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FINANCIAL SECTOR ASSESSMENT PROGRAM

July 2019

TECHNICAL NOTE—FINANCIAL STABILITY ANALYSIS AND STRESS TESTING

This technical note Financial Stability Analysis and Stress Testing on Singapore 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 June 24, 2019.

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TECHNICAL NOTE

FINANCIAL STABILITY ANALYSIS AND STRESS TESTING

Prepared By
Monetary and Capital Markets Department

This Technical Note was prepared in the context of an IMF Financial Sector Assessment Program (FSAP) mission held in Singapore during November 2018. It was led by Mr. Ulric Eriksson von Allmen. This note contains the technical analysis and detailed information underpinning the FSAP assessment's 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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Glossary

AIA	American International Assurance
APNGB	Allowance for the Provision Non-Guaranteed Benefits
ASEAN	Association of Southeast Asian Nations
BIS	Bank for International Settlements
CAR	Capital Adequacy Ratio
CET 1	Core Equity Tier 1
CPF	Central Provident Fund
CSA	Cyber Security Agency
DBS	Development Bank of Singapore
D-SIB	Domestic Systemically Important Bank
EBIT	Earnings Before Interest and Taxes
FSAP	Financial Sector Assessment Program
FTSE	Financial Times Stock Exchange
FX	Foreign Exchange
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GFSR	Global Financial Stability Report
GIC	Government of Singapore Investment Corporation
HQLA	High Quality Liquid Assets
HSBC	Hong Kong and Shanghai Banking Corporation
IAIS	International Association of Insurance Supervisors
IASB	International Accounting Standards Board
ICR	Interest Coverage Ratio
IFRS	International Financial Reporting Standards
IWST	Industry-Wide Stress Test
LCR	Liquidity Coverage Ratio
LGD	Loss Given Default
LTV	Loan-to-Value
MAS	Monetary Authority of Singapore
MLA	Minimum Liquid Asset
NBFI	Non-Bank Financial Institution
NPL	Nonperforming Loan
NSFR	Net Stable Funding Ratio
NTUC	National Trade Union Congress
OCBC	Oversea Chinese Banking Corporation
PD	Probability of Default
RAM	Risk Assessment Matrix
RWA	Risk-Weighted Assets
RBC	Risk-Based Capital
SCB	Standard Chartered Bank
SFRS	Singapore Financial Reporting Standards
SGD, S$	Singapore Dollar
SIBOR	Singapore Interbank Offered Rate
SME	Small and Medium Enterprises
SOC	Security Operations Center
STeM	Stress Testing Matrix
SWIFT	Society for Worldwide Interbank Financial Telecommunication
TDSR	Total Debt Servicing Ratio
TSC	Transport, Storage, and Communication
UOB	United Overseas Bank
USD, US$	U.S. Dollar
WEO	World Economic Outlook

EXECUTIVE SUMMARY[1]

Singapore is a large financial center with a strong regulatory framework and significant external exposures. Singapore is a small and very open economy with a high saving rate and a significant foreign asset position. It boasts a highly developed and sophisticated financial sector, with many foreign branches intermediating funds throughout the region. Regulations are closely aligned to international standards. Since the last FSAP, bank solvency and liquidity has improved, and the authorities have adopted Basel III capital and liquidity requirements and the new International Financial Reporting Standards.

Singapore's financial markets have weathered recent bouts of market volatility but are exposed to external shocks and cyber events. The financial sector is significantly exposed to regional economic activities, especially in China, and to global financial conditions. Non-financial corporates have high gross debt, and households are exposed to volatility in property prices. Singapore is becoming a hub for applications of new technologies in the provision of financial services. Financial firms are increasingly exposed to cyber risk, and the authorities have actively enhanced the regulatory framework in this area.

This technical note contributes to the FSAP's assessment of the stability and soundness of the financial sector with a comprehensive set of risk analyses. The work combines an examination of key risk indicators with detailed stress tests, which simulate the health of banks, insurers, non-financial corporates and households under severe yet plausible (counterfactual) adverse scenarios. Scenarios include global financial market turmoil, a major slowdown of economic activity in China, cyber-attacks and extreme flooding. The analyses include simulations of contagion within the international banking network, within the domestic banking system and between different types of financial institutions in the financial system.

The stress tests reveal that the financial system is broadly resilient to severe adverse shocks, but foreign exchange liquidity is a key vulnerability.

- Households remain resilient under stress, although a small segment of highly-leveraged, low-income and young borrowers in private residential properties could face repayment difficulties.
- Corporates have a healthy debt servicing capacity and significant cash buffers. Corporate debt-at-risk rises significantly under stress, but cash and foreign currency revenues provide a buffer.
- Domestic systemically important banks (D-SIBs) maintain risk-based capital ratios above regulatory requirements under the adverse scenarios. However, banks' exposures to property price volatility, legacy loans to transportation sector, and name concentration risk suggest some caution is needed.

