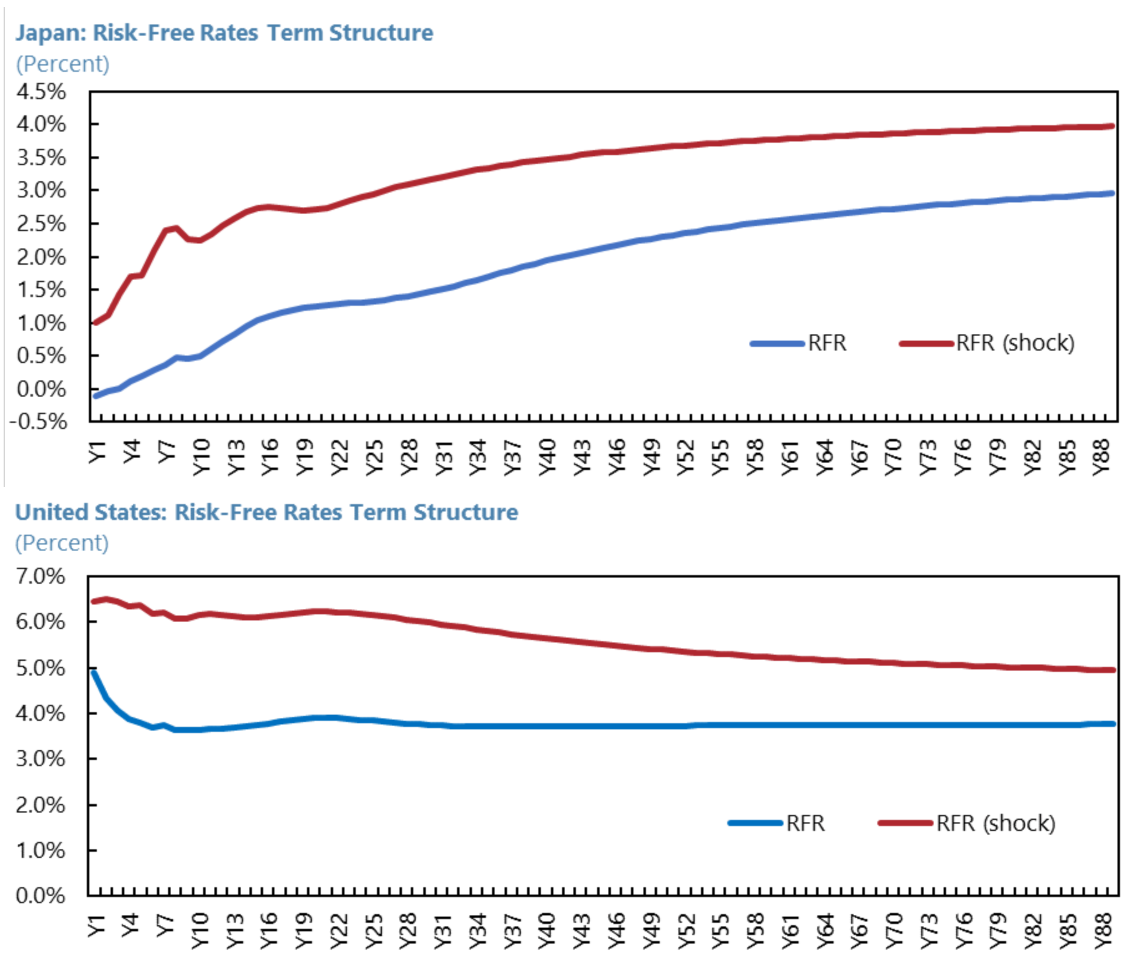
[41] The mass lapse shock was applied to all policies independently of whether the discontinuance would result in an increase of technical provisions (with/without the risk margin) or not.

[42] The FSA Enforcement Ordinance requests that early remedial action be divided into 3 categories in accordance with the level of the SMR. Category 1 is identified as when the SMR is between 100 percent and 200 percent, which would lead to the submission and implementation of a business improvement plan. Category 2 is identified when SMR is between 0 percent to less than 100 percent. This situation requires submission and implementation of a plan for adequate solvency of insurers as well as a series of other potential measures including the prohibition or limitation of dividends, prohibition or limitation of policy dividends or distribution of surplus to policyholders, change in calculation method of premium for policies to be newly underwritten, prohibition or limitation of directors' bonuses, limitation of other operating costs. Category 3, i.e., when SMR less than 0 percent would lead instead to the total suspension of operation for a limited period.

The solvency margin for risks corresponds to the insurer required capital under the SMR and is defined as the risks that will exceed their usual estimates such as the risk of catastrophic loss or a sharp reduction in the value of their asset.

76. For the top-down stress test, the shocks specified in the adverse scenario are applied to investment assets and insurance liabilities. Haircuts in line with the adverse scenario are applied to the market value of directly held assets. A look-through to the level of individual securities held by a fund was not applied, so investment fund holdings were stressed with the corresponding shocks for the underlying asset classes. Fixed-income assets were re-valued with the stressed term structure (for each major currency). The interpolation and extrapolation of the reference interest rate structure for the insurance stress test is performed using the Smith-Wilson extrapolation method. Reference interest curves for Japan and the U.S. are shown in Figure 50. The adverse scenario entails a parallel shift of the entire terms structure for all other currencies.

Figure 50. Japan: Reference Risk Free Interest Rate Term Structures



Sources: Refinitiv; and IMF staff calculations.
Notes: Interpolation between maturities' segments with market information and extrapolation of interest rates beyond the last observed term (LOT) are based on the Smith-Wilson methodology. The control input parameters for the interpolation and extrapolation are the LOT, long-term forward rate (LTFR), the convergence point and the convergence tolerance. Parameters are set following IAIS approach. Market rates for observed maturities correspond to the average of the rates in 2023:Q1. RFR = risk free rates.

77. In the economic value-based balance sheet, insurance liabilities are evaluated based on a "market-consistent" approach. The amount of qualifying capital resources is calculated with necessary adjustments to the value of the net asset on the economic value-based balance sheet. The required capital is calculated for each risk category with a prescribed methodology calibrated at 99.5 percent VaR over one year; thereby corresponding to a 1-in-200 years event. In many of the risk categories, the required capital is defined as the changes in the value of (economic value-based) net assets under prescribed stresses (e.g., changes in parameters, including interest rates and accident rates), while a factor-based approach (multiplying the amount of an exposure by a prescribed factor) is also used for some. The required capital for natural catastrophe risk is based on stochastic models.

78. Insurance-specific elasticities of ESR to key risk factors were used in the top-down stress test for shocks in alignment with the adverse scenario. While under the current solvency regime the statutory requirement is an SMR of 200 percent, the relevant threshold for first remedial action by the supervisor under the economic value-based regime would be an ESR of 100 percent. It should be noted, however, that both the SMR and the ESR thresholds are the level at which the margin equates to the risk, as the risk is halved only when calculating the SMR.

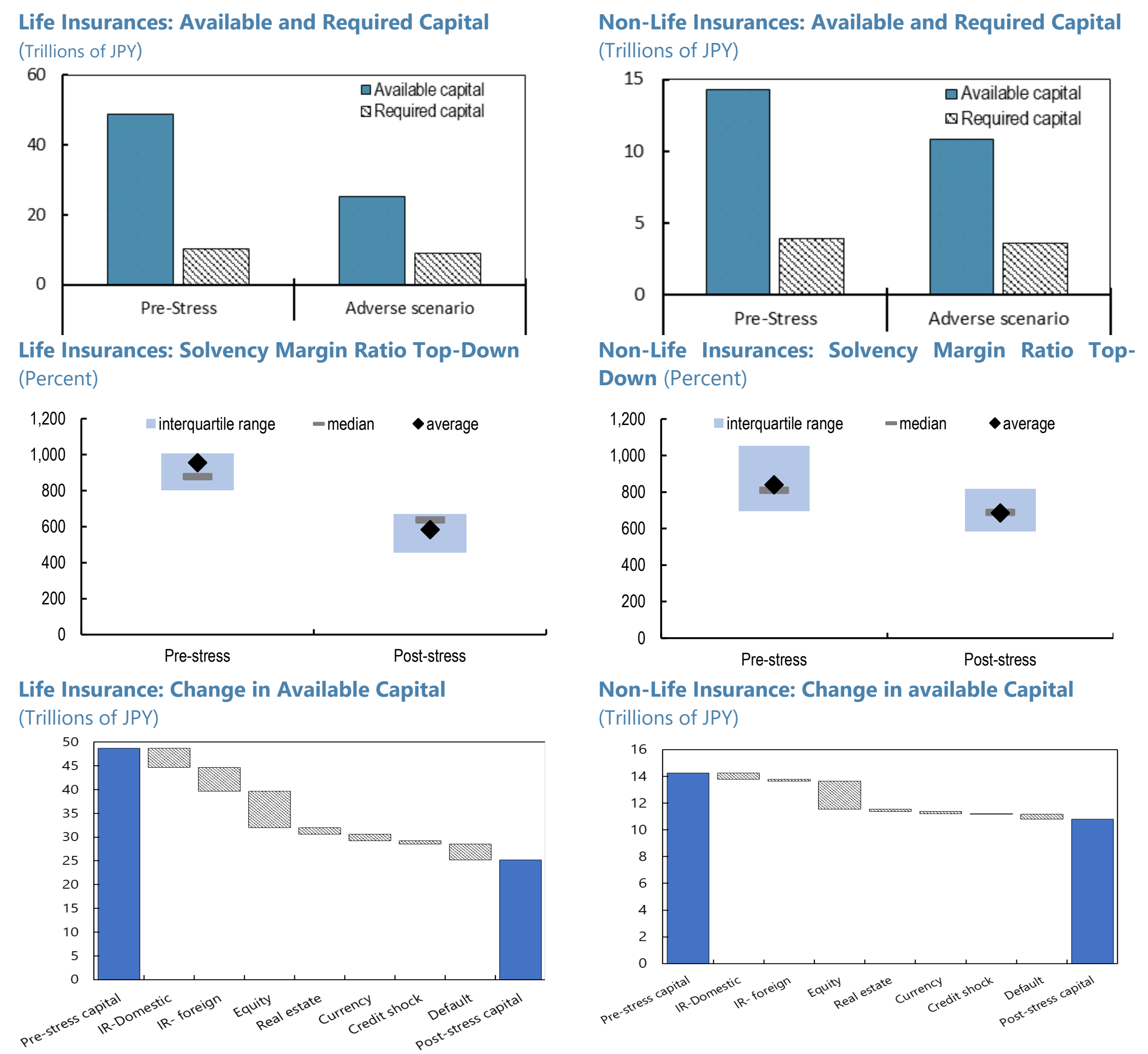
79. Importantly, insurance companies employ diverse risk-mitigation measures which are not entirely captured in the top-down stress test. Reactive management actions were not accounted for in the model. The granularity of supervisory data limits a comprehensive recognition of financial hedges, stop-loss arrangements, or financial reinsurance. In times of financial stress, insurers have various options to restore capital adequacy or profitability, including by adjusting underwriting standards, altering reinsurance programs, or withholding profits. A more efficient means of rapidly improving solvency involves de-risking the balance sheet—selling equity or high-yield corporate bonds and acquiring sovereign bonds can significantly reduce required capital. Given the stress test's assumption of a static balance sheet, these dynamic management actions were not considered.

Results

80. Life insurances experience a substantial decline in their solvency position under the adverse scenario, given their strong sensitivity to interest rates and large equity holdings. Available capital drops in aggregate by about 48 percent under the adverse scenario. For life insurers, the average SMR drops from 956 percent before stress to 583 percent in the adverse scenario (Figure 51). Ten of twelve life insurance companies remain above the statutory SMR requirement of 200 percent, with the two not meeting the requirement. The assumed domestic equity price decline and increase in domestic and foreign interest rates under the adverse scenario contribute to almost three quarters of the decline in available capital for life insurers. In comparison, the nonlife insurance sector is more resilient under the adverse scenario. The assumed shocks lead to a decline in the available capital of nonlife insurers by 24 percent (i.e., half of the impact on life insurances). On average, the SMR declines from 840 percent to 686 percent for non-life insurers, with all nonlife insurers remaining above the SMR hurdle rate.

81. The bottom-up results (BU) are broadly aligned with the top-down (TD) stress test results (Figure 52). As in the top-down analysis, ten life insurers of twelve see their capital position remain above the 200 percent statutory SMR requirement under the adverse scenario. In addition to the impact of an increase in interest rates, counterparty and credit risks have a considerable impact on insurances most affected by the prescribed adverse scenario. By considering lapse risk and additional underwriting, post-stress available capital in the BU exercise is in aggregate slightly lower than those in the TD exercise. Required capital is also lower after stress, with the reduction relative to the TD exercise amounting to 17 percent and 11 percent for life insurers and nonlife insurers, respectively.[43]

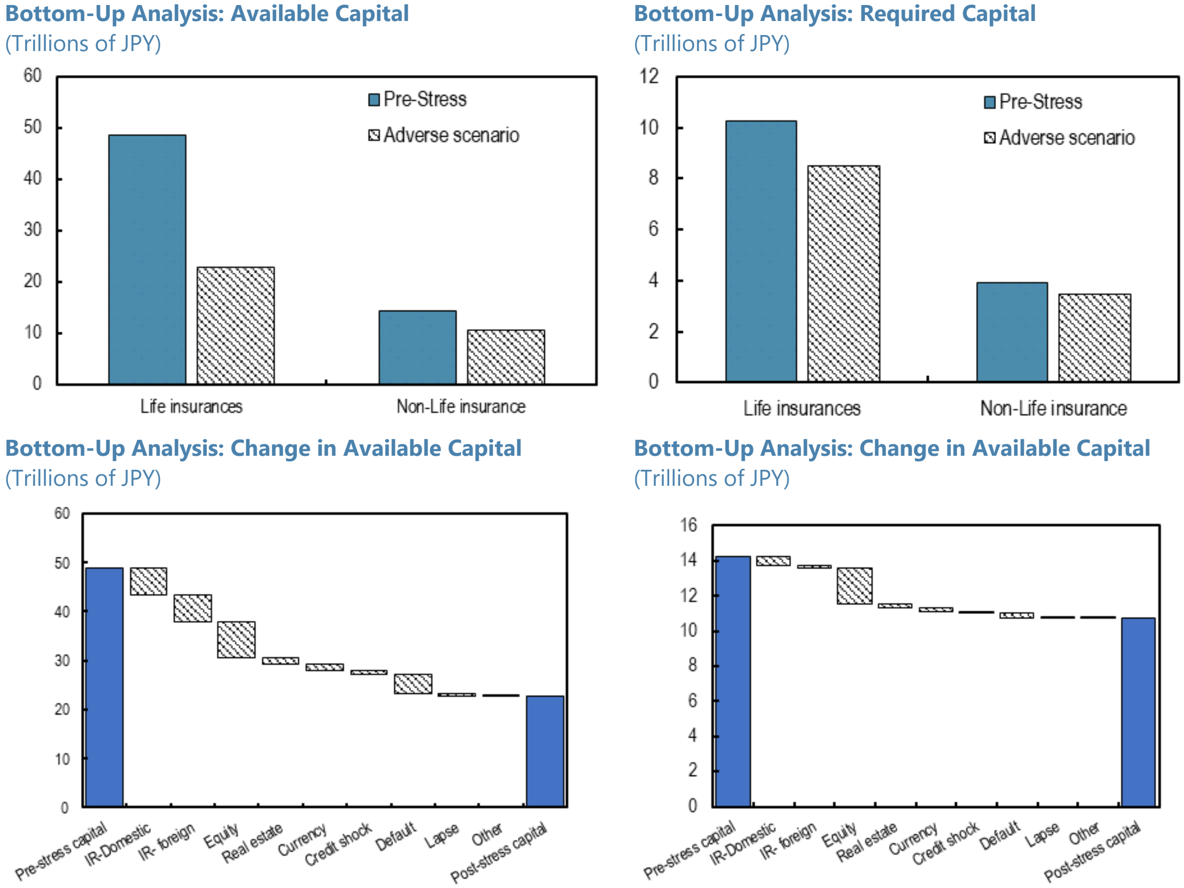
Figure 51. Japan: Insurance Solvency Stress Test Results



Source: IMF staff calculations.

[43] In comparison, required capital in the top-down analysis is on average 12 percent, as calculated by the reduction in the risk of portfolio exposures of insurances without lapse risk.

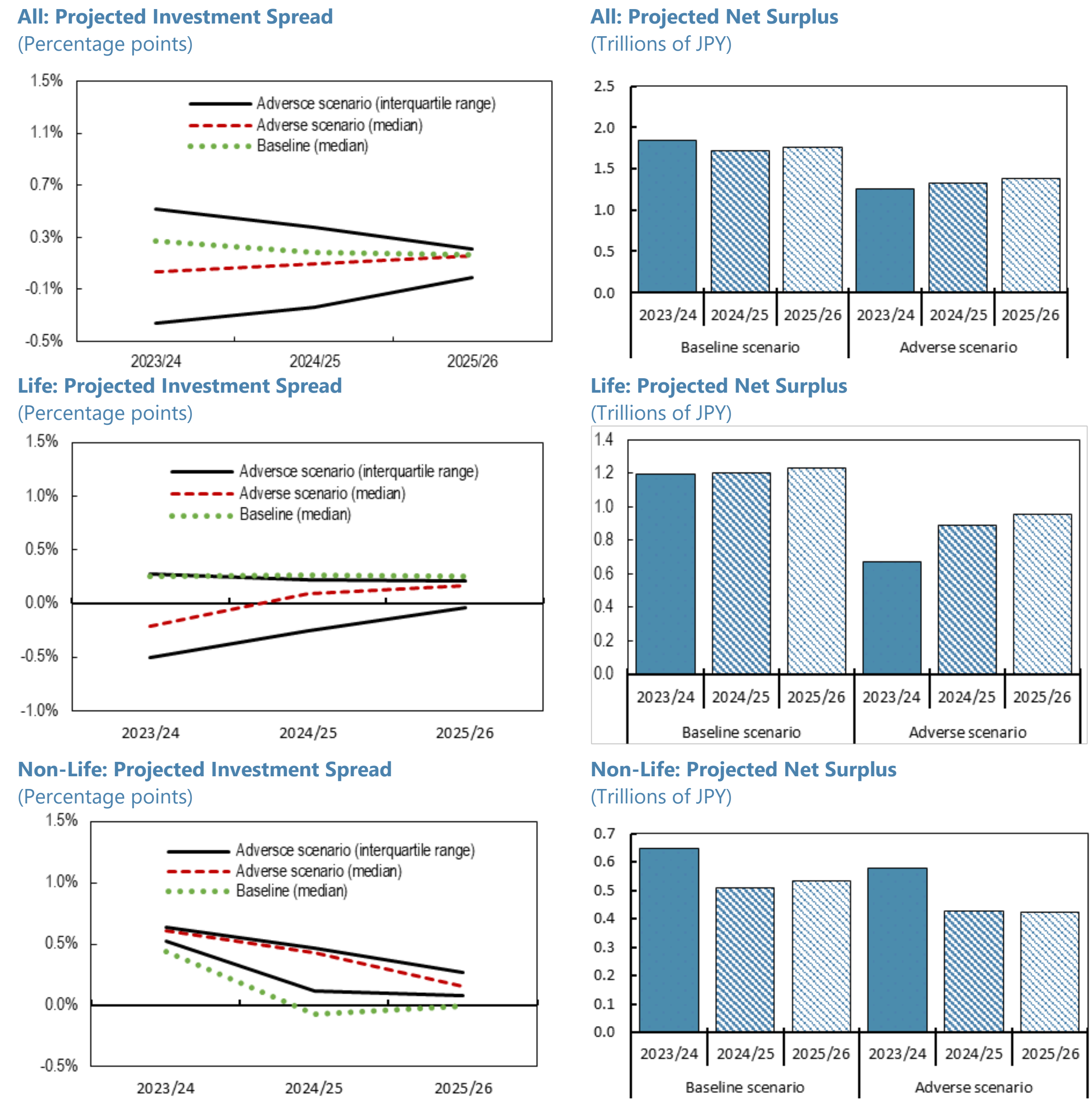
Figure 52. Japan: Insurance Solvency Stress Test Results—Bottom-Up Analysis



Source: IMF staff calculation based on companies' submissions.

82. **The insurers' financial performance initially deteriorates under the adverse scenario but recovers three years after the shock.** Net investment returns, i.e., the spread between investment returns and guaranteed interest rates, declines markedly during the first year of the adverse scenario projections contributing to lower insurance profits (Figure 53). Net surplus projections of life companies also suffer under the adverse scenario and improve only gradually after the shock. Non-life firms show a continued impact on net surplus, but this was already declining in the baseline scenario. Profits decline among non-life firms due to natural disasters, rising COVID-19 related payments, and an increase in the loss ratio for auto insurance for the largest firms. Additional projections do not show a significant effect of the adverse scenario on gross premium projections.

Figure 53. Japan: Insurance Solvency Stress Test Detailed Results—Bottom-Up Analysis



Source: IMF staff calculations based on companies' submissions.
Notes: To complement the instantaneous shock analysis used in the insurance stress test, participating companies have been requested to provide a three-year projection of specific business developments under the baseline and the adverse scenarios indicated. The figure shows results from this analysis using shocks from the banking sector stress specified for each year of the stress test horizon. In the upper left panel, investment spread refers to difference between investment returns and guaranteed interest rates.

83. The stress test results for insurers need to be interpreted cautiously under the current solvency regime. The planned introduction of the new capital regulation in fiscal year 2025 would require insurers to value their assets and liabilities based on market interest rates and calculate risk capital at higher confidence levels. In particular, the economic value-based solvency regime makes life insurers less sensitive to an increase in interest rates, as liabilities would decline in sync with the value of fixed-income assets.[44]

84. Under the ESR, Japanese insurers are broadly resilient under the adverse scenario.[45] Although the capital position of life insurers continues to be affected relatively more than nonlife insurers under the adverse scenario, the gap between the two is reduced compared to that under the SMR. The ESR decreases by 67 percentage points for the average life insurer and by 41 percentage points for the average nonlife insurer (Figure 54). The post-stress ESR for all insurers remains above the prescribed hurdle rate of 100 percent. However, the impact on the insurance sector is heterogeneous, particularly among nonlife insurers. Capital resources decrease by 30 percent in aggregate, with a larger decline for the group of nonlife insurers (about 44 percent).

85. The changes in available capital under the adverse scenario of the ESR stress testing exercise can be attributed mainly to the decline in equity prices and credit shocks. The impact of an increase in domestic and foreign interest varies widely across insurances. Life insurers benefit from a rise in long-term interest rates due to a decline in their liabilities, which offsets the fall in the valuation of their security holdings. However, an increase in foreign currency hedging costs can compress net investment yields on insurers with larger foreign exposures.[46] Among nonlife insurers, the impact of a decline in equity prices dominates, contributing about 60 percent to the overall change in capital resources.

86. The assets-to-liabilities ratio is not materially impacted for the average life insurer in the adverse scenario under the ESR but decreases by 19 percentage points for the average non-life insurer. For these companies, the decline in assets is not fully compensated by lower liabilities under the adverse scenario, leading to the asset-liability ratio for most nonlife firms in the sample to decline. Differences in the valuation impact on assets and liabilities across companies are also reflected by the extent to which individual shocks contributed to the change in net assets. The rise in interest rate (especially domestic) contributes positively to changes in net asset positions among life insurers, but generally negatively impacts nonlife insurers.

87. A rise in interest rates, possibly beyond levels assumed in the adverse scenario, may make a significant number of policyholders surrender their legacy policies and purchase new policies with higher guaranteed interest rates. This could trigger large losses when insurers liquidate their bond portfolio backing the policies amid the increasing interest rate environment to pay surrender benefits. Furthermore, higher inflation sometimes associated with rate rises can

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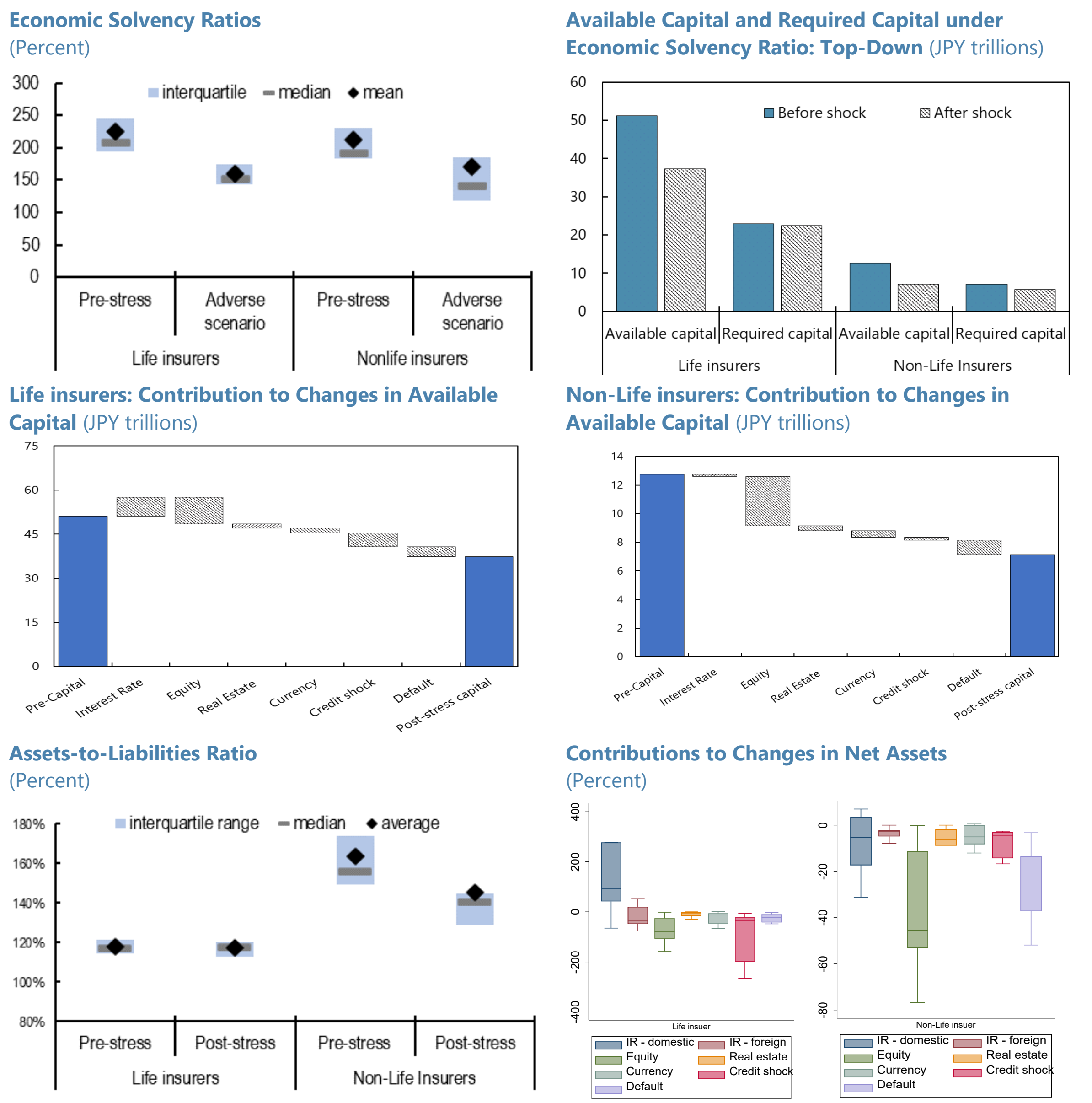
[44] This is because under the current solvency ratio, insurance liabilities are evaluated not on an economic basis and forward-looking manner but using a locked-in method with factor-based risk measurements.

[45] The re-calculation of the ESR after stress was focused on selected risk modules. In the market risk module, the capital charges for market and insurance risks were proportionately adjusted in line with the change in exposures due to the stress.

[46] Among nonlife insurers, e.g., about half of the total equity exposures are toward foreign countries. On average, foreign bonds are more prevalent among life insurers with an average exposure to foreign fixed income assets of 30 percent relative to the total bond exposure, while average nonlife insurer as an average exposure of 25 percent (Appendix I).

increase insurers' claim payments. This could weaken their underwriting profitability if the insurers cannot increase premium rates to offset the growing claims. Such risks might be more prevalent for nonlife insurers, as a large part of life insurer policies are individual (rather than corporate) policies, are purchased for protective (rather than investment) purposes, and have surrender costs that discourage switching to new polies.[47]

Figure 54. Japan: Stress Test Results on Economic Solvency Ratios (Top-Down)



Sources: FSA; and IMF staff calculations.

[47] About 90 percent of life insurance policies are protected by Life Insurance Policyholders Protection Corporation of Japan, which reduces the likelihood of policymakers surrendering their policies in response to insurer insolvency fears.

Sensitivity Analysis

88. Additional single-factor shocks complement the macrofinancial stress test scenarios. The results of various sensitivity analyses are not added to the results of the macrofinancial scenario but considered separately. Such single-factor shocks cover biometric risks, catastrophic events, and selected additional market shocks. The biometric shocks to be calculated for life business include:

- Longevity, i.e., a permanent 20 percent decline in mortality rates; and
- Pandemic event, with temporarily higher disability and morbidity rates, i.e., a temporary 35 percent increase over one year, as well as temporarily higher mortality rates, i.e., a temporary 10 percent increase over one year

89. The effect of catastrophic events is calculated for non-life insurers. The events prescribed are those that have occurred in the past: (1) Great Kantō earthquake (Japan, 1923); (2) The Ise Bay Typhoon; and (3) catastrophic events in 2018 as prescribed by the FSA, such as torrential rains in western Japan, typhoons, or earthquakes. Non-Japanese exposures to catastrophe risks are assessed by calculating the effect of overseas catastrophic events used in internal stress testing. For each of the catastrophic events, insurance undertakings should provide the reinsurance recoveries from the participants' top five reinsurers.

90. Additional sensitivity analyses were carried out for selected market shocks. These include (1) Increase in key domestic interest rates: +1.6 pp in short-term rate (one-year government bond), +2.5 pp long-term rate (10-year government bond); and (2) appreciation/depreciation of JPY relative to USD, AUD, EUR: +/- 10 percent.

91. The sensitivity analysis confirms the large sensitivity to interest rates.[48] A larger increase in domestic interest rates—compared to the original adverse scenario with short-term and long-term rates—by 1.6 and 2.5 percentage points, respectively, lowers life insurers' SMR-based available capital by 24 percent, on average (Figure 55). A separate shock of an appreciation of JPY against major currencies (i.e., by 10 percent) has a more limited impact on the SMR of three percent, although for some insurers, the impact is as large as 14 percent. Part of this variation in the impact can be explained by the extent of FX risk hedging that varies across insurers, but the hedge ratio generally remains at a moderately high level. In response to an assumed increase in hedging costs, life insurers are considered to sell hedged foreign bonds and shift to domestic long-term bonds, extending asset duration and reducing interest-rate risk. As in the initial adverse scenario, the sensitivity of nonlife insurances to the more severe interest rate scenario remains relatively limited.

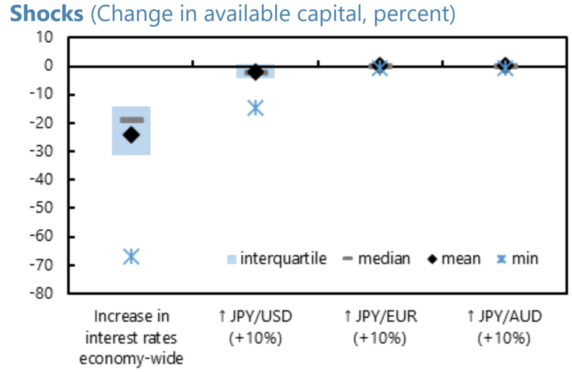
92. The sensitivity analysis on ESR confirm the results of the main stress test exercise. An additional rise in domestic interest rates presumed under the sensitivity analysis provides more income from investments in yen-denominated bonds, partially mitigating the negative impact from

[48] For insurers, additional single-factor shocks cover biometric risks, catastrophic events as well as selected market shocks. Note that the sensitivity analyses for banks entails the assumption of short-term and long-term interest rates increasing to 1.5 percent and 3 percent.

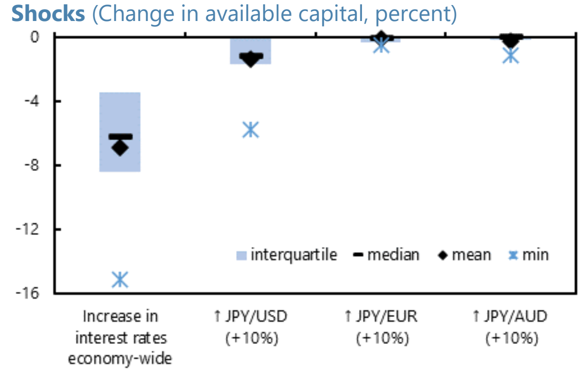
higher hedging costs and fluctuations in stock prices. It can, therefore, potentially be a positive factor for some insurers investing in longer dated government bonds.

Figure 55. Japan: Sensitivity Analysis (SMR and ESR)

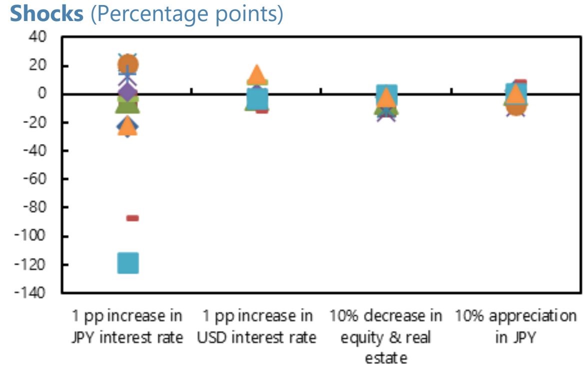
Life Insurers: SMR Sensitivity to Selected Market Shocks (Change in available capital, percent)



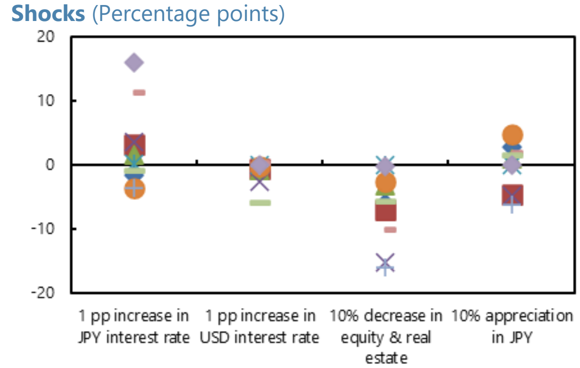
Non-Life Insurers: SMR Sensitivity to Selected Market Shocks (Change in available capital, percent)



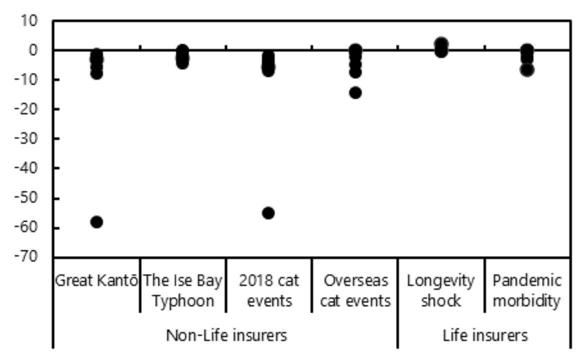
Life Insurers: ESR Sensitivity to Selected Market Shocks (Percentage points)



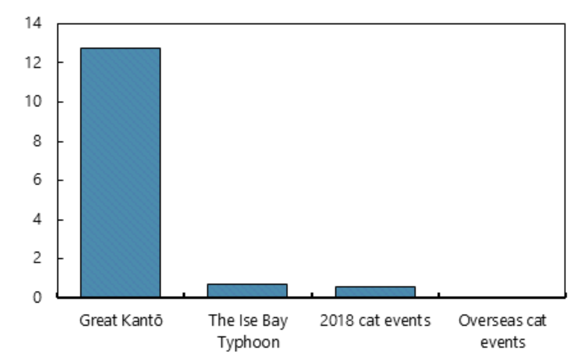
Non-Life Insurers: ESR Sensitivity to Selected Market Shocks (Percentage points)



Changes in Available Capital Following Historically Benchmarked Catastrophic Shocks (Percent, bottom-up)



Reinsurance Recoveries (JPY Trillions, bottom-up)



Source: IMF staff calculations based on companies' data submissions.

93. **The aggregate solvency position of insurers remains resilient under the presumed pandemic and catastrophic natural events considered individually.** The median sensitivity across insurers to biometric shocks is close to zero (Figure 55). On average, the solvency margin for life insurances after the assumed pandemic shock decreases by one percent and increases by 0.2 percent following a longevity shock. The exposure towards catastrophic risks of nonlife insurers is

one of the biggest risk factors, but solvency risk due to such shocks appears manageable. For instance, the potential impact of overseas catastrophic events leads on average to a 7 percent change in capital sources. Furthermore, a repetition of an event such as Great Kantō could cause losses of about 9 percent of the available capital for Japanese non-life insurers exposed to that region.

94. An exception is the Japan Earthquake Reinsurance that could face substantially higher loss rates, resulting in almost 60 percent change in its capital resources. Such a large impact, as discussed in the 2017 FSAP, can be attributed to its central role in the reinsurance system against losses to residential property due to earthquakes (including subsequent tsunamis) and volcanic activity.[49] The largest reinsurance recoveries are reported up to JPY 12 trillion for events as severe as Great Kanto' earthquake, but less for other historic catastrophic events.

C. Insurance Liquidity Stress Test

Methodology

95. The solvency risk analysis is complemented by an in-depth examination of the insurers' liquidity sources and liquidity needs under the main adverse scenario and subject to additional insurance-specific shocks. Variation margining due to interest rate swaps (IRS) exposures is assessed using transaction-level data submitted by insurers participating in the solvency stress test exercise.[50] Liquidity sources and needs are further assessed following two approaches based on the insurers' data submissions: a stock-based approach and a cash flow-based approach. A description of the various approaches is provided below.

Variation Margining Analysis

96. Utilizing a similar approach outlined by de Jong and others (2019), the margin calls analysis examines the impact of significant interest rate increases across varying timeframes. This assessment reflects insurers' ability to leverage different liquidity buffers for meeting margin calls. The analysis delineates two key scenarios: an abrupt one-day market movement without allowance for collateral transformation, and an extended market turmoil scenario where collateral transformation of liquid assets is feasible. Under the prolonged market turmoil scenario, positive and negative contributions from market movements of individual trades within a portfolio are

[49] The Japanese Earthquake Reinsurance was established under the Act on Earthquake Insurance, which was enacted in May 1966 forming the basis of Japan's system of residential earthquake insurance. The institution plays a pivotal role in standardizing risk exposures associated with earthquakes, redistributing a portion of these risks back to non-life insurance companies and governmental entities according to predefined liability limits for each. Any remaining exposure is retained by Japan Earthquake Reinsurance.

[50] Data availability resulted in a smaller sample than for the solvency stress test. In total, the exercise took into consideration reported transactions from only ten life insurers and three nonlife insurers. For this analysis, insurers have been required to report a minimum of 70 percent (in notional amount) of the overall transactions active at the reference date.

netted, acknowledging that market values can increase and decrease concurrently due to an interest rate hike.[51]

97. Individual shocks impacting the market values of IRS collateral are simulated through parallel shifts in the reference curves. Insurers commonly structure IRS positions to receive fixed rates and pay floating rates, making them more susceptible to margin calls with rising interest rates. The analysis entails simultaneous and equal shifts in risk-free rate curves for all currencies. The interest rate shocks that were examined vary from 50 to 250 basis points.

98. Estimating the liquidity shortfall involves generating changes in the market values of individual contracts through several steps. These include: (1) calculating the current value of cash flows from the fixed leg; (2) evaluating the current value of cash flows from the floating leg; (3) determining the value of interest rate swaps (IRS) by contrasting the two legs; and (4) assessing the overall liquidity requirement for insurers in a specific shock scenario involves consolidating margin calls from collateral portfolios and contrasting them with the insurers' liquidity reserves. Although this method accommodates solely parallel shifts in the risk-free rate curve, the model delivers a reasonably precise evaluation of changes in market values during interest rate shifts.

99. Depending on the scenario, the baseline specifications employ two distinct definitions of liquidity buffers: cash under scenario 1 (1-day market movement) and both cash and tradable assets under the prolonged market turmoil scenario. Various definitions of liquid assets are explored by gradually broadening the category of tradable assets (Table 4). The rationale for adopting these two liquidity buffers stems from the fact that daily variation margin payments typically necessitate cash only, and there might be limited opportunities to convert high-quality government bonds into cash during scenario 1 (1-day market movement). Conversely, in the prolonged market turmoil (2-week market movement), insurers are expected to have adequate time for collateral transformation. Hence, the liquidity buffer is considered to comprise both cash and different groups of high-quality liquid assets (HQLA) in this scenario.[52]

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[51] Under the one-day market move scenario, the timing of the collateral inflows and outflows among the various portfolios of an insurer may not coincide. Margins are therefore not netted in this case.

[52] In this context, HQLA assets considered in the analysis include highly rated government bonds, money market funds shares and highly rated corporate bonds as indicated in Table 4. The breakdown follows the approach used in de Jong (2019).

Table 4. Japan: Liquidity Buffers Definition in the Variation Margining Analysis

Instrument	cash positions	cash and bond positions		Cash, gov. bonds and MMF shares position	Cash, gov. and corp. bonds and MMF shares position
	Broad cash	cash & AAA bonds	cash & AAA/ AA bonds		
Cash and cash equivalents	x	x	x	x	x
AAA-rated government bonds		x	x	x	x
AA-rated government bonds			x	x	x
Money market funds shares				x	x
AAA-AA corporate bonds					x

Liquid buffers under 1-day stress test (Broad cash); Liquid buffers during prolonged market stress (remaining columns)

Source: IMF staff.

Stock-Based and Cash Flow-Based Approaches

100. The assessment of liquidity positions is further complemented by an in-depth analysis of liquidity sources and liquidity needs under the main adverse scenario as well as insurance specific shocks. The liquidity stress test has a medium-term horizon spanning 90 days, aligning with the redemption period for lapsable life insurance contracts. The scenario primarily aims to evaluate insurers' resilience against challenges arising from shifts in policyholder behavior (for life insurers), funding risk (applicable to both life and non-life insurers), and exposure to insurable events.

101. The insurers' liquidity risk is gauged based on the same shocks as relevant for the solvency risk analysis, but additional insurance-specific shocks are included. Table 5 provides a list of insurance shocks by line of business differentiating type of shocks to frequency and severity. For instance, shocks to severity are prescribed as a percentage uplift in the annual claims and expense inflation assumed for the calculation of liabilities under the baseline scenario. A shock to severity (claims inflation) are applied linearly to the costs of all the incurred and expected claims as reported.

Table 5. Japan: Additional Shocks Relevant for Solvency and Liquidity Risk Analysis for Insurers

Mass Lapse Shock	
Type of Product	**Instantaneous Discontinuance**
Term insurance	20%
Endowments	20%
Annuities in deferral phase	-
Annuities in pay-out phase	-
Pure unit-linked contracts (without financial guarantees)	20%
Unit-linked contracts with financial guarantees	20%
Disability	20%
Health	-

Mortality
10%

Reinsurance in-Flows
-10%

Written Premia
-10%

Line of Business	Shock to Severity	Shock to Frequency
Direct Business, Including Accepted Proportional Reinsurance		
Medical expense insurance	2%	15%
Income protection insurance	2%	15%
General liability insurance	2%	15%
Credit and suretyship insurance	2%	15%
Legal expenses insurance	2%	15%
Miscellaneous financial loss	2%	15%
Accepted Non-Proportional Reinsurance		
Non-proportional health reinsurance	2%	15%
Non-proportional casualty reinsurance	2%	15%
Non-proportional property reinsurance	2%	15%

Source: IMF staff.

102. Alongside the assumed escalation in severity, the liquidity risk analysis introduces a shock to frequency. In this analysis, insurers are mandated to distinguish between actual payments occurring within the 90-day timeframe: those incurred up to the reference date, subject solely to the severity shock, and those incurred thereafter, subject to both frequency and severity shocks. The shock to frequency is excluded from the solvency ratio calculations and the determination of the liability stock in the liquidity risk analysis. The relevant financial shocks for the insurance sector are summarized in Table 3. Macrofinancial and insurance shocks are allocated as described in Table 6. Differences in the sequencing of the shocks reflect that solvency and liquidity risks have different triggering events and different time horizons of materialization of risks. Insurance-specific shocks are designed to be applied simultaneously.

Table 6. Japan: Allocation of Shocks Across Stress Tests Modules

	Simultaneous Shock	Sensitivity Analysis	Technical Specification
Market Shocks			
Adverse macrofinancial scenario	S, L	S	See Table 3
Underwriting Shocks			
Mass Lapse (life only)	S, L	-	See Table 5
Mortality (life only)	L	S	
Pandemic morbidity and increase in cost of claims (nonlife only)			
Increase in frequency	L	-	
Increase in severity	S, L	S	
Reinsurance in-flows	L	-	
Reduction in written premia	L	-	
Catastrophic events	-	S	Calibrated based on historical events that could occur again
Other Shocks			
Default of relevant counterparties	S	-	Largest financial and nonfinancial counterparties

Source: IMF staff.
Notes: S = Solvency risk analysis, L = Liquidity risk analysis. Shocks shall be applied to both life and nonlife insurances unless otherwise specified.

103. The outcome of the adverse scenario is compared to the baseline scenario. The baseline scenario for the liquidity analysis refers to the actual position at the reference date (March 31, 2023) in the stock-based approach and to the in- and outflows recorded over the three-month window spanning April 2023 to June 2023 period in the cash flow approach. In the stock-based approach, shocks are reflected into the calibration of the weights. In the cash flow approach, the adverse scenario is converted into shocks to the components of the stylized flows on both the source and need sides.