[1] This Technical Note has been prepared by Alan Xiaochen Feng, Galen Sher, Heedon Kang, Jiae Yoo, Jochen Markus Schmittmann, Romain Bouis, and Stephanie Yat Fan Ng at the IMF. Kiran Sastry provided research support.

- Liquidity Coverage Ratios (LCRs) and liquidity stress tests reveal broadly adequate all-currency liquidity of D-SIBs. However, D-SIBs' U.S. dollar LCRs (which are a monitoring tool but not a regulatory requirement) and stress tests suggest shortfalls of liquid U.S. dollar assets of up to 20 percent of GDP in adverse scenarios and many D-SIBs do not pass the liquidity stress tests in U.S. dollars. The adverse scenarios for these risk analyses include assumptions about severe declines in liquidity in the FX swap market.
- Direct general insurers' profitability has declined in a competitive environment, but they remain resilient under stress scenarios. Direct life insurers' solvency positions are vulnerable to falling equity and corporate bond prices, but they do not pose a systemic risk because capital shortfalls under stress are small.
- Despite its size, complexity, and the level of development, domestic contagion through direct financial interlinkages between banks and non-bank financial institutions, within the interbank market, and common exposures to large borrowers, is limited.
- Contagion, however, could occur through cross-border interbank exposures and financial market volatility. Spillovers to and from Singapore largely mirrors a strong foreign bank presence headquartered in advanced economies (e.g., Japan, the U.K., and the U.S.) as well as the strong regional linkages to China and Hong Kong SAR. Banks in Singapore have more outward rather than inward spillover effects for its other Asian neighbors.
- Financial institutions estimate that the potential losses from cyber-attacks as well as explicit and implicit claims from cyber insurance policy coverage would be manageable.

Going forward, the authorities should continue to strengthen U.S. dollar liquidity among D-SIBs. The authorities have the capacity to provide U.S. dollars to banks through money market operations and the FX swap market has historically been resilient to periods of stress. Nevertheless, it is important for banks to self-insure more of their foreign currency liquidity risk. The Monetary Authority of Singapore (MAS) has chosen to use the supervisory process to encourage banks to improve their foreign currency liquidity positions. This approach seems feasible, given that the supervisory process has been successful in reducing banks' reliance on the foreign currency swap market for funding normal U.S. dollar lending activity. Other jurisdictions have found it useful to introduce minimum requirements for specific foreign currency Liquidity Coverage Ratios. MAS should therefore keep this option open if improvement is not achieved through the supervisory process.

MAS should continue strengthening its surveillance by closing data gaps and developing its analytical tools. Further data collection on domestic interlinkages, household mortgage debt at the borrower-level, insurers' balance sheets would enhance surveillance. MAS should consider alternative approaches to estimate credit gap, recognizing changes in credit cycles, which would better support timely macroprudential policy actions. Solvency stress testing could be improved by adopting more elements of the Singapore Financial Reporting Standards 109 and liquidity stress testing could be improved by revising cashflow reporting templates. Cyber risk surveillance would benefit from developing a cyber network map that accounts for both financial linkages and Information and Communication Technology (ICT) connections.

Table 1. Recommendations on Financial Stability Analysis and Stress Testing		
Recommendations	**Time [1/]**	**Responsibility**
MAS should strengthen U.S. dollar liquidity among D-SIBs	M	MAS
Explore alternative approaches to estimate credit-to-GDP gap, recognizing changes in credit cycles	I	MAS
Enhance data collection to assess domestic financial interlinkages	N	MAS
Collect total stock of household mortgage debt at the borrower-level over time	M	MAS
Improve the bank solvency stress testing model by adopting the full aspects of the Singapore Financial Reporting Standards 109	N	MAS
Revise the contractual and behavioral cashflow reporting templates to make them useful for liquidity stress testing	N	MAS
Update and expand on the liquidity guidance for banks issued in 2013	N	MAS
Collect data on direct life insurers' liability cashflow projections and on the underlying asset allocation of their collective investment schemes	N	MAS
Model insurers' corporate bond losses using a cashflow projection method	N	MAS
Develop a cyber network map that takes into account both financial linkages and Information and Communications Technology connections and use it for cyber risk surveillance	M	MAS
1/ "I-Immediate" is within one year; "N-Near term" is within 1–3 years; "M-Medium term" is 3-5 years.		

BACKGROUND

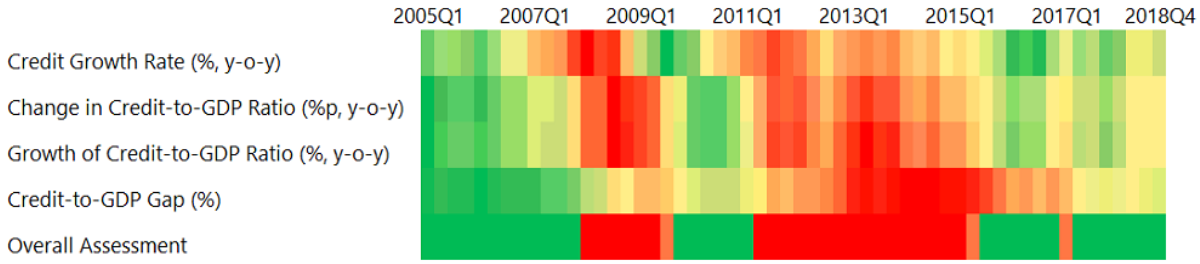
1. Since the last FSAP, the Singaporean economy has navigated economic and financial cycles well. The fall in commodity and house prices affected oil-related sectors and construction in recent years, but overall activity has held up reasonably well. Singapore's financial markets have weathered recent bouts of market volatility with asset prices showing no lasting impact. There is no sign of a build-up of excessive credit as of now (Figure 1). Macroeconomic and financial stability has been preserved thanks to strong policy frameworks, sound policies, and a large net foreign asset position. After a period of subdued economic activity, growth accelerated in 2017 benefitted from the global expansion and easy financial conditions, but growth has started to moderate. To strengthen long-term growth prospects amid population aging, the government is encouraging the economy to adopt emerging digital technologies. This strategy has put Singapore at the forefront in fintech but makes cyber risk as a growing risk to financial stability.

2. Singapore is an important regional financial center with high quality supervisory and regulatory framework but is exposed to external risks. Singapore is a small and very open economy, and its large financial system has significant cross-border linkages and lending exposures, especially to China and ASEAN countries. The financial system is exposed to external macrofinancial shocks through extensive trade and financial channels. A growth slowdown in China or disorderly monetary policy normalization in advanced economies would deeply impact the financial system in Singapore and also in the region. The impact can be amplified by domestic vulnerabilities, like corporate sector leverage and households' sensitivity to property prices.

3. The objective of the FSAP systemic risk analysis is to assess the resilience of the financial system to adverse shocks. The assessment relies on simulations of the capacity of the financial system to withstand severe but plausible macrofinancial shocks. It assesses risks and vulnerabilities in the system and the channels through which adverse shocks are transmitted and amplified. Adverse scenarios are devices for exploring risks and should not be interpreted as macroeconomic forecasts.

4. The remainder of this technical note is structured as follows. The background section describes the macrofinancial environment, the scope of systemic risk assessment, and macrofinancial scenarios used in the analyses. The section on financial stability analyses includes analyses of contagion and cyber risk, and analyses of the resilience of households, non-financial corporations, banks and insurers. The concluding section provides an overall assessment and recommends policy actions to enhance financial stability.

Figure 1. Assessment of Credit Cycle



Source: MAS; Haver Analytics; and IMF staff calculation.

Note: Green and red colors show low and high vulnerable periods in credit cycle, respectively. The first four indicators are standardized with its mean and standard deviation. The red color in the last row ("overall assessment") shows a strong signal of a build-up of systemic risk, with (i) either the change in the credit-to-GDP ratio above 5 percent (y-o-y) or (ii) the credit-to-GDP gap greater than 1.5 times its standard deviation and the annual growth rate of the credit-to-GDP ratio above 10 percent (y-o-y), while the orange color denotes a modest signal of systemic risk build-up with the change in the credit-to-GDP ratio between 3 and 5 percentage points.

A. Financial System Landscape

5. Singapore's financial system is large and dominated by banks (Table 2). The financial system mostly comprises banks (with assets equal to about 600 percent of GDP) and asset management firms (with assets under management equal to 701 percent of GDP). In April 2015, MAS designated seven banking groups as domestic systemically important banks (D-SIBs), including the three local banking groups (DBS, OCBC, and UOB) and four foreign banking groups (Citibank, Maybank, Standard Chartered, and HSBC).[2,3] All but one of the remaining non-DSIBs are foreign branches.[4] The insurance sector holds assets of 55 percent of GDP and Singapore is an important regional center for reinsurance. The asset management industry caters mainly to foreign investors, invests primarily outside of Singapore, and is not a significant source of funding for the banking system.

6. The three local D-SIBs play a key role. They provide a full range of services in retail and institutional banking as well as wealth management, which accounts for a growing share of these banks' total income (Figure 2). Local D-SIBs account for about 60 percent of domestic loans to private sectors and over 80 percent of mortgage loans in Singapore. They also have significant

[2] All banks in Singapore will be assessed for their systemic importance annually based on their size, interconnectedness, substitutability and complexity.