104. Liquidity positions are assessed under two different assumptions: fixed and constrained. In the first scenario, no reactive management actions are permitted, and the sale/purchase of assets should align with "business as usual." Any management actions considered adhere to nondiscretionary rules established at the reference date. In the second scenario, the constraints are relaxed to allow for the inclusion of the impact of reactive management actions, which should align with the stressed scenario.[53]

[53] The differentiation is based on the timing and purpose of reactive management actions: embedded management actions are assumed to be in place at the reference date, designed for business-as-usual circumstances (i.e., nondiscretionary actions), while reactive post-stress management actions are ad hoc measures implemented in response to specific circumstances.

105. The assessment of the liquidity position follows two main approaches:

- **Stock-based approach.** Liquidity needs and sources arising from an entity's asset and liability positions at a specific reference date. The implementation of haircuts (factors) on assets aims to mirror their devaluation attributable to the presumed widespread market upheaval and the adverse effects of a fire-sale situation where a significant number of market participants simultaneously attempt to sell specific assets in large volumes. Haircuts applied to liabilities signify the ease of redeeming a liability within the predetermined time frame following the shock occurrence.

- **Cash flow approach.** The flow-based approach compares the projected or realized liquidity sources and needs of a firm over a predefined time horizon, i.e., 90 days from the reference date, to determine whether and to what extent the inflows can cover the outflows over time.[54] To evaluate the post-stress liquidity position concerning anticipated cash inflows, adjustments are made to the written premiums, encompassing both existing and new business. In the case of life business, the anticipated technical cash outflows, reported through the cash flow approach (which includes surrender cash outflows), are computed with consideration to the impact on lapses. In non-life business, the estimation of cash outflows related to claim settlement incorporates the rise in the cost of claims.

106. The assessment of the liquidity position incorporates both a flow perspective and a stock perspective. Insurers' vulnerabilities are evaluated using a set of indicators in baseline and adverse scenarios, including:

- **The ratio of liquid assets to total assets,** assessed under both narrow and broader definitions of liquid assets. Insurance exposures are categorized and assigned to buckets based on common liquidity characteristics.

- **Estimated net cash-flow,** which can be customized to analyze specific business or product portfolios (e.g., sales of government securities).

- **The liquid asset to net flows ratio, serving as a sustainability indicator.** This indicator is defined as the ratio of estimated liquid assets (after accounting for haircuts) to net flows. Assessing the availability of highly liquid assets to cover potential cash flow shortages provides a comprehensive view of an insurer's liquidity position.

Results

107. The liquidity analysis on margin calls through interest rate swap positions does not indicate systemic liquidity stress for insurers. Cash margin calls on interest rate swaps following a

[54] This methodology encompasses the extensive spectrum of liquidity outlets accessible to insurance entities to meet their liquidity requirements. These sources include underwriting activities (e.g., written premiums), investments (e.g., coupons, dividends), and funding activities (e.g., issuing debt instruments, wholesale funding). Liquidity requirements may arise from traditional insurance operations (e.g., claims, surrenders), financial operations (e.g., margin calls, fees, and collateral needs), and general operational expenditures.

250 basis points increase in domestic interest rate could be met by drawing on about 20 percent of cash equivalents. Although shocks through variation margin calls likely does not lead to a sector-wide phenomenon given the limited size of interest swap position across the market, notable differences can be seen across individual firms. The cash positions of at least two insurers could be inadequate relative to the size of interest rate swap positions under severe one-day market movements.[55]

108. Under the stock-based approach, the share of liquid assets is relatively high. The application of haircuts (factors) to assets reflects their loss of value due to general market turmoil, as envisaged under the prescribed adverse scenario, and the fire-sale externalities resulting when a substantial portion of market participants aims to sell certain assets simultaneously and en masse.[56] The estimated liquid assets to total assets ratio is moderate when considering only cash and cash equivalents, but a large part of insurers' balance sheets is comprised of liquid assets including tradable investment assets—even after applying haircuts and under stress conditions. For instance, the life insurers' liquid assets ratio stands at about 60 (70) percent under the baseline (adverse) scenario (Figure 56).

109. In the flow-based approach, large outflows are projected under stress, but these can be mitigated through reactive management actions. Net outflows (i.e., when the sum of inflow is lower than projected outflows) under the adverse scenario are pronounced for life insurances surging to more than JPY 7 trillion in aggregate. Allowing for reactive management actions including asset sales limits net outflows. In line with the findings from the previous analysis, net outflows are generally met once tradable securities are considered as being part of the liquid buffer stock, but on a case-by-case basis this does not always apply.

110. The forced sale of assets comprises primarily domestic sovereign bonds. For the median life insurer, the sales of domestic sovereign bonds represent 60 percent of the total sales, with some significant variation being notable in the cross-section of insurers.

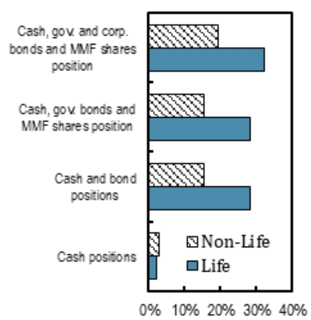
111. Given the heterogeneity in the impact across insurers, the results of the liquidity stress test analysis underline the importance for supervisors to monitor liquidity risks among insurers. This is especially important as the stress tests indicate that insurances with the largest negative net flows under the adverse scenario include companies with a higher solvency risk. In this regard, conducting stress testing exercises to assess cash outflows under different market liquidity conditions should be instrumental for liquidity risk analysis and monitoring.

[55] Note that despite liquid assets cover a sizable part of the balance sheet of Japanese insurers, encumbrance levels for life insurers' high-quality sovereign bond holdings are not trivial relative to the size of such exposures (Figure 56).

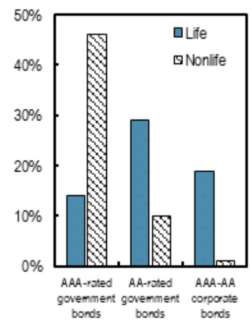
[56] Haircuts to liabilities reflect instead the ease of redeeming a liability over the predefined time horizon after the occurrence of the shock.

Figure 56. Japan: Insurance Liquidity Stress Test Results

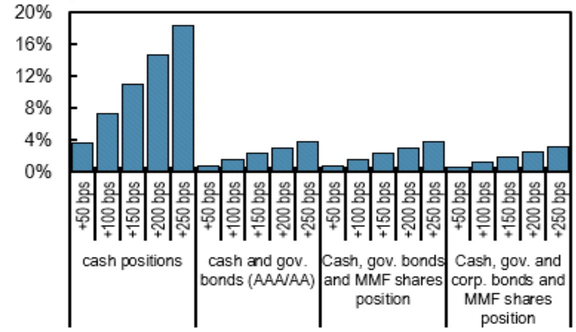
Liquidity Buffers (Percent of total assets)



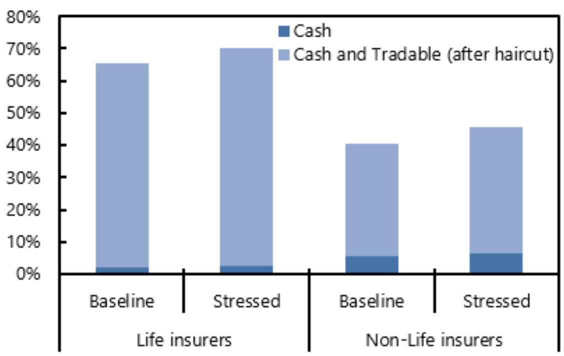
Share of Encumbered (Percent of total positions)



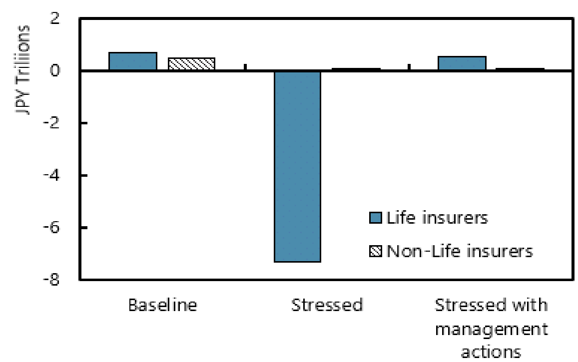
Margin Calls on Interest Rate Swaps for Insurances Exposed to Interest Rate Increases (Percent of liquid assets)



Liquid Assets-to-Total Assets After Stress Under Baseline and Adverse Scenario (Percent)

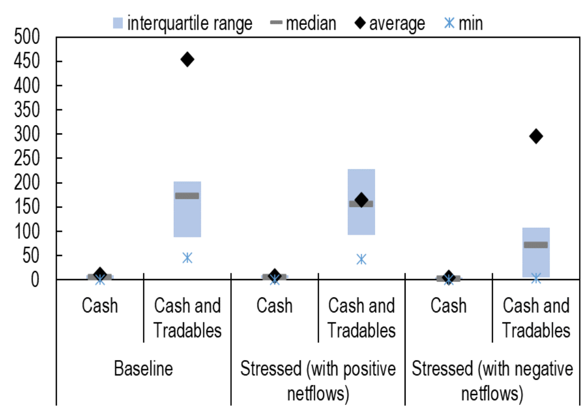


Sum of Inflows and Outflows Under Baseline and Adverse Scenario (JPY trillions)



Life Insurance: Share of Government Securities Sales under Adverse Scenario (Percent of total sales)

Life Insurance: Sustainability Indicator (Ratio of liquid assets over projected net flows)



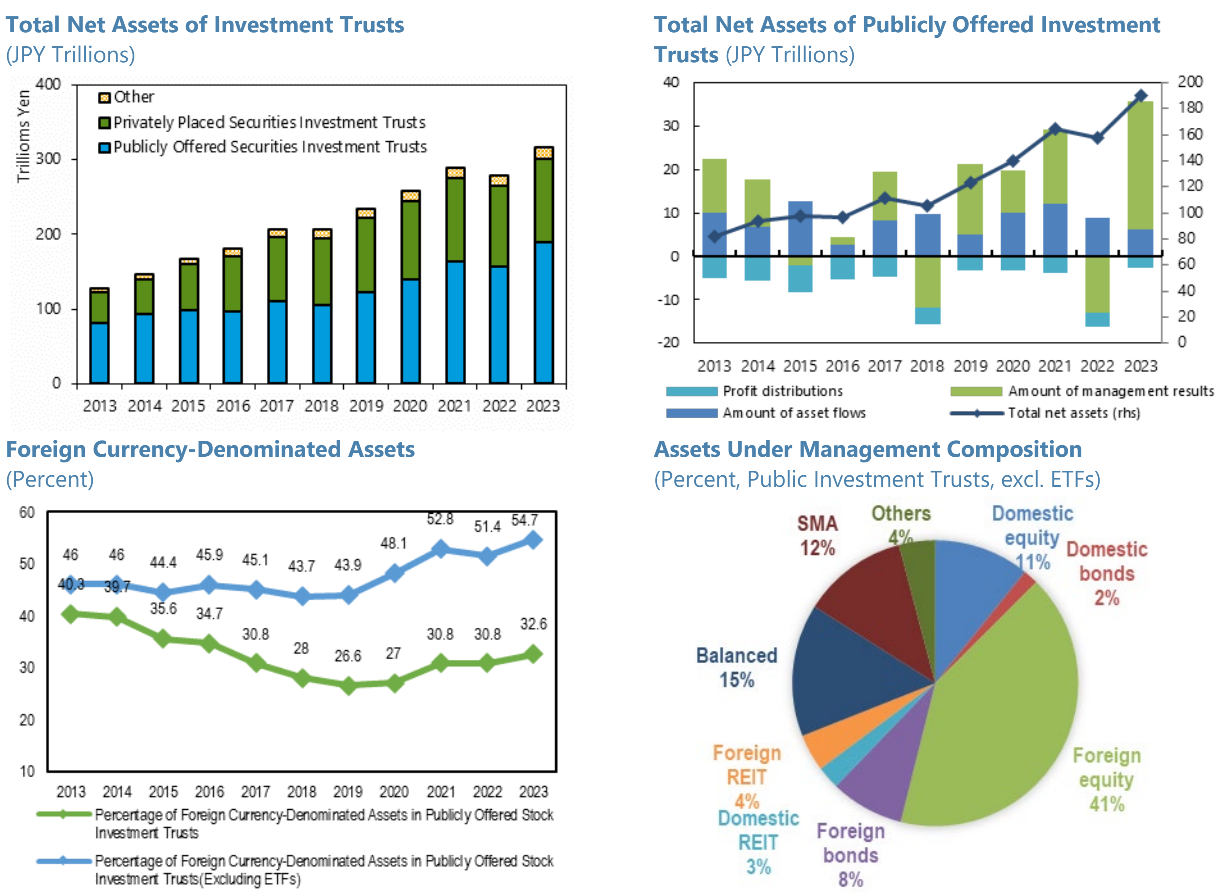
Source: IMF staff calculations.

INVESTMENT FUNDS LIQUIDITY STRESS TEST

A. Overview of Market Structure

112. The asset management sector in Japan has grown steadily in recent years. Total net assets of investment trusts stood at more than JPY 300 trillion in 2023, up from about JPY 170 trillion in 2015. Publicly offered investment trusts account for 60 percent of the total net assets of investment trusts, followed by privately offered investment trusts at about 35 percent. The sustained growth of the sector has been supported by robust investment returns—10 percent for all equity investment trusts—and continuous net fund inflows. About 61 percent of the total cash inflow into publicly offered investment trusts was directed towards global equities, and approximately 54 percent of the total assets were held in foreign currencies (Figure 57).[57]

Figure 57. Japan: Developments and Market Structure in the Investment Trust Market



Sources: NRI, FSA; and IMF staff calculations.
Notes: Data is not adjusted to remove double counting arising from funds that invest in other funds. ETF = exchange-traded fund.

[57] Nearly 90 percent of actively managed investment trusts have delegated their investment decisions to asset management firms located overseas.

113. The majority of publicly offered investment trusts in Japan invest mainly in traditional equity, debt securities, and their associated derivatives. Open-ended investment trusts, which account for the majority of publicly offered investment trusts, have a portfolio comprised mainly of products for which the period between contract and delivery is short.

114. According to the Bank of Japan's flow of funds statistics, about four percent of the Japanese depository financial institutions' assets comprised investments in securities investment trusts, as of December 2022. These include assets managed by non-financial corporations such as real estate investment trusts (REITs). The real estate fund sector, particularly REITs, has faced challenges stemming from increased office vacancies and declining rents in the Tokyo area in the aftermath of the COVID-19 pandemic, which has weakened the Tokyo Stock Exchange REIT Index.

B. Methodology

115. The resilience of investment funds in Japan to liquidity shocks was assessed through a stress testing exercise. The aim of the stress testing exercise was to evaluate the resilience of individual funds to significant, yet plausible, investor redemption shocks given the possibility of liquidity mismatch between their assets and liabilities. Open-ended funds are expected to satisfy redemption requests on a daily basis, making their liabilities highly liquid. However, the assets within certain funds might not be as liquid, presenting a risk of liquidity mismatch.

116. The sample of funds subject to the stress test is predominantly based on selected investment funds for which supervisory data is collected through a survey launched by the FSA in 2023. The sample comprises investment funds with total AUM of more than JPY 50 billion, amounting to 72 percent of total AUM for investment trust products. To generate the final sample for the stress test exercise, an additional selection of investment funds was made based on data obtained from commercial data sources. In addition, time-series information on monthly net flows and portfolio composition for the investment funds covered by the FSA survey was also obtained from commercial data sources for the period 2006-2023.[58]

117. The final number of investment funds used in the stress test exercise is 183 of which a large share is represented by equity funds with a global investment focus (Figure 58). The market is highly concentrated with a few large investment funds, while leverage is less common among mixed allocation funds, and more widespread among funds with investments concentrated in the U.S.

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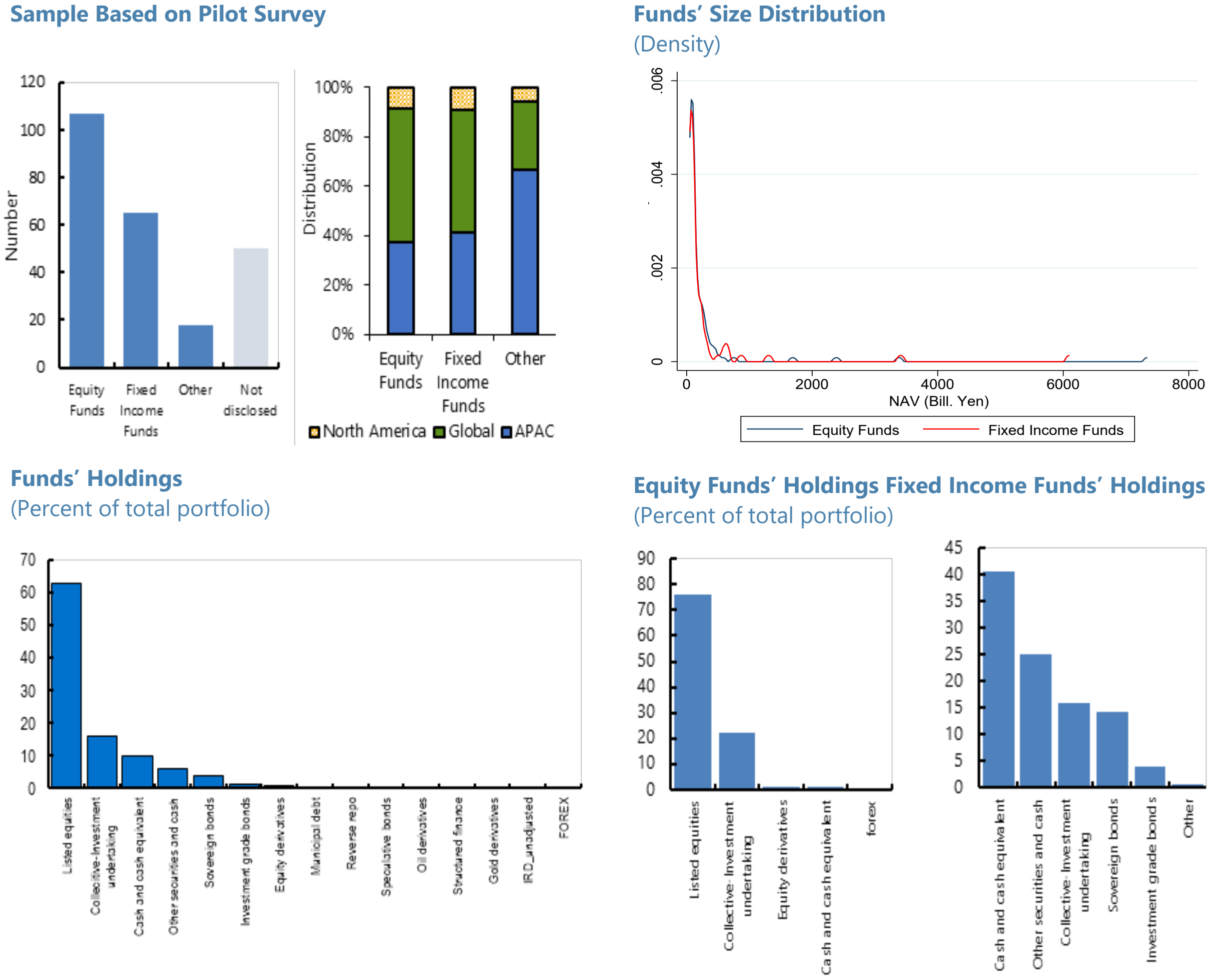
[58] Different data sources were used to match the sample of funds in the FSA Pilot survey, including Bloomberg, Lipper, and Factset.

Figure 58. Japan: Key Features of Investment Funds in the Sample



Source: IMF staff calculations based on companies' submissions.

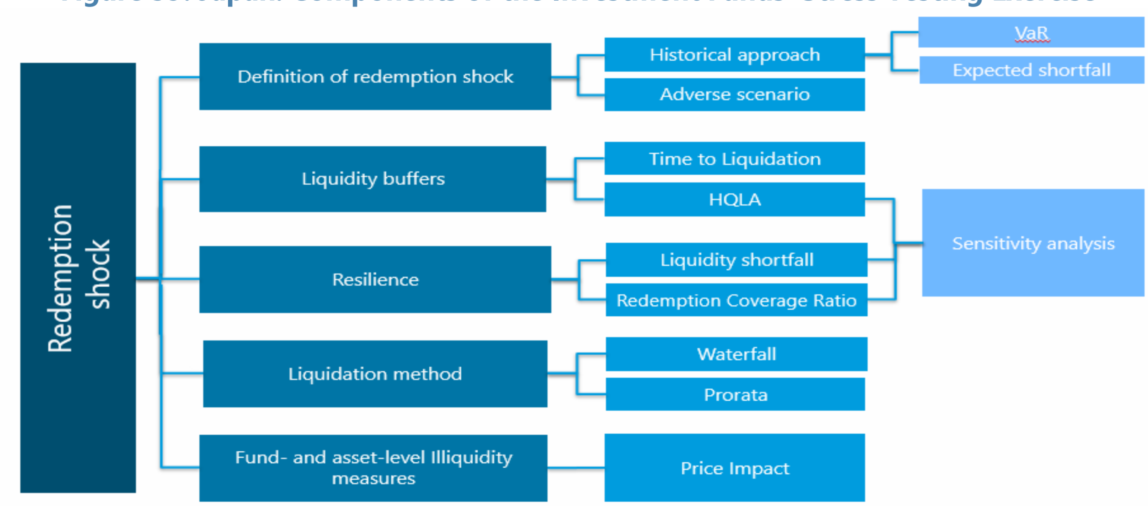
118. The investment fund stress test entails four steps. First, a redemption shock is set using various value-at-risk approaches and a macroeconomic approach relating fund flows to macrofinancial variables. The second step involves the calculation of liquidity buffers on the asset side of the balance sheet. The third step consists of assessing the resilience of investment funds based on the amount of liquidity that funds have available to meet redemption shocks according to specific asset liquidation assumptions.[59] The last step, which is more macroprudential in nature, includes the estimation of the contributions of the funds' illiquidity to asset price fragilities, measured by the impact on market price volatility for specific asset classes. The main components of the stress test for investment funds are illustrated in Figure 59.

119. The stress test does not consider the use of liquidity management tools (LMTs) for two main reasons. These include: (1) there is uncertainty regarding their use and impact due to limited

[59] Usually, most funds tend to sell assets in proportion of their weight in the fund portfolio to preserve the structure of their portfolio and ensure its consistency with their investment policy.

empirical work on LMTs; and (2) the objective of stress tests is to assess the resilience of financial institutions without taking into account mitigating measures. That said, the results of the liquidity stress tests should be viewed in that context, keeping in mind that the availability of LMTs at the fund level could potentially mitigate the risks to some degree.[60]

Figure 59. Japan: Components of the Investment Funds' Stress Testing Exercise



Source: IMF staff.

Modelling Assumptions

120. The redemption shock, defined as net outflows to total net assets, is first calibrated using a historical distribution approach. In this approach, redemption shocks are calibrated based on the distribution of historical net flows (defined as the difference between subscriptions and investor redemptions) at the fund level following a Value-at-Risk (VaR) approach, where different percentiles (e.g., 1st percentile) of net flows are used to calibrate the shock. Formally:

$$Var(\alpha) = F^{-1}(\alpha) \, ,$$

where $\boldsymbol{F^{-1}}$ is the inverse of the distribution function of net flows. Alternatively, the set of redemption shocks is based on the expected shortfall (ES), which is equal to the average value of net flows below the VaR. The ES is thus given by:

$$\text{ES}(\boldsymbol{\alpha}) = \frac{\boldsymbol{1}}{\boldsymbol{\alpha}} \int_0^{\alpha} VaR(l)dl \quad \text{or equivalently} \quad \text{ES}(\alpha) = E(Z|Z < Var(\alpha)) \, ,$$

where Z represents net flows.

121. Redemptions are further calibrated based on two alternative assumptions. In the first case, referred to as the "homogeneity" assumption, each fund within a specific fund type faces the

[60] Liquidity management tools are applied by fund managers in exceptional circumstances to control or limit dealing in fund units. These measures can include anti-dilution levies, redemption fees, redemption gates, and/or bank borrowing facilities available as temporary measures. Otherwise, a fund would need to suspend redemptions.

same-sized redemption shock. In the second case, the "heterogeneity" assumption, the redemption shock is calibrated separately for each fund based only on its historical data. In the stress test exercise, the heterogeneity assumption is used as a benchmark, but the homogeneity assumption is also examined.

122. A model-based approach relating fund flows to macrofinancial variables is also employed to calibrate redemption shocks. For the model, three inputs are needed: (1) a satellite model that translates macrofinancial scenarios into net flows at the fund level; (2) data to estimate the model; and (3) an adverse macrofinancial scenario. The model translates the adverse scenario used in the banking sector stress test into net fund flows, and is estimated at the fund-level as follows:

$$NetFlows_t = \alpha_1 \Delta VIX_t + \alpha_2 \Delta 3M_t + \alpha_3 \Delta 10Y_t + \alpha_4 Term_t + \alpha_5 \Delta JP\ Stock\ Prices + \alpha_6 \Delta US\ Stock\ Prices$$
$$+ \alpha_7 \Delta Bond\ Spread_t + \alpha_8 \Delta NEER_t + \epsilon_t\ ,$$

where ΔVIX is the change in the Chicago Board Option Exchange's Volatility Index in time *t*, $\Delta 3M_t$ is the monthly change in 3-month interbank rate, $\Delta 10Y_t$ is the change in 10-year domestic sovereign yield, *Term* Indicates the term spread, $\Delta JP\ Stock\ Prices$ is the change in the Nikkei 225 price index, $\Delta US\ Stock\ Prices$ is the change in S&P500, $\Delta Bond\ Spread_t$ is the change in Japanese corporate bonds spreads, $\Delta NEER_t$ is the change in the Japanese nominal effective exchange rate, and ϵ_t is a random error term. The model was estimated for the period 2006-2023 and net flows were projected using the values of the macrofinancial variables in the adverse scenario.

123. The measurement of fund-level liquidity buffers follows two main approaches based on the time-to-liquidation approach and grouping of securities by liquidity buckets (tiered approach). In the first approach, according to IOSCO guidelines, estimates for liquidity are based on market conditions over the reporting period and assuming no fire-sale discounting (e.g., for listed equities, assuming less than 20 percent trade of the 90-day average daily trading volume in a single day). The method allows to identify the percentage of funds' portfolios that can be liquidated within each of the specified liquidity periods. The second approach is based on the definition of HQLA.[61] An asset is considered to be part of HQLA if it can be easily converted into cash. Therefore, the concept of HQLA is related to asset quality (if the asset can be sold without discount) and asset liquidity (if the asset can be sold easily and quickly). The stock of HQLA is computed by splitting portfolio positions by asset classes (sovereign bonds, corporate bonds, equities etc.) and ratings, defining eligible assets and applying haircut values (i.e., liquidity weights). The weights are inspired by those proposed by the Basel Committee for the calculation of HQLA under Basel III (Table 7).[62] A

[61] The term HQLA refers to the LCR used for banks under Basel III liquidity regulatory requirements.

[62] For instance, corporate debt securities rated above BBB- are eligible for inclusion, while high yield bonds do not meet the criteria. A reduction of 15 percent is applied to corporate bonds with AA- or higher ratings, and a 50 percent reduction is applied to bonds falling within the A+ to BBB- range. This approach is based on the LCR with a one-month time frame, which assumes that high yield bonds may face liquidity constraints for one month, investment grade corporate bonds can be sold within the month but at a discounted price, and corporate bonds rated AA- or higher may experience a 15 percent loss in value during the month. Corporate bonds rated between A+ and BBB- could potentially incur a 50 percent loss of value within the same time frame.

liquidity index can then be computed using the liquidity weights and the share of each security (or grouping) in the fund portfolio:

$$Liquidity_t = \sum_{k=1}^{n} \omega_k \times s_{t,k} ,$$

where ω_k is the liquidity weight for security *k,* and $s_{t,k}$ is the share of this security in percent of total net assets (TNA).[63] A "liquidation ranking" is constructed based on the liquidity index.

Table 7. Japan: Liquidity Weights Used in the HQLA Approach

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

Source: IMF staff.

124. Liquidation is assessed under two alternative approaches. These include: (1) a waterfall approach, according to which fund managers use HQLA before less liquid assets (i.e., horizontal slicing); and (2) a pro-rata approach. The pro-rata liquidation uses a proportionality rule, implying that each asset is liquidated such that the structure of the asset portfolio is the same before and after the liquidation (i.e., vertical slicing). Such a strategy allows managers to ensure that the portfolio composition follows the investment policy. In period of market stress, however, managers might use a mix of both approaches to ensure that they are able to raise cash quickly to meet redemptions, while limiting the distortion of their portfolio structure.

125. Following the calibration of redemption shocks and estimation of the liquidity buffers, the resilience of investment funds to liquidity shocks can be measured by the Redemption Coverage Ratio (RCR). The RCR is a measurement of the ability of a fund's assets to meet funding obligations arising from the liabilities side of the balance sheet, such as a redemption shock, and is defined as:

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

where net outflows and liquid assets correspond respectively to redemption shocks and the amount of the portfolio that can be liquidated over a given time horizon. The RCR measures the ability of funds' liquidity buffers to meet investor redemptions in the stress scenario, with two possible cases:

[63] In the stress test sensitivity analysis, different weights on equities are considered.

- If the RCR is above 1, then the fund's portfolio is sufficiently liquid to cope with the redemption scenario,
- If the RCR is below 1, then the liquidity profile of the fund may be worsened when the redemption scenario occurs.

126. When RCR is below 1, the amount of additional assets to be sold is defined as the liquidity shortfall:

$$Liquidity\ shortfall\ =\ max\ (0, Net\ outflows\ -\ Liquid\ assets)\ .$$

To compare the liquidity profile of several funds, the liquidity shortfall measure is expressed as a percentage of a fund's TNA.

127. In the scenario envisioned within the liquidity stress test, investment funds exposed to significant redemption pressures may find it necessary to withdraw their deposits to fulfill investor redemption demands. This, in turn, could potentially instigate liquidity challenges for financial institutions, particularly if these funds' deposits constitute a substantial portion of the overall bank deposits. For simplicity, such effect is measured by assuming that all deposits are with a depository bank.

128. The price impact of funds' vulnerability is evaluated. A measure of asset price vulnerability is calculated in two steps following the approach used in Jiang and others (2022) and in the IMF's October 2022 Global Financial Stability Report. First, a fund-level illiquidity measure is constructed as a weighted average of bid-ask spreads (illiquidity) of assets held by the fund:

$$Fund\ illiquidity_{j,t} = \frac{\sum_{i=1}^{I} Holding\ amount_{j,i,t} \times Bid{-}Ask_{i,t}}{\sum_{i=1}^{I} Holding\ amount_{j,i,t}},$$

where $Holding\ amount_{j,i,t}$ is the market value of asset i held by fund j in quarter t, and $Bid - Ask_{i,t}$ is the bid-ask spread of asset i at the end of quarter t.

129. An asset price vulnerability measure is then calculated based on the weighted average of investing funds' illiquidity. Weights used to construct the metric represent funds' relative holdings of the asset, as follows:

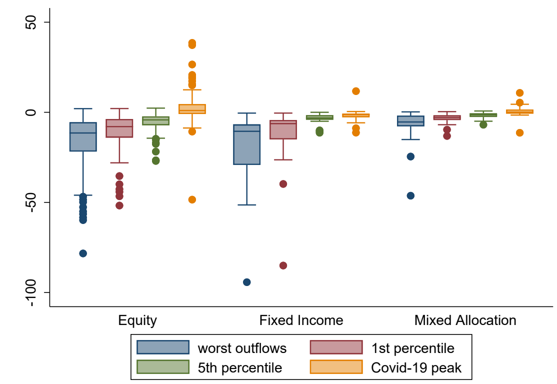
$$Asset\ level\ Vulnerability_{i,t} = \frac{\sum_{j=1}^{J} Holding\ amount_{j,i,t} \times Fund\ illiquidity_{j,t}}{\sum_{j=1}^{J} Holding\ amount_{j,i,t}}.$$

C. Results

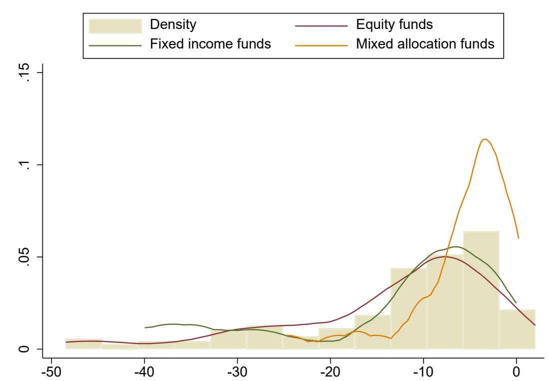
130. The redemption shock calibrated using the first percentile of the historical net outflows is examined to capture tail risk events. Net outflows from funds were more pronounced during the global financial crisis relative to the COVID-19 market turmoil in March 2020, and were generally larger for equity funds, relative to fixed income and mixed allocation funds (Figure 60).[64]

Figure 60. Japan: Investment Funds Liquidity Stress Test Results

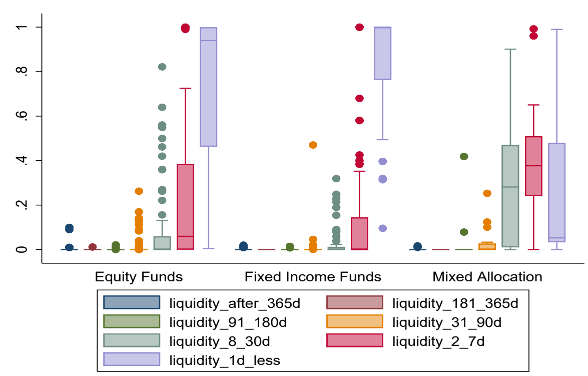
Historical Net Flows in Japanese Investment Funds
(Percent)



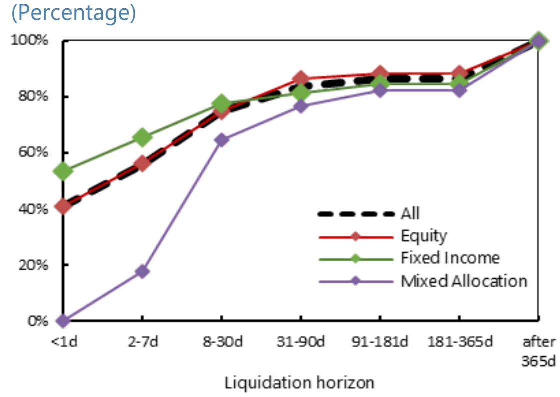
Expected Shortfall Across Different Fund Types
(Density)



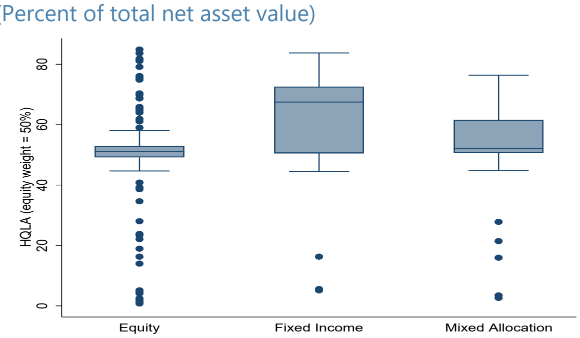
Time-to-Liquidation by Type of Fund
(Share of the total portfolio)



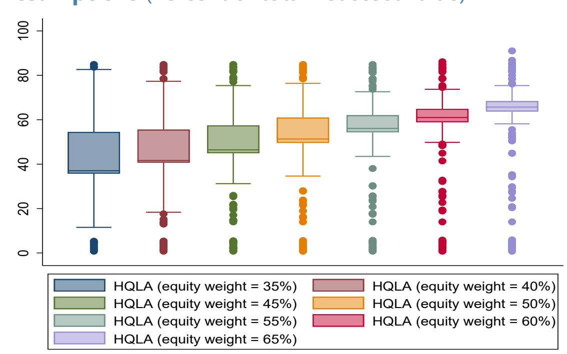
Time-to-Liquidation: Proportion of Funds
(Percentage)



High Quality Liquid Assets
(Percent of total net asset value)



High Quality Liquid Assets for Different Weight Assumptions (Percent of total net asset value)



Sources: Bloomberg; Lipper; Factset; and IMF staff calculations.

64 Data from the Japanese Investment Trusts Association (JITA) show that the cancellation amount of both equity investment trusts and bond investment trusts increased slightly in March 2020, but the overall change in net assets was small, and net assets started to increase after 2-3 months.

131. As VaR does not take into account tail events beyond the VaR threshold, the historical approach is complemented by an alternative set of redemptions shocks based on the expected shortfall (ES). The median estimated ES is 10.2 percent for equity funds and 8.3 percent for fixed-income funds. There exists, however, a large heterogeneity across investment funds as illustrated by the large skewness in the ES distribution, reaching troughs up to negative 50 percent.

132. Liquidity buffers in the stress test using the time-to-liquidation approach and the liquidity bucket approach confirm the general sufficiency of liquid buffers. A majority of publicly offered investment trusts in Japan invest mainly in equity, debt securities, and their associated derivatives. Funds hold a large share of products for which the period between contract and delivery is short (1 to 3 days). About 75 percent of the funds can fully liquidate their portfolio position between seven days up to a one-month horizon. The results are similar for equity and fixed income funds, while mixed allocation funds tend to face longer periods of liquidation. Notably, none of the mixed allocation funds have reported positions that can be liquidated during a short term (within one day).

133. The amount of HQLA was found to be moderate to high across funds. The median HQLA is 52 percent of the total assets position. Fixed income funds have the largest median HQLA at 68 percent, although there is also considerable variation in the size of HQLA holdings in that group.

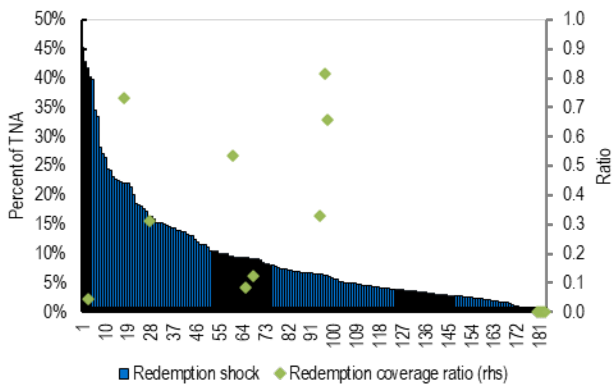
134. Overall, the redemption shocks in the adverse scenario are typically larger than the potential redemption shocks derived from the historical approach, with a median estimated redemption shock of more than 20 percent. Therefore, a more significant percentage of investment funds must withdraw deposits to cope fully with the redemption shock in that scenario. The percentage of drawdown varies, however, depending on the liquidation method adopted. On a pro-rata basis (i.e., in the same proportion to maintain balance sheet composition), the total bank deposit withdrawal tends to be about half of the withdrawal needed when adopting a waterfall approach (i.e., selling HQLA first before less liquid assets).

135. The stress test results indicate that most Japan-domiciled funds are resilient to the considered shock, but vulnerabilities can arise under more extreme market stress scenarios. Most of the funds in the stress test sample can withstand severe but plausible redemption shocks. However, under more severe redemption shocks, the share of funds with lower liquidity buffers can widen, leading to more widespread liquidity shortfalls. For instance, the liquidity shortfall associated with outflows consistent with the adverse scenario could reach up to 18 percent of total assets (Figure 61).

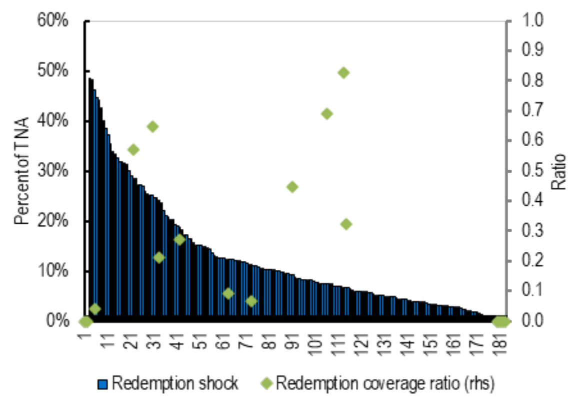
136. The liquid buffer depletion due to redemption shocks is larger among equity funds (on average 21 percent), followed by mixed allocation funds (11 percent) and fixed income funds (5 percent). The more limited impact on fixed income can be partially explained by the presence of money market mutual funds with large cash and cash equivalent positions (more than 40 percent of the total portfolio) leading to larger liquidity buffers for such institutions.

Figure 61. Japan: Investment Funds' Resilience and Liquidity Shortfall

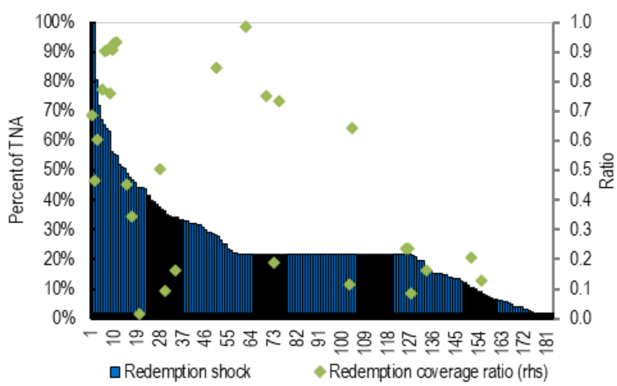
Var Approach: Redemption Shock and Redemption Coverage Ratio



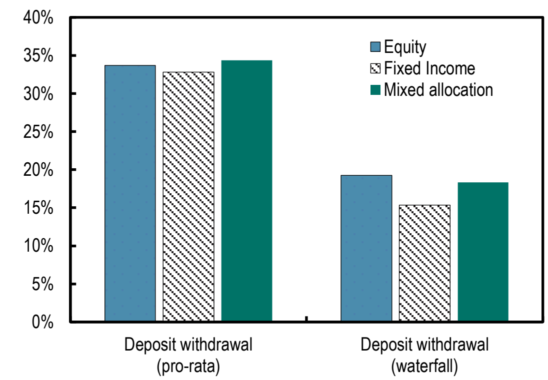
ES approach: Redemption Shock and Redemption Coverage Ratio



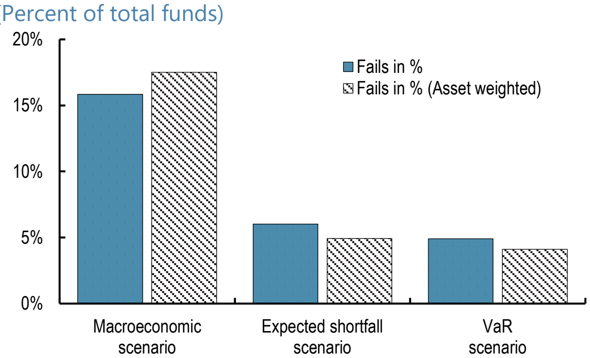
Macroeconomic Approach: Redemption Shock and Redemption Coverage Ratio



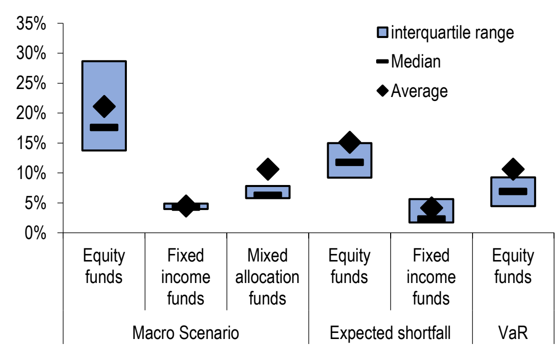
Macroeconomic Approach: Deposit Withdrawals
(Percent of the total)



Funds' Resilience
(Percent of total funds)



Liquidity Shortfall (For Funds That Fail Stress Test)
(Percent of total net asset value)



Sources: Bloomberg; Lipper; Factset; and IMF staff calculations.
Notes: The upper panels show estimated redemption shocks and the redemption coverage ratio (RCR) under VaR and ES approach. RCR measures the ability of funds' liquidity buffers to meet investors' redemptions in the stress scenario. The middle-left panel show results using the macroeconomic scenario consistent with the banking sector stress test to calibrate redemption shocks. RCR is shown only for funds with values of RCR below one, corresponding to funds that are subject to a liquidity shortfall following a redemptions shock. Bottom left panel shows the percent of funds whose liquidity buffers are not enough to meet severe but plausible outflows calibrated with different stress scenarios. ES = expected shortfall, VaR=value at risk.

137. Given the prominence of equity shares in the portfolio of funds' in the benchmark sample, a sensitivity analysis was performed by varying the equity weight used for the computation of liquid buffers. The parameter range varies from 30 to 70 percent. The lower the weight, the lower is the quality of equity holdings considered in the HQLA computation. Assuming a larger percentage of low-quality equity holdings yields up to 28 percent of the funds may not meet redemption shocks (Figure 62). For robustness, the analysis was repeated also under the homogeneity assumption (i.e., considering the same shock across funds). The stress test outcomes were no worse for the sample of investment funds included in the stress test exercise.