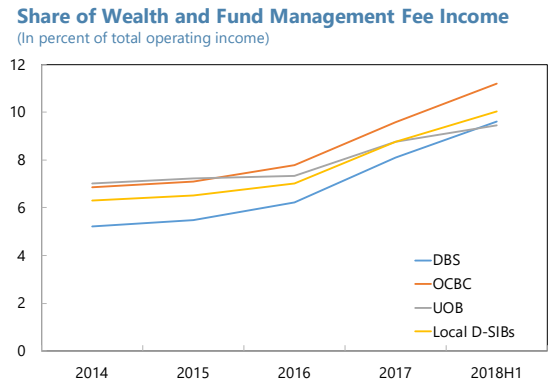
[3] Citibank, SCB, HSBC and Maybank operate both a branch and a subsidiary in Singapore. For these banks, both the branch and the subsidiary are classified as D-SIBs.

[4] The lone locally incorporated non-DSIB, Bank Pictet & Cie (Asia) Ltd., is licensed for wholesale activities only. It accounts for less than 0.1 percent of total banking assets.

cross-border lending to China and ASEAN countries (about a quarter of total lending), an activity that picked up strongly in the last two years (Figure 2).

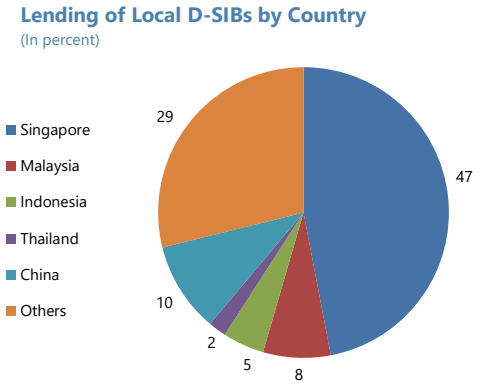
Figure 2. Cross-border Linkages of the Banking System

Share of non-interest income has increased in recent years.



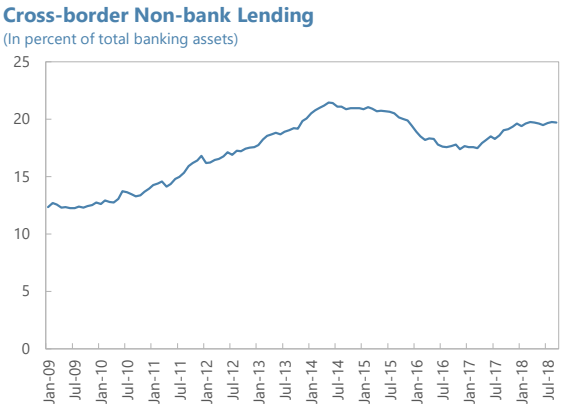
Source: Banks' financial results; and IMF staff calculations.

ASEAN-5 and Greater China account for most cross-border lending



Source: MAS.
Note: Data as of 2018Q2.

Cross-border lending has picked up but stabilized recently



Source: MAS.

7. Foreign banks have a significant presence. They account for a half of total financial sector assets. Except for the four foreign D-SIB subsidiaries and one small locally incorporated wholesale bank, the rest operate as branches. Foreign D-SIB subsidiaries focus on local retail banking, while foreign branches use corporate deposits and intragroup funding to lend non-financial corporates and provide financial services like treasury and wealth management across the region. Particularly, non-DSIB foreign branches focus on cross-border banking services with their non-resident loans

and liabilities accounting for over a two-third of total lending and liabilities to private sectors, respectively.[5]

8. Though less systemically important than banks, insurance activity has grown in recent years. Life insurance is primarily written domestically while general insurance is written across the region. Life insurance covers protection products (mainly against mortality, morbidity and accident risks) and savings products. Only a small amount of annuity products is underwritten, given the dominance of the Central Provident Fund's (CPF) Lifelong Income for the Elderly scheme—a life annuity scheme administered by the government and associated with the compulsory pension scheme. The assets of the insurance sector are concentrated in the four largest direct life insurers by assets: AIA, Great Eastern, NTUC Income and Prudential. Reinsurance activity is growing, but only accounts for about 7 percent of the assets of the sector.

9. The asset management industry serves as a gateway to the region for funds from around the world. As of 2017 there are 715 licensed and registered fund managers in Singapore. Assets under management of financial institutions have grown by 15 percent per year to reach some 701 percent of GDP in 2017 (Table 2).[6] Even though it is large, its links to the domestic economy are limited because much of its activity is cross-border. Some 78 percent of assets under management are sourced from abroad, and 50 percent are invested outside Singapore in the Asia-Pacific region. Resident collective investment schemes, which intermediate savings of Singaporean individuals, are significantly smaller at 11 percent of GDP.[7] Asset managers comprise about 23 percent of all securities financing activity in Singapore, against which banks are the primary counterparty (MAS, 2018). In addition to the Government of Singapore Investment Corporation (GIC) and Temasek, seven global public investors maintain offices in Singapore.[8]