Figure 62. Japan: Investment Funds Sensitivity Analysis

Stress test based on VaR (1st percentile)										
Equity weight -->		30	35	40	45	50	55	60	65	70
Heterogeneity assumption	Fails in %	7.1%	6.6%	6.0%	5.5%	4.9%	4.9%	4.9%	4.9%	4.4%
	Fails in % (Asset weighted)	5.2%	4.9%	4.6%	4.6%	4.1%	4.1%	4.1%	4.1%	4.0%

Stress test based on Expected Shortfall										
Equity weight -->		30	35	40	45	50	55	60	65	70
Heterogeneity assumption	Fails in %	12.0%	9.3%	7.7%	6.6%	6.0%	6.0%	6.0%	6.0%	6.0%
	Fails in % (Asset weighted)	7.9%	6.8%	5.6%	5.2%	4.9%	4.9%	4.9%	4.9%	4.9%

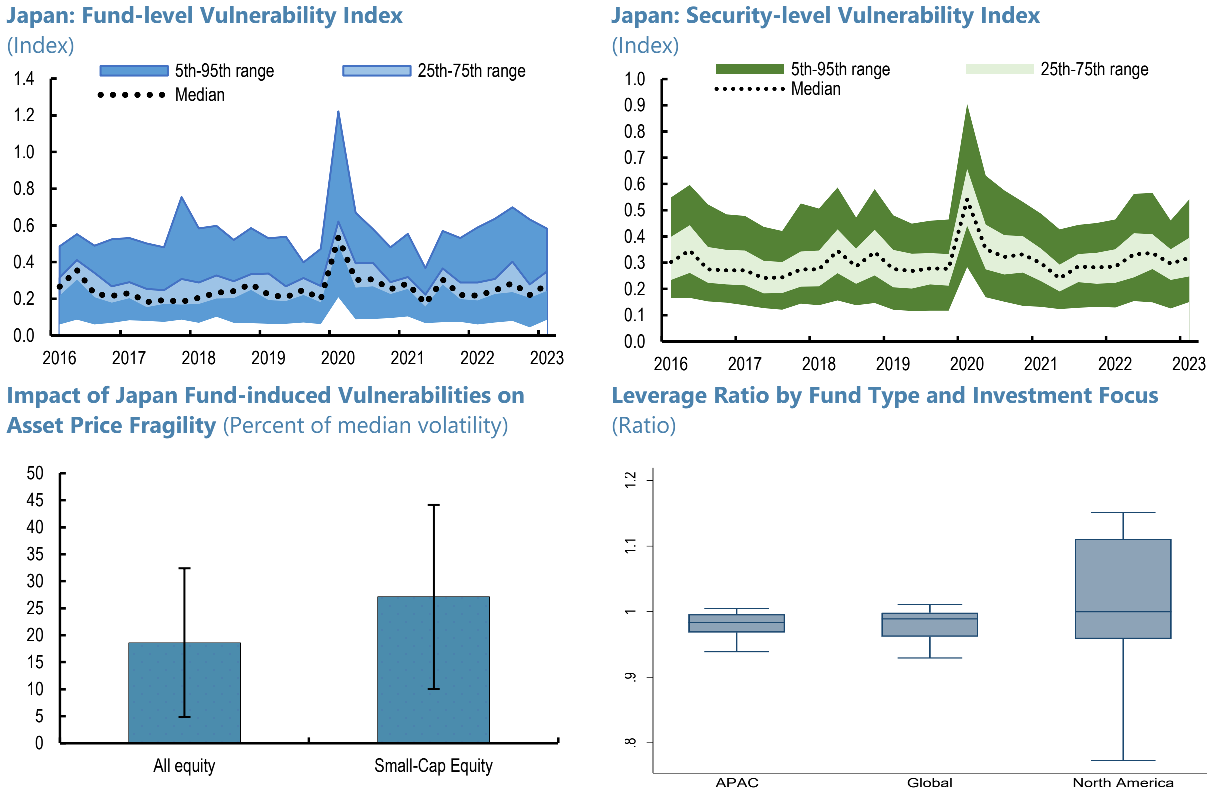
Stress test based on macroeconomic scenario										
Equity weight -->		30	35	40	45	50	55	60	65	70
Heterogeneity assumption	Fails in %	28.4%	22.4%	21.3%	19.7%	15.8%	14.2%	13.7%	12.6%	9.8%
	Fails in % (Asset weighted)	28.7%	20.3%	19.2%	18.7%	17.5%	16.4%	15.7%	15.5%	10.0%

Sources: Bloomberg; Lipper; Factset; and IMF staff calculations.
Notes: The sensitivity analysis is performed by varying the equity weight used for the computation of liquid buffers. The parameter range varies from 30 to 70 percent. The lower the weight the less is the quality of equity holdings held by the funds.

138. An analysis of the price impact reveals that assets held by less liquid funds are more susceptible to selling pressure caused by large redemptions. Higher vulnerability of assets held by less liquid funds domiciled in Japan is apparent from two recent episodes of market stress, i.e., the COVID-19 pandemic and around the start of monetary policy normalization in other major advanced economies (Figure 63). An empirical analysis shows that the illiquidity of Japanese investment funds can contribute to the fragility of equity returns. Quantitatively, a one standard deviation increases in asset-level vulnerability of funds domiciled in Japan could imply an 18 percent increase in equity price volatility (relative to the median). The effect is more prominent for small-cap equity and can be exacerbated by funds with greater leverage.

139. Taken together, these observations suggest that the vulnerabilities of investment funds subject to redemptions could adversely affect specific asset markets where such funds holdings are mostly concentrated. This highlights the need for further strengthening the systemic risk monitoring of the investment funds sector through a broader coverage of data and regular liquidity stress testing as part of offsite monitoring of firms, as discussed in the accompanying FSAP TN on the Regulation and Supervision of Investment Funds.

Figure 63. Japan: Investment Funds Vulnerabilities and Asset Price Fragilities



Sources: Bloomberg; Lipper; Factset; and IMF staff calculations.
Notes: The upper left panel shows the median and dispersion of the fund-level illiquidity measure for investment funds with headquarter in Japan and computed as the weighted average of the bid-ask spreads of the funds' portfolio of securities. The upper right panel shows the median and dispersion of asset-level vulnerability computed based on the illiquidity of the funds holding that asset (following the approach in Jiang and others 2022 and October GFSR 2022). The bottom left panel shows the coefficient on the (lagged) asset-level vulnerability measure in a regression of quarterly asset return volatility. Controls include bid-ask spread, log of market capitalization, weekly returns, mutual fund ownership, time to maturity, and security ratings. Coefficients are shown by asset class. Asset return volatility is calculated based on weekly returns over one quarter and is expressed relative to the sample median. Asset-level vulnerability is defined as a z-score. In the bottom right panel, leverage is calculated as the ratio of long plus short positions over total net assets.

CORPORATE AND HOUSEHOLD SECTOR RISK ANALYSIS

A. Methodology

140. The PDs and LGDs of the nonfinancial corporate (NFC) sector are projected using a model that is anchored in firm-level data from Moody's Orbis. A fixed effect firm-level panel regression was estimated to identify the key determinants of firm PDs, which takes default rates from Moody's KMV as a primary input. This model was combined with a structural simulation scheme for the predictor variables included in that PD model component, with "structural" meaning that these are simulated at the firm-micro level (including indicators such as cash to debt ratios, leverage defined as debt over assets, interest coverage ratios, and others). The model is then used to project each individual firm's balance sheet dynamics into the future (2024-2026), conditional on the macrofinancial scenarios. The evolution of firm LGDs is derived by means of an embedded Vašíček model structure as laid out in Frye and Jacobs (2012).[65]

141. The PDs and LGDs of the household sector are projected using a model that was anchored in household survey data. The household micro data were sourced from the Japan Household Panel Survey (JHPS/KHPS) from the Panel Data Research Center at Keio University. The structural micro-macro simulation model of Gross and Poblacion (2017) and Gross and others (2022) was employed. It was used to simulate each household's balance sheet dynamics (including each household member's employment status) into the future (2024-2026), conditional on the aggregate macrofinancial scenarios. The data, comprising of detailed anonymized balance sheet information for a large set of households and household members, matches well several key population census statistics, aggregate unemployment rate, and several key mortgage-related risk metrics. The model takes into account several key features of the Japanese mortgage market, including a full-recourse system–which voids strategic default incentives—a high share of floating-rate mortgages, and the industry practice of "the 5-year/125 percent rule."[66] Appendix IV provides further details on the data and the methodology.

B. Results

142. The aggregate default probability for the NFC sector (debt-weighted aggregate of firms) would rise under the adverse scenario. Annual PDs rise, on average, by 0.6 percentage point in the first year of the shock under the adverse scenario (Figure 64). The aggregate PD increases more under the sensitivity analysis, which assumes an additional interest rate increase on top of the initial adverse scenario but remains somewhat below the level observed during the global financial crisis, primarily as the result of sizeable cash buffers that firms accumulated during the pandemic. The projected PDs and LGDs are key inputs for the bank solvency stress test, as the loans to NFCs (excluding real estate) account for more than 30 percent of the exposures for banks in the sample.

143. Smaller firms experience a larger increase in PD relative to large firms. The PD model features five key factors underpinning firms' default probability, in a structural manner: leverage, interest coverage ratio, profitability, cash buffers and real GDP growth. Firms with higher initial leverage and lower profitability and cash buffers would experience a larger increase in PD under the adverse scenario. Small and medium-sized firms are affected more in the adverse scenario due to their higher initial leverage and lower initial interest coverage ratio.

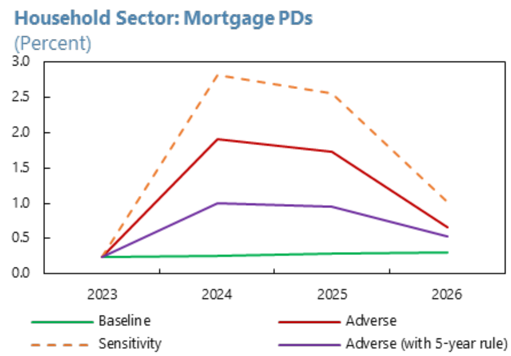
[65] The model follows the same structure, in most parts, as that employed for the corporate climate risk analysis presented later in this note. See Appendix III for further details.

[66] The practice can be dated back to a government notice issued in April 1983. The notice was later removed (July 1994) but is reportedly practically followed by the industry since then (see, e.g., https://www.mlit.go.jp/common/000109268.pdf). The "rule" stipulates that the periodic annuities faced by borrowers are to change only infrequently (every five years) and that it should not rise by more than 25 percent at a time.

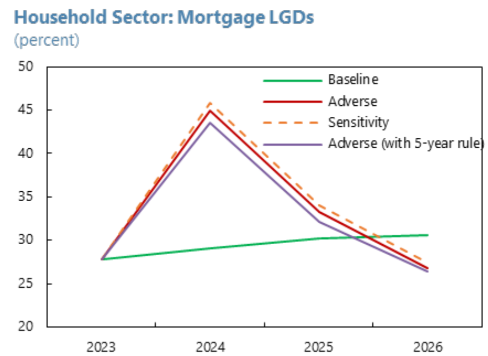
144. The household sector was found to be broadly resilient under the adverse scenario.[67] In the adverse scenario, mortgage probability of defaults would rise, due primarily to higher interest rates and unemployment rates, reaching 1.9 percent in the first year. The default rate appears higher in the sensitivity analysis, driven by higher short-term (borrowing) interest rates. When taking into account the "5-year/125 percent rule" and assuming that it prevails over the forecast horizon, mortgage probability of defaults rises less, reaching one percent in the first year (Figure 64). Mortgage LGDs increase under the adverse scenarios (with or without the 5-year rule), as well as for the sensitivity analysis, reaching at most 46 percent in the first year. The rise in LGDs is primarily driven by the material drop in residential house prices in the adverse scenario (Figure 21), as well as by rising interest rates that implies a more sizeable discounting of the expected recovery value of the housing collateral. The mortgage PD trajectory would be to an extent lower when considering the 5-year/125 percent rule (Figure 64).

Figure 64. Japan: Results from Household and Corporate Sector Risk Analyses

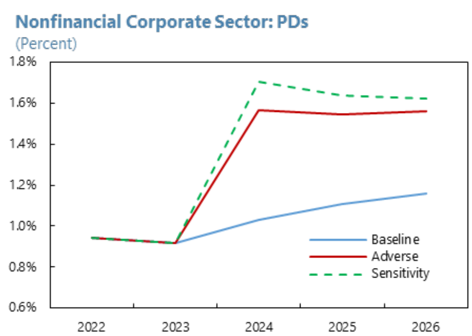
Mortgage default rates rise in the adverse scenario primarily due to higher unemployment and interest rates.



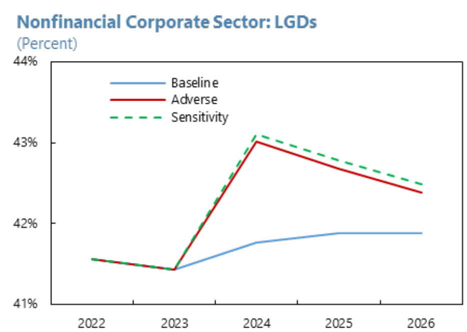
Mortgage LGDs rise in response to strongly falling house prices, and higher interest rates.



PDs of NFCs rise notably under the adverse scenarios due to a less favorable macrofinancial environment.



The LGDs of NFC credit exposures rises under the adverse scenario, alongside the higher default probability.



Source: IMF staff estimates.
Notes: In the top two panels, the adverse scenario with industry practice (5-year/125 percent rule) does not fully reflect the potential impact of the practice if followed by the industry over the stress test horizon, particularly for mortgage LGDs. The sensitivity analysis in all panels refers to the additional increase in interest rates.

[67] The anchor (initial) points for mortgage PDs and LGDs at the population level for mortgages were informed by bank-specific data for the respective parameters from the bank solvency data submission.

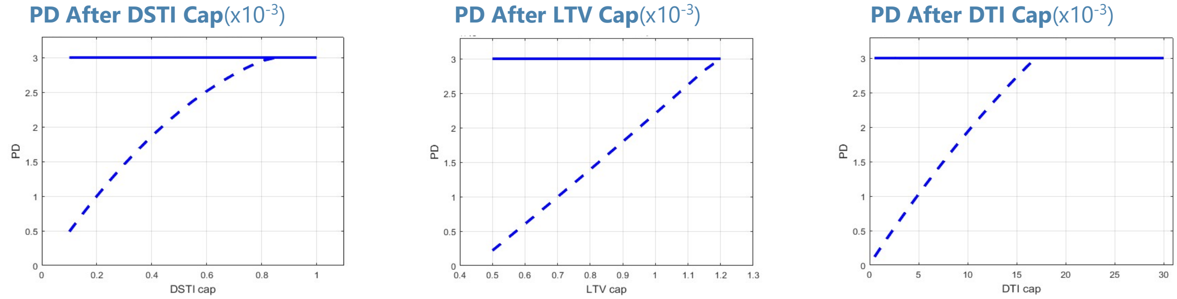
145. Against the emerging vulnerabilities in the real estate markets, the household simulation model was used to assess the impact of various macroprudential measures. To do so, different caps on DSTI, LTVs, and DTI ratios ("at origination") were considered under both the baseline and adverse scenarios. Potential macrofinancial feedbacks are also assessed as part of the model framework, which are triggered by the policy-induced credit demand shocks that result from the imposition of the caps. The resulting path of mortgage PDs and LGDs under the policy counterfactuals are used to calculate the impact on banks' capital ratios through loan losses and risk weighted assets.

146. A grid-based analysis suggests that tighter policy caps result in lower mortgage PDs and LGDs. The simulations being "grid-based" means that a full range of caps are examined (Figure 65). As structurally expected, LTV caps affects primarily the LGD, while PDs are structurally driven by DSTI caps. However, it is found that PDs react notably to all caps, including an LTV cap. This seems to be mainly driven by the positive observed correlation between DSTIs and LTVs across households.

Figure 65. Japan: Grid-Based Assessment of Borrower-Based Tools

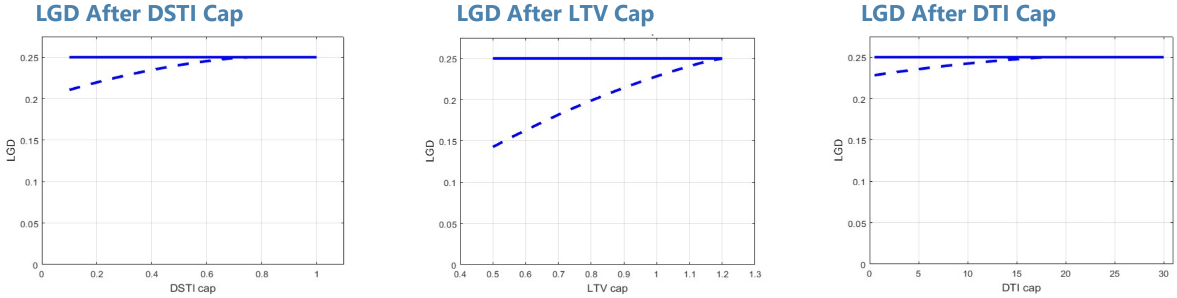
A tighter borrower-cap induces lower mortgage PDs along the grid, …

PD After DSTI Cap(x10^{-3}) **PD After LTV Cap**(x10^{-3}) **PD After DTI Cap**(x10^{-3})



…with an LTV cap having a greater impact on LGD, than DSTI or DTI, as structurally expected.

LGD After DSTI Cap **LGD After LTV Cap** **LGD After DTI Cap**

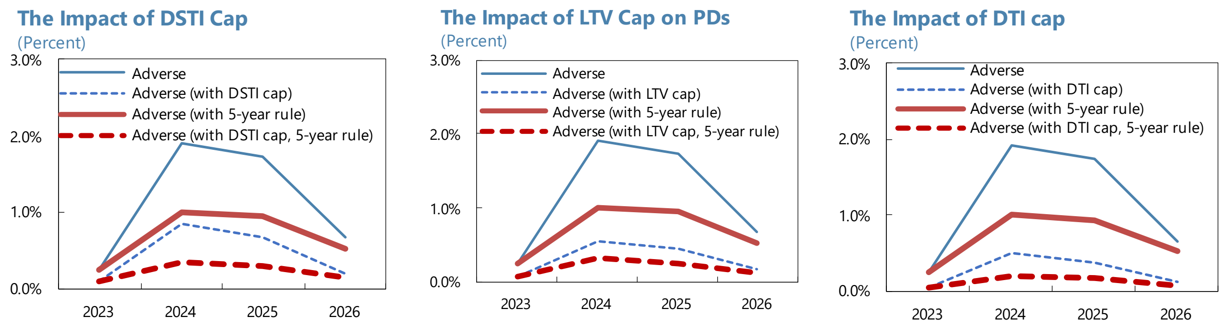


Source: IMF staff calculations.
Notes: The chart collection shows the impact of caps on DSTIs, LTVs, and DTIs (all at origination) on PDs and LGDs. The horizontal solid lines show the initial, pre-policy values of the risk parameters. All PD and LGD metrics are debt weighted population aggregates, based on the underlying household-level PDs and LGDs in the model.

147. The grid-based analysis is accompanied by concrete self-defined caps, for which macrofinancial feedback effects are also examined. The distributions of initial DSTI, LTV and DTI ratios across households was examined to inform the calibration of the concrete caps (Figure 66). DSTI and DTI caps were set at 35 percent and 6, respectively, which correspond to the 90th percentile of the sample. The LTV cap was set at 95 percent, which corresponds to the 60th percentile of the LTV distribution (there is some notable "bunching" at an LTV of 100 percent).

Figure 66. Japan: Mortgage PDs Under Policy Counterfactuals

Tighter borrower-based policy caps imply lower PDs…



Source: IMF staff calculations.

Note: All PD and LGD metrics are debt weighted population aggregates, based on the underlying household-level PDs and LGDs in the model.

148. Introducing borrower-based tools lowers household PDs and LGDs, while not having a significant impact on credit growth. A DSTI cap at 35 percent more than halves the increase in mortgage PDs under the adverse scenario (with or without the industry practice of "5-year rule/125 percent rule"). A similar conclusion applies to other caps. Details are provided in the following Figure 67.

- The left chart shows that under the 5-year/125 percent rule, a certain fraction of floating-rate mortgages is to be re-priced (about one fifth, each year). Using the exact year of origination for each mortgage (as covered in the household micro data), the year at which each mortgage is to be re-priced (in particular, the mode 5 of number of years since the origination) was examined. The share of mortgages that is to be re-priced each year was then linked to the increase in interest rates along the forecast horizon, implying a model-implied path for interest rates that is smoother (less steep). In effect, this corresponds to a hypothetical case where all floating mortgages are re-priced but at a much lower rate to reflect that only a fraction is re-priced conditional on the current industry practice.
- The middle chart underlines the notion that households can endogenously reduce their consumption to avoid mortgage defaults, which is an additional counterfactual calculation that was considered. In light of previous results, this gives rise to the interpretation that introducing borrower-based policy caps can result in enhancing resilience of the household sector and mitigate the adverse impact on their consumption during economic downturns.
- The third chart shows the implied reduction in private credit growth due to the introduction of the policy caps. This was quantified using a vector autoregressive model embedded in the micro-macro simulation model for Japan, where the estimated volume cut due to the implementation of such measures is taken as a negative credit demand shock.[68] The implied reduction in aggregate credit is small, with the decline in quarterly credit growth being less than 1.5 percentage points.

[68] See Gross and Poblacion (2017) for details on the methodology.

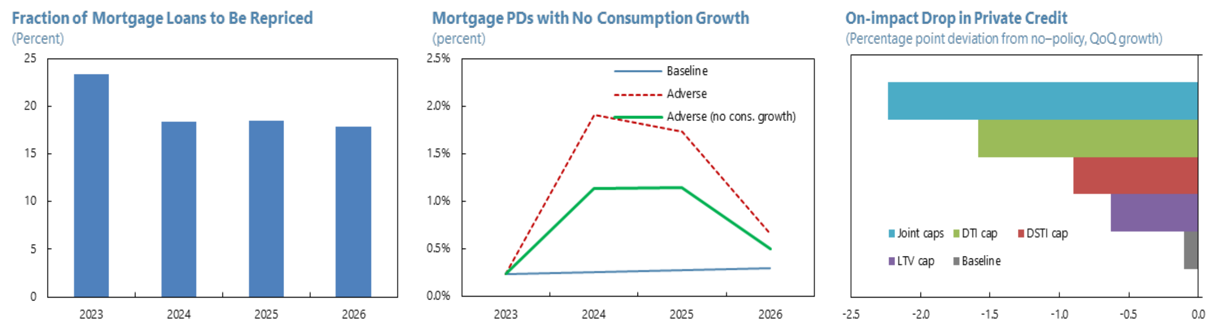
149. The calibrated policy caps are not meant to be interpreted as "optimal" in any sense but rather serve as an illustration. More granular data—for example, credit registry data, which would allow examining individual housing loans linked to individual banks—would be required to inform the cap levels, and the pace at which they may be introduced, in a more meaningful way.[69] When considering the introduction and design of such measures, the authorities should also be mindful of the following points to mitigate any potential unintended consequences: first, a microprudential policy perspective should be kept in mind, which could impact real estate markets and complement the macroprudential policy approach. Second, the authorities need to be mindful of possible leakages. Third, a phased implementation of these measures could be considered, such as through "speed limits."

Figure 67. Japan: Mortgage PDs Under Policy Counterfactuals: Further Aspects

Under the 5-year rule, a fraction of floating-rate mortgages is repriced.

Households can endogenously lower mortgage PDs at the expense of lower consumption.

Policy caps induce a mild impact on private credit growth.



Source: IMF staff calculations.
Note: The PD metric (middle chart) is a debt weighted population aggregate, based on the underlying household-level PDs in the model.

INTERCONNECTEDNESS AND CONTAGION ANALYSIS

A. Methodology

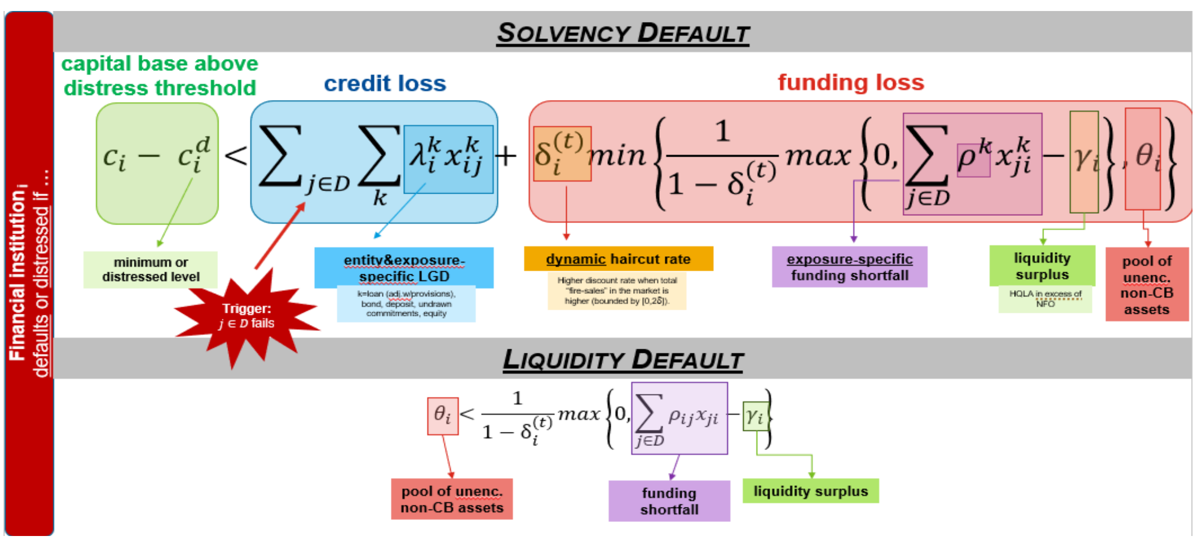
150. To assess domestic financial interconnectedness and contagion risks, first a network mapping exercise was conducted. Disaggregated data on gross bilateral exposures (loans, short-term money placements, equity, bonds, and banks' undrawn commitments) are aggregated for network mapping purposes. In the network map, each node represents a financial institution, colored differently based on the sector (banks, insurers, or securities firms), and among banks, according to whether it is a G-SIB/D-SIB, an internationally active bank (excluding G-SIBs/D-SIBs) or a domestic bank. The edges (lines connecting the nodes) in the network are colored the same as the source node (i.e., with claims on the other institution). The map is based on Fruchterman-Reingold algorithm, a force directed layout algorithm. The network map analysis is corroborated with two additional statistics: (1) the number of direct links each financial institution has with others in the

[69] The analysis also does not consider any potential welfare effects of the imposition of macroprudential measures, which are theoretically and empirically ambiguous (Frost and Stralen, 2018; Georgescu and Martin, 2021).

domestic financial network (the sum of direct inward and outward linkages); and (2) gross bilateral claims of each sector as percent of total sectoral capital buffers.[70]

151. Second, the potential for contagion in the domestic financial network was analyzed through a structural model following Covi, Gorpe, and Kok (2021). The trigger in the model is a hypothetical failure of a financial institution, as typical in contagion simulation models, which induces a "credit shock" or a "funding shock" on other institutions. Financial institutions that have claims on the failing institution incur losses on those claims ("credit shock"), the extent of which depends on LGD rates. Bilateral exposures (separately for loans, short-term money placements, equity, bond and undrawn commitments) and exposure-specific LGDs are sourced from proprietary data sources. Financial institutions may also incur losses due to fire sales of their assets if the failing institution is a funding source ("funding shock"). The extent of such fire sale losses would depend on the liquidity surplus (high-quality liquid assets in excess of net funding outflows), the volume of available for sale assets of each institution, and the discount rate. The discount rate is assumed to depend on the share of central bank eligible assets (which tend to be more liquid) in total unencumbered available-for-sale assets and is assumed to be dynamic (the higher the system-wide fire sales, the higher the discount rate up to a cap). Financial institutions are assumed to fully realize these losses (with a direct impact on their capital), and if their capital or liquidity buffers are not enough to cover total losses, they default. Each simulation ends when no further default occurs in the network. Figure 68 summarizes the model's main features. Further methodological details, including calibration, are provided in Appendix V.

Figure 68. Japan: Domestic Financial Contagion Model



Sources: Covi, Gorpe, and Kok (2019); and IMF staff.

[70] A capital buffer is defined as the difference between total regulatory capital (CET1 capital for internationally active banks and core capital for domestic banks, solvency margin for insurers and net capital for securities firms) and the risk-based assets (total risk-weighted assets for banks, ½ * risk amount for insurers, and risk-equivalent amount for securities firms).

152. In addition to domestic contagion, cross-border contagion risks from key financial partners were also analyzed using a structural model. A simpler structural model was employed to assess cross-border contagion (Espinosa-Vega and Sole, 2010), where the unit of analysis is a country-level banking system (consolidated), as opposed to individual financial institutions as in the domestic contagion analysis. Bilateral exposures are sourced from BIS Locational Banking Statistics (on a consolidated ultimate borrower basis), and aggregate capital from Fitch/Bankscope (consolidated).[71]

B. Results

Domestic Contagion

153. The Japanese financial system is highly interconnected, with G-SIBs and D-SIBs playing a central role.[72] G-SIBs and D-SIBs appear central in the domestic financial network map, and have, on average, the largest number of direct links with other financial institutions (Figure 69). Moreover, within each cluster of institutions, there is notable heterogeneity in terms of direct links in the network, and hence regarding their potency to exert direct impact on others. Some domestic banks, securities firms and insurers appear to be particularly widely connected with other financial institutions. The very question, then, is whether such linkages are underpinned by significant exposures of financial institutions relative to their capital buffers.

154. At a sectoral level, bilateral claims relative to capital buffers appear moderate. Banks in general are more exposed to each other (than to insurers or securities firms), with interbank claims averaging 35 percent of banks' total capital buffers. Banks also hold relatively sizeable claims on securities firms–that amount to 9 percent of banking sector's total capital buffers. Insurers also hold notable claims on banks, in the form of deposits, which is 13 percent of insurers' total capital buffers. Deposits, followed by loans, appear to be the main type of bilateral exposures.[73]

155. Simulation results show that G-SIBs/D-SIBs are the most impactful nodes in the network, in line with their centrality in domestic financial network as previously shown. The impact of a shock on G-SIBs/D-SIBs amounts to losses of about 10 percent of system-wide capital buffers (as shown by the contagion index, Figure 69), and transmits primarily through credit shocks (as opposed to funding shocks). Following G-SIBs/D-SIBs, insurers appear as the second most impactful sector, in total exerting losses close to 5 percent of system-wide capital buffers.

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[71] Given limited cross-country data, the LGD, the discount rate, and the funding short-fall rate were assumed to be homogenous across countries. Moreover, unlike the domestic spillover analysis, the distress threshold and provisions were assumed to be zero. The results do not take account of liquidity buffers which may mitigate potential spillovers.

[72] The analysis covers 50 financial institutions in total, including 23 banks, 22 insurers, and five large securities firms. The sample of banks and insurers used in the analysis is same as the ones used in solvency or liquidity analyses.

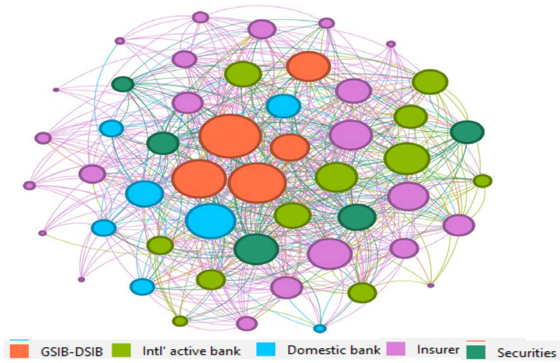
[73] While bilateral deposits across the members of the deposit insurance system (e.g., banks) are in general not insured, the deposits from other financial institutions (e.g., insurers, securities firms) are insured through the Japanese deposit insurance system. The deposits for payment and settlement purposes are fully insured. The analysis presented here assumes that all bilateral deposits across financial institutions are uninsured.

Vulnerability of financial institutions to contagion risks from shocks to other institutions appears moderate on average, up to one percent of own capital buffers at a cluster-average level.

Figure 69. Japan: Domestic Interlinkages and Contagion

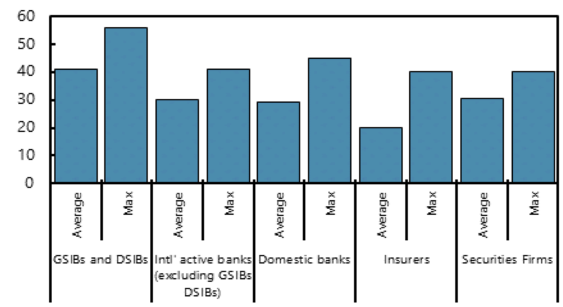
The domestic financial system is highly interconnected, …

Domestic Financial System Network



… with GSIBs and DSIBs, followed by securities firms, appearing more central to the network

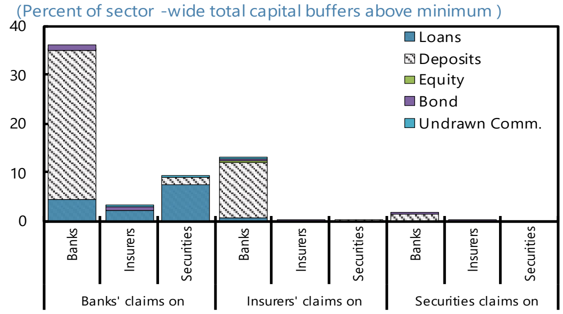
Average Degree of Connectedness



Bilateral exposures, driven mostly by intercompany deposits, are moderate relative to sector-wide capital buffers.

Sector-Level Bilateral On-Balance Sheet Exposures

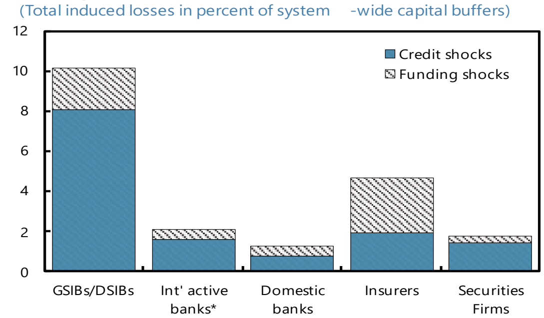
(Percent of sector -wide total capital buffers above minimum)



System-wide losses (relative to system-wide capital buffers) is on average moderate, with G-SIBs and D-SIBs exerting the highest impact, driven mostly by credit shocks.

Contagion Index

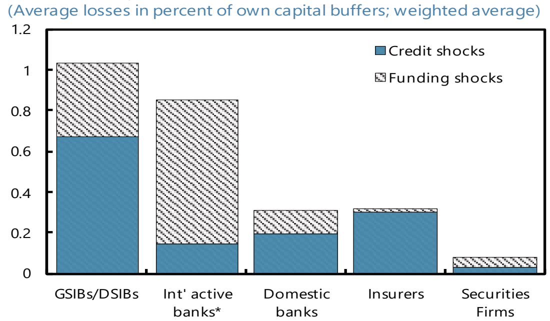
(Total induced losses in percent of system -wide capital buffers)



Average vulnerability to the hypothetical failure of others in the system appears moderate.

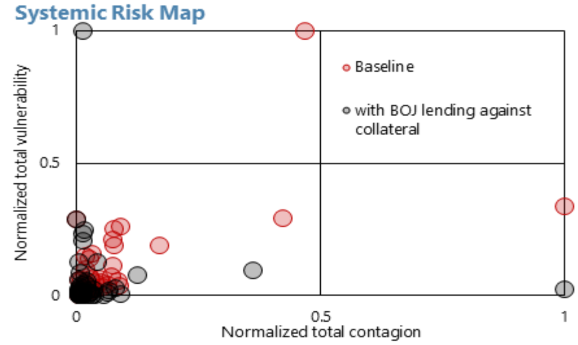
Vulnerability Index

(Average losses in percent of own capital buffers; weighted average)



Systemic contagion risks appear contained, with BOJ liquidity provision reducing such risks further.

Systemic Risk Map



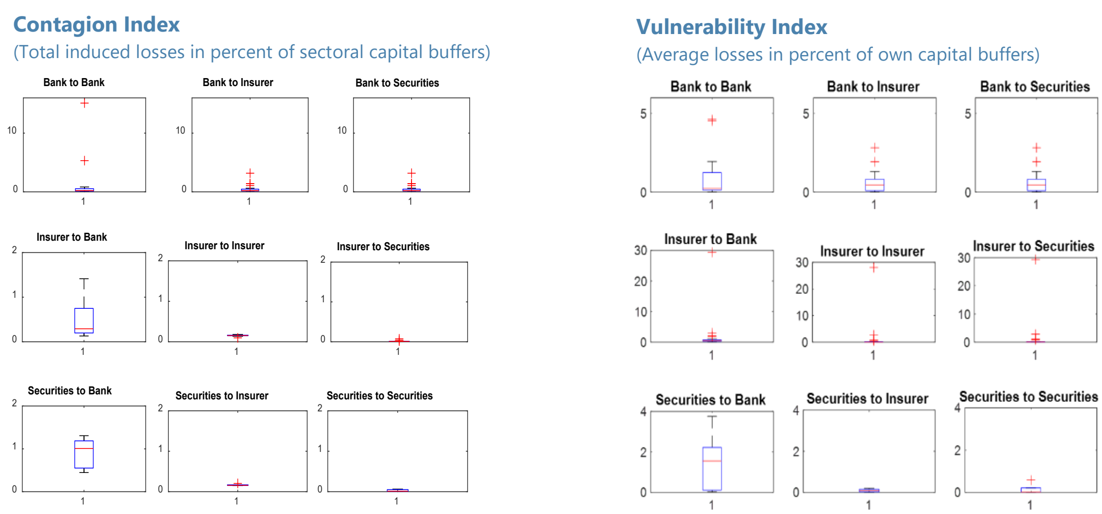
Sources: FSA; and IMF staff calculations.

Notes: In the top-left panel, the colors of the nodes are based on the specific type of financial institution. The network map is based on Fruchterman-Reingold algorithm. Top-right panel shows degree of connectedness (total number of incoming and outgoing linkages as an average or max within each cluster). Contagion index is defined as total system-wide losses induced by a hypothetical failure of financial institutions in each cluster in percent of system-wide capital buffers. Vulnerability index is defined as average loss of financial institutions in each cluster across N-1 simulations in percent of own capital buffer. Systemic risk map, shown in bottom-right panel, plots the average vulnerability of each institution against its contagion potential (computed in absolute JPY terms and normalized between 0 and 1). The grey dots show the computed vulnerability and contagion potential of each institution when taking into account possible BOJ liquidity provision in the face of systemic risks.

156. To further understand the nature of contagion in the network, the potential of individual financial institutions to transmit a shock to other institutions and to receive the shock from others is examined (Figure 70). Banks appear to exert an impact primarily on other banks in the system (than to insurers or securities firms). A shock to a bank can exert losses on other banks that can reach as high as 14 percent of the banking sector capital buffers. The impact of shocks to individual banks on insurers or securities firms appear moderate, mainly due to insurers' and securities firms' large statutory capital buffers. In terms of the vulnerability to receive shocks, financial institutions appear moderately vulnerable to the failure of others. The average loss a bank can face due to individual shocks to other banks reaches close to 5 percent of its own capital buffers. While an insurer appears more vulnerable to the failure of others—with the average loss reaching 30 percent of own capital buffers, the loss is small in JPY terms.

157. Overall, domestic systemic contagion risks due to bilateral on-balance sheet exposures appear limited. Financial institutions are neither highly impactful nor highly vulnerable at the same time, with only a few institutions appearing close to the zone that entails high vulnerability and high impact (Figure 69).[74] Moreover, in the face of a shock, liquidity provision by the BOJ against collateral appears to be helpful in containing systemic contagion risks. These results should, however, be interpreted with caution as they are solely based on bilateral balance sheet exposures, and do not reflect potential changes in market sentiment or valuations in commonly held assets in response to the shocks considered in the analysis.

Figure 70. Japan: Domestic Contagion—Cross-Sectional Distribution of Contagion and Vulnerability



Sources: FSA; and IMF staff calculations.

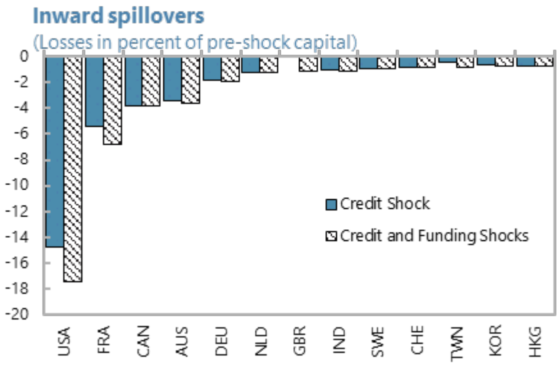
[74] Normalized contagion in the systemic risk map corresponds to total amount of system-wide losses triggered by failure of a financial institution, in absolute yen terms, re-scaled between 0 and 1. Similarly, normalized vulnerability is defined as average losses triggered by failure of other nodes in the system, measured in absolute yen terms, and re-scaled between 0 and 1.

Cross-Border Spillovers

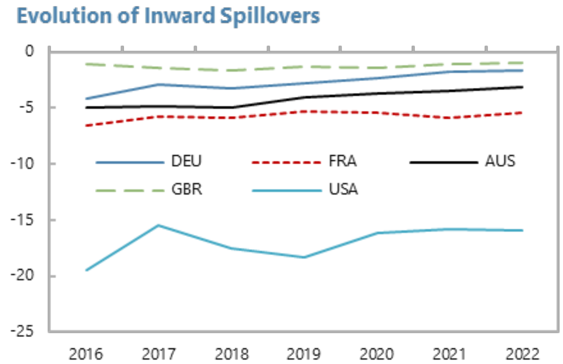
158. Cross-border inward spillovers from a failure of foreign financial institutions could be sizeable, with the strongest impact emanating from the U.S. The capital of Japanese banks would, on average, decline by 17 percent in an assumed scenario where a portion of their claims on U.S. banks had to be written off and moderate funding shortfalls were to occur. Most of the impact, though, stems from the former, in line with Japan's large creditor status. The exposure to French banks and to a lesser extent Canadian banks, also appears to exert notable cross-border inward spillovers. The degree of inward spillovers appears to have been broadly stable over the last decade (Figure 71).

Figure 71. Japan: Cross-Border Spillovers

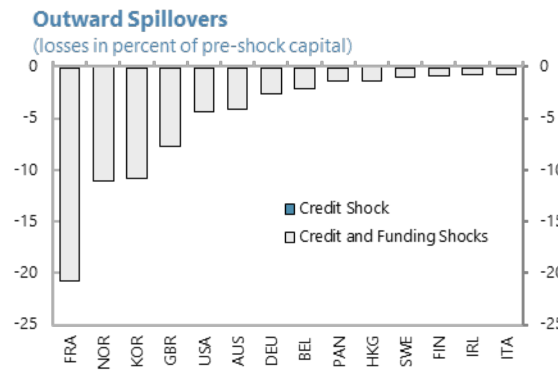
U.S. banks could exert the strongest impact on Japanese banks ...



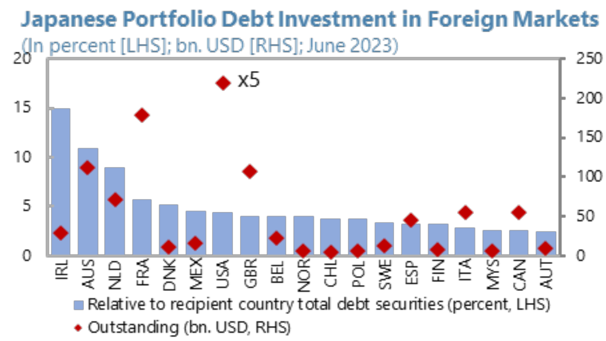
The extent of possible inward spillovers has stayed fairly stable over time.



Japanese banks can induce sizable outward spillovers through counterparty banks facing funding shortfalls ...



... with the geographical distribution aligned with Japan's importance as a creditor for recipient economies.



Sources: BIS Consolidated Banking Statistics (ultimate borrower basis); Bloomberg; Fitch Connect; and IMF staff calculations.
Notes: The model estimates are based on Espinosa-Vega and Sole (2010), with the LGD parameter assumed to be 65 percent, the discount rate 20 percent, and the funding shortfall rate at 35 percent. The inward spillover results are governed primarily by the assumed level of LGD, given Japan's creditor status. Outward spillovers reflect loss of counterparty country banks, in percent of total regulatory Tier 1 capital.

159. Cross-border outward spillovers operate mainly through counterparties' facing funding shortfalls and could also be sizeable. Broadly in line with the geography of Japanese investors' footprint in international debt markets, a sudden and sharp withdrawal of funding by Japanese banks could exert sizeable funding shortfalls for banks in some major economies (Figure

71). However, the overall impact would depend on the extent of liquidity buffers held by the exposed financial institutions of debtor countries.[75]

CLIMATE RISK ANALYSIS

160. The systemic risk assessment included a detailed climate-related transition risk analysis and a high-level physical risk analysis. Transition risks are highly pertinent for Japan given its status as a major carbon emitter and government's plans to reduce greenhouse gas (GHG) emissions to net zero by 2050. Japan is also highly exposed to physical risks (such as floods and tropical cyclone/typhoon) but appears to have a strong capacity to cope with such risks.

A. Climate Transition Risk Analysis

161. Climate-related transition risks are highly relevant for Japan, given its status as one of the world's major carbon emitters. Since the Fukushima nuclear accident in 2011, Japan has mainly relied on fossil fuels as a source of power generation and maintained fossil fuel power generation at levels exceeding 70 percent.[76] Seven emission intensive industries ranging from electricity and gas to basic metal and other non-metallic mineral products collectively contribute to about 80 percent of Japan's total CO_2 emissions (Figure 72).