[5] There are two types of foreign banks: full and wholesale. Full banks can conduct the whole range of banking business, including retail deposit taking, while the wholesale banks can only take wholesale deposits, not retail. Qualifying full banks, a special type of the full banks, have privileges regarding the number of places of business (up to 50). This classification differentiates foreign banks by the range of business, not by their systemic importance. In April 2015, MAS announced a list of D-SIBs, based on their systemic impact on the stability of the financial system and proper functioning of the broader economy. Banks with a significant retail presence in Singapore are required to locally incorporated their retail operations and to meet higher capital requirements, an extra 2 percent of Common Equity Tier 1 capital. The FSAP focuses on the contribution to systemic risk for which the D-SIB classification is more relevant, which was not in place at the time of the 2013 FSAP.

[6] This AUM figure includes AUM of fund managers, banks, insurers, institutional investors and other entities that engage in asset management activities."

[7] Based on assets under management of 'authorized' schemes of S$ 48 billion (MAS, 2017b), and GDP of S$ 447 billion, in 2017. Authorized schemes are resident and supervised in Singapore, and offered to retail investors in Singapore. These contrast with recognized non-resident schemes that are licensed to manage the assets of retail investors in Singapore but are constituted and supervised in their home jurisdiction.

[8] These investors include the Investment Company of the People's Republic of China, Korea Investment Corporation, Korea National Pension Service, La Caisse de Dépôt et Placement du Quebec, Norges Bank Investment Management, Swiss National Bank and the Ontario Municipal Employees Retirement System.

Table 2. Financial Sector Structure (2013-2018Q2)

(In billions of Singapore dollars)

	2013			2018Q2		
	Number	Total Assets	In percent of GDP	Number	Total Assets	In percent of GDP
Commercial banks	**124**	**2,147.9**	**564**	**128**	**2,644.9**	**569**
Local Banks	5	719.6	189	4	982.7	211
Foreign Banks	119	1,428.3	375	124	1,662.2	358
Merchant Banks	**41**	**84.9**	**22**	**29**	**86.5**	**19**
Finance Companies	**3**	**15.0**	**4**	**3**	**16.9**	**4**
Insurance Companies	**171**	**169.8**	**45**	**176**	**254.5**	**55**
Direct Insurers	76	153.4	40	76	225.4	48
Life Insurers	16	72.3	19	16	119.7	26
General Insurers	56	11.5	3	53	13.8	3
Composite Insurers	4	69.6	18	7	91.8	20
Reinsurers	31	13.3	3	31	25.1	5
Captive insurers	64	3.1	1	69	4.1 2/	1
Insurance Brokers	**67**	**2.0**	**1**	**80**	**2.8** 2/	**1**
Central Provident Fund 1/	**1**	**255.6**	**67**	**1**	**363.2** 2/	**78**
Holders of CMS license	**295**	**44.8**	**12**	**694**	**66.9** 2/	**14**
Brokers-Dealers	97	36.6	10	134	51.0 2/	11
Licensed Fund Managers	158 5/	7.1	2	497	13.4 2/	3
Others 7/	40	1.1	0	63	2.5 2/	1
Holders of Financial Advisers Licenses	**58**	**0.3**	**0**	**64**	**0.5** 2/	**0**
Licensed Trust Companies	**51**	**0.3**	**0**	**58**	**0.4** 2/	**0**
Asset Management Firms (AUM) 4/	**553** 6/	**1,818.0** 3/	**477**	**715** 2/	**3,260** 2/,3/	**701**
Discretionary AUM	.. 10/	955.0 3/	251	.. 10/	**1,735** 2/,3/	373
Advisory AUM	.. 10/	863.0 3/	227	.. 10/	**1,525** 2/,3/	328
Memo:						
Domestic Systemically Important Banks	– 11/	– 11/	– 11/	**12**	**1,390.5** 8/	**299**
Local D-SIBs	– 11/	– 11/	– 11/	4	982.7	211
Foreign D-SIBs	– 11/	– 11/	– 11/	8	407.8	88
Foreign Banks	**119**	**1,428.3**	**375**	**124**	**1,662.2** 9/	**358**
Foreign subsidiaries	2	69.8	18	4	95.7	21
Foreign branches	117	1,358.4	357	120	1,566.5	337
Nominal GDP		**381.0**	**100**		**464.9** 2/	**100**

Sources: MAS; Haver; and IMF staff calculations.
Notes: 1/ Data from the Central Provident Fund.
2/ Data for 2017.
3/ Based on annual Singapore Asset Management Survey for 2013 and 2017. Financial Institutions surveyed and responded include Banks, Capital Markets Services licensees and other financial sector entities conducting asset management activities.
4/ AUM = Assets under management.
5/ As at March 31, 2013.
6/ Registered and licensed fund managers.
7/ Other holders of CMS license comprise real estate investment trust managers, credit rating agencies, and corporate finance advisers.
8/ The MAS has designated three local banking groups and four foreign banking groups as D-SIBs in April 2015, which comprise twelve individual D-SIB entities.
9/ Foreign banks include foreign D-SIBs.
10/ Data not available.
11/ Not reported.