162. The CO_2 emission intensive sectors hold substantial significance within the Japanese economy. The CO_2 emission intensity, which quantifies the amount of CO_2 released into the atmosphere per unit of output resulting from direct fuel combustion, is a pivotal factor in assessing the impact of mitigation policies on firms' financial performance and the broader macroeconomy. In comparison to its G7 peers, Japan stands out with the second-highest output share of sectors characterized by high emission intensity, trailing behind Canada (Figure 72). Beyond the direct emission-intensive sectors shown in the middle bottom panel of Figure 72, it is essential to consider sectors that rely on emission-intensive inputs throughout their production processes, which are also exposed to transition risks through their supply chains. Together, the direct and indirect emission-intensive sectors represent approximately 13 percent of GDP and account for about 22 percent of total bank loans in Japan. The subsequent analysis thus focuses both on the direct and indirect emission-intensive sectors.

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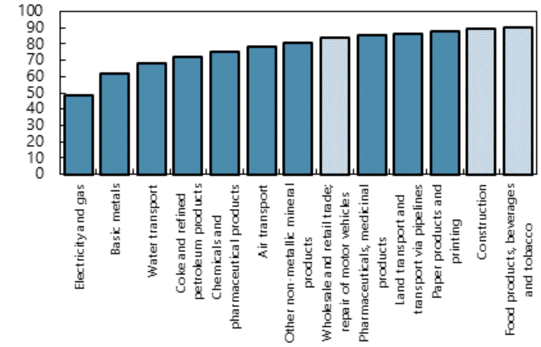
[75] Absolute numbers for outward spillovers should be read with the caveat that the cross-country simulation model employed here does not consider the liquidity buffers of counterparties. Considering such buffers could imply lower losses, as banks facing funding shortfalls, would be able to at least partly absorb the shock.

[76] According to Agency for Natural Resources and Energy in Japan, the share of each source in power generation for 2021 is as follows: LNG (34.4 percent), coal (31.0 percent), oil (7.4 percent), solar (8.3 percent), hydropower (7.5 percent), nuclear (6.9 percent), and others (4.4 percent). The current fossil fuel power generation level (73 percent) is lower than in the year of 2012 when it reached its peak at 89 percent.

Figure 72. Japan: Climate Transition Risk

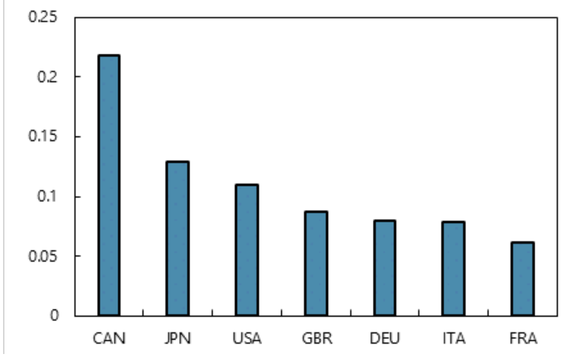
Seven emission intensive sectors account for about 80 percent of total Japanese CO_2 emissions.

Cumulative CO2 Emissions Shares in Total
(In percent)



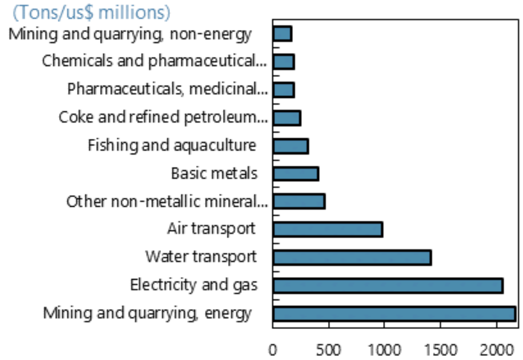
Among G7 countries, Japan stands out with the second-highest output share of sectors with high emission intensity.

Output Shares of Sectors with High Emission Intensity, 2018



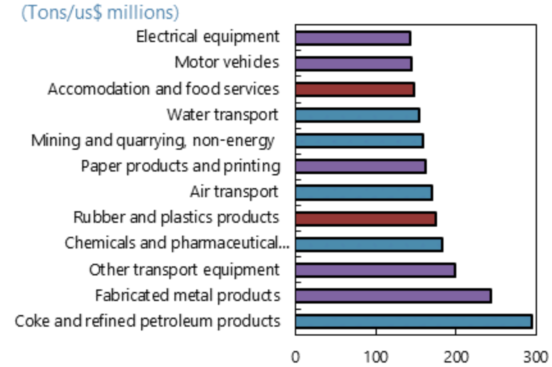
Direct emission intensive sectors include mining and quarrying, electricity and gas, and water transport.

Direct CO2 Emission intensities by Sector
(Tons/us$ millions)



Sectors relying on emission intensive inputs include fabricated metal, transport equipment, and paper products.

Indirect CO2 Emissions Effects by Sector
(Tons/us$ millions)



Sources: Global Carbon Atlas; IMF Climate Change Dashboard (Climate Change Indicators Dashboard (imf.org)); BOJ; and IMF staff calculations.

Notes: Direct emission intensive sectors, or sectors with high emission intensity, are defined as those whose emission intensities fall within the top quantile among those of industries in the G7 countries, encompassing (45×7) sectors. In the top left panel, blue-gray bars represent direct emission intensive sectors, with light blue-gray bars indicating non-emission intensive sectors. In the bottom right panel, blue-gray bars denote sectors that are also assessed as directly emission intensive. The remaining bars refer to sectors that depend on emission-intensive inputs downstream, with the purple bars being distinctly considered in the subsequent analyses.

163. **The government of Japan has pledged to substantially reduce greenhouse gas emissions in the coming decade.** In accordance with the United Nations Climate Change Convention, Japan has set an interim target to reduce GHG emissions by 46 percent from 2013 levels by 2030, with an objective of achieving net-zero GHG emissions by 2050. To realize this ambitious goal, Japan enacted the Green Transformation Promotion Act in May 2023 and laid out, based on the law, a comprehensive strategy to facilitate the transition to a green economy. This strategy emphasizes an upfront investment of JPY 20 trillion over the next decade in decarbonization initiatives, to be largely funded through the issuance of Japan Climate Transition

Bonds, along with plans to introduce a carbon levy on fossil fuel supplies from FY2028.[77] Considering Japan's aspirational target of achieving net-zero emissions by 2050 as well as the current low effective carbon rates, a notable increase in carbon tax rates may be needed to align with its objective.[78]

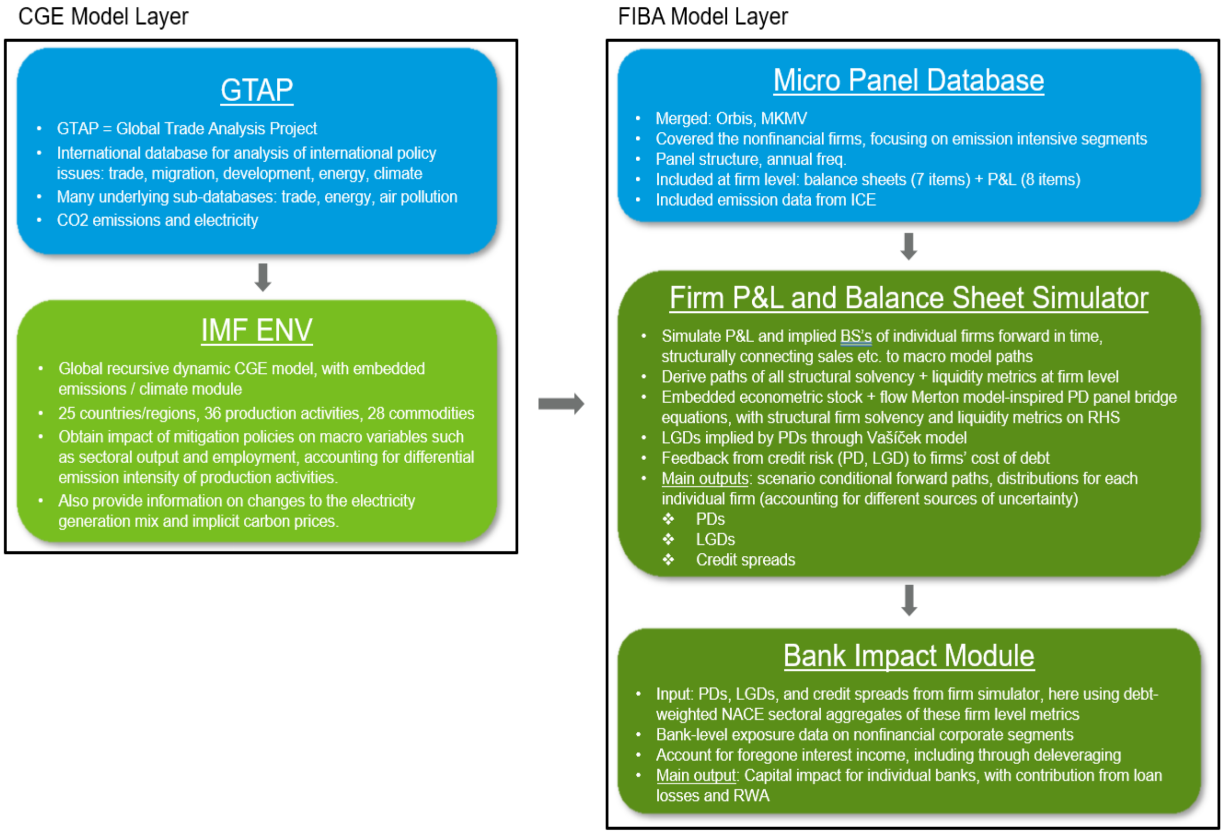
164. Against this backdrop, climate-related transition risks in Japan were assessed through scenario-based analyses. An integrated micro-macro simulation model, with transition risk focus, has been employed as a backbone for the analysis. This model framework, illustrated in Figure 73, entails linking a multi-country, multi-sectoral computational general equilibrium (CGE) model with a micro simulation layer for firms and banks. As the first layer of this framework, the IMF-ENV model—a global CGE model operated by the IMF's Research Department—is used to derive scenario-conditional paths for macroeconomic and sectoral variables, including carbon taxes, tailored to Japan's trajectory up to 2040. The micro simulation layer is technically connected to the CGE model to project financial flow variables, such as profits and losses, and the subsequent balance sheet dynamics of both firms and banks in the future, all contingent upon the climate risk scenarios under consideration. This micro simulation layer encompasses approximately 271,000 nonfinancial firms from Japan, with a particular focus on those operating within emission-intensive sectors. In addition to this extensive firm sample, the bank module comprises 22 banks, all of which are covered in the bank solvency stress test.[79] This comprehensive approach has allowed for a nuanced understanding of the potential impacts of climate-related transition risks on Japan's economy and financial sector.

[77] In addition to the carbon levy, Japan is set to implement the emissions trading system in high-emission industries starting from FY2026. The allowance auctioning to power generation companies is planned to be gradually phased in from FY2033.

[78] Japan implemented a carbon tax on fossil fuels, known as the Tax for Climate Change Mitigation, in 2012. Currently, the tax is set at JPY 289 (approximately $2) per ton of CO2 equivalent, with certain exemptions granted for competitive reasons. In comparison to its G7 peers, Japan's effective carbon price level is the second lowest, following the United States, according to OECD (2021).

[79] One bank, included in the bank solvency stress test, was excluded due to the absence of its portfolios in emission-intensive sectors.

Figure 73. Japan: Transition Risk Analysis Framework



Source: Gross, M., Yoo, J., Barrail, Z., Dehmej, S., Saxegaard, M., and Sheldon, H. "The IMF Environment-Firm and Bank (ENV-FIBA) Model Framework for Climate Risk Analysis—Conceptual Framework, Model Details, and Guide," forthcoming.

Climate Policy Macro Scenarios

165. The scenarios align with those set forth by the Network for Greening the Financial System (NGFS) Phase IV scenarios, which are comparable to the scenarios by the Intergovernmental Panel on Climate Change (IPCC). The scenarios are anchored in the NGFS scenarios' emission and temperature paths and expected benefits of mitigation policies in the form of a reduction in GDP losses due to chronic physical risks (Box 2). Three focal scenarios are employed for the analysis, as shown in Figure 74: (1) Net Zero 2050 (NZ), (2) Fragmented World (FW), and (3) Current Policies (CP). Under the NZ, global warming is limited to 1.5°C above pre-industrial levels through stringent climate mitigation policies and innovation, achieving global net-zero CO_2 emissions by around 2050. The CP maintains only currently implemented policies, resulting in high physical risks. In the FW, there is a delayed and divergent climate policy response among countries globally, leading to high physical and transition risks. Specifically, currently implemented policies are to be maintained until 2030 (delayed transition); thereafter, countries with net-zero targets achieve an 80 percent reduction only by 2050, while others continue with current policies (divergent transition). The CP serves as the "reference" scenario, relative to which the impacts of the other two scenarios will be presented.

166. The carbon price paths have been derived from the CGE model, conditional on the emission and temperature targets that are to be achieved. The model operates under the premise of maintaining fiscal income-expense balances neutral: any revenues generated from carbon taxes must be offset either by increased government expenditures, reduced taxes in other areas, or a combination of both. Two approaches for recycling carbon tax revenues within the CGE model were considered: In the first approach (Rule 1), all generated revenues are transferred to households, while in the second approach (Rule 2), half of the revenues are allocated to feed-in tariffs for the renewable energy sector, with the remaining half directed towards households as transfers. This second rule aims to emulate a crucial component of the Government of Japan's Green Transformation (GX) policy. The analysis reveals that required carbon tax rates are lower when applying Rule 2 as compared to Rule 1 (Figure 74).

167. In terms of the macroeconomic impact by 2040, the NZ scenario exhibits slightly larger adverse effects compared to the FW scenario, though Rule 2 helps to mitigate some of the negative repercussions. The impact on employment remains relatively subdued in the NZ scenario (Figure 74). When analyzing sectoral impacts, significant variations in Gross Value Added (GVA) are observed, primarily contingent on the sectors' direct emission intensity and inter-industry linkages (Figure 75). Relative to the CP scenario, emission intensive sectors, such as natural gas, petroleum and coal, chemical products, iron and steel, and air transport, experience a large decline in GVA. By contrast, the electricity sector on the whole thrives, yet it displays notably diverse outcomes among its sub-sectors. While coal and gas power see a reduction in GVA, renewable energy sources experience growth. Labor costs exhibit a similar, albeit less pronounced, degree of variation when compared to GVA.

168. To guide the subsequent micro simulation, the focus centers on scenario-specific sectoral variables that encompass inter-industry relationships and price adjustments stemming from carbon taxes. Sectoral output, intermediate input, and GVA exhibit synchronized impacts, but their magnitudes differ across sectors (Figure 75). In certain sectors such as land transport and business services, output (accounting for both real and price effects) displays positive growth relative to the CP scenario, but GVAs decline due to a more pronounced increase in intermediate input. Within the micro module, different sectoral metrics such as output, GVAs, labor costs, and emissions are relied upon to guide and inform the simulation.

Box 2. Japan: IMF-ENV Model and Climate Macro Scenarios

- The IMF-ENV model is a global recursive dynamic computable general equilibrium (CGE) model operated by the IMF's Research Department. Dynamic CGE models are well suited for the analysis of structural change and sectoral impacts that result from energy and climate shocks and policies. The model allows simulating impacts on energy demand and supply, greenhouse gas (GHG), macroeconomic variables, sectoral outcomes, and trade. The model entails an optimization of consumption and production decisions by households and firms and deals mainly with real values and with almost perfectly competitive markets for commodities and production factors (labor, capital, land). However, an important feature of IMF-ENV is that capital stocks have vintages such that firms' production and behavior are different in the short and long run.

- The model describes how economic activities and agents are inter-linked across economic sectors and countries or regions. Production follows a series of nested constant-elasticity-of-substitution (CES) functions to capture the different substitutability across all inputs. International trade is modeled using the Armington specification that posits that demand for goods is differentiated by region of origin. The model also links economic activity to environmental outcomes, specifically to the emission of greenhouses gases and other pollutants.

- The model is built primarily on a database of input-output (I-O) tables, combined with national accounts and bilateral trade flows. The central input of the model is the GTAP 10 Power database that contains country-specific I-O tables for 141 countries and 65 commodities and real macro flows. The current version of the model employs 36 activities, 28 sectors and 26 country/regions. These include all G20 countries and 5 aggregated regions (Latin America, Eurasia, Asia, Africa, and other oil exporting countries). Electricity generation is separated into 8 power sources: coal, natural gas, oil (diesel), hydro, nuclear, solar, wind and others (e.g., geothermal, biomass).

- For this analysis, the model initially generates the NFGS Current Policies scenario by utilizing IMF projections of key macroeconomic variables (real GDP, current account balance, government budget and labor supply), as well as NGFS projections for overall GHG emissions and electricity generation by power source under the CP scenario. For the alternative scenarios—namely, the Net Zero 2050 and Fragmented World—the model endogenously estimates the overall carbon tax paths that achieve the greenhouse gas emission paths for each NGFS scenario. In the context of the NZ scenario, a degree of progress in green technology development is assumed, which includes an increase in the penetration of electric vehicles and the expectation that carbon capture technology contributes approximately 18 percent of the total emission reductions, amounting to 536 million tons.

- Reduced GDP losses from chronic physical risk is incorporated via the adjustments in overall Total Factor Productivity growth. The CP scenario accounts for the macro impact of the estimated chronic physical risk from NGFS, which represents a reduction of GDP levels of 2.7 percent by 2040. The alternative scenarios include reduced values, which reflect the lower risks when global mitigation policies are implemented. These are negligible for the FW scenario but represent a reduction of around 25 percent of the risks for the NZ scenario (or a 0.7 percent higher GDP level in 2040 with respect to the CP scenario).

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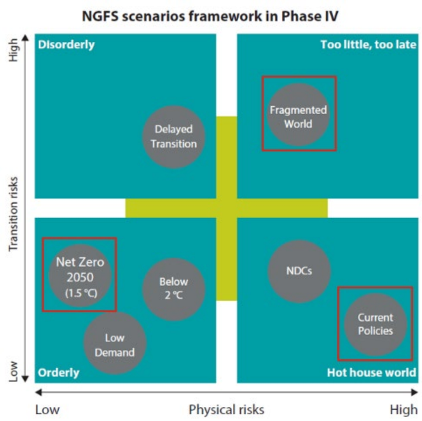
1 Chateau, J., Rojas-Romagosa, H., Thube, S. (2024), The IMF-ENV model: A technical overview. Version 1.01. Research Department, International Monetary Fund. forthcoming.

Figure 74. Japan: Macro Scenarios

Three focal NGFS scenarios are employed…

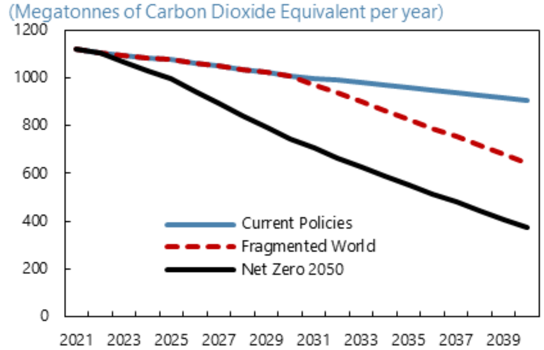
NGFS Scenarios Framework in Phase IV



Total emissions in Net Zero 2050 and Fragmented World are 60% and 30% lower by 2040, respectively, compared to Current Policies. Mitigation efforts in Fragmented World are designed to start from 2031.

Japan: GHS Emission Paths by Scenario

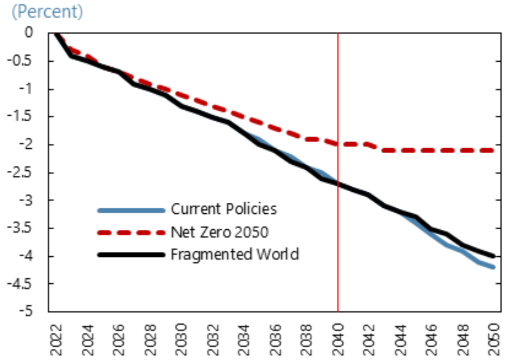
(Megatonnes of Carbon Dioxide Equivalent per year)



GDP losses from chronic physical risk is incorporated via the adjustments in overall Total Factor Productivity growth. The benefit of the orderly transition is getting increasingly larger after 2040.

GDP Losses from Chronic Physical Risks

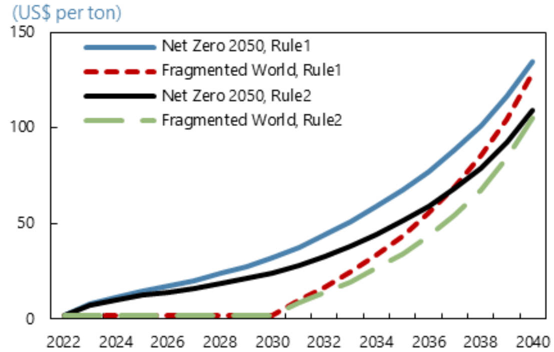
(Percent)



Carbon tax rates are lower in Rule 2, with half of the revenues going to feed-in tariffs for the renewable sector and half to households, compared to Rule 1, where all revenues are transferred to households.

Japan: Carbon Tax Paths by Scenario

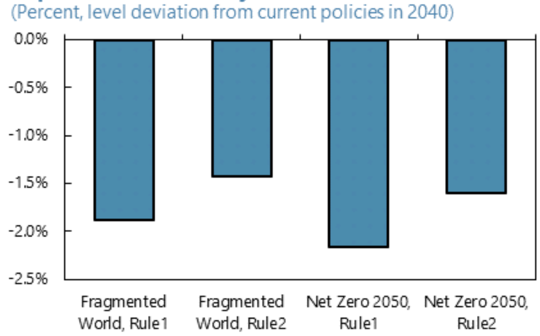
(US$ per ton)



Macro impacts by 2040 are somewhat greater under Net Zero 2050 compared to Fragmented World. Under Rule 2, negative impacts are mitigated.

Impacts on Real GDP by Scenario

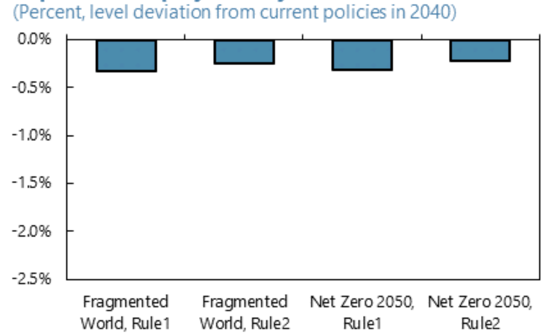
(Percent, level deviation from current policies in 2040)



The influence on employment remains relatively subdued.

Impacts on Employment by Scenario

(Percent, level deviation from current policies in 2040)



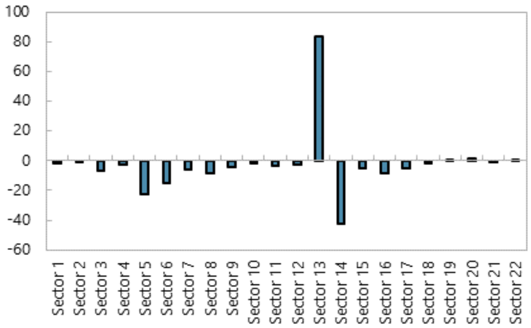
Sources: NGFS; and IMF staff calculation.

Note: In the topmost left hand side chart, positioning of scenarios is approximate, based on an assessment of physical and transition risk out to 2100.

Figure 75. Japan: Sectoral Impacts Under Net Zero 2050 vs. the Current Policies Scenario

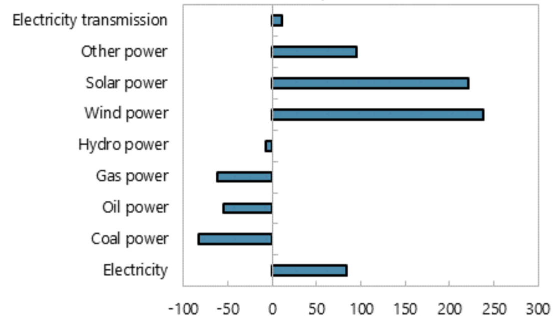
Sectoral GVA impacts vary based on sectors' emission intensity as well as inter-industry linkages, among others.

Impacts on Sectoral Real GVAs
(Percent, level deviation from current policies in 2040)



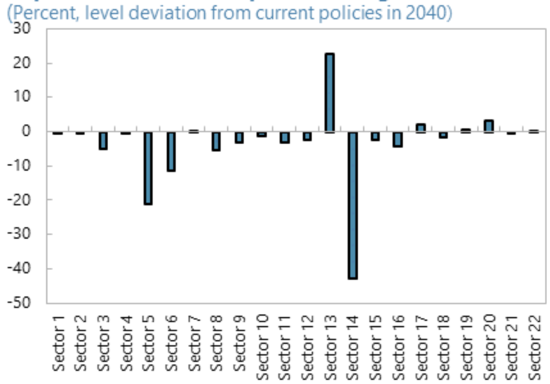
The electricity sector thrives overall, yet outcomes vary across sub-sectors.

Impacts on Real GVAs in the Electricity Sector
(Percent, level deviation from current policies in 2040)



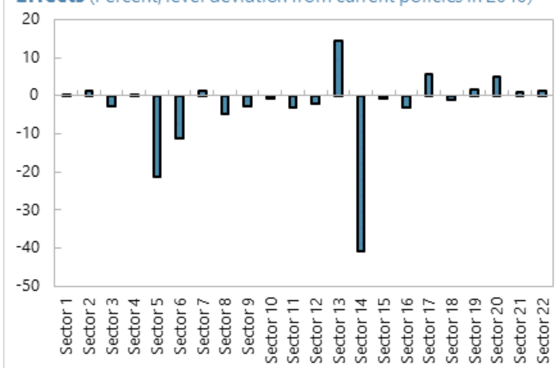
Sectoral output, intermediate input, and GVAs exhibit broadly synchronized impacts…

Impacts on Sectoral Output, including Price Effects
(Percent, level deviation from current policies in 2040)



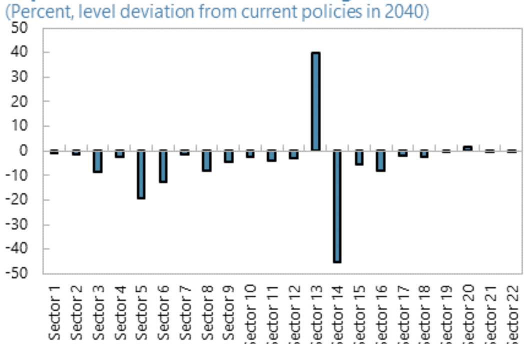
But their magnitudes are different across various sectors.

Impacts on Sectoral Intermediate Input, including Price Effects (Percent, level deviation from current policies in 2040)



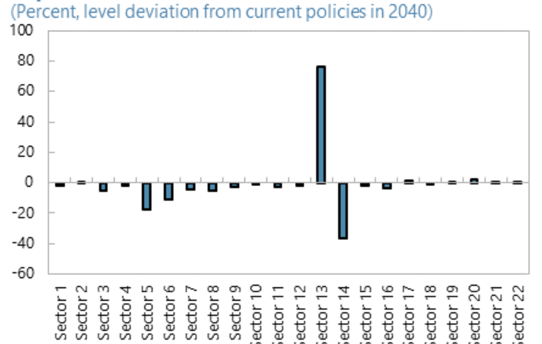
In certain sectors, output and GVAs move in opposite directions due to a larger increase in intermediate inputs.

Impacts on Sectoral GVAs, including Price Effects
(Percent, level deviation from current policies in 2040)



Labor costs exhibit a similar degree of variation to GVAs, albeit with a less pronounced response.

Impacts on Labor Costs
(Percent, level deviation from current policies in 2040)



Sources: NGFS; and IMF staff calculation

Note: A mapping table for sectors used in the macro and firm-level micro simulations is as follows:

Sector 1	Agriculture	**Sector 9**	Non-ferrous metals	**Sector 16**	Air Transport
Sector 2	Fisheries	**Sector 10**	Fabricated metal products	**Sector 17**	Land transport
Sector 3	Mining and quarrying	**Sector 11**	Electronic equipment	**Sector 18**	Other manufacturing
Sector 4	Paper products	**Sector 12**	Transport equipment	**Sector 19**	Construction
Sector 5	Petroleum and coal	**Sector 13**	Electricity	**Sector 20**	Water supply
Sector 6	Chemical products	**Sector 14**	Natural gas	**Sector 21**	Collective services
Sector 7	Non-metallic minerals	**Sector 15**	Water Transport	**Sector 22**	Business services
Sector 8	Iron and steels				

FIBA Model Layer—Firm Module

169. The firm module relies on three key sources of micro data, with the primary source being Japanese firms balance sheets and income statements from Moody's/Orbis. This dataset spans the period 2005-2023, and features a panel structure, encompassing between 150,000 to 280,000 firms annually (Table 8). A "no double counting" principle was employed when dealing with the consolidation level of nonfinancial firms. This means that firms were included at the highest consolidation level, while excluding lower-level subsidiaries if their parent companies from Japan were incorporated in the database. The firm sample is defined based on a range of balance sheet and profit and loss flow metrics (Table 9). Additional details regarding the compilation of the micro data are available in Appendix III.

170. To mitigate potential distortions caused by the pandemic in the model simulations, a "T0" database was constructed that contains pre-pandemic data for flow variables, such as revenues, and the latest data for stock variables such as total assets. The "T0" database serves as the initial "anchor" for the microsimulation. The emission-intensive sectors represent 5.6 percent of the total number of firms, yet they constitute a significant portion, accounting for 42 percent of total assets and 26 percent of total sales within the firm sample. According to the Japan Industrial Productivity database, these sectors comprise 13.4 percent of the total GVA.

171. The second data source involves PD data from Moody's KMV, covering approximately 1,900 listed Japanese firms from 2005 to 2020. Daily PD data were converted to yearly averages for each firm, while accounting for the time shift in individual firms' financial reporting. Subsequently, the PDs were merged with the Moody's/Orbis dataset and were employed in the estimation of a firm-fixed effects panel model. For the majority of unlisted firms that lack PD data, their historical PDs were imputed using the estimated model based on the listed firms.

172. Scope 1 emissions data was obtained from Intercontinental Exchange (ICE) to account for direct emission costs within the FIBA module. The ICE dataset includes firm-level reported emission intensities, measured in ton CO_2/USD million revenue, including about 360 Japanese firms. For firms lacking reported emission data, industry-average values for NACE Level 4 industries in the Asia-Pacific region were used, as also sourced from ICE.[80] The data reveal considerable variation among several sub-industries, such as mining (3) and non-metallic minerals (7), as illustrated in Figure 76.

[80] A comparative exercise was conducted between the industry-average emission intensity of ICE and 45-sector emission intensity data for Japan, obtained from the IMF Climate Change Dashboard. The median emission intensity was selected from sub-industries corresponding to each of the 45 sectors. The results showed a significant degree of correlation, with a correlation coefficient of 75 percent excluding electricity and gas sector.

Table 8. Japan: Firm Micro Data for the FIBA Model Layer at the Outset (T0)

#	Sector classification		Number of firms per segment (T0)		Total assets per segment (T0), US$ bn		Annual sales per segment (T0), US$ bn		Total sectoral GVA in 2021 (macro stats), Yen bn	
			abs.	% of total	abs.	% of total	abs.	% of total	abs.	% of total
1	Agriculture	A1-2	1,276	0.5%	12	0%	12	0%	5,039	0.9%
2	Fishing and aquaculture	A3	68	0.0%	2	0%	3	0%	637	0.1%
3	Mining and quarrying	B	307	0.1%	93	1%	25	0%	368	0.1%
4	Manufacture of paper and paper products	C17-18	2,078	0.8%	133	1%	121	1%	4,746	0.9%
5	Manufacture of petroleum and coal products	C19	174	0.1%	154	1%	212	2%	6,877	1.3%
6	Manufacture of chemical products	C20-21	1,402	0.5%	786	7%	495	4%	11,834	2.2%
7	Manufacture of non-metallic mineral products	C23	1,569	0.6%	102	1%	81	1%	3,237	0.6%
8	Manufacture of iron and steels	C24_1	734	0.3%	241	2%	206	2%	7,549	1.4%
9	Manufacture non-ferrous metals	C24_2	379	0.1%	68	1%	58	0%	2,490	0.5%
10	Manufacture of fabricated metal products	C25	5,587	2.1%	150	1%	161	1%	5,141	0.9%
11	Manufacture of electronic equipment	C26_1	1,283	0.5%	672	6%	455	4%	8,465	1.5%
12	Manufacture of transport equipment	C29-30	993	0.4%	1,355	13%	1,001	8%	13,456	2.5%
13	Electricity	D351	347	0.1%	559	5%	297	2%	5,950	1.1%
14	Manufacture and distribution of gas	D352	98	0.0%	67	1%	44	0%	884	0.2%
15	Water transport	H50	192	0.1%	90	1%	54	0%	1,346	0.2%
16	Air transport	H51	33	0.0%	28	0%	21	0%	473	0.1%
17	Land transport	H49	5,907	2.2%	474	4%	289	2%	19,314	3.5%
18	Other manufacturing	C-1	31,320	11.6%	1,724	16%	1,569	13%	48,906	8.9%
19	Construction	F	106,828	39.4%	797	7%	853	7%	18,812	3.4%
20	Water supply	E	2,470	0.9%	26	0%	20	0%	8,332	1.5%
21	Collective services	S1	4,735	1.7%	145	1%	125	1%	66,799	12.2%
22	Business services	S2	103,335	38.1%	4,563	43%	4,616	38%	252,826	46.2%
	Total		271,115	100%	10,720	100%	12,239	100%	493,482	90.1%

Sources: Moody's/Orbis; Japan Industrial Productivity database; IMF Climate Dashboard; and IMF staff calculations.
Notes: 1) The total GVA shares in this table refer to aggregate, industry-wide statistics. All others are based on the firm micro data. 2) Direct emission intensive sectors are colored in orange, and sectors that depends more on inputs from emission intensive upstream industries in light orange. The classification of sectors is based on the analysis of sector-level emission intensities mentioned in a note of Figure 72.

Table 9. Japan: Micro-Level Variables Relevant for the FIBA Model Layer

Firm Balance Sheets

Variable	Moody's/Orbis variable name
Total assets	Total assets
o/w cash and cash equivalent	Cash_and_cash_equivalent
o/w non-cash assets	Non-cash assets
o/w current assets excl.cash	Current assets excl. cash
Total liabilities	
o/w non-current liabilities	Non_current_liabilities
o/w long-term debt	Long_term_debt
o/w other non-current liabilities	Other_non_current_liabilities
o/w current liabilities	Current_liabilities
o/w loans	Loans
o/w creditors	Creditors
o/w other current liabilities	Other_current_liabilities
Shareholder funds	Shareholders_funds
o/w capital	Capital
o/w other shareholder funds	Other_shareholders_funds
Number of employees	Number_of_employees

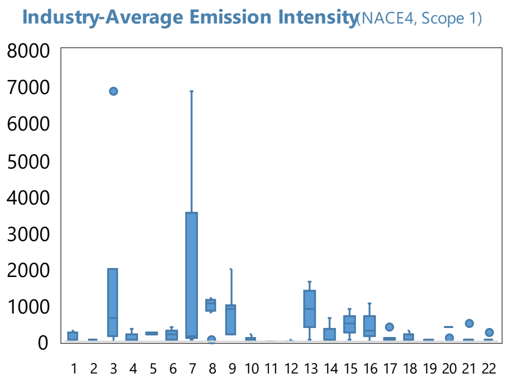
Firm P&L Flows

Variable	Moody's/Orbis variable name
Sales revenue [A]	Operating_revenue_Turnover
Operating expenses [B = C+D]	
o/w Costs of goods sold [C]	Costs_of_goods_sold
Other operating expenses [D]	Other_operating_expenses
o/w Costs of employees [E]	Costs_of_employees
Rest of operating expenses [F = B-E]	
EBIT [A-B]	Operating_P_L_EBIT
Financial revenue [G]	Financial_revenue
Financial expense [H]	Financial_expense
o/w interest expense	Interest_paid
Net profit after net fin. Income, before tax [EBT=EBIT+G-H]	P_L_before_tax
Tax [I]	Taxation
Net profit after tax [P=EBT-I]	P_L_after_tax

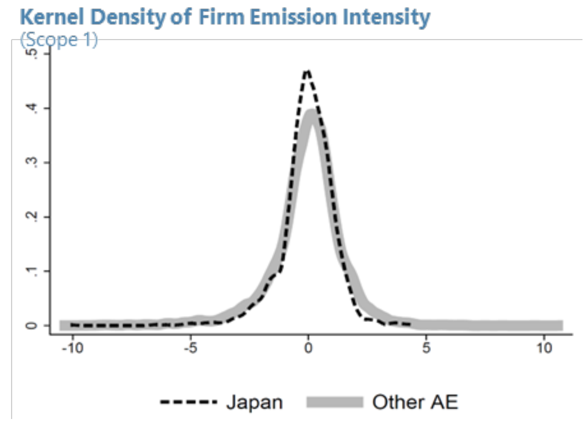
Sources: Moody's/Orbis; and IMF staff.
Notes: The variables in light grey are not effectively needed as input to the FIBA model layer but shown for completeness to include information on the remaining "of-which" categories. In the P&L category, the grey items are those that do not need to be obtained from the micro database as they can be computed from the other items. Various additional details regarding the firm-level data, the data cleaning process, etc. are provided in Appendix II.

Figure 76. Japan: Data on Emission Intensity

There is a considerable variation in industry-mean emission intensity...



Large heterogeneity in firms' emission intensity is observed within a certain industry...



Sources: ICE; Capelle and others (2023); and IMF staff calculations.
Notes: The left chart shows industry-average emission intensities for NACE level 4 industries in the Asia-Pacific region. Please refer to the mapping table for sector numbers in the note of Figure 75. In the right chart, emission intensity is measured as the log of emissions over revenues, and residuals are extracted after controlling for industry × year fixed effects.

173. The firm P&L modeling comprises several structural sub-components, notably the linkage between the IMF-ENV model's sectoral variables and corresponding firm-level variables, as outlined in Table 10. Firms' sales revenues are modeled to move proportionally with output growth for the sector that firms belong to. Projections for cost of employees are linked to growth of sectoral labor income that is computed by multiplying sectoral employment and equilibrium wage. Operating expenses net of cost of employees are linked to sectoral intermediate input, which can be obtained by subtracting GVA from output. Further, the direct costs associated with a firm's Scope 1 emissions was reflected in the calculation of its earnings. It was assumed that a firm's CO2 emissions, the multiplication of its emission intensity and sales revenues, move along with the sectoral emission path.

174. Income tax expense flows during the simulation are computed based on net income before tax using the industry-specific relevant rates. The tax rates are informed by the micro data themselves (Figure 77) and applied when earnings before tax for any given firm and per time period along the simulation horizon are positive. When firms' pre-tax earnings are negative, they do not pay taxes. Tax credits are not considered.

175. The model framework delineates two primary channels through which an increase in carbon prices influences firms' profitability. Firstly, carbon taxes impact firms by inducing changes in sectoral variables that are linked to corresponding firm-level variables, representing the macro channel. Secondly, carbon taxes directly affect firms' profitability through direct emission costs incurred on firms, constituting the micro channel.

Table 10. Japan: Firm P&L Modeling–Overview

P&L Component		Model Approach
Sales revenue [A]		Align with output projections from the IMF ENV
Operating expenses [B=C+D=E+F]		E + F
	Costs of goods sold [C] Other operating expenses [D]	
	Costs of Employees [E]	Align with labor cost projections from the IMF ENV
	Rest of operating expenses [F=B-E]	Align with intermediate input projections from the IMF ENV
Financial revenue [G]		Moving proportionally with sales revenue
Financial expense (interest paid) [H]		Credit spread moving endogenously as function of firm specific PD and LGD
Tax expense [I]		Ratio of tax to EBT constant, zero for firms in periods when EBT<0

EBIT = = [A] – [B] - *Direct emissions costs (a firm's emission (scope1) × carbon price)*

EBT = Earnings after net financial income and before tax = EBIT + [G] - [H]

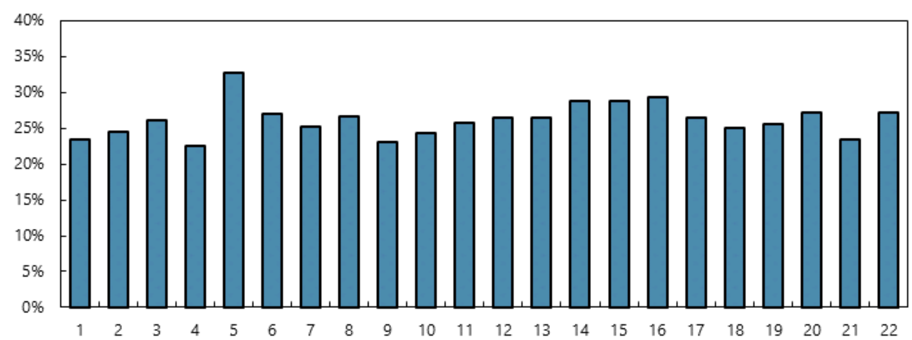
NI = Earnings after net financial income and tax = EBT - [I]

ICR = EBIT / [H]

$$NI_{fh} = rev_{fh} - oe_{fh} + fi_{fh} - ie_{fh} - tax_{fh}$$

Source: IMF staff.

Figure 77. Japan: Corporate Tax Rates Across Firm Industries



Sources: Moody's/Orbis; and IMF staff calculations.
Notes: The tax rates were computed as the sum of all firms' tax expenses over the sum of their earnings before tax at T0. Please refer to the mapping table for sector numbers in the note of Figure 75.

176. To address the uncertainty surrounding individual firm emissions, a Monte Carlo simulation module for simulating the firms' partially unobserved emissions was included in the model. Capelle and others (2023) find that the variation in emission intensities among firms within the same industries is remarkably significant, comparable to or even exceeding the heterogeneity observed in other measures of firms' performance such as total factor and labor productivity. The right chart in Figure 76 presents the distribution of residuals in firm emission intensity (represented as the logarithm of CO_2 emissions over revenues in megatons per million USD) after accounting for industry-year fixed effects, separately for firms headquartered in Japan and other advanced economies (AEs). Despite Japanese firms emitting less than their counterparts in AEs, a substantial variation in emission intensities can be observed within Japan and other AEs. In the case of Japan, the 75th and 90th percentiles of "residualized" emission intensities are about 2 and 3 times greater than the median in the sample, highlighting the significant uncertainty surrounding individual firms' emissions. Given this, a Monte Carlo simulation module was embedded in the model, based on the estimated Kernel density of firm emission intensity within a certain industry, alongside the average emission intensity for industries from ICE. The impact of the uncertainty surrounding the emission intensity on individual firm risk metrics will be assessed based on the 50th, 75th, and 90th percentiles, respectively.

177. **The dynamics of the firms' implied balance sheets are primarily determined by their periodic post-tax profits.** These profits are added to firms' cash and cash equivalents, as well as to their total assets. However, in case a firm's cash holdings fall into negative territory, an adjustment is considered by adding an amount equivalent to the shortfall to the firm's short-term debt. The implicit assumption throughout the simulation is that the value of nonfinancial assets remains constant, and outstanding debt is continuously rolled over.

178. **The PD model component is designed to establish a link between various evolving solvency and liquidity metrics over the simulation horizon and the likelihood of firms defaulting.** This PD model is structured as a firm-fixed effects panel econometric equation, featuring logit-transformed firm-level PDs on the left-hand side.[81]

$$logit\left(PD_{ft}\right) = \alpha_f + \beta LEV_{ft} + \gamma ICR_{ft} + \delta EBITR_{ft} + \theta CDR_{ft} + \varepsilon_{ft}\ .$$

On the right-hand side, a set of variables is utilized to reflect the rationale of a stock and flow-oriented Merton model: the stock-stock leverage ratio (*LEV*), defined as the sum of short-term debt and half of long-term debt divided by total assets, plays a crucial role in assessing firms' solvency conditions in the conventional Merton model framework; the interest coverage ratio (*ICR*), defined as EBIT (Earnings Before Interest and Taxes) over interest expense, relates to flow-type Merton models, capturing firms' short-term liquidity conditions; the EBIT/assets ratio (*EBITR*) represents a blend of both stock and flow aspects, capturing various facets of firms' financial health; the cash/short-term debt metric (*CDR*), being a stock-stock ratio, provides valuable information about firms' short-term liquidity coverage capacity. Additional macrofinancial variables on the right-hand side of the PD equation were not included because they feed structurally through the other regressors in the model.

179. **The PD equation was estimated using pre-pandemic data (2005-2019) for listed firms, and the estimates suggest a quantitatively prominent role for leverage.** The coefficient estimates (Table 11) are all statistically significant and their signs are as expected from a theoretical perspective. An increase in leverage implies a rise in PDs, while an increase in the ICR, EBITR and CDR implies a decline in PDs. The normalized coefficient for leverage, normalized by its standard deviation, is about twice as large as the normalized coefficients for all other regressors combined.

---

[81] The logit transformation: $logit(PD) = \ln(PD/(1-PD))$. The inverse calculation to undo the logit is the sigmoid function: $logit^{-1}(x) = e^x/(e^x+1)$. This transformation scheme guarantees that the predicted default rates remain within the [0-1] interval.

180. When embedding the PD equation in the FIBA module, an intercept adjustment was implemented for anchoring the model-implied firm PDs. For unlisted firms that were not part of the PD model estimation sample, industry -averages of the estimated firm fixed effects were used. Subsequently, the historical PDs and, based on those, the through-the-cycle (TTC) PDs as long-term averages of the PiT PDs could be computed for all unlisted firms.

181. The modeling of LGDs and credit spreads closely mirrors the approach used for the corporate sector risk analysis. The LGD model component is essential for computing credit spreads endogenously and serves as a necessary input for assessing the impact on bank capitalization. Credit spreads are calculated at the firm level throughout the simulation based on a loan pricing formula, allowing to capture the feedback loop between firms' credit risk and the cost of their debt.