10. Singapore's two sovereign wealth funds and a public mandatory saving scheme are important components of the financial landscape but somewhat insulated from the financial system. Temasek Holdings and the GIC are responsible for managing government savings. As they have diverse portfolios focusing on foreign assets, they are not tightly connected with the financial system. But Temasek is a major shareholder of two D-SIBs, DBS and SCB. The CPF invests its assets (80 percent of GDP) mostly in the Special Singapore Government Securities, whose proceeds are managed by GIC, without connection to other financial institutions.[9]

11. The foreign currency (FX) swap market is a global center for exchanging major currencies. Singapore boasts the third-largest foreign currency market in the world (BIS, 2016), which is linked to the economy's role in international trade and as a gateway to Asia.[10] Some three-quarters of foreign currency exchange activity takes place in the form of derivatives, including forwards and swaps.[11] In turn, the foreign currency swap activity is concentrated in FX swaps, mostly with a maturity of less than one year, rather than in cross-currency basis swaps. Typically, foreign banks provide foreign currency to the swap market and domestic banks provide Singapore dollars (MAS, 2017). The largest participants are European banks, followed by U.S. banks, and then Singaporean and Japanese banks. MAS participates in the FX swap market as part of its money market operations. Notably, MAS is currently a significant provider of foreign currency to the swap market.[12] Since the last FSAP, D-SIBs have significantly reduced their reliance on the FX swap market for funding normal foreign currency lending. Nevertheless, domestic banks' value still seems to be associated with the price of borrowing U.S. dollars from this market (Box 1). The U.S. dollar plays a special role in the FX swap market as an intermediate currency between other pairs of currencies. The largest volumes of transactions are against the Japanese yen, followed by the euro, and some 88 percent of trading is with counterparties outside Singapore. The commercial banks that play the largest role in the FX swap market are foreign branches (Figure 3). Price and quantity measures show some resilience of the FX swap market under past stress episodes.[13]

[9] The CPF is a compulsory comprehensive savings plan for working Singaporeans and permanent residents primarily to fund their retirement, healthcare, and housing needs.

[10] This ranking is based on daily average turnover, on a net-gross basis, in OTC foreign exchange instruments of US$517 billion. Instruments include spot transactions, outright forwards, foreign exchange swaps, currency swaps and foreign exchange options. Daily turnover in October 2018 amounted to US$508 billion (SFEMC, 2019).

[11] Total turnover for all instruments is US$517 billion, of which US$122 billion is in spot transactions, US$105 billion is in outright forwards, US$248 billion is in foreign exchange swaps, US$6 billion is in currency swaps, and the remaining US$37 billion is in foreign exchange options.

[12] The purpose of money market operations is to sterilize foreign exchange interventions and to manage banking system liquidity.

[13] MAS has found that swap prices in Singapore remained stable during recent episodes of high global market volatility (MAS, 2017). Turnover in the Singapore FX swap market fell by a relatively modest 36 percent between April 2008 and April 2009 (Figure 3).

Box 1. Banks in Foreign Currency Swap Markets

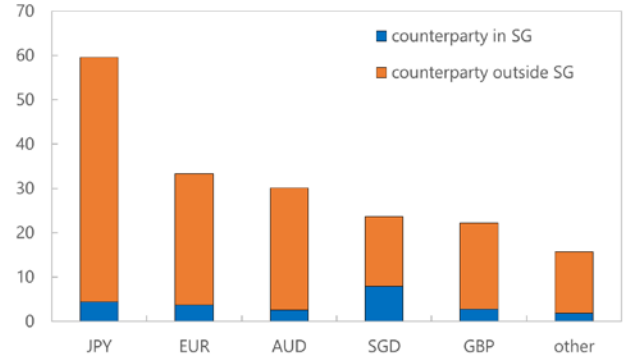
Since the global financial crisis (GFC), the spread on the long-term cross-currency basis swap has deviated from zero and become negative for many major currencies against the U.S. dollar. The existence of non-zero cross-currency basis reflects deviation from the covered interest parity and presents an opportunity for banks to profit from participating in the FX swap market. In theory, with a negative spread for the SGD/USD cross-currency swap, banks in Singapore can earn a risk-less profit by exchanging U.S. dollars for Singapore dollars and lend the Singapore dollars received. Recent studies have found that a main reason for the presence of a persistent negative currency basis in recent years is that bank capital has become costlier since the GFC (Du and others, 2018). In other words, the negative cross-currency basis reflects the dislocation in the FX swap market and capital constraints of participants in the market. While Singaporean banks generally do not rely on the FX derivative market for their structural funding needs, dislocation in the market can still pose risk to banks, especially in stress conditions.