Table 11. Japan: Estimation Results for the PD Equation

	(1) *logit* (PD)
LEV	3.534***
	(.0917)
ICR	-0.01***
	(0.0002)
EBITR	-0.791***
	(.1568)
CDR	-0.016***
	(.0037)
_cons	-6.031***
	(.0327)
Observations	26,793
Within R^2	.173

Sources: MKMV and IMF staff calculations.
Notes: Standard errors are in parentheses *** p<.01, ** p<.05, * p<.1. ICR, EBITR, and CDR are winsorized at 5 (95) percent, while LEV is winsorized at one.

182. Following the scenario-based simulations for firms, aggregate firm credit risk indicators were computed, including debt-weighted PDs, LGDs, and credit spreads. This aggregation results in industry-level risk indicators, which are then utilized as inputs into the bank module.

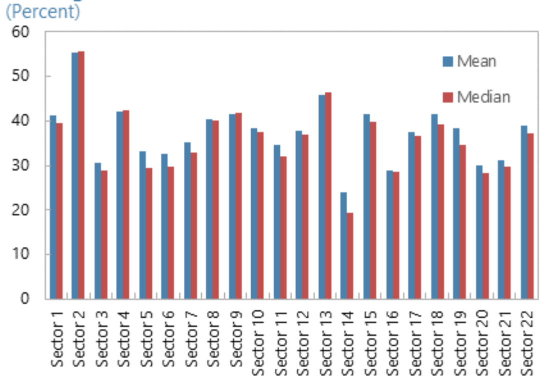
183. Notable heterogeneity exists in the initial (pre-simulation) solvency and liquidity metrics for Japanese firms (Figure 78). Sectors such as fishery (2), electricity (13), iron and steel (8), other manufacturing (18), and business services (22) exhibit high levels of leverage at the outset, while gas (14), mining and quarrying (3), and chemical products (6) appear to be among the least leveraged. In terms of the ICR, many sectors demonstrate sufficient earnings to cover interest payments, but there are some exceptions such as electricity (13), water transport (15), paper products (4), and fishery (2). In case of the EBIT to total asset ratio (EBITR), the weakest sectors include agriculture (1), water transport (15), paper products (4), and collective services (21). Regarding the cash debt metric, sectors such as iron and steel (8), non-ferrous metals (9), and paper products (4) appear to have weaker initial positions.

184. Reflecting the four aforementioned risk metrics, Japanese firms' PD values at the outset exhibit significant variation both across sectors and within sectors. Among emission-intensive sectors, non-metallic minerals (7), iron and steel (8), non-ferrous metals (9), fabricated metal products (10), electronic equipment (11), and water transport (15), exhibit relatively high initial PDs. Similarly, among non-emission-intensive sectors, water supply (20) and services (21-22) appear to face elevated PDs at the outset. Substantial variations in initial PDs are observed within certain industries.

Figure 78. Japan: Firms' Risk Characteristics and Initial PDs

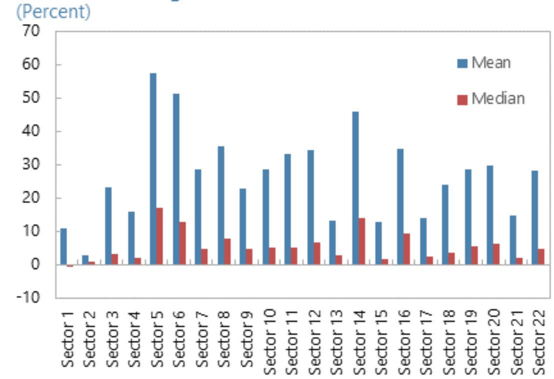
Firms in fishery, electricity, iron and steel, other manufacturing, and business services generally exhibit higher levels of leverage…

Leverage
(Percent)



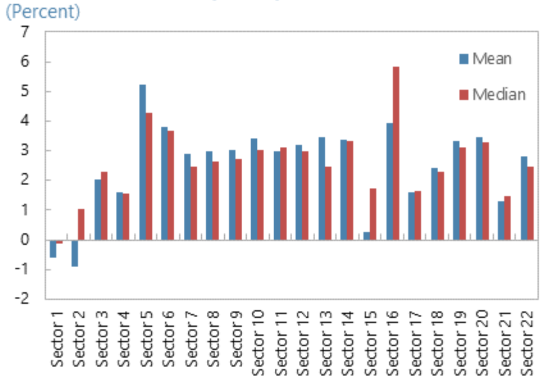
…while firms in electricity, water transport, paper products, and Fishery have weaker initial ICR levels.

Interest Coverage Ratio
(Percent)



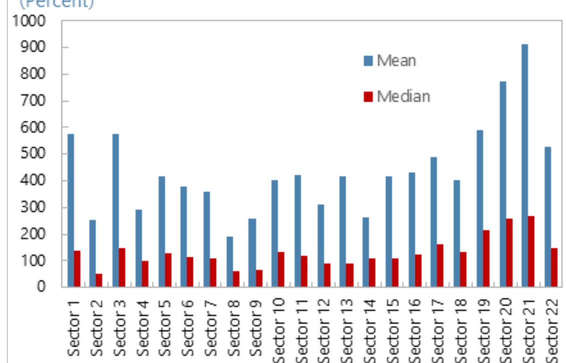
Agriculture, water transport, paper products, and collective services show weak profitability…

EBIT to Total Assets (EBITR)
(Percent)



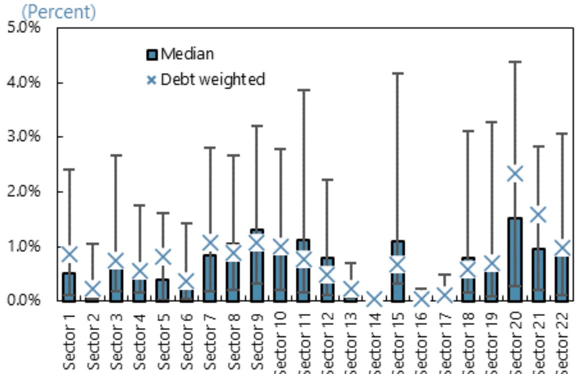
Iron and steel, non-ferrous metals, and paper products have weaker cash positions…

Cash to Short–Term Debt (CDR)
(Percent)



PDs at the outset exhibit significant variation both across sectors and within sectors.

PDs at the Outset
(Percent)



Mapping Table for the Sectors in the Figures

Sector 1	Agriculture	Sector 12	Transport equipment
Sector 2	Fisheries	Sector 13	Electricity
Sector 3	Mining and quarrying	Sector 14	Gas
Sector 4	Paper products	Sector 15	Water transport
Sector 5	Petroleum and coal	Sector 16	Air transport
Sector 6	Chemical products	Sector 17	Land transport
Sector 7	Non-metallic Minerals	Sector 18	Other manufacturing
Sector 8	Iron and steels	Sector 19	Construction
Sector 9	Non-ferrous metals	Sector 20	Water supply
Sector 10	Fabricated metal products	Sector 21	Collective services
Sector 11	Electronic equipment	Sector 22	Business services

Source: IMF staff calculations.
Note: In the bottom left panel, the error bars represent the 10th and 90th percentiles of initial PDs among firms for each sector.

FIBA Model Layer—Bank Module

185. Establishing the connection to bank balance sheets and their capitalization necessitates access to individual banks' industry exposure data. Industry exposure data as of end-March 2023 were sourced from the banks. Focus was placed on emission-intensive sectors and those reliant on emission intensive inputs from 22 banks, following the BOJ classification of Loans and Bills Discounted by Sector. To cover the entire nonfinancial corporate sector, these exposure data were supplemented with data extracted from the banks' publicly available financial reports. The latter comprise loans provided to manufacturing, construction, and transportation and postal activities, enabling to construct 17 distinct portfolio segments. These portfolios are used as a starting point for computing the scenario-conditional credit losses and interest income for banks. To align with these 17 distinct loan portfolios, PDs, LGDs, and credit spreads at the firm industry levels are reaggregated, using each firm's debt as the weighting factor.

186. The composition of the loan portfolios, particularly the loan exposure to emission intensive sectors, exhibits significant variability across banks (Figure 79). Internationally active banks have higher exposure to emission intensive sectors, compared to the other types of banks. On average, the loan exposure to these sectors is roughly 30 percent, which is somewhat higher than the share calculated based on the BOJ's loan statistics (of 22 percent).

187. The analysis employs a dynamic balance sheet approach, which considers the deleveraging and leveraging of industries that are declining and thriving, respectively, under the scenarios. It accounts for the fact that industries that are shrinking (growing) will generate less (more) interest income for banks. It is further assumed that rising credit spreads due to rising default risk and LGDs are priced in the lending rates for industries that are vulnerable to the transition.[82] The general loan growth (in Box 1) pertaining to gross loans is aligned with a rolling multi-year average of scenario-based sectoral GVA growth for each industry.

188. The calculations for credit loss follow the approach of the bank solvency stress test. The evolution for the nonperforming loan stock for bank *b*'s exposure to sector *n* at horizon *h* ($NPL_{n,b,h}$) is calculated as below (and outlined in Box 1):

$$NPL_{n,b,h} = NPL_{n,b,h-1}(1 - WROR - CURER) + PD_{n,b,h}(L_{n,b,h-1} - NPL_{n,b,h-1}) .$$

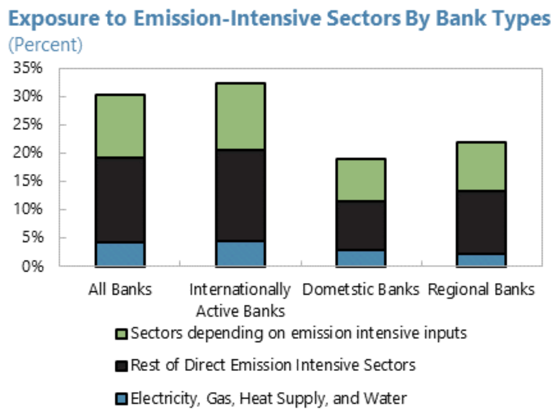
$L_{n,b,h-1}$ refers to gross loans. The write-off rate (*WROR*) and the cure rate (*CURER*) are set to 100 percent and zero percent, respectively, for the application of the climate risk model. The cure rate being set to zero reflects the interpretation of (MKMV) PDs as being closer to ultimate bankruptcy rates, not to a 90-day past due criterion-based default rate (which is used as an anchor point in the bank solvency stress test). The NPL write-off rate being set to 100 percent is instrumental for not having to design the rate such that NPL ratios in the long run do not diverge. Performing exposures

[82] The debt interest rate for the Japanese corporate sector, which stood at about one percent in 2022, was used for the "base" lending rate. The lending rate is composed of such a "base lending rate" and the "credit spread" component on top.

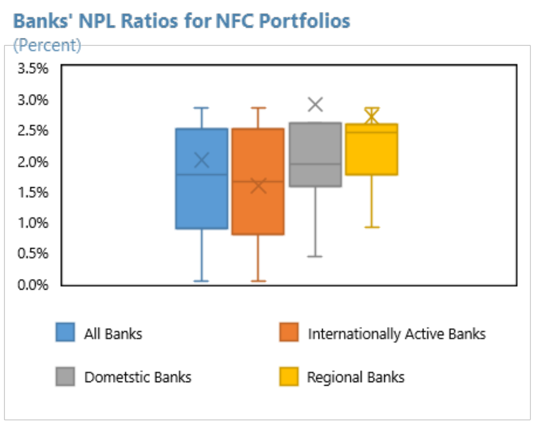
are computed as a residual of gross exposures (driven by *g*) and the nonperforming exposure stock, driven by the equation above.

Figure 79. Japan: Banks' Loan Portfolios by Sector and Risk Profile by Type of Banks

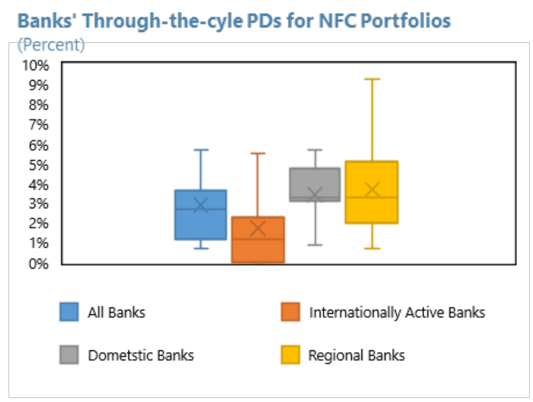
Internationally active banks have higher exposures to emission-intensive sectors, compared to other types of banks.



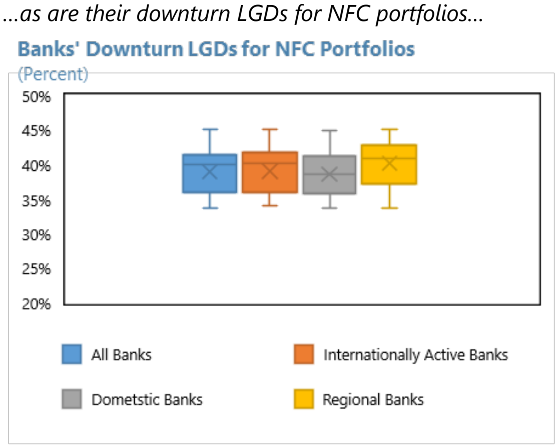
NPL ratios for NFC portfolios of regional banks in the sample are higher than those of internationally active banks…



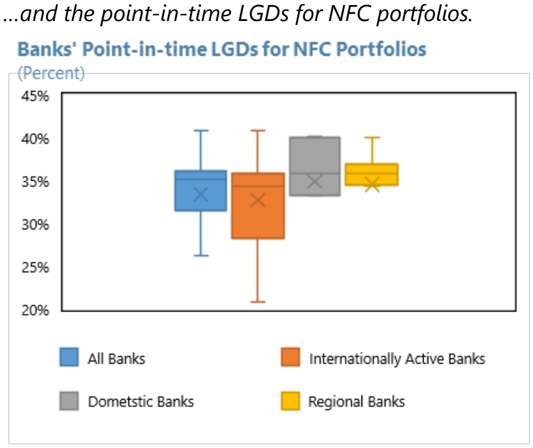
…through-the-cycle PDs are, on average, higher and more diverse…



…as are their downturn LGDs for NFC portfolios…



…and the point-in-time LGDs for NFC portfolios.



Sources: FSA; and IMF staff calculations.
Notes: In the top panels, the loan exposure data is as of March 2023. In the box plots, lines in the middle of the box are medians, box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles.

189. The model-consistent provision stocks for the NPL portfolios, denoted $PROV_{n,b,h}^{NPL}$, are computed as:

$$PROV_{n,b,h}^{NPL} = LGD_{n,b,h} \times NPL_{n,b,h}.$$

The provision flows, i.e., loan losses ($LL_{n,b,h}$), in turn, are computed as:

$$LL_{n,b,h} = PROV_{n,b,h}^{NPL} - PROV_{n,b,h-1}^{NPL} + WRO \times LGD_{n,b,h} \times NPL_{n,b,h-1}.$$

This loan loss flow changes the banks' capital, for the numerator of their capital ratio, period by period.

190. PDs and the LGDs at the bank level for the NFC portfolio were employed as "anchor points" to account for structural cross-bank differences in their risk profile. As depicted in the middle and lower panels of Figure 79, regional banks in the sample tend to exhibit higher risk parameters, including through-the-cycle PDs and LGDs, compared to other types of banks. An alternative approach is to use the PDs and LGDs at the bank-portfolio level if data is available. This was partly tested and yielded quantitatively similar outcomes for impacts on banks' capitalization.[83] Throughout the simulation, the NFC PDs and LGDs of each bank were updated forward in time to align with the PD and LGD trajectories at firm industry level, as implied by the firm-level simulation. This alignment was made using micro firm debt weighted aggregates and involved a logistic transformation/attachment scheme.

191. All banks' risk weights were modeled following the IRB approach. The risk weights were recomputed using the Basel risk weight formula for the corporate segment, using TTC PDs and downturn LGDs as input. A 100 percent pass-through from point-in-time PDs to regulatory TTC PDs was assumed, while a 20 percent pass-through was assumed for the solvency stress test. The 100 percent pass-through here is rationalized by the long-term horizon of the climate risk analysis. Downturn LGDs were held constant at the initially observed levels.

Results

192. In interpreting the scenario-conditional estimates for both firms and banks, the multiple sources of heterogeneity that contribute to the outcomes should be kept in mind. These include: (1) heterogeneous sectoral impacts across industries, according to differential emission intensity across industries and inter-industry linkages; (2) the initial risk characteristics across different industries, alongside wide variations within each segment; (3) differential loan

[83] To estimate LGDs at the bank-portfolio level at the outset, provision coverage ratios (PCR) for nonperforming loans were first computed within three industry clusters: agriculture and fishery, manufacturing, and the rest of the nonfinancial corporate industries, as well as for the overall NFC total. These calculations were performed using aggregated bank data. Subsequently, the differences between the PCR of each industry cluster and the PCR of the overall NFC portfolio were employed to adjust both point-in-time LGDs and downturn LGDs of individual banks at the outset. This adjustment scheme was employed since LGDs were not available at the detailed industry level at the outset, while NPL provision coverage ratios were.

exposures to different industries; and (4) the varying risk profiles across banks. Primary focus in the results will be on the median (50th percentile) outcomes, which result from the Monte Carlo simulation component of the model, related to the emission intensities of the firms.

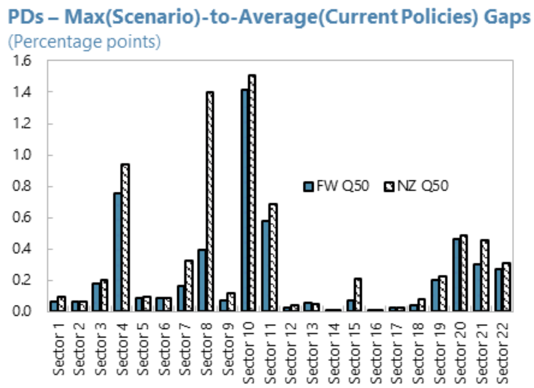
193. Under the policy scenarios compared to the CP scenario, PDs, LGDs, and credit spreads exhibit significant variations across sectors. Notable impacts are observed for firms operating within emission-intensive sectors such as paper products, iron and steel, and fabricated metal industries (Figure 80). Several emission-intensive sectors such as chemical products, and petroleum and coal show only a modest increase in PDs due to favorable initial conditions, despite experiencing a substantial decline in sectoral GVAs. Other services and construction, which are not considered emission intensive, experience a somewhat higher increase in both PDs and LGDs.

194. The analysis reveals that substantial uncertainty surrounding the firms' emission intensity can have a noteworthy impact on their financial performance. To assess this influence, the Monte Carlo simulations around individual firms' emission intensity for those lacking emission intensity information was conducted. The firm risk metrics at the 50th (Q50), 75th (Q75), and 90th (Q90) percentiles of the outcome distributions were investigated and aggregated by sector. There are no noticeable differences in outcomes between the 50th and 75th percentiles, but for the 90th percentile, a large increase in both PDs and LGDs for certain emission-intensive sectors (such as mining and iron and steel) could be observed (Figure 81). This finding underscores the sensitivity of firms' credit risk to their emission intensity levels. It raises concerns about firms that lack emission data, as should their emission intensity turn out to be significantly worse than those that have reported emissions data, the potential impacts on their financial performance could be more substantial.

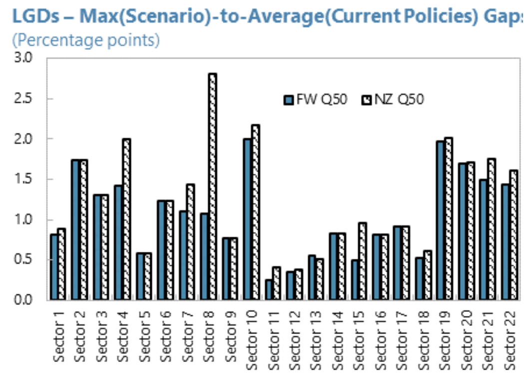
195. The overall impact on bank capital appears not too sizeable at the system level, while it is surrounded by notable heterogeneity in the cross-section of banks. Under the Net Zero 2050 scenario, the aggregate capital ratio for the banking system is estimated to decrease by about 0.6-0.7 percentage points by 2040, translating to an annual decline of around 0.03-0.04 percentage points per annum when compared to the CP scenario (Figure 81). Under the FW scenario, the banking system's aggregate capital ratio is projected to decline by 0.3 percentage points by 2040. However, considering that the mitigation efforts in this scenario are designed to commence from 2031 onwards, the annual decline in capital ratios during the 2030s is estimated to be about 0.03 percentage points per year, which is comparable to the average annual rate observed in the NZ scenario.

Figure 80. Japan: Firm PDs, LGDs, and Credit Spread Impacts (22 Sectors)

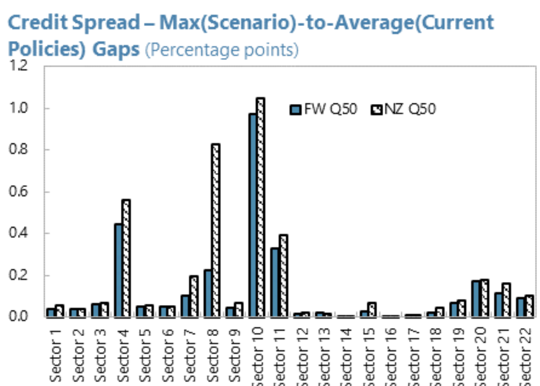
Notable impacts are observed for firms operating within emission-intensive sectors such as paper products, iron and steel, and fabricated metal industries…



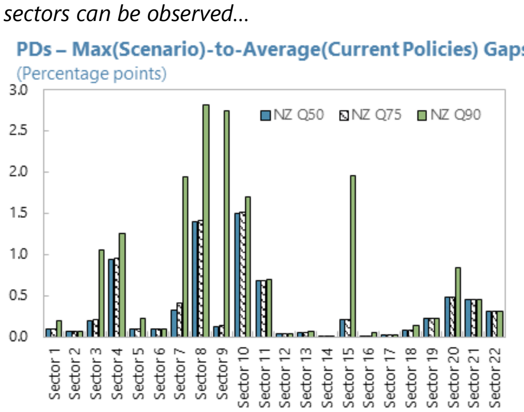
Several non-emission-intensive sectors such as other services and construction experience somewhat higher increases in LGDs…



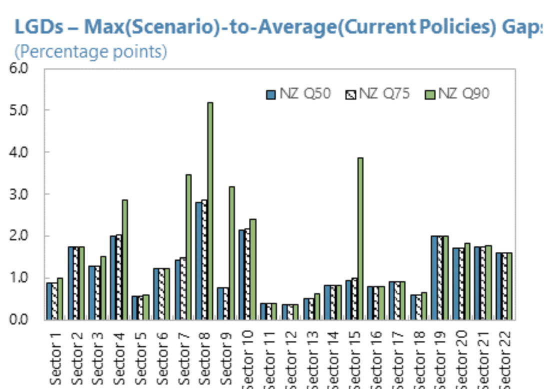
The chart for credit spread mirrors those for PDs and LGDs.



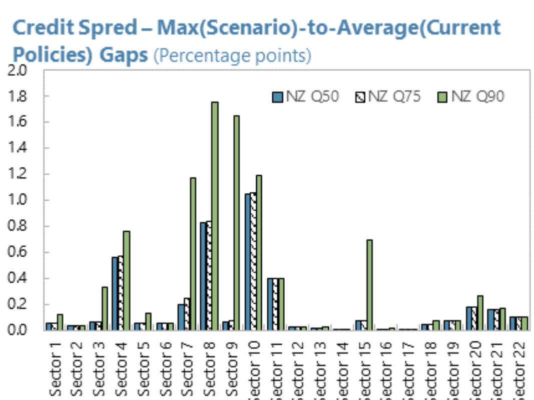
There are no noticeable differences in outcomes between the 50th and 75th percentiles, but for the 90th percentile, a large increase in PDs for certain emission-intensive sectors can be observed…



…along with a large increase in LGDs for certain emission intensive sectors…



…and a large increase in credit spreads for certain emission intensive sectors.



Source: IMF staff calculations.

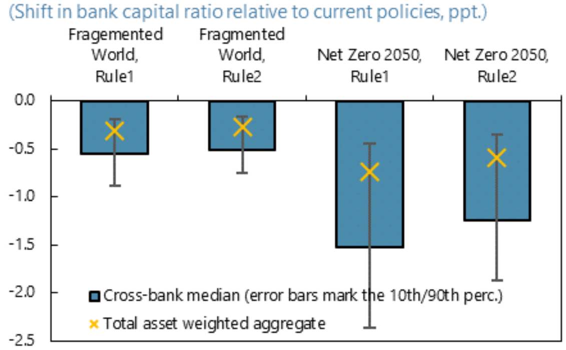
Notes: Please refer to the mapping table for sector numbers in the note of Figure 78. The policy sceanrios are simulated under Rule 2 where a half of revenues are allocated to feed-in tariffs for the renewable energy sector, with the remaining half to be transferred to households.

Figure 81. Japan: Banking System Capital Impact by 2040

The aggregate impact on bank capital ratios aligns with the macroeconomic impact. Significant heterogeneity among individual banks is observed.

Banking System Capital Shift by 2040

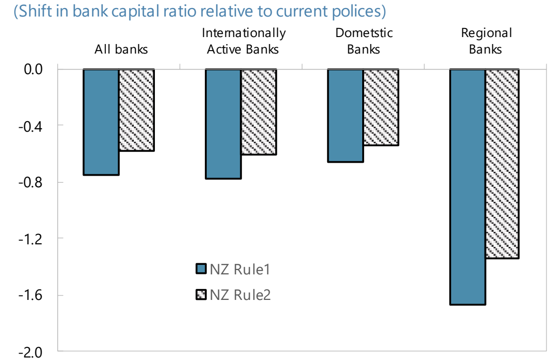
(Shift in bank capital ratio relative to current policies, ppt.)



Regional banks in the sample experience the most pronounced effects.

Banking System Capital Shift by Type of Bank

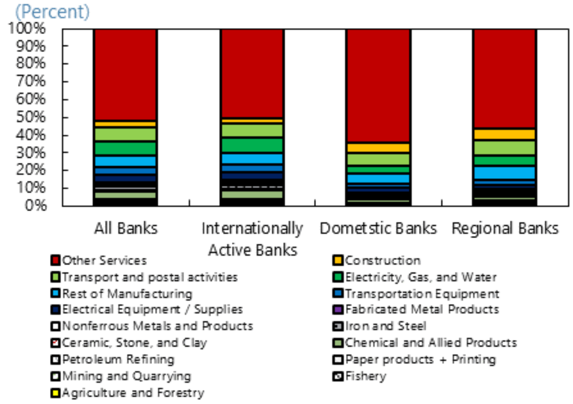
(Shift in bank capital ratio relative to current polices)



Internationally active banks have a notable exposure to emission intensive sectors, but …

Composition of Loan Portfolios by Type of Banks

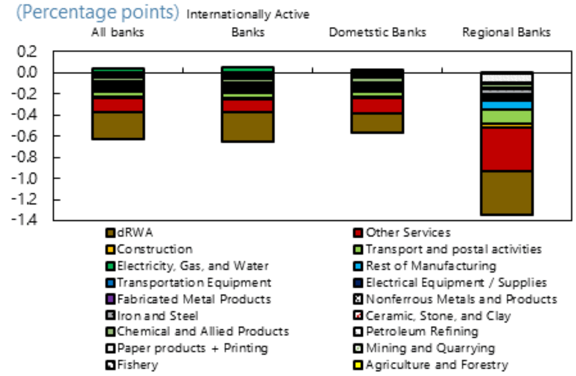
(Percent)



…non-emission intensive sectors account for about 30 percent of the shift in banking system capital ratio. One-third to one-half of the capital ratio shift can be attributed to changes in RWAs.

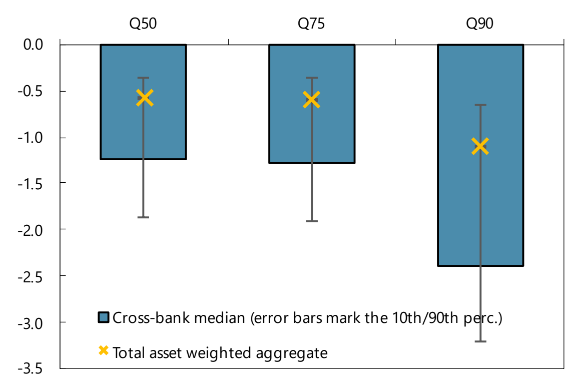
Sectoral Contributions to Banking System Capital Ratio Shift Under Net Zero 2050 by Type of Banks

(Percentage points)



Significant uncertainty in firms' emission intensity may have a substantial impact on banks' capital ratios…

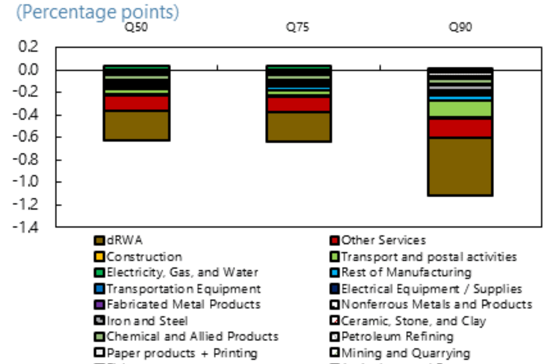
Effects of Firms' Emission Uncertainty on Bank Captial Under NZ (Shift in bank capital ratio relative to current policies)



…. primarily through direct emission intensive sectors.

Sectoral Contributions to Banking System Capital Ratio Shift by Emission Intensity Levels

(Percentage points)



Sources: FSA; and IMF staff calculations

196. The capital impacts vary across banking clusters. Internationally active banks are modestly impacted because of the more favorable risk profiles of their borrowers, while the impact on regional banks—those that are contained in the sample—is more pronounced (Figure 81). The contribution analysis reveals that non-emission intensive sectors, such as other services, account for approximately 30 percent of the shift in the banking system capital ratio.[84] This finding suggests that spillover effects through macroeconomic channels, the initial risk characteristics of borrowing firms, and individual banks' risk parameters all play pivotal roles in determining the overall outcomes.[85] In addition, about one-third to one-half of the capital ratio shift can be attributed to changes in risk-weighted assets (RWAs). This is partly due to rising risk weights resulting from rising PDs and LGDs in emission-intensive sectors. The contribution analysis for individual banks highlights the heterogeneity in terms of the size and composition of the impact on capital ratios.

197. The substantial uncertainty surrounding firms' emission intensity levels could have a significant impact on bank capitalization. The implications for the shift in bank capital ratios closely align with those observed for firm industry risk metrics. No notable differences are observed in outcomes between the 50th and 75th percentiles of individual firms' risk metrics. However, at the 90th percentile, substantial differences in the impacts on bank capitalization can be observed, primarily driven by increased loan losses incurred in direct emission-intensive segments (Figure 81).

198. Considering the dynamic evolution of firm debt is important in climate risk analysis as it allows to capture any shifts in industry structure and its potential effect on bank profitability. To illustrate this, two industries were analyzed in more detail: the chemical products and the electricity and gas segments (Figure 82). In Scenario 5 (Net Zero 2050 with Rule 2, considering the 50th percentile of firms' risk metrics) compared to Scenario 1 (Current Policies), a notable loan growth differential can be observed, with the chemical sector experiencing an average annual decrease of 0.8 percentage points in growth, while electricity and gas sector sees an increase of 1.2 percentage points of growth per annum until 2040. When the chemical sector shrinks, it leads to a decline in interest income for banks, and loan losses become less negative, even though PDs and LGDs rise relative to the CP scenario. Conversely, in the case of electricity and gas experiencing growth, interest income increases, and loan losses become more negative, despite reductions in PDs and LGDs relative to the CP scenario. Additionally, loan growth has a direct impact on RWAs. More

[84] In the contribution analysis, a shift in bank capital ratios can be decomposed into three parts: a change in interest incomes (ΔII) relative to RWAs, a change in loan losses (ΔLL) relative to RWAs, and a residual change related to RWAs ($\delta RWAs$).

$$\Delta CAPR = {}^{\Delta II}/_{RWAs} + {}^{\Delta LL}/_{RWAs} + \delta RWAs$$

The first two components are summed up by sectors. The average of the initial and end-horizon RWAs are used for normalizing the interest income and loan loss contributions. $\delta RWAs$ represents the combined effect of (a) rising/falling risk weights due to rising/falling PDs and LGDs and (b) loan growth (either positive or negative for the underlying industries).

[85] Abe and others (2023) also find that an increase in carbon price impacts non-emission-intensive sectors through inter-industry linkages, thereby increasing their credit cost.

positive loan growth puts downward pressure on capital ratios, whereas less positive or negative growth exerts upward pressure on these ratios from this perspective.

199. Under a dynamic balance sheet, the banking system's capital ratio in the NZ scenario further declines by 0.1 percentage points compared to a static balance sheet where zero gross loan growth is assumed (Figure 82). This decline primarily results from the fact that the foregone interest income from shrinking industries outweighs the increasing interest income from growing industries and the reduction in asset riskiness via deleveraging within the negatively affected sectors. However, when examining the impact on individual banks, capital ratios of several banks improve under a dynamic balance sheet compared to a static balance sheet. These banks benefit from reduced loan losses from shrinking industries and a decline in RWAs, which outweigh the foregone interest income from shrinking industries. Banks with riskier portfolios (e.g., higher through-the-cycle PDs) tend to show better performance when adopting the dynamic balance sheet.

Figure 82. Japan: Effects of Dynamic Balance Sheets under the Net Zero 2050 Relative to Current Policies Scenario

With dynamic balance sheets, shifts in industry structure and their resulting effects on bank profitability can be accounted for.

Industry #6: Chemical (Shrinking in S5 relative to S1)

[JPY million, cumulative flows until 2040, under scenario 5 minus scenario 1]

	Static	Dynamic
Interest income	9,623	-218,213
Loan loss	-29,468	21,322
Sum	-19,845	-196,890

Industry #14: Electricity and Gas (Growing in S5 relative to S1)

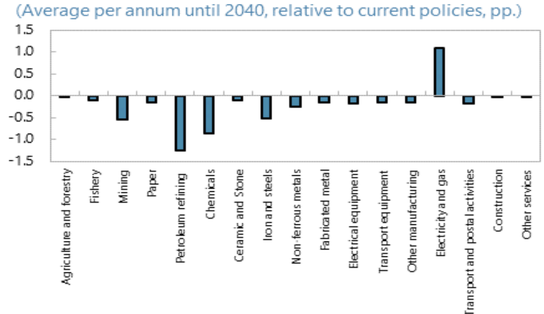
[JPY million, cumulative flows until 2040, under scenario 5 minus scenario 1]

	Static	Dynamic
Interest income	-2,153	598,422
Loan loss	14,963	-348,908
Sum	12,811	249,514

While loans to electricity and gas grow under the NZ relative to the CP, loans to other sectors decline.

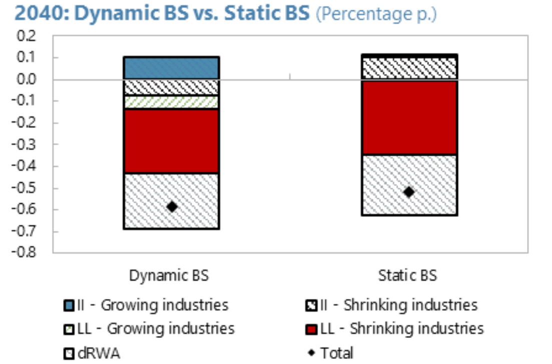
Loan Growth Differentials

(Average per annum until 2040, relative to current policies, pp.)



Under a dynamic balance sheet, the banking system's capital ratio declines by 0.1 percentage points compared to a static balance sheet.

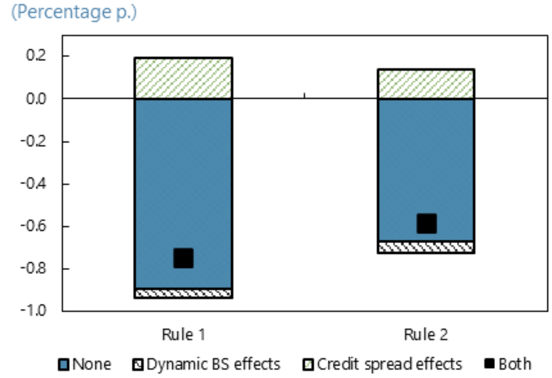
Contributions to Banking System Capital Ratio Shift by 2040: Dynamic BS vs. Static BS (Percentage p.)



It turns out that effects of pricing in credit risk outweigh those of adopting a dynamic balance sheet.

Effects of Dynamic Balance Sheets and Interest Income

(Percentage p.)



Source: IMF staff calculations.

Note: The Net Zero 2050 scenario with Rule 2 is used for this exercise.

200. It turns out that the effects of pricing in credit risk outweigh those of adopting a dynamic balance sheet. While taking a dynamic balance sheet approach leads to a modest decline in the aggregate capital ratio, approximately 0.05 percentage points, the increase in lending rates for industries experiencing an uptick in credit risk enables banks to generate a higher interest income relative to RWAs, by approximately 0.15 percentage points. This increase in interest income is three times as large as the impact of moving from a static to a dynamic balance sheet.

201. Several caveats should be considered when interpreting the model results. First, the firm module lacks elements related to firm entry and exit dynamics. Second, the credit risk assessment of borrower firms is based on an estimated PD model using the stock and flow-oriented Merton approach, but certain sectors may demand sector-specific considerations for a more accurate evaluation of credit risk during the transition to the green economy. Third, although several firm-level heterogeneity, including in emission intensity, has been accounted for from a model perspective, it is crucial to acknowledge that the analysis may be affected by additional layers of heterogeneity such as the quality of physical capital and the intensity of knowledge in green technology. Finally, more granular bank-industry specific risk parameters would be instrumental for refining the analysis, using models of a kind as employed here, going forward.

B. Climate Physical Risk Analysis

202. Japan is significantly exposed to climate-related physical risks. Based on Moody's 427 dataset, which illustrates the anticipated levels of climate physical risk for each country over the next two decades assuming no global mitigation policies, the overall physical risk score for Japan is categorized as "very high" (Figure 83). When assessing individual hazards, the risks associated with hurricanes and sea level rise are deemed exceedingly high, and flood risk is classified as high. In terms of the occurrence of disasters, flood-related disasters, including storms, floods, and landslides, account for over 70 percent of major natural disasters in Japan. Damages due to floods have been increasing in recent years, indicating Japan's growing vulnerability to these climate-related events.

203. Japan's capacity to cope with physical risks is, however, strong. According to the Climate-driven INFORM Risk indicators, Japan is recognized for its strong adaptive capabilities in dealing with climate risks (Figure 83). These risks are managed through the maintenance of high-quality manuals pertaining to flood control, regular updates to the "Expected Flood Inundation Area" as stipulated by the Flood Prevention Act, and the implementation of innovative flood prevention measures.[86] Consequently, Japan's overall vulnerability to climate physical risks is relatively low compared to other countries. Nevertheless, the possibility of climate-related disasters

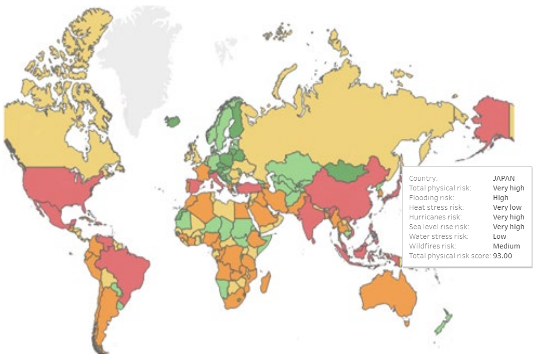
[86] "Expected Flood Inundation Areas" commenced to be made public in 2001 following the revision of the Flood Prevention Act. These areas were designated based on maximum possible rainfall occurrences, such as those expected once in 1,000 years. An example of innovative flood prevention initiatives is the construction of one of the world's largest underground discharge channels, situated near Tokyo. This channel effectively channels overflow from small to mid-size rivers, redirecting it through a 6.3-kilometer tunnel located 50 meters below ground to the larger Edogawa River.

persists due to erratic changes in weather patterns, including the increasing frequency of extreme precipitation.

Figure 83. Japan: Climate Physical Risk

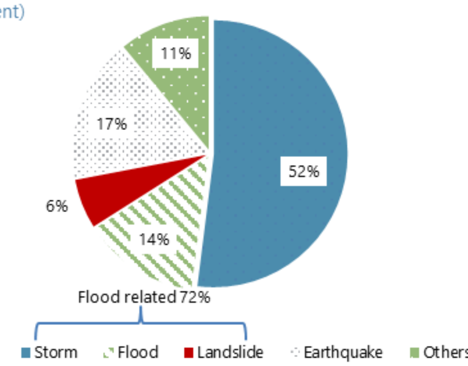
Japan's overall exposure to physical risk is considered as very high.

Heatmap for Climate Physical Risk (Risk Index)



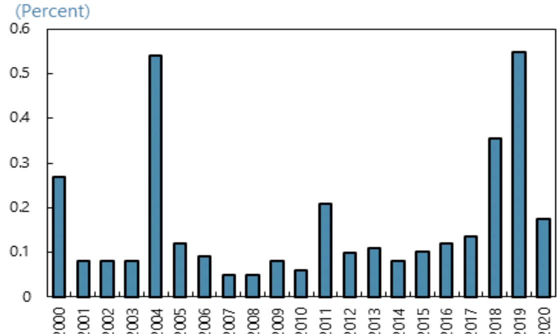
Flood-related disasters account for over 70 percent of major natural disasters in Japan.

Occurrence of Disasters in Japan by Type
(Percent)



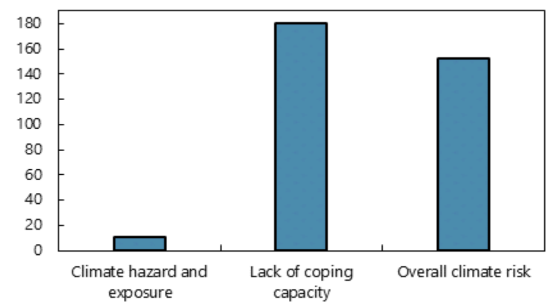
Flood damages have been rising in recent years…

Flood Damage Relative to National Income
(Percent)



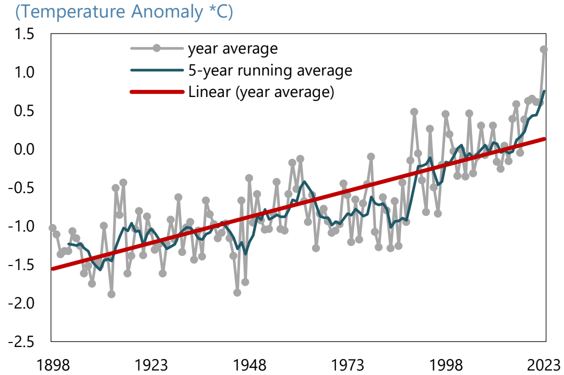
But Japan is recognized for its strong adaptive capability in dealing with physical risks.

Japan's Ranking in Climate Driven INFORM Risk Indices
(Rank)



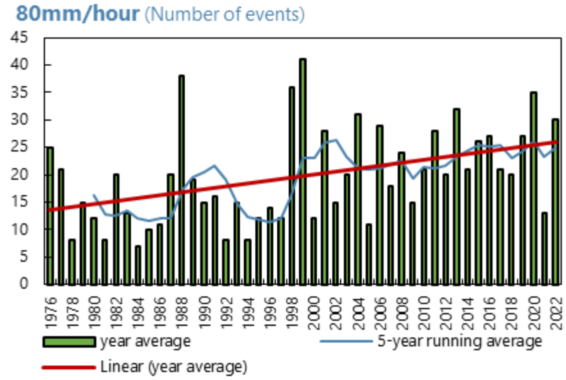
Recently, the average surface temperatures have consistently risen above the long-run trend …

Annual Japan Average Temperature Anomalies
(Temperature Anomaly *C)



The annual number of heavy rain events has increased steadily.

Annual Number of Events with Precipitation over 80mm/hour (Number of events)



Sources: Moody's 427; EM-DAT; Flood damage statistics from Ministry of Land, Infrastructure, Transport, and Tourism (MLIT); the European Commission Disaster Risk Management Knowledge Center; Japan Meteorological Agency; and IMF staff calculations.
Note: The ranking in the middle right panel is out of 191 countries, with a lower rank indicating greater risk.

204. A high-level risk analysis of climate-related physical risk, focusing on flood risk in Japan, was conducted as part of the systemic risk assessment. The analysis centers on evaluating the susceptibility of physical assets across the country to flooding. The extent of current exposure to flood risk among physical assets was assessed, alongside the impact of climate change on flooding. The potential implications of these shifts in flood risk on underlying asset values were analyzed, including potential damages, paying attention to regional disparities in the impacts across prefectures. For the analysis, publicly available gridded asset exposure data were combined with flood depth projections for both 1-in-100-year and 1-in-1,000-year hazards in both current and future climatic conditions. The analysis is the groundwork for understanding the intersection between flood hazards and financial stability, thereby shedding light on its potential ramifications for the financial sector.

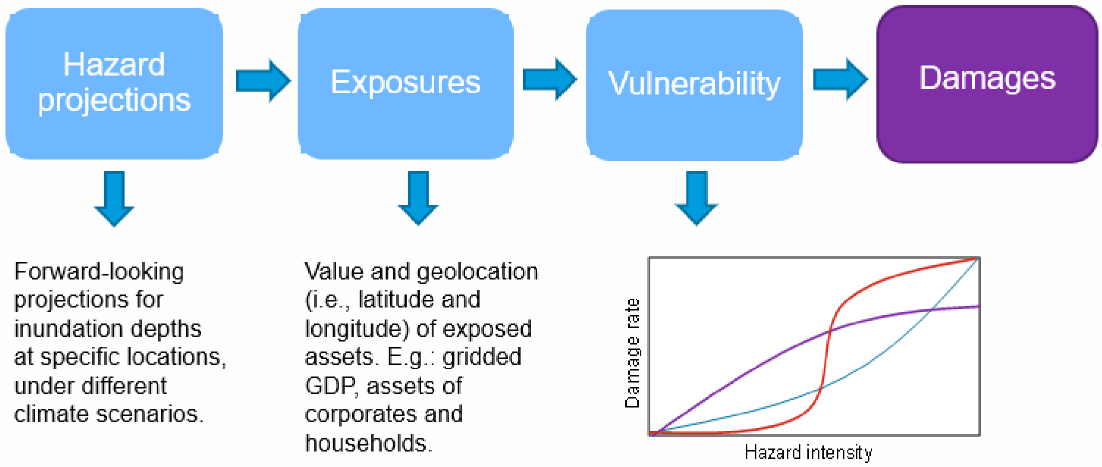
Methodology and Data

205. The analysis relies on a methodology for estimating damages caused by projected climate hazards to households and businesses in affected areas, as outlined in the recent IMF Staff Climate Note (IMF, 2022). Central to this methodology are the damages incurred by individual climate hazards, such as the extent of capital stock destruction or productivity loss resulting from significant weather events. Damages serve as the vital link connecting climate science with the realms of finance and economics. Estimating damages involves connecting hazard projections with the geolocational data of physical assets and assessing their vulnerability, i.e., their propensity to be adversely affected when exposed to hazard events (Figure 84).

206. The initial step in the methodology involves acquiring hazard projections at specific locations under varying climate scenarios. In the context of floods, the crucial metric is flood depth. A comprehensive dataset on flood hazards developed by MS&AD LaRC-Flood® Project was used for the analysis.[87] The dataset encompasses four hazard maps, each covering inundation depths for 100-year and 1000-year hazards, and for the current climate conditions and the projected conditions for 2080 under the Shared Socioeconomic Pathways 585 (SSP 585, Figure 85). It covers approximately 17.4 percent of Japan's total land area, and the maps' resolution is set at 15 arcseconds, providing a spatial granularity of approximately 500 square meters.

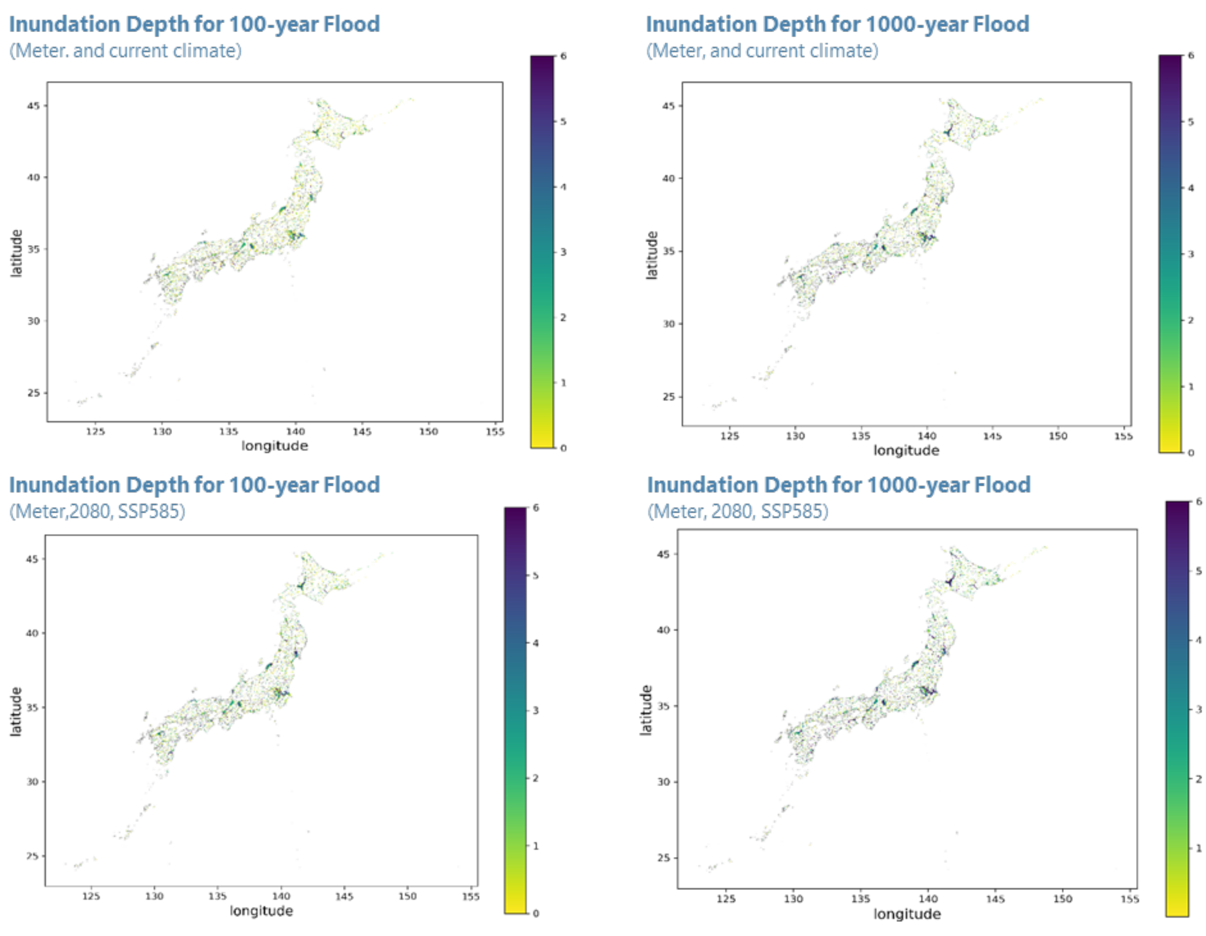
[87] This dataset is sourced from MS&AD LaRC-Flood® Project, which is joint research project among the University of Tokyo, Shibaura Institute of Technology, MS&AD Insurance Group Holdings Co., Ltd., and MS&AD InterRisk Research & Consulting, Inc. Detailed methodology is explained in Kimura and others (2023).

Figure 84. Japan: Physical Risk Analysis—Estimating Damages



Source: IMF (2022)

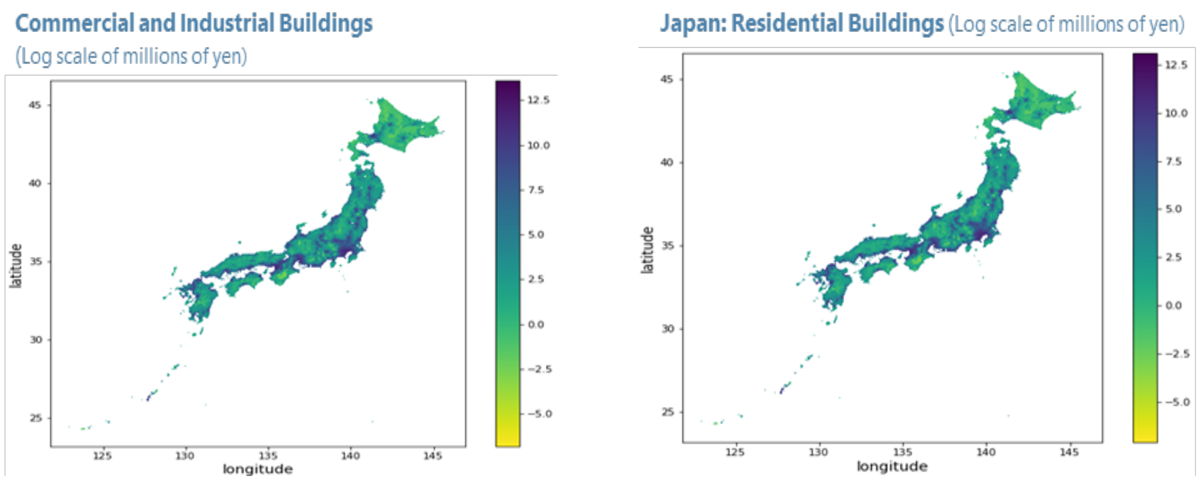
Figure 85. Japan: Projections for Flood Hazards (Inundation depth)



Source: MS&AD LaRC-Flood® Project.
Note: For better visualization, inundation depth more than 6 meters is set to 6 meters.

207. The second step involves gathering geolocational exposure data. To assess the potential implications for individual financial institutions, it is crucial to obtain data on the geolocational exposure of their loans, or at least reliable estimates thereof. Since such a dataset was not readily available, the analysis relied on a "proxy" dataset on the normalized product of gridded nightlight intensity and gridded population density, provided by Eberenz and others (2020). The dataset allows us to infer the distribution of physical assets across Japan and to downscale national total physical asset values proportionally according to the proxy's distribution. To refine the estimates further, prefecture-level data for private corporate capital stock and household net capital stock were used instead of national total capital stock (Figure 86).[88] The resolution of the proxy dataset is set at 30 arcseconds, roughly equivalent to 1 square kilometer. In mapping datasets for inundation depth and physical asset exposures at a 15 arcsecond resolution, assets within each 30 arcsecond grid were assumed to be uniformly distributed.

Figure 86. Japan: Distribution of Gridded Physical Assets



Sources: Eberenz and others (2020); Cabinet Office; Japanese Statistics Bureau; and IMF staff calculations.
Note: Gridded physical assets for 2021 are constructed by downscaling estimated prefecture-level data proportionally to geolocational exposure data provided by Eberenz and others (2020).

208. The final building block of the analysis pertains to data on vulnerability, a crucial element that translates hazard intensities into the damage incurred by physical assets. This block is subdivided into two components: fractional damage and maximum damage values. For fractional damage, damage functions by flood depth for buildings in Japan were employed, which was taken from the guidelines provided by the Flood Control Economic Survey Manual (MLIT, 2020). Two adjustments were made to applying these functions: Firstly, a depth of 0.45 meters for subfloor flooding was considered, based on Japan's "Building Standard Law," that mandates a minimum height of 45 cm from the ground to the floor; Secondly, assets exposed to flood were corrected based on the number of stories in buildings. For buildings with up to two floors, the correction

88 Private corporate capital stock, representing commercial and industrial buildings, is estimated based on prefecture-level corporate capital stock for 2018 and corresponding national data for 2021. Similarly, household net capital stock, representing residential buildings, is estimated based on the number of dwellings by prefecture for 2018 and nationwide household net capital stock for 2021.

factor is set at one, while for those with more than two floors, the correction factor becomes two divided by the average number of floors in buildings. Average numbers of stories in buildings by prefecture were computed using data on dwellings by stories in buildings from the 2018 Housing and Land Survey.[89]

209. Maximum flood damage values are typically considered in the literature reflecting construction costs and the use of flood-resistant materials, among other factors. Huizinga and others (2017) have estimated globally consistent maximum damage values through regression analysis and a review of national case studies. The lower end of the 90 percent confidence interval from the proposed maximum damage values were selected, given Japan's high capacity for climate adaptation (Table 12). They were further adjusted to account for price changes between 2010 and 2020, as well as for currency conversion.[90]

Table 12. Japan: Data on Physical Vulnerability

Damage Rate by Flood Depth for Buildings

Flood depth	Damage rates (buildings)
<=0.49m	0.189
0.50 ~ 0.99m	0.253
1.00 ~ 1.99m	0.406
2.00 ~ 2.99m	0.592
>=3.00m	0.800

Maximum Damage Values
(Structure, land-based)

Building Class	Maximum damage values (E/m^{2}, 2010)	Uncertainty range
Residential	105.7	(**76.1**, 161.8)
Commercial	164.7	(**113.7**, 222.4)
Industrial	106.7	(**74.7,** 163.2)

Sources: Flood Control Economic Survey Manual (MLIT, 2020); Huizinga and others (2017); and IMF staff calculations.
Note: In the right panel, the uncertainty range represents the 90 percent confidence interval of the estimated maximum damage values.

Results

210. Approximately one-third of the physical assets in Japan are potentially exposed to flooding risk, with a significant disparity among prefectures. The analysis finds that roughly 60 percent of the country's physical assets fall outside the scope of flood risk assessment mainly due to their locations such as in mountainous regions (Figure 87). Around 4 to 12 percent of physical assets are subject to inundation depths of less than 45cm, so are not assessed prone to flood risk, given the implementation of Japan's "Building Standard Law." A substantial variation in flood risk emerges when examining different prefectures. In certain prefectures, more than half of the physical assets are exposed to flood risk, indicating a higher vulnerability to potential flood-related damages.

211. Climate change increases the exposure of physical assets to flood risk. Under the "SSP 585" scenario, the flood depths for a 100-year and 1000-year hazards are projected to increase, on average, by about 0.5-0.6 meters by 2080, when compared to current hazard maps. More than 25 percent of the areas exposed to flood risk is anticipated to experience inundation depths exceeding 0.8 meters for 1000-year flood events. The assets exposed to flood depths greater than 3.45 meters

[89] These data were equally applied to all building classes.

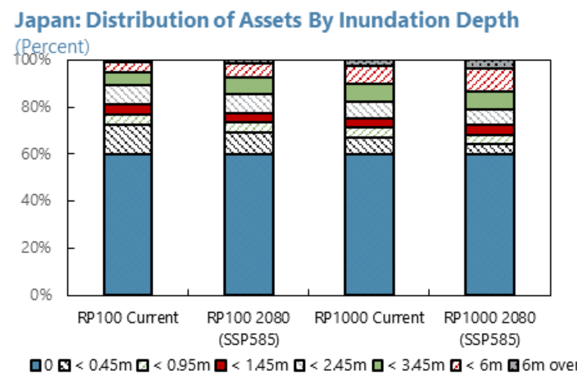
[90] In 2020, the resulting maximum damage value for residential buildings is JPY 2,275 million per 500m^2, while for corporate buildings, it is JPY 2,814 million per 500m^2.

are projected to rise. Geographically, certain prefectures, particularly those in the Tohoku region, the upper part of Japan, are poised to experience a relatively significant increase in inundation depth due to the effects of climate change.

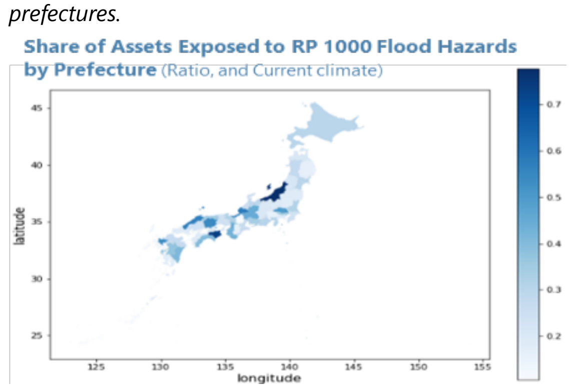
212. An increase in flood risk can potentially exert downward pressure on property prices. Koide and others (2022) find that a one-meter rise in inundation depth is associated with a 1.1 percent decrease in residential land prices and a more significant 4.8 percent decline in commercial land prices. Building upon these findings, the aforementioned increase in inundation depth could imply a decline in commercial land prices by, on average, about 3 percent (Figure 88). Prices may drop by more than four percent and ten percent, respectively, for about 25 percent and 5 percent of the commercial land exposed to flood risk. This impact exhibits some variation among prefectures, reflecting the regional disparities in flood risk. Several prefectures may experience an average decline in total commercial land values exceeding 5 percent for the areas exposed to flood risk.

Figure 87. Japan: Flood Risk and Climate Change

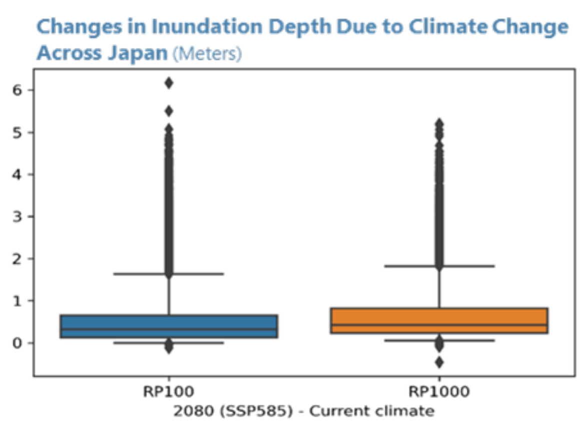
Approximately one-third of the physical assets are exposed to potential flooding risk.



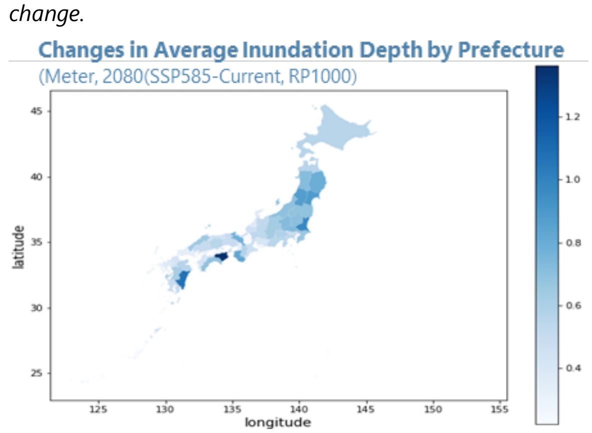
A substantial variation in flood risk emerges among prefectures.



The flood depth is projected to increase, on average, by about 0.5-0.6 meters in 2080.



Certain prefectures are poised to experience a relatively significant increase in inundation depth due to climate change.

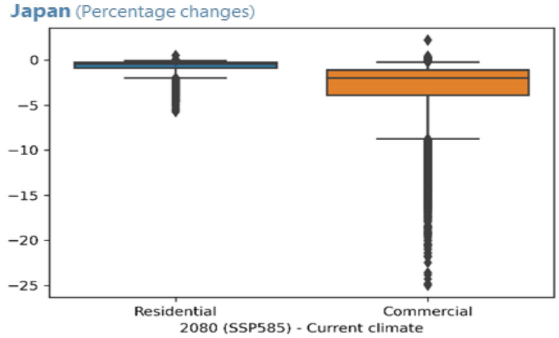


Sources: MS&AD LaRC-Flood® Project; Eberenz and others (2020); and IMF staff calculations.
Notes: In the bottom left panel, a box plot displays the median (middle line) along with the 25th and 75th percentiles (box), while the upper and lower lines represent the 95th and 5th percentiles, respectively. RP100 (1000) 2080 SSP8585 (Current climate) refers to flood depth projections for 1-in-100 (1000)-year hazards for 2080 under the Shared Socioeconomic Pathways 585 (the current climate conditions).

Figure 88. Japan: Impact of Climate Change on Real Land Prices

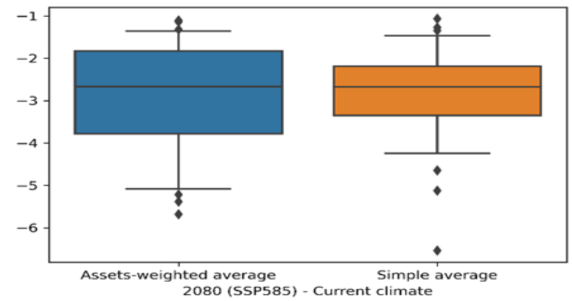
Anticipated increase in inundation depth could lead to a decline in commercial land prices by, on average, about 3 percent.

Changes in Land Prices Due to Climate Change Across Japan (Percentage changes)



Some prefectures could experience a decline in total commercial land values exceeding 5 percent for the areas exposed to flood risk.

Changes in Average Commercial Land Prices Among Prefectures (Percentage changes)



Sources: MS&AD LaRC-Flood® Project; Eberenz and others (2020); and IMF staff calculations.
Note: A box plot displays the median (middle line) along with the 25th and 75th percentiles (box), while the upper and lower lines represent the 95th and 5th percentiles, respectively.

213. The assessment of flood damage rates, defined as damage relative to underlying asset values, reveals that expected damage rates in 2080 surpass the present rates by, on average, about 20 percent. In absolute terms, the average damage rate for 1000-year floods rises from 28 percent to 32 percent by 4 percentage points (Figure 89). Similarly, for 100-year floods, the damage rate, on average increases by 5 percentage points. The profile of the increase in damage rates differs between these two flood hazards. For 100-year floods, the level of the 75th percentile rises, suggesting that areas already exposed to significant flood risk may face more severe disasters in the future. Conversely, for 1000-year floods, the level of the bottom 25th percentile moves up, indicating that wider areas could be at risk of experiencing severe flood damage once such an event occurs. Geographically, several prefectures, particularly in the Tohoku and Kanto regions, exhibit a heightened vulnerability to increasing flood hazards.

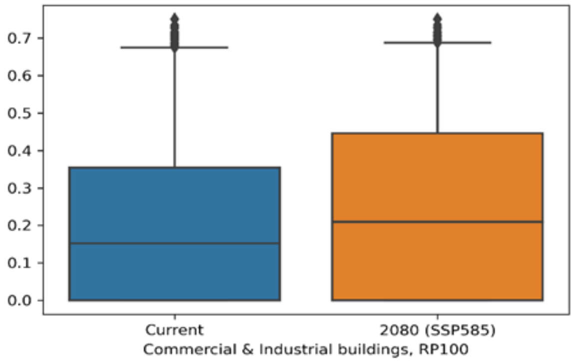
214. The prefecture-level regression analysis indicates that there is a negative correlation between average damage rates and the ratios of bank loans to the total private assets of firms and households (Table I.9). Specifically, a 5 percentage points increase in damage rates is associated with a 1.5-3 percentage points lower overall loan-to-asset ratios. This suggests that banks may have relatively limited direct exposure to flood risks, though they could still be impacted indirectly such as through macroeconomic spillovers or the interconnectedness of financial institutions.[91]

[91] This finding should be interpreted with caution as the data documents a disproportionally high share of loans for Tokyo compared to other prefectures. While Tokyo's share is about 20 percent in overall GDP, nearly half of the loan share is allocated to Tokyo. This discrepancy may be attributed to the common practice of registering loans to firms based on the location of the firms' headquarters, rather than considering the location of the actual investments or assets through which banks may be exposed to physical risk. This observation highlights that the actual exposure to physical risks could be underestimated when evaluating financial vulnerabilities associated with floods.

Figure 89. Japan: Flood Damage Rates—Corporate Buildings

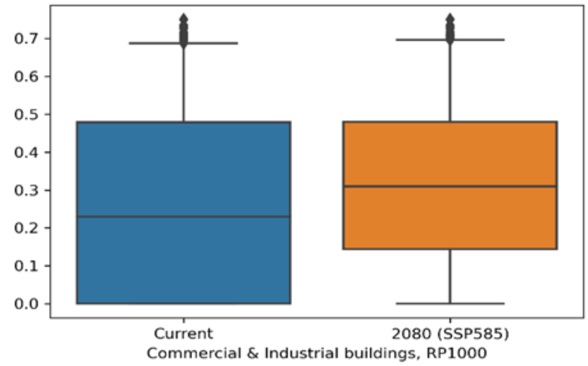
Damage rates in 2080 are expected to surpass the present rates, on average, by about 20 percent…

Comparison of Damages Rates of 100-year Flood Hazards (Ratio)



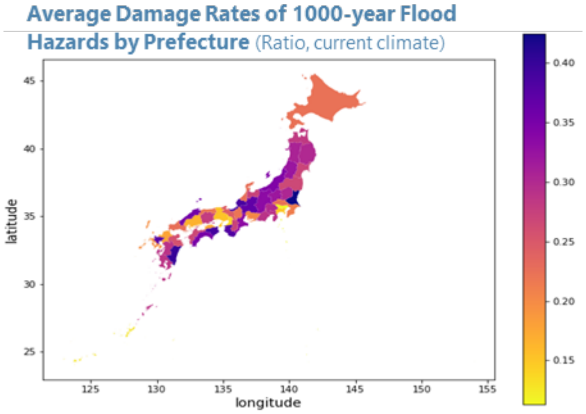
…in absolute terms, the average damage rate for RP 1000-year floods is expected to rise by 4 percentage points.

Comparison of Damages Rates of 1000-year Flood Hazards (Ratio)



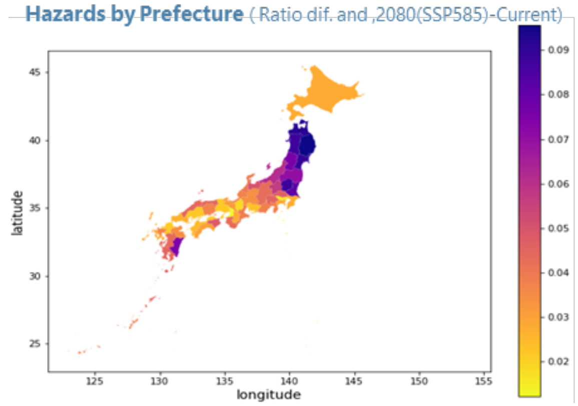
Large heterogeneity exists in average damage rates across prefectures….

Average Damage Rates of 1000-year Flood Hazards by Prefecture (Ratio, current climate)

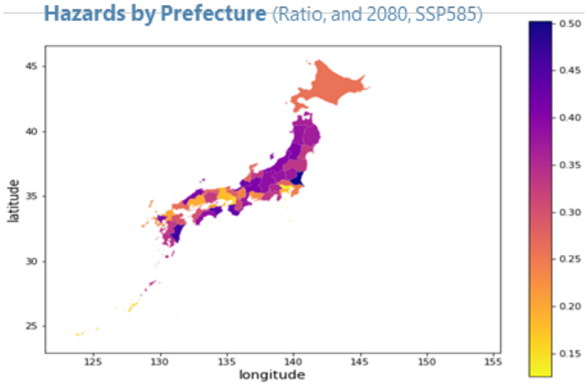


…several prefectures exhibit high vulnerability to increasing flood hazards.

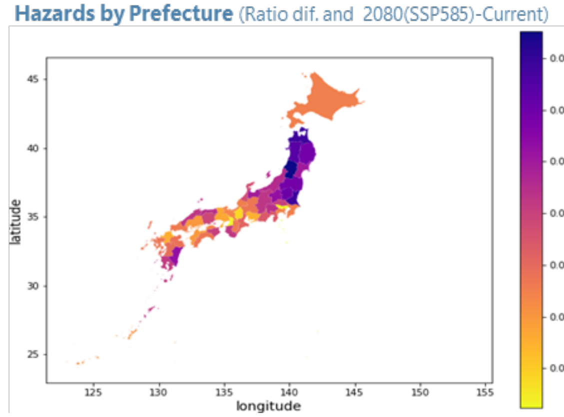
Change in Average Damage Rates of 100-year Flood Hazards by Prefecture (Ratio dif. and ,2080(SSP585)-Current)



Average Damage Rates of 1000-year Flood Hazards by Prefecture (Ratio, and 2080, SSP585)



Change in Average Damage Rates of 1000-year Flood Hazards by Prefecture (Ratio dif. and 2080(SSP585)-Current)



Sources: MS&AD LaRC-Flood® Project; Eberenz and others (2020); and IMF staff calculations.
Notes: In the top panels, box plots display the median (middle line) along with the 25th and 75th percentiles (box), while the upper and lower lines represent the 95th and 5th percentiles, respectively. In the middle and bottom panels, the average damage rates by prefecture are calculated based on physical assets exposed to flood risk.

215. The analysis should be viewed as an attempt to assess flood risk in Japan, using the available data and tools. Several areas could benefit from further improvement. First, it is crucial to obtain data on geolocational exposures of individual financial institutions, or at least reliable estimates, to evaluate potential impacts on financial resilience. Second, the analysis can be refined by employing more granular data, such as flood hazard maps with higher resolution and municipality-level data on the average number of stories in buildings. Access to flood hazards for various return periods would allow for the estimation of expected aggregate damage rates across Japan. Nevertheless, hazard maps alone may not capture the interplay of disasters across regions. The use of natural disaster models together with localized climate scenarios may be required to probabilistically evaluate flood risk across Japan.

HOLISTIC VULNERABILITY ASSESSMENT OF THE JAPANESE BANKING SECTOR AND RECOMMENDATIONS

A. Methodology

216. To support an overall assessment of the vulnerability of banks, a holistic analysis across all components of the systemic risk analysis was conducted. Banks were first ranked across multiple dimensions of vulnerability (with a lower rank indicating higher vulnerability). These dimensions pertain to banks' initial balance sheet characteristics (that is, in 2023Q1/FY2022 for which supervisory information is available), alongside all forward-looking analyses related to solvency risk, liquidity risk, interconnectedness, and climate transition risk. Table 13 summarizes the 22 individual indicators considered in the holistic assessment. Subsequently, a composite weighted-average ranking was computed for every bank, using weights for the 22 indicators based on their relative importance, which were judgmentally set.[92]

B. Results

217. The top three most vulnerable banks based on the composite indicator represent five percent of total assets of the sample of the 23 banks. These include two internationally active banks and one domestic bank, but no SIB. Across the various banking clusters, internationally active banks are, on average, more vulnerable than domestic banks, while regional banks—as a separate cluster—are on average the most vulnerable (Figure 90). Domestic banks have composite rankings above the banking system average but are below the average when considering the forward-looking dimensions of solvency and liquidity risks.

[92] Substantially more weight is assigned to forward-looking metrics based on the solvency, liquidity, and contagion analyses. Climate risk is included as market participants may already be pricing in the climate risk profile of banks but is assigned a smaller weight given its longer time horizon and substantial uncertainty surrounding the analysis. Not considering banks' climate risk in the holistic assessment would not change the conclusions of the holistic assessment in a notable way.

218. The distributions of the vulnerability rankings for the underlying components show some heterogeneous patterns across banking clusters. A decomposition of the vulnerability metrics shows that internationally active banks are overall more vulnerable due to greater interconnectedness, while domestic banks appear more vulnerable with a view to the solvency and liquidity stress test results (Figure 91).

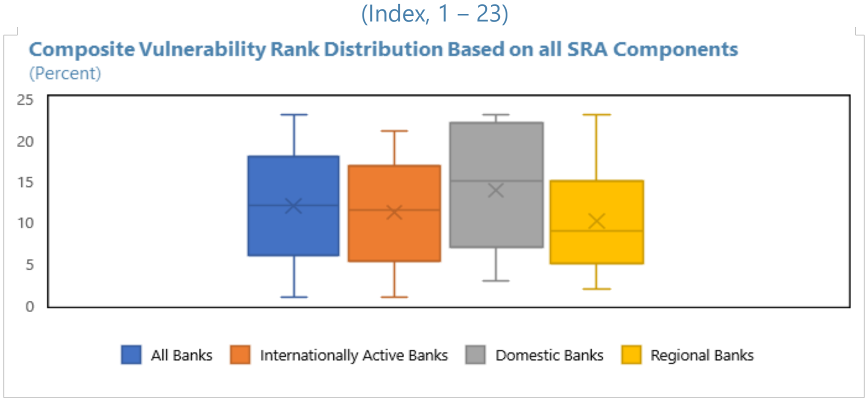
Table 13. Japan: Holistic Vulnerability Assessment—Indicators and Weights for Banks' Composite Rankings

			Weights	
Initial conditions	1	Capital ratio	2.3%	30%
	2	Return on assets (RoA)	2.3%	
	3	Net interest margin (NIM)	2.3%	
	4	Annual cost of risk (loan loss flows / gross loans)	2.3%	
	5	Annual other operating expenses / total assets	2.3%	
	6	Risk weight density	2.3%	
	7	NPL ratio	2.3%	
	8	Share of FV exposures in TA	2.3%	
	9	Share of FV exposures in TA (treat AfS of regional banks as FV)	2.3%	
	10	Materiality of unrealized losses for non-FV exposures	2.3%	
	11	Cash and reserves relative to total liabilities	2.3%	
	12	Sum of 10 largest exposures / capital	2.3%	
	13	Undrawn credit and liquidity lines over TA	2.3%	
Forward-looking analysis	14	Solvency stress test: CET1 ratio Y1 adverse - Y0	10%	70%
	15	Solvency stress test: CET1 ratio under adverse Y1	10%	
	16	Liquidity ST shortfall (min cumul. along horizon over initial LA)	17%	
	17	HtM (and AfS for domestic banks) sales pressure	3%	
	18	LCR	3%	
	19	NSFR	3%	
	20	Default cascade simulations: Vulnerability to all FIs	10%	
	21	Default cascade simulations: Vulnerability to banks	10%	
	22	Vulnerability to climate transition risk	4%	

Source: IMF staff.
Notes: Solvency stress test results, liquidity stress test results, and interconnectedness analysis each receive a weight of 20 percent. From the interconnectedness analysis, the vulnerability metrics were taken into account for the holistic risk assessment, because it assumes a vulnerability/susceptibility perspective (not impact). Considering FX funding liquidity risks as a separate vulnerability dimension (instead of it being subsumed under item 16) in the composite ranking would not significantly change the overall assessment.

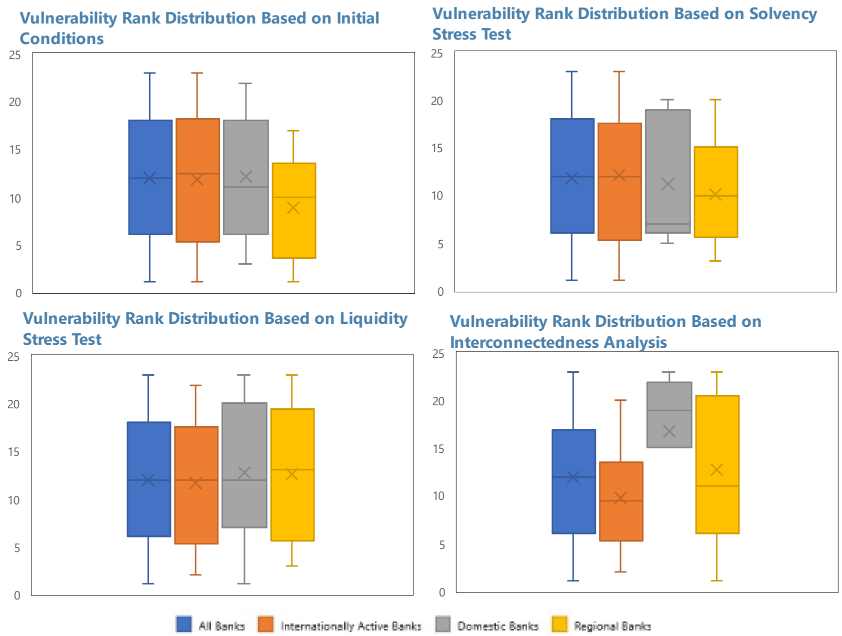
Figure 90. Japan: Holistic Vulnerability Assessment—Distribution of Composite Vulnerability Indicators

(Index, 1 – 23)



Source: IMF staff.
Notes: The box plots depict the distribution of the compositive indicator-based ranking for the underlying individual banks. A lower rank (closer toward 1) means a higher vulnerability. The maximal value that an underlying bank individual composite ranking indicator can attain is 23. In the box plots, lines (crosses x) in the middle of the boxes are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles.

Figure 91. Japan: Holistic Vulnerability Assessment for Banks—Composite Vulnerability Rankings—All SRA Components vs. Sub-Components



Sources: BOJ; FSA; and IMF staff calculations.
Notes: The underlying individual indicators behind each set of composite indicators are summarized in Table 13. In the box plots, lines (crosses x) in the middle of the boxes are medians (means), box edges are the 25th/75th percentiles, and the ends of the whiskers mark the 1st/99th percentiles.

C. Recommendations

219. The systemic risk assessment suggests that the financial system is broadly resilient to the shocks considered in the stress testing exercises for all financial sector components, but some areas merit attention and close monitoring. Some regional banks and internationally active banks are susceptible to solvency and FX funding liquidity risks. Some domestic banks may face notable shifts in their capital position due to valuation losses on available-for-sale securities—which would be shielded by the regulatory treatment of such securities, but could have an important economic impact, thereby warranting close monitoring. The notable FX exposure of internationally active banks and their heavy reliance on unsecured wholesale funding and FX swap markets highlights the need for continued intensive monitoring of FX funding liquidity risks across a wide spectrum of banks.

220. Notable progress has been made to upgrade systemic risk analysis, but the authorities' model framework could be enriched further. The BOJ has expanded the scope of its systemic risk assessment since the last FSAP, and its stress testing model has been enriched in various dimensions.[93] The FSA has recently started to publish its "FSA Analytical Notes," which are used to

[93] The BOJ conducted stress testing of SMEs during the pandemic, estimated stress interest rates for mortgage borrowers, and analyzed connectedness of domestic banks with foreign financial institutions in syndicated loan

(continued)

present topical analyses with a system-wide view, by utilizing granular data for the financial sector and its underlying entities. However, given the evolving nature of the vulnerabilities and risks in the financial system, the systemic risk assessment should be broadened and deepened further to identify trends and risks in a timely manner:

- The BOJ should continue enhancing its macro stress test model, e.g., by developing its credit risk module further.[94]

- The liquidity risk analysis for banks should be enhanced further with, e.g., stress testing tools and models for exposures in both JPY and FX and made an integral part of systemic risk assessment.

- The systemic risk analysis should be broadened to cover stress testing of investment funds. The FSA should also continue its efforts to enhance the data collection and quality assurance process to ensure high-quality supervisory reporting by investment funds. As a basis for the FSA's risk analysis work, supervisory reporting should be thoroughly scrutinized, and funds should be guided to report data more completely and consistently, particular regarding investment assets, derivatives positions, and investment fund classifications.

- For insurers, the FSA would benefit from considering ESR top-down analysis across different combinations of market liquidity conditions and macroeconomic shocks that are more aligned with conjunctural risks, and a more comprehensive liquidity risk analysis.[95] Supervisory reporting could be further expanded to include information on granular derivative positions.

- Given the strong interconnectedness of the financial system, the authorities should more formally assess potential contagion risks (including NBFIs), as an integral part of systemic risk monitoring and to inform financial supervision.

- Given the recent real estate market conditions, the authorities should continue to assess vulnerabilities in real estate markets, and consider conducting more comprehensive analyses utilizing granular information on real estate loans and borrower characteristics. Consideration should be given to assessing the extent of price misalignments in housing and real estate markets through formal modeling approaches.

- The FSA and the BOJ could explore interagency collaboration in systemic risk analyses, with both authorities having access to rich, granular data, and contributing to systemic risk assessment.

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markets and securities investment amid their rising overseas investment. For recent improvements in the macro stress testing model, see BOJ (2020).

[94] For example, it would be beneficial to model the LGDs for corporate lending portfolios explicitly, instead of assuming that the associated provision coverage ratios remain constant under the stress test scenarios. For retail portfolios, risk parameters such as PDs, LGDs, cure rates, etc. should be modelled separately, to allow capturing and analyzing the pressure arising through rising mortgage LGDs in response to house price drops.

[95] More comprehensive liquidity risk analysis for insurers could include, analysis of margin calls due to interest rate swaps.

- The authorities should continue to develop their analytical capacity to analyze climate-related risks for the Japanese financial system, e.g., by accounting for dynamic balance sheets. In this context, the recent work by the BOJ on top-down scenario analysis of transition risk is commendable.[96]

- Interagency collaboration should be strengthened for climate risk-related analysis, recognizing the multidisciplinary nature of such work. The authorities are encouraged to collaborate with other government agencies and research institutions, levering their expertise in climate and natural disaster modeling. This collaboration can help assess the impact of climate risks in a granular and data-driven manner and incorporate them into the analysis of financial institutions' resilience to climate-related hazards, both from a transition risk and a physical risk perspective

221. To broaden and deepen systemic risk analysis, further improvements with regard to data are necessary. Progress has been made to collect granular data under the "Common Data Platform" initiative, through surveys (including "Investment Fund Survey") and the newly established Financial Monitoring Council (FMC).[97, 98] These initiatives are indicative of the authorities' continued forward momentum and are welcome. These efforts should be strengthened by enriching the scope of the Common Data Platform and integrating related databases for more comprehensive risk assessment. In particular, granular data on loan exposures will: (1) help to enhance credit risk analysis and modeling, as an input for bank solvency stress testing; and (2) be instrumental in modeling and assessing real estate-related vulnerabilities and supporting policy making (especially so once integrated with detailed borrower-level information). Moreover, the FSA should strengthen efforts to collect more data on NBFIs and ensure that the scope of the "Investment Fund Survey" allows for comprehensive risk assessment.[99] Finally, remaining gaps related to climate data are encouraged to be closed. Enhanced disclosure mechanisms should be implemented to gather granular data that provides insights into the emissions of a wide spectrum of firms. To evaluate the implications of physical climate risks for individual financial institutions, it is important that geospatial exposure data be compiled. This should encompass not only the location of a firm's headquarters but also consider the location of investment through which the financial institution would be exposed to physical risk.

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[96] The FSA and BOJ conducted the first bottom-up scenario analysis in August 2022, covering both transition and physical risks. Also, the researchers from BOJ recently published the top-down scenario analysis of transition risk (Abe and others, 2023).

[97] The platform, jointly run by the FSA and the BOJ, aims to collect transaction-level loan data from a large number of banks. The platform has been operational since FY2023.

[98] The FMC, comprising of senior officials from the FSA and BOJ, aims to improve coordination in monitoring risks and streamline/combine data templates to reduce burden on financial institutions.

[99] The FSA has recently carried out a survey across investment funds to collect information on leverage and asset exposures. This is a welcome step and an example of authorities' increasing focus on the sector. The survey, however, is in pilot phase, does not cover all funds, and currently provides limited information necessary for comprehensive fund-level stress tests.

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Appendix I. Additional Tables

Appendix I. Table 1. Japan: Selected Economic Indicators

Nominal GDP: US$ 4,213 Billion (2023) GDP per capita: US$ 33,806 (2023)
Population: 125 Million (2023) Quota: SDR 30.8 billion (2023)

	2021	2022	2023	2024	2025	2026	2027	2028	2029
			Est.			Proj.			
					(In percent change)				
Growth									
Real GDP	2.6	1.0	1.9	0.9	1.0	0.8	0.6	0.6	0.4
Domestic demand	1.5	1.5	0.9	0.8	1.1	0.6	0.6	0.5	0.4
Private consumption	0.8	2.2	0.6	0.3	0.9	0.6	0.6	0.4	0.2
Gross Private Fixed Investment	0.4	1.0	1.9	1.9	1.5	0.6	0.3	0.3	0.3
Business investment	0.5	1.9	2.1	2.3	1.8	0.8	0.4	0.4	0.4
Residential investment	-0.3	-3.5	1.1	-0.1	0.3	0.0	0.0	0.0	0.0
Government consumption	3.4	1.7	0.9	1.3	0.7	1.0	0.9	1.2	1.2
Public investment	-1.8	-9.6	2.8	0.1	-0.2	-0.2	-0.3	-0.3	-0.3
Stockbuilding	0.5	0.3	-0.1	-0.1	0.1	0.0	0.0	0.0	0.0
Net exports	1.1	-0.5	0.9	0.2	0.0	0.2	0.0	0.0	0.0
Exports of goods and services	11.9	5.3	3.0	3.3	1.7	2.5	1.8	1.6	1.5
Imports of goods and services	5.1	7.9	-1.3	2.2	2.0	1.7	1.6	1.4	1.3
Output Gap	-1.6	-0.9	0.2	0.1	0.0	0.0	0.0	0.0	0.0
					(In percent change, period average)				
Inflation									
Headline CPI	-0.2	2.5	3.3	2.2	2.1	2.0	2.0	2.0	2.0
GDP deflator	-0.2	0.3	3.8	2.3	2.3	2.1	2.0	2.0	1.9
					(In percent of GDP)				
Government									
Revenue	36.4	37.6	36.5	35.8	36.5	36.5	36.5	36.5	36.5
Expenditure	42.5	41.9	42.2	42.3	39.7	39.4	39.6	39.9	40.2
Overall Balance	-6.1	-4.4	-5.8	-6.5	-3.2	-2.9	-3.1	-3.4	-3.8
Primary balance	-5.5	-3.9	-5.6	-6.4	-3.0	-2.7	-2.8	-2.8	-2.9
Structural primary balance	-4.8	-3.9	-5.7	-6.5	-3.0	-2.7	-2.8	-2.8	-3.0
Public debt, gross	253.9	248.7	252.4	254.6	252.6	251.3	251.0	251.0	251.7
					(In percent change, end-of-period)				
Macro-financial									
Base money	8.5	-5.6	6.3	2.3	2.3	2.6	2.6	2.5	2.4
Broad money	2.9	2.2	2.1	1.5	2.0	2.1	2.1	2.0	1.6
Credit to the private sector	1.9	4.2	4.4	2.6	1.9	1.9	1.6	1.3	1.3
Non-financial corporate debt in percent of GDP	155.0	159.4	155.2	156.8	156.5	155.5	155.7	156.7	156.6
					(In percent)				
Interest rate									
Overnight call rate, uncollateralized (end-of-period)	0.0	0.0	0.0	...	...	...	...	...	...
10-year JGB yield (end-of-period)	0.1	0.4	0.6	...	...	...	...	...	...
					(In billions of USD)				
Balance of payments									
Current account balance	196.4	84.5	144.7	142.6	149.7	162.6	161.5	165.5	154.5
Percent of GDP	3.9	2.0	3.4	3.5	3.5	3.6	3.5	3.4	3.1
Trade balance	16.4	-117.5	-49.1	-31.4	-28.9	-20.5	-19.4	-17.8	-19.1
Percent of GDP	0.3	-2.8	-1.2	-0.8	-0.7	-0.5	-0.4	-0.4	-0.4
Exports of goods, f.o.b.	749.2	751.8	713.2	728.6	754.9	784.0	799.9	818.3	835.6
Imports of goods, f.o.b.	732.7	869.4	762.2	759.9	783.8	804.5	819.2	836.0	854.7
Energy imports	127.8	195.5	152.6	143.0	128.9	118.6	111.0	105.3	100.8
					(In percent of GDP)				
FDI, net	3.5	2.9	3.8	3.0	2.7	2.9	2.8	2.8	2.7
Portfolio Investment	-3.9	-3.4	4.7	-0.7	-1.0	-1.0	-0.3	0.5	-0.4
					(In billions of USD)				
Change in reserves	62.8	-47.4	29.8	11.5	11.5	11.5	11.5	11.5	11.5
Total reserves minus gold (in billions of US$)	1356.2	1178.3	1238.5	...	...	...	...	...	...
					(In units, period average)				
Exchange rates									
Yen/dollar rate	109.8	131.5	140.5	...	...	...	...	...	...
Yen/euro rate	129.9	138.6	152.0	...	...	...	...	...	...
Real effective exchange rate (ULC-based, 2010=100)	73.5	62.0	56.4	...	...	...	...	...	...
Real effective exchange rate (CPI-based, 2010=100)	70.7	61.0	58.0	...	...	...	...	...	...
					(In percent)				
Demographic Indicators									
Population Growth	-0.3	-0.3	-0.4	-0.5	-0.5	-0.5	-0.5	-0.6	-0.6
Old-age dependency	48.7	48.9	49.3	49.8	50.3	50.7	51.1	51.5	52.0

Sources: Haver Analytics; OECD; Japanese authorities; and IMF staff estimates and projections.
Note: Table 1 presents the baseline projections of April 2024 WEO. Real GDP growth rate is projected to be 0.2 percentage points higher on average over 2024-2026 in the April 2024 WEO compared to the October 2023 WEO, while inflation is unchanged on average over 2024-2026.