The SGD/USD cross-currency basis appears to be a systematic risk factor that prices equity returns of Singaporean banks, although the magnitude is small (text figure) and causality is not straightforward. For daily returns of Singaporean banks since 2010, the five-year SGD/USD cross-currency basis appears to be a systematic risk factor that prices these daily equity returns.[1/] Based on an augmented Fama-French four-factor model (with ex-Japan Asian factors based on Kenneth French's website), a more negative value of the basis is associated with, on average, a contemporaneous lower return for Singaporean banks.[2/] The statistical significance and economic magnitude of this relationship appear to be small overall and slightly different across the banks.

Note: 1/ As longer-term contracts are not frequently used, the measured basis may be influenced by liquidity and other market-wide factors. The empirical analysis includes standard market risk factors (such as Fama-French factors based on data from Kenneth French's website) to exclude the potential confounding effects from these factors.
2/ The augmented Fama-French four-factor model is the standard Fama-French three-factor model with the addition of a cross-currency basis factor. The Fama-French three factors include the market factor in Singapore and the SMB and HML factors based on daily returns of ex-Japan Asian stocks from Kenneth French's website. The cross-currency basis factor is the spread for the SGD/USD cross-currency swap (deviation from the annual mean).

Figure 3. Structure of the FX Swap Market in Singapore

USD FX Swap Turnover
(In billions of U.S. dollars, daily average)



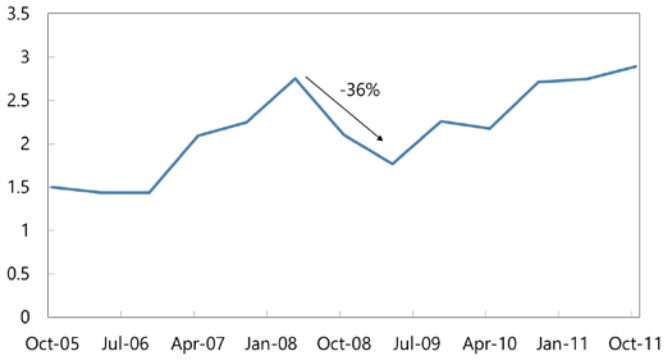
Source: Singapore Foreign Exchange Market Committee.
Note: The data apply to the month of October 2018.

Largest market shares in FX swaps
(In percent)

Bank of America	22
Union Bank of Switzerland	11
BNP Paribas	7
Standard Chartered	7
Citibank	4
Toronto-Dominion	4
Credit Suisse	3
Development Bank of Singapore	3
Barclays	3
Australia-New Zealand Bank	3
Total	**67**

Source: MAS.

FX Swap Market Monthly Volume
(Trillions of U.S. dollars)



Source: Singapore Foreign Exchange Market Committee.
Note: The chart shows the monthly trading volume in FX swaps in Singapore.
The fall of 36 percent occurs between April 2008 and April 2009.

B. Current Situation in the Financial System

Banking Sector Soundness

12. The financial health of Singapore's banks compares well to those of other financial centers. Risk-weighted capitalization is strong (16.9 percent in 2018) and provides a buffer of 7 percentage points that can be used in a stress scenario (Table 3).[14] Although capital ratios are lower than ones in other similar-sized financial centers, they compare well with neighbors and other international banks and also reflect conservative risk-weighted asset calculation. D-SIBs' leverage ratio stands at 7.2 percent, higher than the 6.0 percent average for global systemically important banks (Figure 4).

13. Profitability is strong and asset quality is broadly sound, but some risks remain. Banks have enjoyed solid profits with stable net interest margins, higher than those in other financial centers, and increasing fee and commission income (Figure 4). Nonperforming loans (NPLs) are low—especially for D-SIBs (1.9 percent of total loans) relative to non-DSIBs (2.1 percent of total loans)—and are adequately provisioned. However, there exist legacy exposures to transportation (including in oil-related sectors) and manufacturing firms. Also, "problem loans" (NPLs plus special mention loans and restructured loans) remain relatively high in a few foreign D-SIBs. Cross-border asset quality has stabilized as NPL ratios for loans to Malaysia and Indonesia have fallen over the past year. However, if China growth slows down, regional spillovers could be considerable and NPLs could rise. Loans directed towards the property sector, including residential mortgages and loans to building and construction sector, accounted for about 30 percent of total loans, exposing banks to property price movements.