Appendix I. Table 2. Japan: Financial System Structure

Financial System Assets

(In trillion of yen)

	2016	2017	2018	2019	2020	2021	2022
Banks	1759	1808	1843	1891	2104	2210	2236
City and trust banks	706	733	747	788	860	901	953
City banks	573	594	625	670	734	767	817
Trust banks	132	139	122	118	126	134	136
Regional banks I	311	320	329	324	394	422	410
Regional banks II	75	76	75	71	80	84	81
Shinkin Banks	151	155	158	159	175	180	175
Others	516	524	534	549	594	622	618
Foreign banks	47	52	59	68	69	73	77
Japan Post Bank	210	211	209	211	224	233	230
State-owned banks 1/	82	81	81	81	101	108	108
New types of banks, and others 2/	177	180	185	190	200	208	204
Credit Associations	22	23	24	25	27	27	27
Credit Cooperatives	192	198	203	204	209	210	209
Insurance companies	408	414	420	424	445	453	439
Life	376	381	388	393	412	420	407
of which: Japan Post Insurance	80	77	74	72	70	67	63
Non-life	31	32	31	30	32	32	31
Reinsurance	1	1	1	1	1	1	1
Pension funds	237	245	250	241	274	296	301
Public 3/	145	156	159	151	186	197	200
Corporate 4/	92	89	91	90	88	99	101
Investment funds	176	197	205	200	258	272	276
Consumer finance companies	22	24	25	27	33	35	...
Stock exchanges	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Financial dealers and brokers	141	148	151	174	175	191	206
Total (In trillions of yen)	2935	3034	3096	3159	3492	3659	3696
Nominal GDP (In trillions of yen)	545	556	557	557	538	551	563
Total (In percent of GDP)	539	546	556	567	649	664	657

Number of Institutions

(Number of institutions)

	2016	2017	2018	2019	2020	2021	2022
Banks	467	467	463	458	451	453	452
City and trust banks	18	17	16	16	15	15	15
City banks	5	5	5	5	5	5	5
Trust banks	13	12	11	11	10	10	10
Regional banks I	64	64	64	64	62	62	62
Regional banks II	41	41	40	38	38	37	37
Shinkin Banks	265	264	261	259	255	254	254
Others	79	81	82	81	81	85	84
Foreign banks	57	59	59	58	58	60	59
Japan Post Bank	1	1	1	1	1	1	1
State-owned banks 1/	6	6	6	6	6	6	6
New types of banks, and others 2/	15	15	16	16	16	18	18
Credit Associations	153	148	146	145	145	145	145
Credit Cooperatives	796	789	764	738	711	683	662
Insurance companies	93	94	94	95	95	96	97
Life	41	41	41	42	42	42	42
of which: Japan Post Insurance	1	1	1	1	1	1	1
Non-life	43	44	44	44	44	45	46
Reinsurance	9	9	9	9	9	9	9
Pension funds							
Public 3/	1	1	1	1	1	1	1
Corporate 4/	18823	18883	19091	19078	18969	18939	18917
Investment funds	11095	11784	12455	12951	13562	14235	14301
Consumer finance companies	1865	1770	1716	1647	1638	1580	1548
Stock exchanges	4	4	4	4	4	4	4
Financial dealers and brokers	256	260	261	261	265	267	269
Total							

Source: FSA.

1/ State-owned Banks includes the Development Bank of Japan, the Japan Bank of International Cooperation, the Shoko Chukin Bank, Japan Finance Corporation, the Okinawa Development Finance Corporation, and the Japan International Cooperation Agency.

2/ Including Shinkin Central Bank, Norinchukin Bank, Aozora Bank, and SBI Shinsei Bank.

3/ Government Pension Investment Fund.

4/ Including defined benefit corporate pension, defined contribution corporate pension, Employee's pension fund, and Pension Fund Association.

Appendix I. Table 3. Japan: Financial Soundness Indicators [1/]

	2017	2018	2019	2020	2021	2022	2023
Capital Adequacy and Asset Quality							
Regulatory capital to risk-weighted assets [2/,3/]	16.0	17.1	17.2	16.4	16.6	15.4	14.9
Regulatory tier 1 capital to risk-weighted assets	13.5	14.9	15.1	14.3	14.6	13.8	13.4
Capital-to-total assets [2/,3/]	4.9	5.2	5.2	4.7	4.6	4.3	4.1
NPL net of provisions/capital [2/,4/]	6.2	4.8	4.3	4.8	5.7	6.9	4.9
Non-performing loans (NPL) to total loans ratio [2/,4/]	1.3	1.1	1.1	1.1	1.2	1.3	1.2
Earnings and Profitability							
Return on assets [2/,4/]	0.2	0.2	0.1	-0.1	0.1	0.1	0.2
Return on equity [2/,4/]	5.1	5.4	2.3	-1.3	3.5	2.6	5.8
Interest margin	1.1	1.1	1.1	1.0	0.9	0.9	1.1
Net interest income to gross income [2/,4/]	62.6	62.2	70.4	60.3	63.5	69.1	66.6
Non-interest expenses to gross income [2/,4/]	67.8	69.0	82.7	73.5	70.7	69.8	70.4
Personnel expenses to non-interest expenses [2/,4/]	59.6	44.2	43.7	43.0	42.9	42.7	43.8
Liquidity							
Liquid assets to total assets [2/,4/]	28.7	29.6	29.4	29.5	34.4	35.8	33.3
Liquid assets to short-term liabilities [2/,4/]	49.7	49.9	49.2	47.4	52.6	53.3	50.8
Customer Deposits to Total (Non-interbank) Loans [2/,4]	136.5	139.4	139.5	139.1	147.6	148.6	146.9
Other							
Gross derivative asset to capital [2/,4/]	43.8	35.8	35.2	55.8	43.3	57.1	75.9
Gross derivative liability to capital [2/,4/]	42.3	33.2	33.7	52.0	42.7	59.9	79.9

Source: IMF, Financial Soundness Indicators (FSI) database.
1/ Data for these series are for Q1 of each year.
2/ Including city banks and regional banks but not Shinkin banks.
3/ Aggregated based on a consolidated basis.
4/ Aggregated based on an unconsolidated basis.

Appendix I. Table 4. Japan: Pandemic-Related Financial Sector Policy Measures

Risk	Dates	Details
Capital Measures	March 17, 2020 April 8&17, 2020	The FSA published a Notice to banks that (1) banks can assign zero-risk weight for loans that are guaranteed by credit guarantee associations or those under emergency guarantee program by credit guarantee associations; and (2) their capital buffers are expected to be released in downturns to support credit. The FSA and the BOJ also agreed to relax leverage-ratio exposure rules by exempting deposits at the central bank from the leverage ratio exposure (April 8/17, 2020). This measure is scheduled to end at end-March 2024 (per the FSA's Notice dated March 25, 2022).
Liquidity Measures	March 17, 2020	The FSA published a Notice to banks that banks can appropriately use their stock of HQLA and thereby fall below the minimum during periods of distress. The FSA also postponed implementation of the Net Stable Funding Ratio by 1 ½ year (became effective by September 2021 for internationally active banks).
Changes to market conduct by insurers	March 17, 2020	The FSA requested insurance companies to take appropriate measures such as setting a grace period on payment of insurance premiums and renewal of insurance contracts.
Lending measures and Guidance	March 24, 2020 (Followed by further Notices in the following months)	The FSA requested financial institutions (FIs) to (1) inform customers about the COVID-19 crisis-related special loans offered by Japan Finance Corporation and other institutions; (2) respond respectfully to customers' need, including extending the repayment period and deferred principal payment period with a leeway; followed by further Notices on April 7 and 27, May 8, and June 10 that request FIs to continue to proactively provide new loans and respond promptly and flexibly to borrowers' requests (including providing bridge loans on demand until businesses receive loans from FIs based on government sponsored-lending programs, proactively offering support to borrowers of housing loans by deferring principal payments for a sufficient period or otherwise promptly modifying loan terms and conditions depending on customers' needs, providing 0/0 loans promptly and flexibly to SMEs or individuals for rent payment); and refrain from registering requests to modify loan terms and conditions by customers affected by the pandemic as arrearage to credit information agencies and from charging fees for the modification of loan terms and conditions. Fully guaranteed 0/0 loans have started to be phased out (September 2022), with rollovers expected to be mostly over by mid-2024. These pandemic-related guidelines are expected to be discontinued in 2024.
Postponing national implementation of new regulations	March 30, 2020	The FSA initially announced a one-year deferral of the national implementation date of the finalized Basel III standards and later for another year to end-March 2024, in line with the change to the implementation date by the international agreement. Several banks opted for earlier adoption of the finalized standards, starting end-March 2023.
Fund-Provisioning by the BOJ	May 22, 2020	The BOJ introduced a fund-provisioning measure, "Special Funds-Supplying Operations to Facilitate Financing in Response to the Novel Coronavirus (COVID-19)" to support financing of mainly micro enterprises and SMEs, providing funds against loans such as interest-free and unsecured loans made by eligible counterparties based on the government's emergency economic measures (0/0 loans). The total size of the scheme reached about ¥90 trillion at end-FY21 (equivalent to about US$740 billion at the time). The Policy Board of the BOJ decided to phase out the scheme at its meeting in September 2022, given improved financial conditions on the whole, including some segments of SMEs that are affected by the pandemic, and the decline in the demand for the scheme. Loans through this scheme has completely unwound by June 2023.

Source: IMF staff.

Appendix I. Table 5. Japan: FSAP Risk Assessment Matrix

Risk	Overall Level of Concern	
	Likelihood	**Expected Impact if Materialized**
Intensification of regional conflict(s) and geo-economic fragmentation	High	**High** • Global trade and supply-chain disruptions and increased uncertainty leading to an abrupt global and domestic economic slowdown. • Significant commodity price volatility and upward pressure on inflation leading to a sharp increase in foreign and domestic interest rates. • Valuation losses from holdings of foreign and domestic debt securities under mark-to-market accounting. • Increase in sovereign risk premia, repricing of risky assets, and higher funding costs and lending rates leading to a sharp deterioration of financial conditions and increasing liquidity risks to financial institutions. • Nominal wage growth lags inflation, implying reduction in real wages and private sector borrowers' debt service ability, raising credit risk for banks and NBFIs.
Abrupt global slowdown or recession	Medium	**High** • Lower domestic GDP growth leading to a deterioration in domestic asset quality, bankruptcies, and erosion of bank capital buffers. • Deterioration in macroeconomic fundamentals leading to a reassessment of fiscal risk and higher sovereign risk premia, triggering a negative feedback loop between the sovereign and financial sectors. • Increase in credit risk from overseas exposures. • A rise in global risk premia and strains in offshore U.S. dollar funding markets, implying higher hedging/funding costs for the financial and nonfinancial sectors, impairing their profitability and investment.
Bond market stress from a reassessment of sovereign risk	Medium	**High** • An increase in sovereign risk premia would worsen public debt dynamics and transmit risk to the financial sector because of the sovereign financial sector nexus.
Extreme climate events/disorderly energy transition.	Medium	**High/Medium** • Economic damage leading to large credit losses in the financial sector, amplified by productivity losses and collateral devaluations, triggering a tightening of financial conditions. • Global and domestic decarbonization efforts to mitigate climate change, leading to side-effects, i.e., transition risks to the financial sector depending on the global/domestic policy ambitions and degree of exposure to carbon-intensive firms and industries.
Cyberthreats	Medium	**High** • Cyberattacks on critical infrastructure and systemic financial institutions could threaten macrofinancial instability by undermining confidence and disrupting financial services and real activities.

Source: IMF staff.
Note: The RAM reflects the FSAP team's views on the source and likelihood of risks and expected impact if materialized as of the time of FSAP discussions with the authorities. Non-mutually exclusive risks may interact and materialize jointly.

Appendix I. Table 6. Japan: Macrofinancial Scenario

#	Variable	Units	2023	Baseline			Adverse		
				2024	2025	2026	2024	2025	2026
1	**Real GDP**	Level (a.f., 2023=100)	100	101.0	101.5	102.0	98.2	97.7	98.5
		YoY in %	2.0	1.0	0.6	0.5	-1.8	-0.5	0.8
2	**GDP Deflator**	Level (a.av., 2023=100)	100	103.1	105.4	107.2	105.9	108.4	108.7
		YoY in %	3.6	3.1	2.2	1.7	5.9	2.4	0.2
3	**Nominal GDP**	Level (a.f., 2023=100)	100	104.0	106.9	109.2	104.1	106.0	107.1
		YoY in %	5.2	4.0	2.8	2.2	4.1	1.9	1.0
4	**CPI**	Level (a.av., 2023=100)	100	102.9	104.9	106.6	105.3	109.8	112.9
		YoY in %	3.2	2.9	1.9	1.6	5.3	4.2	2.9
5	**Core CPI**	Level (a.av., 2023=100)	100	102.8	104.7	106.3	105.3	110.2	113.3
		YoY in %	3.8	2.8	1.9	1.6	5.3	4.7	2.8
6	**Unemployment Rate**	Level (a.av.) in %	2.5	2.3	2.3	2.3	3.9	4.3	4.0
		Abs. YoY change in p.p.	-0.1	-0.2	0.0	0.0	1.4	0.4	-0.3
7	**Interest Rates Japan**	Short-term (a.av.) in %	-0.1	0.0	0.1	0.2	1.0	1.0	0.6
		Long-term (a.av.) in %	0.5	0.6	0.8	0.9	2.25	1.5	0.9
		Term spread (a.av.) in p.p.	0.6	0.7	0.7	0.7	1.25	0.5	0.3
8	**Interest Rates US**	Short-term (a.av.) in %	4.9	5.0	3.7	2.6	6.4	4.5	2.7
		Long-term (a.av.) in %	3.6	4.0	3.8	3.7	6.1	5.3	3.6
		Term spread (a.av.) in p.p.	-1.3	-1.0	0.1	1.0	-0.3	0.8	0.9
		Spread short-term US-JP in p.p.	5.0	5.0	3.6	2.4	5.4	3.5	2.1
9	**Effective JPY FX: Nominal**	Level (a.av., 2023=100)	100	97.1	99.0	100.5	103.4	106.7	104.0
		YoY in %	-4.8	-2.9	2.0	1.5	3.4	3.2	-2.5
10	**Effective JPY FX: Real**	Level (a.av., 2023=100)	100	94.3	94.4	94.3	98.1	97.2	92.0
		YoY in %	-7.8	-5.7	0.1	-0.1	-1.9	-0.9	-5.3
11	**USD-JPY: Nominal**	Level (a.av.) in JPY	139.4	143.8	140.9	138.9	135.2	130.9	134.3
		YoY in %	6.0	3.2	-2.0	-1.5	-3.0	-3.2	2.6
12	**USD-JPY: Real**	Level (a.av., 2023=100)	100	100.3	96.4	93.5	92.2	85.6	85.3
		YoY in %	2.8	0.3	-3.9	-3.1	-7.8	-7.2	-0.3
13	**Wages: Nominal**	Level (a.f., 2023=100)	100	103.1	105.1	106.8	103.0	105.5	109.1
		YoY in %	2.3	3.1	1.9	1.6	3.0	2.4	3.4
14	**Wages: Real**	Level (a.f., 2023=100)	100	100.2	100.2	100.2	97.8	96.1	96.6
		YoY in %	-0.9	0.2	0.0	0.0	-2.2	-1.7	0.5
15	**Residential Property Prices: Nominal**	Level (a.av., 2023=100)	100	102.9	104.9	106.6	87.9	87.9	93.9
		YoY in %	4.8	2.9	1.9	1.6	-12.1	0.0	6.9
16	**Residential Property Prices: Real**	Level (a.av., 2023=100)	100	100.0	100.0	100.0	83.5	80.1	83.2
		YoY in %	1.6	0.0	0.0	0.0	-16.5	-4.1	3.9
17	**Commercial Property Prices: Nominal**	Level (a.av., 2023=100)	100	102.9	104.9	106.6	78.6	77.4	86.1
		YoY in %	2.7	2.9	1.9	1.6	-21.4	-1.5	11.2
18	**Commercial Property Prices: Real**	Level (a.av., 2023=100)	100	100.0	100.0	100.0	74.7	70.5	76.2
		YoY in %	-0.4	0.0	0.0	0.0	-25.3	-5.6	8.1
19	**Stock Prices: Nominal**	Level (a.av., 2023=100)	100	105.4	107.5	109.2	73.0	68.4	78.8
		YoY in %	9.4	5.4	1.9	1.6	-27.0	-6.4	15.3
20	**Stock Prices: Real**	Level (a.av., 2023=100)	100	102.5	102.5	102.5	69.4	62.3	69.8
		YoY in %	6.0	2.5	0.0	0.0	-30.6	-10.3	12.1
21	**Private Sector Credit Stock**	Level (e.o.p, end-2023=100)	100	102.0	104.7	107.2	100.4	101.5	102.3
		YoY in %	3.8	2.0	2.6	2.4	0.4	1.2	0.7
22	**Oil Price (Brent Crude)**	Level (a.av.) in USD	81.9	81.1	77.1	73.8	122.9	111.2	99.3
		YoY in %	-17.1	-1.1	-4.9	-4.2	50.0	-9.5	-10.7

Source: IMF staff.

Appendix I. Table 7. Scenario Profile for Other Jurisdictions

Variables	Countries	2023	Baseline			Adverse		
			2024	2025	2026	2024	2025	2026
Real GDP	United States	100	101.5	103.3	105.5	98.4	98.3	100.7
	China	100	104.2	108.4	112.9	98.8	100.9	103.2
	United Kingdom	100	100.6	102.6	104.7	95.2	94.3	96.1
	Germany	100	100.9	102.9	104.9	96.8	96.3	98.1
	France	100	101.3	103.2	104.9	97.9	97.8	99.7
	Spain	100	101.7	103.8	105.7	96.5	96.7	100.1
Short-Term Interest Rates	United States	4.9	5.0	3.7	2.6	6.4	4.5	2.7
	China	0.4	0.4	0.4	0.4	1.0	0.5	0.3
	United Kingdom	5.6	5.8	5.0	4.6	7.1	5.7	4.1
	Germany	3.7	3.7	3.4	2.9	6.6	5.7	3.6
	France	3.3	2.9	2.5	2.5	6.3	4.9	3.0
	Spain	3.5	3.3	3.0	3.1	6.5	5.3	3.6
Long-Term Interest Rates	United States	3.6	4.0	3.8	3.7	6.1	5.3	3.6
	China	2.7	2.6	2.7	2.7	6.6	5.4	2.7
	United Kingdom	4.0	4.2	4.3	4.4	6.5	5.4	3.3
	Germany	2.4	2.6	2.7	2.7	5.7	4.8	2.4
	France	3.0	3.3	3.5	3.6	6.3	5.5	3.2
	Spain	3.4	3.9	4.0	3.8	7.6	6.2	3.4

Source: IMF staff.

Appendix I. Table 8. Japan: Stress Test Matrix (STeM)

Domain		Scope and approaches for the 2023 Japan FSAP
Banking Solvency Stress Test		
1. Institutional perimeter	Institutions included	• 23 banks, which include internationally active banks and domestic banks. The Two specialized banks, Japan Post Bank and Norinchukin bank, are also included.
	Market share	• 82 percent in terms of total assets.
	Data source and cut-off date	• Supervisory data provided by the FSA or obtained from banks. • Cut-off date: March 2023. • Scope of consolidation: The data for the stress testing exercise captures the foreign exposure of banks, which is through lending via foreign branches, direct cross-border lending, as well as foreign security holdings. Japanese banks' exposures through foreign subsidiaries are marginal at the banking system level. Hence, the solo level data for Japanese banks—including all foreign business through branches and foreign bond holdings—was deemed adequate. • Other data sources: commercial databases. • Coverage of sovereign exposures: domestic and main foreign countries exposures, by accounting classification. • Coverage of credit risk exposures: domestic and main foreign countries exposures, by economic sectors.
2. Methodology	Overall framework	• Dynamic bank balance sheet model. • Satellite models developed by the FSAP team; largely structural models in the case of Japan.
	Satellite models for macrofinancial linkages	• Credit risk: Parameter (PD, LGD, EAD) projections, including also for write-off rates and cure rates. Using historical data provided by authorities and relying largely on structural models. Analysis used as starting points the PDs and LGDs reported by banks. • Net Interest Income: structurally-informed econometric pass-through equations for banks' interest income and cost of funding. The cost of funding model accounted for feedback from solvency and for the Japanese banks' non-negligible funding dependence in USD, i.e., USD interest rates. The interest income models capture the pass-through market rates and banks' own cost of funding. • Net Fees and Commission income and other income/expenses: bank-panel regression model using a Bayesian Model Averaging (BMA) methodology. • Market risk: Modified duration model for bonds, including with an account for hedging, and allowing for counterfactual analysis that switches the interest rate hedges off. Equity investments revalued with equity price assumptions in the scenarios. FX net open position: revalue in line with FX paths in the scenario; account for FX hedges. The hedging related data was sourced from banks included in the stress test in relation to their trading and may to an extent be incomplete.
	Stress test horizon	• 3 years: 2024-2026.
3. Type of analyses	Scenario analysis	• Baseline scenario from October 2023 WEO projections. • Adverse scenario, calibrated with at least 2 standard deviation shock relative to historical, and guided by GaR estimates; i.e., overall, with a cyclical state dependency in mind. • Modeling of adverse scenario based on MCM's GFM simulations for Japan and main foreign countries of exposures, combining shocks from global layers (tightening of global financial conditions, a sharp global downturn, and geopolitical fragmentation) and domestic layers (rising inflation and domestic interest rates).
	Sensitivity analysis	• Interest rate risks, interest rate hedging on vs. off, concentration risks.

Domain		Scope and approaches for the 2023 Japan FSAP
		• As additional shock to adverse scenario (short-term interest rate: 1.5 percent in 2024, long-term interest rate: 3.0 percent in 2024, GDP growth rate: -3.2 percent in 2024), or stand-alone.
4. Risks and buffers	Risks/factors assessed	• Credit losses, profitability, funding costs, market risk, fixed income securities (interest rate, spreads, and FX), exchange rate, taxes.
	Behavioral adjustment	• Dynamic balance sheet with growth informed by macro model outcome. • Write-offs calibrated; new business implied such that desired gross loan growth is matched. • Portfolio composition unchanged over time. • Hurdle rate for internationally active banks: 4.5 percent for CET1 ratios, 8 percent for total capital ratios. Hurdle rate for domestic banks' core capital ratio at 4 percent. Capital Conversation Buffer (CCoB) allowed to be consumed in the adverse scenario, including a separate analysis of the extent to which banks consumer their CCoB under the baseline and adverse scenarios.
5. Regulatory and accounting standards	Calibration of risk parameters	• PDs and LGDs and numerous other required risk parameters obtained from supervisory databases. • Regulatory risk parameters, as input to risk weight formulas: downturn LGDs kept constant; pass-through from point-in-time PDs to through-the-cycle PDs assumed to be 20 percent. • Expected loss-based provisioning for performing exposures, as per JGAAP, accounted for; the pass-through from PiT expected losses to provision coverage for performing exposures was assumed to be 20 percent; this was informed by information provided by the BOJ/FSA in terms of the extent to which Japanese banks use forward-looking provisioning models to inform the provision coverage for performing exposures.
	Regulatory/accounting standards	• Regulatory capital ratios and national GAAP accounting standards.
6. Reporting format for results	Output presentation	• System-wide capital shortfalls. • Aggregated contributions to evolution of capital ratios (profit and loss, tax, dividends, post-P&L OCI effects, risk weighted asset contributions, etc.
Banking Liquidity Stress Test		
1.Institutional parameters	Institutions included	• 23 banks (the same as in the banking solvency stress test).
	Market share	• 82 percent.
	Data and cut-off date	• Supervisory data. • Reference date: March 2023.
2. Methodology	Overall framework	• The cash-flow stress test analyzes the net cash balance, accounting for available unencumbered assets, contractual cash inflows and outflows, and behavioral flows. • The analysis also considers Basel III LCR and NSFR and stressed LCR and NSFR. • Scenarios of increasing severity of shocks (haircuts, outflows, FX swaps, etc.). • Account for solvency feedback through the possibly required sale of securities that are held in investment categories that do not require continuous marking-to-market (e.g., HTM, and AFS for domestic Japanese banks with an AFS filter).
	Stress test horizon	• 30 days for LCR-type analysis. • 180 days (6 months) for the cash flow-based stress test simulations.

Domain		Scope and approaches for the 2023 Japan FSAP
3. Type of analyses	Scenario analysis	• Baseline and various scenarios are considered, with varying intensity of adverse liquidity conditions and reflecting different liquidity risks.
	Sensitivity analysis	• Higher, more severe, run-off rates.
4. Risks and buffers	Risks	• Funding liquidity risk is reflected in funding and asset roll-off 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.
	Buffers	• 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. • HQLA in different jurisdictions can be transferred without restrictions. • FX conversion risks are assumed to be absent in the all-currency cash flow stress test.
	Calibration of risk parameters	• Stress funding run-off rates informed by the LCR calibration as relevant for Japanese banks. • Valuation changes for bonds and equity aligned with those implied by the macrofinancial scenario, as used for the solvency stress test
5. Regulatory and accounting standards	Regulatory/accounting and market-based standards	• The LCR hurdle rate is set at 100 percent at the aggregate currency level (per Basel III). There is no regulatory minimum defined for foreign currency LCRs in Japan. NSFR per Basel III; limit of 100 percent.
6. Results reporting format	Output presentation	• Outputs include (1) Changes in the system-wide liquidity position, and their drivers, (2) distribution of banks' liquidity positions, (3) number of institutions with LCR/NSFR below regulatory limits or with cash shortfalls, and (4) amount of liquidity shortfall.

Insurance Stress Test

	Top-Down by IMF and Authorities	Bottom-Up by Insurance Undertakings
1. Institutions included	• Top life and non-life insurances to cover at least 70 percent of annualized new business premiums	• Top life and non-life insurances to cover at least 70 percent of annualized new business premiums
2. Data	• Statutory and voluntary reporting	• Voluntary reporting
3. Reference date	• March 31, 2023	• March 31, 2023
4. Methodology	• Investment assets: market value changes after price shocks, affecting the solvency margin. • Stock-based assessment of liquidity sources and liquidity needs (e.g., according to BCBS, IAIS classifications) • Revaluation of interest rate swaps positions after interest rate shock	• Investment assets: market value changes after price shocks, affecting the solvency margin ratio. • Sensitivity analysis: effect on available capital and solvency margin ratio. • Stock/flow assessment of liquidity sources and liquidity needs (optional).
5. Stress test horizon	• Instantaneous shock	• Instantaneous shock • 3-year projection of profitability indicators (only in the baseline and the adverse scenario).
6. Scenario analysis	• Baseline	• Baseline

Domain	Scope and approaches for the 2023 Japan FSAP	
	• Adverse scenario (in line with narrative severity of the banking sector stress test).	• Adverse scenario (in line with narrative severity of the banking sector stress test).
7. Sensitivity analysis	• Sensitivity to market risk variables and interest rate term structure • Default of largest financial and nonfinancial counterparties.	• Sensitivity to longevity shock, mortality shock, and selected natural disaster events.
8. Risks/ factors assessed	• Market risks: interest rates, stock prices, property prices, credit spreads, currency • Counterparty risks: default of largest financial counterparties • Liquidity risk: relation between decreases in future liquidity sources and increases in future liquidity needs. • Summation of risks, no diversification effects.	• Market risks: interest rates, stock prices, property prices, credit spreads, currency • Counterparty risks: default of largest financial and nonfinancial counterparties • Underwriting risks: catastrophe events, lapses • Liquidity risk: shock to market value of assets, mass lapse shock, mortality shock, morbidity shock and increase of non-life cost of claims, shock to reinsurance inflows, reduction in written premiums. • Summation of risks, no diversification effects.
9. Buffers	• None	• Buffers inherent to product design and regulatory framework
10. Behavioral adjustments	• None	• Management actions limited to non-discretionary rules in place at the reference date for the solvency risk analysis. • Reactive management actions are allowed in parts of the liquidity risk analysis
11. Regulatory standards	• J-GAAP • Economic value-based solvency ratio (ESR) regulation.	• J-GAAP
12. Output presentation	• Impact on solvency margins. • Contribution of individual shocks • Dispersion measures of solvency ratios, liquid assets to liquid liabilities ratios, margin calls-to-liquid assets	• Impact on solvency margins. • Impact on profitability (e.g., net income) • Contribution of individual shocks • Dispersion measures of solvency ratios, profitability measures and liquidity measures
Investment Funds Stress Test		
1. Institutions included	• Open-ended investment funds	
2. Data	• Commercial data (Bloomberg, FactSet, Lipper) • Statutory reporting	
3. Reference date	• March 31, 2023	
4. Methodology	• Calibration of various redemption shocks and comparison to the level of highly liquid assets at the fund level	

Appendix I. Table 8. Japan: Stress Test Matrix (STeM)

Domain	Scope and approaches for the 2023 Japan FSAP
	• Price impact on securities due to fund illiquidity
5. Stress test horizon	• Instantaneous shock
6. Scenario analysis	• Adverse scenario (in line with narrative severity of the banking sector stress test). • Pure redemption shock: severe outflows based on historical distribution
7. Risks/ factors assessed	• Market risk: interest rates, share prices, credit spreads, volatility measures, exchange rates. • Liquidity risk: severe redemption shock.
8. Buffers	• Level of highly liquid assets
9. Behavioral adjustments	• Choice of liquidation strategy used: slicing (prorata), waterfall (most liquid assets first) and mixed approach (cash then slicing) • Liquidity Management Tools (LTM) are not considered in the stress test.
10. Output presentation	• Dispersion of liquidity shortfall; number of funds with the ratio of highly liquid assets to redemptions below one • Aggregate price impact (for different asset classes) • Aggregate vulnerability of the investment fund sector
Interconnectedness and Contagion Analysis	
1. Institutions involved	• Domestic spillovers: Banks (same set of banks in the Bank Solvency Stress Testing), major life insurers (same set of insurers in the Insurance Stress Testing), major securities firms • Cross-border spillovers: Country-aggregate banking sector

2. Data and starting position	• Domestic spillovers:
	  • Confidential bilateral exposure data (supervisory): 2023Q1
	• Cross-border spillovers:
	  • Cross-border banking claims exposure data (BIS Consolidated/ultimate guarantor basis): 2016.
	  • Bank regulatory Tier 1 capital data (Fitch Connect): 2016

3. Methodology	• Domestic spillovers: Co-Map (Covi, Gorpe, and Kok, 2019) • Cross-border spillovers: Espinosa-Vega and Sole (2010)
4. Risks	• Credit and funding losses related to bilateral exposures, and fire-sale of assets following sizeable withdrawals of deposits. • Cross-border exposures
5. Buffers	• Domestic spillovers: Institution's own capital and liquidity buffers • Cross-border spillovers: Banking sector's aggregate capital buffers
6. Size of shocks	• Default of institutions (flexibly reflecting institution-specific capital buffer thresholds)
7. Output/Presentation	• Network mapping of the domestic financial system • Entity-level contagion index, vulnerability index; and systemic risk map
Climate Risk Analysis – Transition Risk	
1. Institutions included	The banking sector, the same coverage as in the banking solvency stress test
2. Data and starting position	• Micro firm-level data for balance sheet and income statement (P&L) for 2005-2023 from Moody's/Orbis

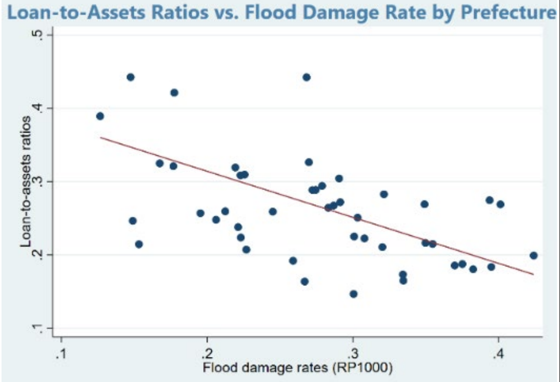
Domain	Scope and approaches for the 2023 Japan FSAP
	• PDs of listed firms for 2005-2020 from Moody's KMV • Data for firms' reported emissions and industry-median emission intensities for Asia-Pacific region (scope 1) from ICE • Individual banks' loan exposures by sectors in March 2023. Source: Supervisory data and each bank's financial summary reports • Individual banks' NPL coverage ratios by sectors
3. Methodology	• In-house developed micro-macro simulation model (Gross and others, "The IMF Environment-Firm and Bank (ENV-FIBA) Model Framework for Climate Risk Analysis—Conceptual Framework, Model Details, and Guide," forthcoming) • Step 1 (Macro module): An IMF CGE model is employed to derive aggregate and sectoral GDP paths, other environmental and macro variables' paths, as well as carbon price paths, that are consistent with NGFS emissions and temperatures target paths. • Step 2 (Micro module): These macro impacts are then used as input to assess the impact of carbon taxes on firms' balance sheets in the firm-level micro simulation. The firm-level credit risk indicators, such as PDs, LGDs, and credit spread, are debt-weighted aggregated into the sectoral-level risk indicators. • Step 3 (Bank module): The sectoral-level credit risk will be translated into impacts on individual banks' capital based on their industry exposures. When assessing the impact on bank capitalization, deleveraging and leveraging of industries that are declining and thriving, respectively, are accounted for.
4. Scenarios	• NGFS Phase IV scenarios (Net Zero 2050, Fragmented World, Current Policies)
5. Time horizon	• Up to 2040
6. Risks/factors assessed	• The impact of carbon taxes on firms' balance sheets and income statements through the changes in GVAs of the sectors to which firms belong (macro channel), as well as direct emission costs (micro channel) • Foregone interest income (dynamic balance sheet channel)
7. Behavioral adjustments	• In the Micro module, an econometric stock-flow Merton model-inspired PD panel model and Frye-Jacobs LGD modeling are employed. In addition, given huge uncertainty in individual firm's emissions, a Montecarlo simulation is conducted over the firm-level emission intensity based on its' estimated kernel density function for Japan. • In the Bank module, individual banks' sectoral loan exposures are assumed to vary at the growth rates of sectoral GVAs to account for foregone/expected interest income from deleveraging/leveraging.
8. Output presentation	• Delta PDs, delta LGDs, and delta credit spreads by sector • Individual banks' capital ratio impacts and the loss contributions from the underlying industry segments

Table I.9. Japan: Flood Risk Versus Loan-To-Asset Ratios

VARIABLES	(1)	(2)	(3)	(4)
	Loan-to-Asset Ratio			
Flood damage rate	-0.560***	-0.502***	-0.405**	-0.287*
	(0.142)	(0.141)	(0.163)	(0.160)
Loan growth		1.135*		1.427**
		(0.569)		(0.552)
Loan share			1.350*	1.746**
			(0.739)	(0.711)
Constant	0.378***	0.338***	0.328***	0.263***
	(0.0313)	(0.0364)	(0.0408)	(0.0459)
Observations	46	46	46	46
R-squared	0.260	0.323	0.314	0.408

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Loan-to-Assets Ratios vs. Flood Damage Rate by Prefecture



Sources: BOJ; Cabinet Office; and IMF staff calculation.
Notes: The dependent variable is the loan-to-asset ratio by prefecture for 2018, where assets are defined as the total of private firms' net capital stock and households' net capital stock. The right-hand side variables include flood damage rates for 1000-year RP hazards under the current climate, the annual growth rate of loans from 2010 to 2017, and the loan share among prefectures for 2017. Tokyo was excluded, as an outlier, from the regression and the graph.

Appendix II. Real Estate Market Analysis

Construction of the Price Acceleration Indicators

This section describes the econometric methods employed to test for explosive behavior in real estate prices. The detection of periods of real estate price exuberance is based on Augmented Dickey-Fuller (ADF) tests. The ADF regression equation can be defined as:

$$\Delta y_t = a_{r_1,r_2} + \beta_{r_1,r_2} y_{t-1} + y_{t-1} \sum_{j=1}^{k} \psi_{r_1,r_2}^{j} \Delta y_{t-j} + \epsilon_t, \epsilon \sim N\left(0, \sigma_{r1,r2}^2\right)$$

where y_t denotes a generic time series (using the notation of the previous section, y_t can be either log house price or price-to-rent ratio, Δy_t for j=1, ..., k are the differenced lags of the time series, and ϵ t is the error term. Moreover, r_1 and r_2 denote fractions of the total sample size that specify the starting and ending points of a subsample period, k is the maximum number of lags included in the specification, and a_{r_1,r_2}, β_{r_1,r_2} and ψ_{r_1,r_2}^{j} with j=1,...,k are regression coefficients.

The emergence of explosive behavior in house prices defines a period of exuberance and is indicated by a shift from a random walk to mildly explosive behavior. Therefore, we are interested in testing the null hypothesis of a unit root in y_t. This corresponds to the null hypothesis: β_{r_1,r_2} = 0. The test statistic corresponding to this null hypothesis (H_0) is defined as:

$$\mathrm{ADF}_{r_1}^{r_2} = \frac{\widehat{\beta_{r_1,r_2}}}{se}$$

Setting r_1 = 0 and r_2 = 1 yields the standard statistic ADF_0^1.

The ADF test compares the statistic with the right-tailed critical value from its limit distribution. When the test statistic exceeds the corresponding critical value, the unit root hypothesis is rejected in favor of the alternative of explosive behavior. Although widely employed, the standard ADF test has extremely low power in detecting episodes of explosive behavior when these episodes end with a large drop in prices, i.e., in the presence of boom-bust dynamics. A recursive procedure is therefore added following:

$$\mathrm{SADF}(\mathrm{r}_0) = \sup_{r2 \in [r_{0,1}]} ADF_0^{r_2}, \qquad \text{with limit distribution under } H_0: \qquad \sup_{r2 \in [r_{0,1}]} \frac{\int_0^{r_2} W dW}{\left(\int_0^{r_2} W^2\right)^{\frac{1}{2}}}$$

where W is a Wiener process, and the window size of each estimation is $r_w = r_2 - r_1$. The rejection of the unit root hypothesis in favor of explosive behavior requires that the test statistic exceeds the right-tailed critical value from its limit distribution given.

If the null of a unit root in y t is rejected, then the SADF procedures can be used to obtain a chronology of exuberance in the housing market. The identification of periods where house prices (or price-to-fundamental ratios) displayed mildly explosive behavior is particularly relevant for shedding light on developments that might lead to overheating in the market. Date stamping (i.e., the identification of periods of exuberance in the real estate market) can be carried out using the Backward SADF statistic allowing both the ending point, r_2, and the starting point, r_1, to change:

$$\mathrm{BSADF}(\mathrm{r}_0) = \sup_{r1\,\in[0,r_2-r_0]} SADF_{r1}^{r_2}$$

The origination date of the period of exuberance is defined as the first observation for which the BSADF statistic exceeds its critical value,

$$\hat{\mathrm{r}}_{\mathrm{e}} = \inf_{r2\,\in[r_0,1]}\left\{r_2\colon SADF_{r2}(r_0) > scu_{[r_2T]}^{\alpha}\right\}$$

Where $scu_{[r_2T]}^{\alpha}$ is the 100(1- α) percent critical value of the SADF on $[r_2T]$ observations and α is the chosen significance level. The termination date is defined similarly as the first observation after r_{e} for which the BSADF falls below its critical value.

Housing and CRE Price Overvaluation

The estimation of misalignment is done following two alternative approaches. First, misalignments in house prices are estimated using an error correction model (ECM), where changes in real estate prices serve as the dependent variable.

$$y_t \;=\; \beta_1 \;+\; \beta_2 X_t \;+\; u_t$$

Where β_1 is the constant. The estimation is performed based on the Engel two-step procedure ("benchmark model"). This entails estimating the parameters β_1, β_2 with a first-stage OLS, and then use the actual residuals from this first stage in a second-stage OLS regression using the first difference of y as dependent variable:

$$\Delta y_t \;=\; \beta_3 \;+\; \beta_4 \Delta X_t \;+ \alpha(y_{t-1} - \widehat{\beta_1} - \widehat{\beta_2} x_{t-1}) \;+\; \epsilon_t$$

where α is the coefficient of the estimated lagged residual from the previous equation, $\widehat{\beta_2}$ is the long-run coefficient, and $\widehat{\beta_4}$ is the short-run coefficient (i.e., immediate impact of a change in X_t on the change in y_t). The two-step procedure provides consistent estimates of the β values (in the first stage), provided that y and X are cointegrated. The order of integration of the variables in the model is tested through an augmented ADF test. The explanatory variables are meant to capture mainly demand-side factors, while supply is assumed to be relatively inelastic in the short run but has an impact on house prices in the long run.

The second approach models real house price changes as a function of changes in an affordability measure using OLS. The model takes the following form:

$$\Delta y_t \;=\; \beta_0 \;+\; \beta_1 \Delta X_t + \theta\, Affordability_{t-1} \;+\; \epsilon_t$$

Here affordability acts as an anchor for deviations from the long-run equilibrium. Assuming housing is a normal good, demand for it would be increasing with income gains. Yet, depending on how sluggish the supply response is, an income shock can push prices away from fair values leading to a deterioration in housing affordability. Therefore, housing demand would have to subside so that house prices come back in line with income. In other words, affordability is used as a benchmark for any unsustainable deviation from the equilibrium level of house prices to correct itself over the long run. This could be interpreted as an error correction mechanism as well. as it reflects the concept of a long-run equilibrium level of house prices determined by economic fundamentals.

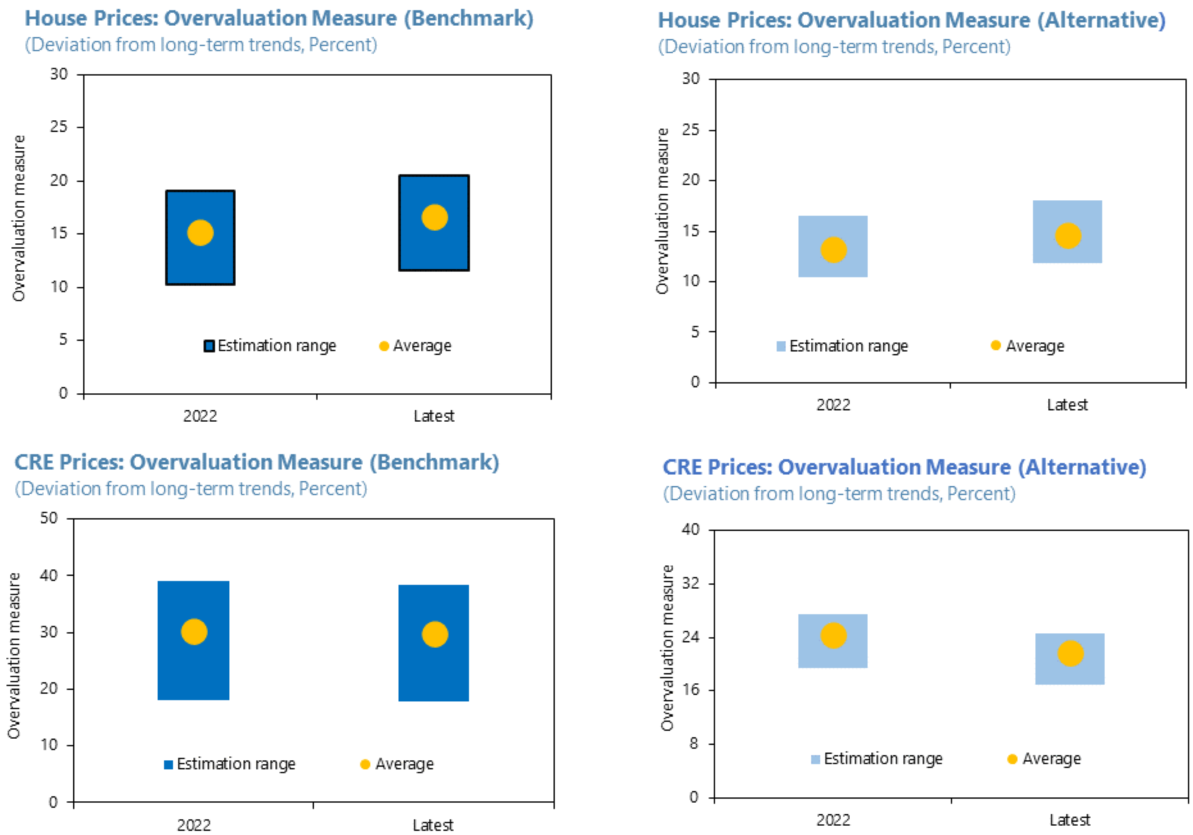
In both approaches, a set of covariates is included to capture supply and demand factors. Specifically, the model to assess house price overvaluation includes changes in income per capita, short- and long-term interest rates, credit growth, growth in equity prices, growth in the fraction of working age population, and an affordability measure. The affordability measure is based on price-to-income ratios.[1] In addition, construction costs serve as a proxy for supply-side factors.

The levels of house prices in years from 1997 to 2001 are used as alternative base levels from which the fitted values of the house price increases are accrued. The misalignment then is calculated as the average over these base years.

The estimation of overvaluation in the CRE market follows a similar approach as the one used for housing market prices. Given the specificity of CRE markets, in addition to the previous set of variable rental growth, vacancies rate and capital inflows are added to the baseline model. As measure of affordability the misalignment of capitalization rates is used in the regressions. Results from the two models for both house and CRE prices are provided in Figure I.1.

[1] In the ECM specification, affordability is measured as deviation of price-to-income ratio relative to the estimated historical trend.

Appendix II. Figure.1. Japan: Overvaluation Measure in Housing and Commercial Real Estate



Sources: BIS Statistics; Haver; MSCI Real Estate; OECD; and IMF staff calculations.
Notes: The panels show overvaluation measures for housing markets and commercial real estate estimated using an error correction model ("benchmark") and with the alternative liner model incorporating error correction feedback from affordability measures. The models control for demand-and supply-side factors including changes in income per capita, short and long-term interest rates, credit growth, equity price growth, change in the fraction of working age population, and change in issued permits. The estimated range (bars) derives from different levels of base prices (for years 2000-15) that are used to obtain changes in fitted valuations to derive estimates of price misalignments relative to fair values. The average misalignment is the mean over different base years (yellow marker).

Measuring Downside Risks to Real Estate Prices

In order to determine what is the likelihood of a price correction we use a house price at-risk model. The model is based on Adrian and others (2023). House price-at-risk corresponds to downside risks to house prices, defined as the forecast house price growth at the 5th percentile of the house price distribution. As shown in earlier studies, the measure of house prices at risk is a relevant indicator as it helps forecast downside risks to GDP growth over and above other simpler measures of house price imbalances, and thereby adds to early-warning models for financial crises.

Estimation is carried out using a two-step procedure for panel quantile regressions, following Canay (2011). The first step estimates (log annualized) changes in real house prices by a standard fixed effect estimation and then constructs a demeaned version of the dependent variable subtracting constant term and the (unobserved) fixed effects:

$$\Delta_h Y_{i,t+h,\tau} = \alpha_{i,h,\tau} + \beta_{h,\tau} X_{i,t} + e_{i,t,h,\tau}$$

$$\Delta_h \tilde{Y}_{i,t+h,\tau} \equiv \Delta_h Y_{i,t+h,\tau} - \hat{\alpha}_{i,h,\tau}$$

The second step runs a quantile regression for each quantile q and horizon h. The quantile function can be represented as the solution to an optimization problem, where rho is the quantile loss function:

$$\hat{\beta}(\tau) \equiv argmin\, \mathbb{E}_{nT}\left[\rho_\tau\left(\Delta_h \tilde{Y}_{i,t+h} - X'_{it}\beta_{h,\tau}\right)\right])$$

$$\widehat{Q_{\iota,t+h|x_{\iota,t}}}(\tau) = X_{i,t}\hat{\beta}$$

House-Price-at-Risk is then defined as the value at risk of future house price growth, by

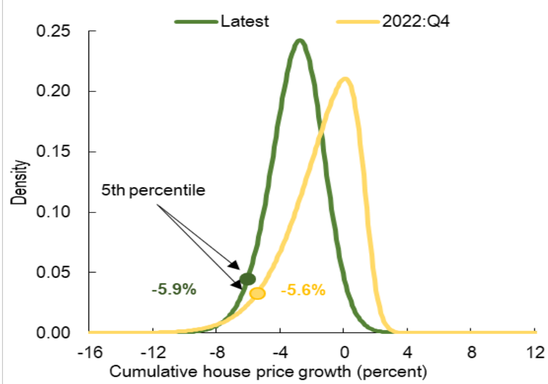
$$\Pr(\Delta_h \tilde{Y}_{i,t+h,\tau} \leq \mathrm{HaR}_{\mathrm{i,h}}(1-\tau|X_t)$$

The main control variables used for the estimation of the house price-at-risk indicator include past growth in house prices, financial conditions, real GDP growth, a credit boom indicator, and an overvaluation indicator capturing the degree of deviation of house prices from fundamental valuation levels.

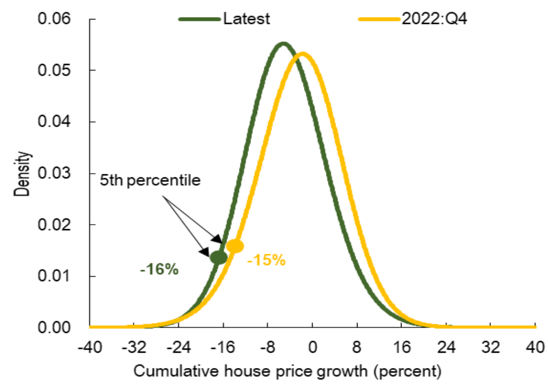
The baseline model for the construction of the at-risk measure for CRE prices adopts a similar estimation approach used for house price-at-risk. The baseline CRE price-at-risk specification includes selected fundamental factors such as past growth in CRE prices (to capture momentum effects), CRE price misalignment, GDP growth, credit-to-GDP growth, capital-flow-to-GDP ratio, monetary aggregates, and vacancy rates. The specification is based on Deghi, Mok and Tsuruga (2021). Figure II.2 provides an overview of the results across sectors and time horizons.

Appendix II. Figure 2. Japan: Downside Risks in Housing and Commercial Real Estate

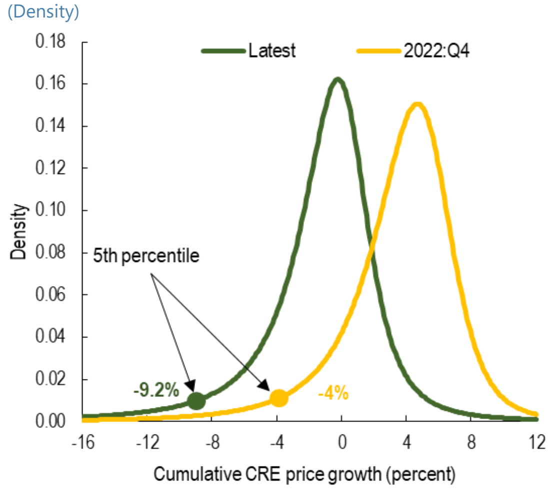
One-Year Ahead: House-Prices-at-Risk Model
(Density)



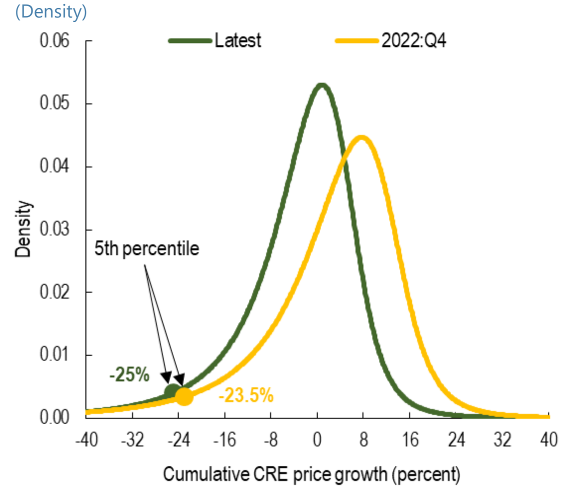
Three-Years Ahead: House-Prices-at-Risk Model
(Density)



One-Year Ahead: CRE-Prices-at-Risk Model
(Density)



Three-Years Ahead: CRE-Prices-at-Risk Model
(Density)



Sources: BIS Statistics; Haver; MSCI Real Estate; OECD; and IMF staff calculations.
Notes: The panels show the probability densities estimated for the one-year-ahead and three-year-ahead house and CRE price growth distributions (cumulative). Forecast density estimates assume the GDP growth path projected by the WEO. Filled circles indicate the price decline with a 5 percent probability (5th percentile) in an adverse scenario.

Appendix III. Nonfinancial Corporate Risk Analysis

Data

Moody's/Orbis database provides historical balance sheet and income statement data for nonfinancial firms. For the analysis of corporate risk and climate transition risk, entities operating within sectors such as finance and insurance (NACE Rev. 2, 64-66), public administration (84), and activities of households (97-98) were excluded. The dataset encompasses an 18-year time frame, spanning 2005 to 2022.

An important detail regarding the data relates to the firms' consolidation level. A "no double counting" principle was adopted, that is, firms were included at the highest level of consolidation and lower-level firm subsidiaries were excluded if their parents were Japanese firms and included as such in the sample. The consolidation codes available that were relevant for reflecting the "no double counting" principle are referred to as "C1," "C2," "U1," and "U2" in the dataset. One consolidation code per firm was to be kept. The preference order was defined as C2-C1-U1 in that order (see the table below for a description of these consolidation codes). The U2 code is not relevant because unconsolidated results are not used when consolidated results are available. The "filing type" was used to remove any remaining duplicates for a given consolidation code per firm and year. "Filing type" references whether the financials are from the annual report or from a local registry filing.

Moody's/Orbis Firm Consolidation Codes	
C2	Contains the consolidated financial statements. The unconsolidated results are also available in Orbis.
C1	Contain the consolidated financial statements. The unconsolidated results are not available in Orbis.
U1	Contains unconsolidated financial statements and assumes that these firms do not have controlled subsidiaries (or it could be that they do have controlled subsidiaries, but that information is not public).
U2	Contains the unconsolidated financial statements, without integrating the controlled subsidiaries, but the consolidated financial statements are available in Orbis.

Sources: Moody's; and Orbis.

Various filters were imposed to clean the dataset as shown in the table below.

Moody's/Orbis Variables and Filtering Conditions	
Cash_and_cash_equivalent **(>0)**	Operating_revenue_turnover **(>0)**
Total_assets **(>0)**	Operating_P_L_EBIT **(≠0)**
Debt_holding* **(>0)**	P_L_before_tax **(≠0)**
Long_term_debt** **(>0)**	P_L_after_tax **(≠0)**
	Costs_of_goods_sold** **(≥0)**
	Costs_of_employees** **(≥0)**

Sources: Moody's; and Orbis.
Notes: * Debt_holding = Loans + Creditors + Long-term_debt.
** This filtering is only applied to climate risk analysis.

The Moody's/Orbis dataset was further augmented with PDs, sourced from Moody's/KMV. Daily one-year PDs were converted to annual by taking annual averages for each firm, aligning these averages with the respective closing data for a firm' financial statement and for each year. Subsequently, these PD averages were merged with the Moody's/Orbis dataset based on firms' identification numbers.

Methodology

The merged Orbis / KMV dataset was used to estimate the key determinants of PD with a firm fixed effects econometric model (equation 1). The dependent variable is the logit transformation of 1-year PD and the independent variables include leverage, interest coverage ratio (ICR), earnings before interest and taxes over total asset ratio (EBITR), cash over short-term debt ratio (CDR) and real GDP growth. The estimated model is then used to impute PDs for unlisted firms (whose PDs are not available from Moody's/KMV).

$$logit\left(PD_{ft}\right) = \alpha_f + \beta LEV_{ft} + \gamma ICR_{ft} + \delta EBITR_{ft} + \theta CDR_{ft} + \lambda RGDP \text{ growth} + \varepsilon_{ft} \quad (1)$$

Since Orbis database does not cover 2023, firm performance was estimated in 2023 based on macro variables and industry-level trends.

Firm performance is simulated in 2024-2026 under the baseline scenarios as well as under the various stress scenarios used for the bank stress test. The key variables needed to forecast PDs include revenues, cost of goods sold, other operating expense, financial revenue, interest paid and tax expense. Revenues are assumed to grow in line with nominal GDP; cost of goods sold is assumed to have a constant elasticity to sales where the elasticity is estimated using historical data; other operating expense is assumed to grow with inflation; financial income is affected by financial market performance and sales revenue, and tax rate is assumed to be constant (zero if earnings are negative). Interest rates are firm specific and are endogenous to PD and LGD due to credit spread.

For LGD, we use a Vašíček model structure as laid out in Frye and Jacobs (2012).[1] The equation links an LGD trajectory to a PD trajectory at the firm level.

$$\mathrm{LGD_{t0+h}} = \frac{\Phi(\Phi^{-1}(\mathrm{PD_{t0+h}}) - \mathrm{k})}{\mathrm{PD_{t0+h}}} \text{; where } \mathrm{k} = \frac{\Phi^{-1}(\mathrm{PD}) - \Phi^{-1}(\mathrm{PD} \times \mathrm{LGD})}{\sqrt{1-\rho}}$$

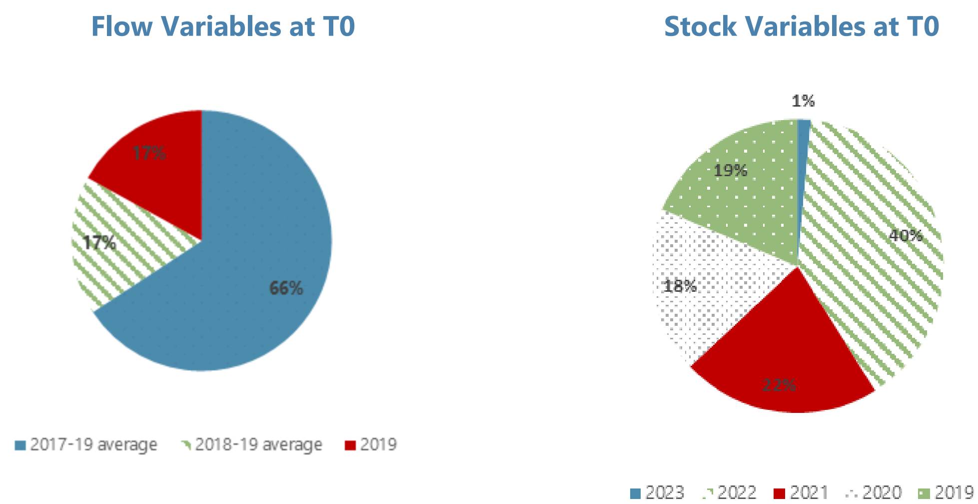
After forecasting firm-level PDs and LGDs for all firms, the aggregate nonfinancial corporate sector PD (or LGD) in 2024-2026 is obtained by taking the average of PD (or LGD) weighted by each firm's debt level.

Regarding climate risk analysis, a "T0" database was constructed that serves to anchor the microsimulation and to mitigate potential distortions caused by the pandemic while leveraging the latest information. To achieve this, pre-pandemic data up to March 2020 was employed for flow variables, such as revenues, and the most recent data for stock variables like total assets. In the case

[1] For details, see Frye and Jacobs 2012, "Credit Loss and Systematic Loss Given Default," Journal of Credit Risk.

of flow variables, averages over a period of up to three years were considered, whenever data was available. The year profiles for both flow and stock variables are presented in Figure III.1.

Appendix III. Figure 1. Japan: Year Profiles for Flow Variables and Stock Variables at T0



Sources: Moody’s/Orbis; and IMF staff calculation.

Several additional filters were utilized. In addition, the “T0” database retained only active firms, that is, firms that defaulted or merged or were resolved for other reasons in the past, were removed.

In the final step of our data processing, some missing values for two key variables were imputed. For the cost of employees, the industry median wage at the NACE Level 2, in combination with the firm's number of employees was used to estimate missing values. Similarly, for interest expenses, the industry median interest rate and the firm's debt holdings were used to impute missing data points.

Appendix IV. Household Stress Testing

Data

The micro data is sourced from the Japan Household Panel Survey (JHPS/KHPS), compiled by the University of Keio (KHPS since 2004, and JHPS since 2009). The survey covers a wide range of topics and data at a household- and household-member level. Most importantly for the purpose of the household stress testing analysis, it includes household-member level data on age, education, marital and employment status, labor income, and unemployment benefits. At a household level, it includes detailed questions on financial assets, financial liabilities, income and expense flows, and mortgage loans (e.g., type of mortgage (fixed/floating), maturity, loan amount, house (and plot) value at the origination). The survey, in several respects, is similar to the Panel Study of Income Dynamics (PSID) in the U.S., the European Community Household Panel (ECHP) in Europe, and the HFCS in Europe.

The latest available wave of the survey is used (January 2021). It provides information for the year 2020 or end-2020 depending on the survey question. As will be discussed later, several income and expenditure variables are then extrapolated to 2022, or end-2022, using macroeconomic variables to make future projections. The full list of variables used in the model are provided in Table IV.1.

Appendix IV. Table 1. Japan: Survey-based variables used in the Household Stress Testing

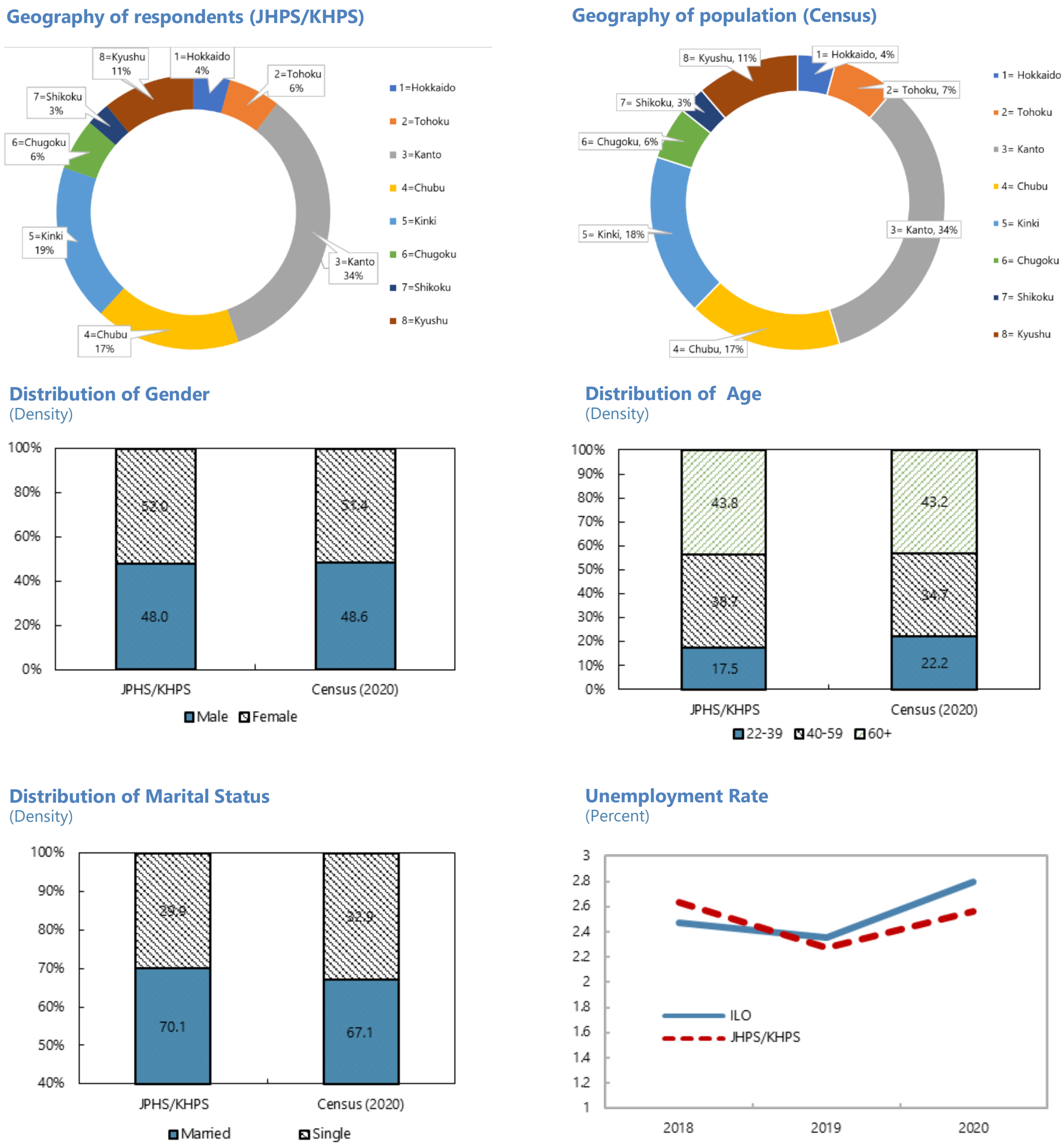
	Chapter	Variable code	Description
HH Level	Assets	H	Current value of house
		B	Current market value of bonds
		S	Current market value of stocks
		TFA	Total financial assets (incl. cash, stocks, bonds, pensions, life, insurance)
	Liabiltiies	D	Total Debt
		D_M	Outstanding balance of mortgage debt
		D_NM	Outstanding balance of non-mortgage debt
	Income Flows	I	Household income total, quarterly, gross of tax
		I_2	Household income total, quarterly, net of tax
		RI	Rental income, quarterly
		OI	Other regular income, quarterly, e.g. child benefit, alimony, etc.
		II	Interest Income, quarterly
	Expense Flows	A_M	Annuity for mortgage debt, quarterly
		A_NM	Annuity for non-mortgage debt, quarterly
		A	Total expense, quarterly
		OE	Rental expense, quarterly
		E	Living expense, excl. annuities and rent, quarterly
		E_2	Living expense excluding rent - other expenses
	Other	HH_ID	Household ID
		HH_RES	Country of residence
		Myear	Year of 1st mortgage origination;
		MiniDur	Duration of 1st mortgage at origination in years;
		DType	Rate type of total debt
		Etol	Living expenses (excl. Annuities and rent) as share of gross income

	Chapter	Variable code	Description
HM Level	Income inflows	INC_E	Labor income (gross of tax) from employment or selfemployment, public/private pension income (net of tax), quarterly
		INC_U	Unemployment benefit, net of tax, quarterly
	Other	LAB	Labor status
		MAR	Marital status
		EDU	Level of education
		GEN	Gender
		AGE	Age
		HM_ID	Household member ID
		HM_HH_map	Household members' household IDs

Sources: JPHS/ KHPS; and IMF staff calculations.

The survey data matches well the 2020 Census (Figure IV.1), particularly on variables that are a required input for the model. First, the geography of respondents to JHPS/KHPS closely mimics the Census data. Second, several key household characteristics such as gender, age, and marital status, are very similar to the Census data. Finally, the survey data appears to match well the aggregate unemployment rate.

Appendix IV. Figure 1. Japan: Household Characteristics in JHPS/KHPS vs. Census (2020)



Sources: BIS Statistics; Haver; MSCI Real Estate; OECD; and IMF staff calculations.

The survey comprises 4,817 households and 14,318 household members in the latest wave. One-fourth of households hold mortgage debt, and 38 percent hold either mortgage or consumer debt. These figures are lower than the U.S. or the European average, but the loan-to-value ratio at origination or at current levels appears higher than those in peers, at a median of 90 and 69 percent, respectively. The median current DSTI ratio is 17 percent, moderate in absolute terms, though somewhat higher than the US or European average. (Table IV.2).

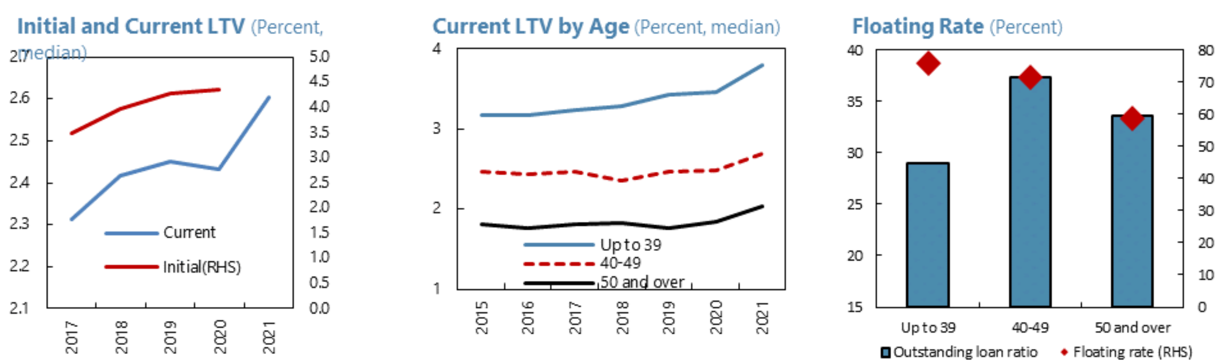
Appendix IV. Table 2. Japan: Household Data—Summary Statistics

Country	#HHs	#HMs	HMs / # HHs	HHs with mortgage debt	.../# HHs	HHs w/ consumer debt	.../# HHs	# HHs with debt	.../# HHs	Initial LTV (mortgages)	Current LTV (mortgages)	Current DSTI (total debt)
Japan (JHPS&KHPS)	4817	14318	3.0	1197	25%	902	19%	1820	38%	90%	69%	17%
US (PSID)	9607	24998	2.6	3036	32%	4734	49%	5924	62%	--	64%	14%
Germany (HFCS)	4942	11251	2.3	1356	27%	1388	28%	2253	46%	59%	32%	11%
France (HFCS)	13685	32799	2.4	4560	33%	4342	32%	7040	51%	81%	43%	18%
Italy (HFCS)	7420	16462	2.2	478	6%	1019	14%	1340	18%	80%	35%	12%
EU average (HFCS)	4293	10479	2.4	1137	26%	1314	31%	1936	45%	83%	40%	12%

Sources: JPHS/ KHPS; and IMF staff calculations.
Notes: LTV and DSTI ratios are for the median household. DSTI is calculated for households with debt (that is, excluding households with zero debt) and based on gross income.

Loan-to-income ratios, measured at current levels or at origination, exhibit a notable increase, from below 2.3 in 2016 to 2.6 in 2021 for current LTI, and from below 4 percent in 2015 to 4.3 in 2020. The increase in LTI ratio is mainly driven by younger age groups, which constitute close to 30 percent of outstanding loans. The share of floating rate mortgages is relatively higher for the young age group, at 80 percent. (Figure IV.2).

Appendix IV. Figure 2. Japan: Household Loan Characteristics in JHPS/KHPS vs. Census



Sources: JHPS/KHPS; and IMF staff calculations.

Before simulating the model, the data of key household-level variables used in the model—such as the market value of houses and plots, households' financial assets and liabilities, income and expenses—is extrapolated to 2022 using data on macro variables such as the aggregate house price index, stock price index, consumption price index, the gross disposable income, etc. A summary of the aggregate data used to extrapolate the household—or household member—level data is provided in the text table. Note that between 2020 and 2022, aggregate house prices (including plots) have increased by 15 percent, aggregate stock prices by 20 percent, the overall consumer price index by 2.3 percent, household debt-to-income by 3 percent, household consumption by 6 percent, nominal wages by 2 percent, and household assets (currency and deposits) by 6 percent. During the same period, household holding of government debt declined by 6 percent, the gross disposable income declined by 1 percent, while rent prices remained broadly stable.

Japan: Macro Data Used to Extrapolate Household-Level Variables for 2022

Variables	2021	2022
	Relative to 2020	
House price	6%	15%
Household holding government bonds	-5%	-6%
Stock price	27%	20%
Household debt to income	5%	3%
Gross disposable income	-3%	-1%
CPI(rent)	0.1%	0.1%
CPI	-0.2%	2.3%
Household consumption	1%	6%
Nominal Wage Income of Employees	1%	2%
Households: Assets: Currency & Deposits	3%	6%

Source: IMF staff calculations.

Methodology

The model is a structural micro-macro model, IDHBS+ (Integrated Dynamic Household Balance Sheet+) (Gross and Poblacion, 2017; Gross et al. 2022), previously applied to the U.S. and European household panel surveys for household sector stress testing and to conduct policy counterfactual analyses, and currently in use by several central banks to inform policy making.

The baseline and adverse macrofinancial scenarios are used as inputs to simulate the household member employment status and household balance sheets, and eventually, aggregate mortgage PDs and LGDs. The model simulation involves several steps:

- *Building macrofinancial scenarios.* For this step, the scenarios are taken from the bank solvency stress testing.
- *Simulate employment status.* This step operates at the household member level (excluding retirees and students). The employment status of each individual over the forecast horizon is linked to her/his characteristics (age, education, marital status, and gender). The regression results suggest that individuals with 4-year university degrees, or who are male or married are more likely to be employed, while age appears to be not a significant factor. The model does well in capturing employing status: "Area Under the Receiver Operating Characteristic" (AUROC) suggest that the model can predict about 72 out of 100 cases correctly (Table IV.3). The regression then serves as an input to the "Employment Status Simulator", which simulates the employment status of household members based on the logistic model coefficients (taking most characteristics as it is, while dynamically adjusting household member's age in each year in the forecast horizon), while adjusting the intercept term of the logistic model to match the aggregate unemployment rate in the forecast horizon. Moreover, the error term of the logistic

model is assumed to be persistent, with a degree of persistence such that aggregate duration of unemployment in the data is matched (3 quarters, the OECD). This "Simulator" is then used to simulate employment status of household members along the forecast horizon. Finally, each household member is assigned to its household to then simulate the household balance sheets.

Appendix IV. Table 3. Japan: Logistic Regression and AUROC/Gini Curve

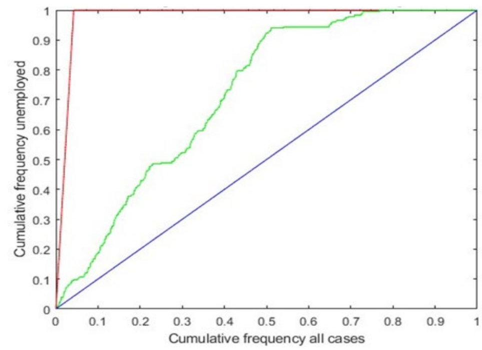
Logistic Regression

Dependent Var.: Prob (Employed)	
Maritial Status	-0.28
(Single = 1)	(0.08)
Education	-0.626
(No Uni. Degree=1)	(0.00)
Gender	1.642
(Male=1)	(0.00)
Age	-0.002
	(0.64)
Intercept	3.074
	(0.00)

Notes: p-values in parantheses.

Source: IMF staff calculations.

AUROC/Gini Curve



- *Simulate household balance sheets.* Financial assets of a household evolve according to the following equation:

$$\Delta FA_{hh,t} = II_{hh,t} + OI_{hh,t} - E_{hh,t} - A^{Tot,Q}_{hh,t} - OE_{hh,t} + \begin{cases} INC^{E}_{n,t}(1-\tau_c), & \text{empl. HH members} \\ INC^{U}_{n,t}, & \text{unempl. HH members} \end{cases} + \Delta B_{hh,t} + \Delta S_{hh,t}$$

- $II_{hh,t}$: Interest income, e.g. on deposits
- $OI_{hh,t}$: Other certain income, e.g. child benefit and alimony
- $E_{hh,t}$: Consumption expenses
- $A^{Tot,Q}_{hh,t}$: Debt service flow for consumer and/or mortgage debt
- $OE_{hh,t}$: Other expense, e.g. rent
- INC term: Stochastically simulated and macro-consistent employment status of HH members from the employment simulator determines whether employment income or unemployment benefit is received
- $\Delta B_{hh,t}$: Change in market value of bonds
- $\Delta S_{hh,t}$: Change in market value of stocks

where households earn interest from their deposits or other certain income (e.g., alimony), receive employment income and/or unemployment benefits (collected by individual household members),[2] and gain from change in the value of bond and stock holdings. These income flows are then used to finance their consumption expenses, debt repayments and other expenses such as rent. Total debt repayments (debt service flow) are either constant along the forecast horizon (or till the maturity, if comes first) if the loan is fixed rate, or moves with the short-term interest rates if the debt is floating rate. The interest and principal payment flows evolve non-linearly (with the share of principal payment in total payment rising gradually), in line with contract designs in reality. Stock and bond holdings are re-valued based on aggregate stock market return and risk-free interest rate path assuming an average bond duration, respectively. Interest income flows on deposits are based on deposit rates, which are assumed to linked to 3-month money market rate.

[2] If a household member is employed, they earn a certain level of after-tax income, and if unemployed, they receive a replacement wage, that is on average about 35 percent in the forecast horizon.

The default happens when financial assets become negative (under a full-recourse system as in Japan). Nominal consumption over the forecast horizon is assumed to move in tandem with the assumed path of inflation, based on a cointegrating relationship.

To this end, household balance sheet is simulated, using information on employment status of household members, as well as various components of income and expenditures, as discussed above. Moreover, loss-given default is calculated based on economic mode (where expected mortgage return measure moves parallel to interest rate path in the scenarios), and is based on discounted expected recovery value of the underlying house, with a cure rate of 5 percent.

Various model parameters are calibrated to 2022 using aggregate data sourced from the OECD and country sources, including income tax rate (21.6 percent), unemployment benefit replacement rates relative to previous gross-of-tax income (52.5 percent in the first year, 31.5 percent in the second year, and 18.9 percent in the third year of unemployment), unemployment duration of 3 quarters and deposit rate of 0.1 percent. Moreover, the model's "raw" estimates for mortgage PDs and LGDs for 2022 are shifted to external anchor (starting) points, sourced from bank solvency data templates. In particular, various mortgage portfolio-related parameters across banks are examined, and PD and LGD anchor parameters are set at 0.3 percent and 25 percent, respectively.

To this end, a grid-based simulation is undertaken to assess the drivers of mortgage PDs and LGDs, with grid boundaries are selected widely to cover historical ranges and the adverse scenario for key macroeconomic variables below. Grids with 5 equally spaced points have the following range for each variable:

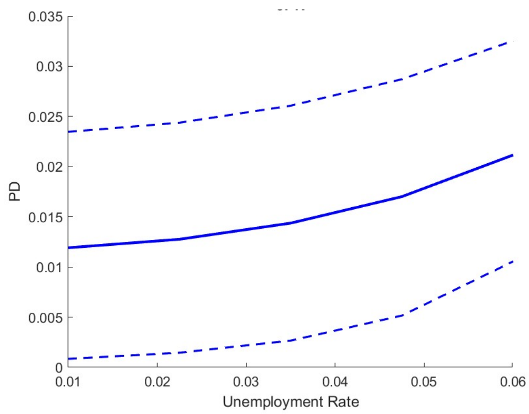
- Unemployment rate, from 1 to 6 percent,
- Interest rates, from 0 to 8 percent,
- Compensation per employee growth, from -6 to 8 percent,
- Stock price growth, from -50 to 60 percent,
- Nominal consumption growth, from -1.5 to 6 percent.

The polynomial analyses for mortgage PDs show that higher unemployment rate, higher interest rates, lower nominal wage growth, lower stock price growth, and higher consumption growth implies higher mortgage PDs (Figure IV.3). Mortgage PDs appear to be more sensitive to changes in unemployment, interest rates, and consumption, and notably less so to changes in stock price growth, as share of households with investments in stocks is small. Also note that the polynomial estimates have squared terms to reflect nonlinearities. The estimation of these polynomials involves first derivative constraints to make sure that the marginal effects are positive or negative (depending on the variable).

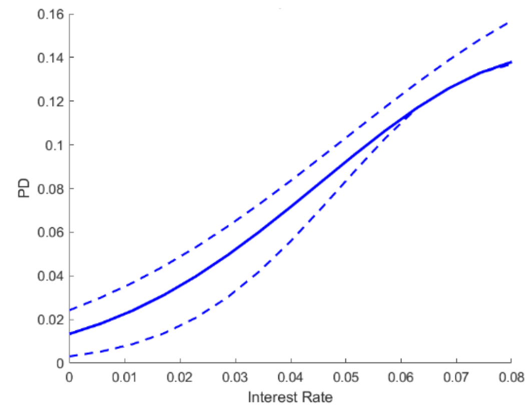
Mortgage LGDs appear to be tightly linked, as expected, to house price growth, cure rates, and interest rates. A decline in house price growth, cure rates, or an increase in interest rates imply higher mortgage LGDs (Figure IV.4).

Appendix IV. Figure 3. Japan: Dependence of Mortgage PDs on Macroeconomic Variables

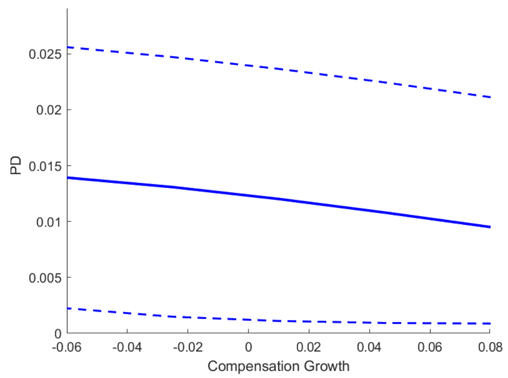
Mortgage PD vs Unemployment Rate



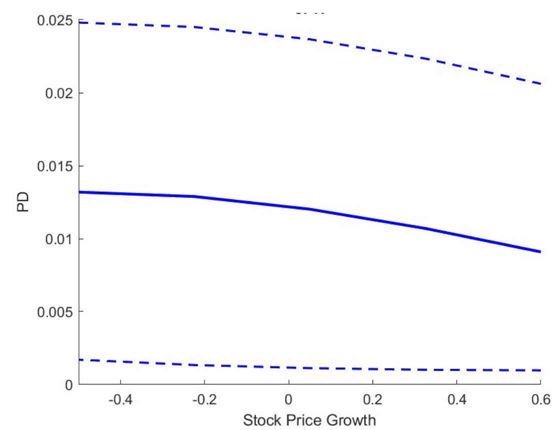
Mortgage PD vs Interest Rate



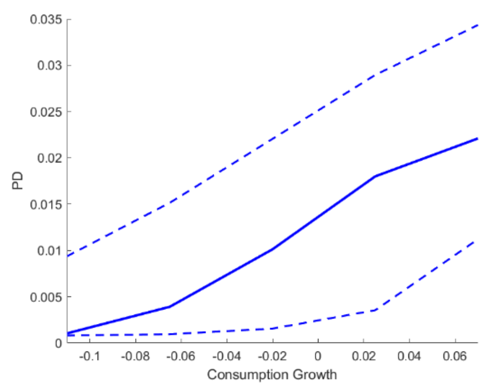
Mortgage PD vs Nominal Compensation Growth



Mortgage PD vs Stock Price Growth



Mortgage PD vs Nominal Consumption Growth



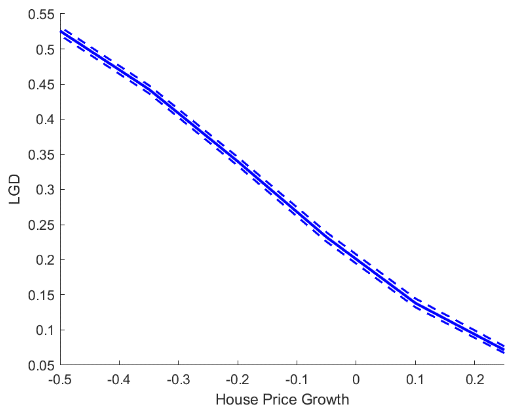
Mortgage PD Polynomial Estimates

	Coeff	R^2
Intercept	-6.71	
Unemployment rate (URX)	20.79	
Unemployment rate (URX) ^2	91.46	0.96
Short-term interest rate (STN)	94.4	
Short-term interest rate (STN) ^2	-590	0.95
Compensation per employee growth	-16.32	
Compensation per employee growth ^2	3.61	0.93
Stock price growth	-0.13	
Stock price growth ^2	0.11	0.39
Consumption growth	18.54	
Consumption growth ^2	84.28	0.86

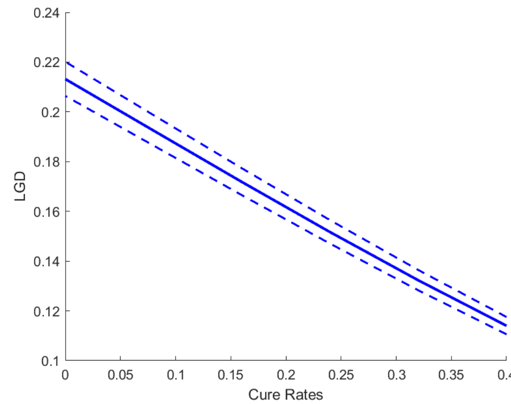
Source: IMF staff calculations.

Appendix IV. Figure 4. Japan: Dependence of Mortgage LGDs on Macroeconomic Variables

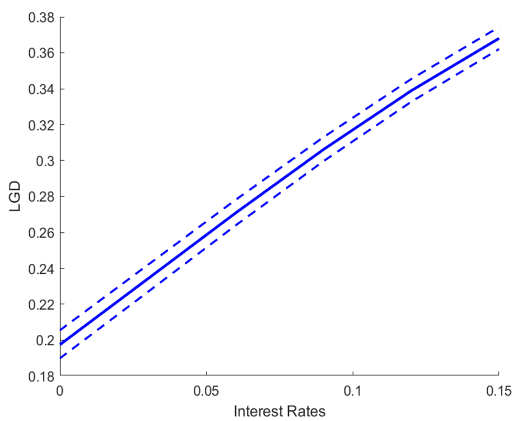
Mortgage LGD vs House Price Growth



Mortgage LGD vs Cure Rate



Mortgage LGD vs Interest Rate



Mortgage LGD Polynomial Estimates

	Coeff	R^2
Intercept	-0.69	
House price growth	-4.11	
House price growth ^2	-2.22	1
Cure rate	-1.54	
Cure rate ^2	-0.81	1
Short-term interest rate (STN)	7.38	
Short-term interest rate (STN) ^2	-11.73	1

Source: IMF staff calculations.

Appendix V. Domestic Contagion Modeling

The domestic contagion model is a variant of CoMap (Covi, Gorpe and Kok, 2021). It adopts a sequential default algorithm as in Furfine (2003), where the trigger, failure of a financial institution, leads to subsequent defaults in the network. The simulation is repeated for each trigger, failure of each node in the network. Two shocks are considered:

a. **Credit shock**. When a financial institution or a group of financial institutions defaults on their obligations, the creditors incur a loss, depending on the nature and counterparty of the exposure. In the simulations, loss-given default parameters are institution- and exposure-specific, and sourced from the proprietary data, Exposure types considered are loans, short-term money placements, equity, bonds and undrawn commitments. The data on credit default swap exposures and other derivative exposures were limited and not incorporated into the analysis. For bilateral loan exposures, corresponding provisions are accounted for.

b. **Funding shock**. A failing financial institution is assumed to withdraw all its funding from other financial institutions in the network. This may force them to fire sale their assets at a discount, and thus, to incur losses. The extent to which they need to roll-over the funding shortfall (funding shortfall rate) is a function of maturity structure of funding. Financial institutions can pledge excess liquidity (in particular, high-quality liquid assets in excess of net funding outflows) to the central bank to meet the funding shortfall. Remaining funding shortfall, if still not met, is then covered by unencumbered non-HQLA assets. If such assets prove not sufficient to meet the funding short fall, liquidity default occurs.

In both cases, losses are assumed to be fully absorbed by capital. The default mechanism is that a financial institution becomes insolvent if its capital falls below a certain threshold, and becomes illiquid if its remaining assets are insufficient to meet the liquidity shortage.

Credit Shock Calibration

Loss given default. Proprietary data provides institution- and exposure-specific loss-given defaults. Averages are used to impute missing observations. For the financial sector as a whole, the averages are 50 percent for loans, 44 percent for short-term money placements, 84 percent for equity, 49.8 percent for bonds, and 43 percent for undrawn commitments.

Funding Shock Calibration

Funding shortfall rate. The model assumes that financial institutions cannot rollover a portion of the funding shortfall. The assumed funding short-fall rates are exposure-specific and the same as in the previous FSAP, 50 percent for loans, 100 percent for deposits, and 14 percent for bonds.

Discount rate. It is assumed to be a weighted average of share of unencumbered central bank-eligible and non-eligible assets, with a higher weight for the latter to reflect the fact that these assets tend to be less liquid. It is dynamically adjusted, which is increasing in the total amount of fire sales in the system and capped to be at most twice as large: $\delta_i^{(t)} = \delta_i \; x \; (2 - e^{-\bar{\theta}})$; where $\bar{\theta} = \sum_j fire\ sales_j / \sum_k \theta_k$. Sectoral averages for the discount rates are 0.27 (banks), 0.26 (insurers), 0.28 (securities firms).

Default thresholds. Regulatory minimums, in addition to some buffers as applicable, are used. For GSIBs and DSIBs, the threshold is 4.5 percent (plus the systemically-important-institution-surcharge ratio as appliable to each GSIB/DSIB) of total risk-weighted assets. For internationally active banks (excluding GSIBs and DSIBs), it is 4.5 percent of total risk-weighted assets. For domestic banks, it is 4 percent of total risk-weighted assets. For insurers, it is 200 percent of ½* risk amount, per the statutory solvency margin regime. For securities, it is 100 percent of risk-equivalent amount.

Liquidity buffers. It is defined as high-quality liquid assets (HQLA) in excess of net funding outflows, per the liquidity coverage ratio (LCR) templates. For insurers, which do not file LCR forms, it is calculated using individual items requested in the LCR templates. The overall liquidity buffer for insurers is then calculated by applying the average liquidity buffer-to-HQLA ratio for banks to insurers.

Central bank eligible/non-eligible assets for insurers. The ratio of unencumbered central bank eligible assets-to-total available for sale assets for banks is applied to insurers, for which only available for assets information is available. Unencumbered central bank non-eligible assets are calculated similarly.