14. The banking system has adequate liquidity overall. Narrowly-defined liquid assets are 12 percent of assets and 15 percent of short-term liabilities (Figure 5).[15] Loans are about 99 percent of deposits, which is high amongst advanced economy peers and reflects the significant presence of foreign branches with intragroup funding. However, loans have been growing faster than deposits, mainly as a result of foreign currency activity (Figure 5). D-SIBs have healthy buffers over minimum regulatory LCR requirements in all currencies and in Singapore dollars. Their (asset-weighted) LCRs in these currencies are 132 percent and 287 percent respectively. In the LCR, most liquid assets are high quality, and LCR requirements are driven by derivatives and margin calls (Figure 6). D-SIBs' Net Stable Funding Ratio (NSFR) is 110 percent. For domestic banks, this NSFR provides a narrow margin over the 100 percent requirement, but MAS assesses that the 10-percentage point buffer is sufficient given the low volatility of these ratios.

[14] Minimum capital requirement includes a total capital requirement of 8 percent and D-SIB surcharge of 2 percent. Banks must also maintain a capital conservation buffer of 2.5 percent and a countercyclical capital buffer. MAS has not activated the counter-cyclical capital buffer, but banks maintain it as part of reciprocity agreement due to exposures in other countries such as Hong Kong SAR and Sweden.

[15] These are high-quality liquid assets according to the definition for the LCR requirement, and they are liquid assets according to the definition for the MLA requirement, which are defined in MAS Notice 649.

Table 3. Financial Soundness Indicators (2013-2018)

(In percent)

Financial Soundness Indicators for Banks

	2013	2014	2015	2016	2017	2018
Capital adequacy						
Regulatory capital to risk-weighted assets	16.4	15.9	15.9	16.7	17.2	16.9
Core Tier-1 capital to risk-weighted assets	13.8	13.5	13.8	14.6	15.5	15.0
Leverage ratio of D-SIBs	-	-	7.5	7.7	7.8	7.2
Asset quality						
Nonperforming loans to gross loans (NPL ratio	1.2	1.1	1.6	2.2	2.0	1.9
NPL ratio of local banks	1.0	0.9	1.1	1.4	1.6	1.5
Provisions to unsecured NPLs	154.8	160.1	128.1	105.9	111.5	98.0
Earning and profitability						
Return on average assets of local banks	1.2	1.1	1.2	1.1	1.3	1.3
Net interest margin of local banks	1.7	1.7	1.8	1.7	1.8	1.8
Liquidity and funding						
Liquid assets to total assets	-	-	-	11.0	11.8	13.9
Loan to deposit ratio	107.0	109.1	104.4	100.6	105.6	107.6
Loan to deposit ratio of local banks	85.9	86.4	87.4	86.9	86.1	88.5

Financial Soundness Indicators for Insurers

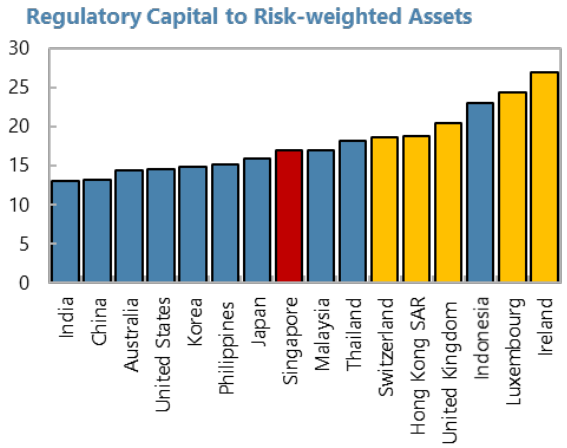
	2013	2014	2015	2016	2017	2018
Direct insurers						
Capital adequacy ratio	258	239	241	240	251	247
Return on equity	9	19	11	12	14	5
Return on assets	1.0	1.9	1.3	1.1	1.6	0.4
Reinsurers						
Financial resources to policy liabilities	72	76	76	75	71	50

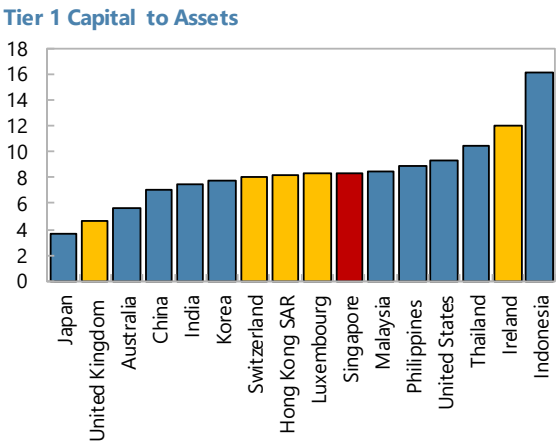
Source: MAS.
Note: The capital adequacy ratio is defined under Singaporean risk-based capital regulations to be the ratio of available capital to risk-weighted assets (i.e., required capital).

Figure 4. Singapore and Peer Countries: Financial Soundness Indicators

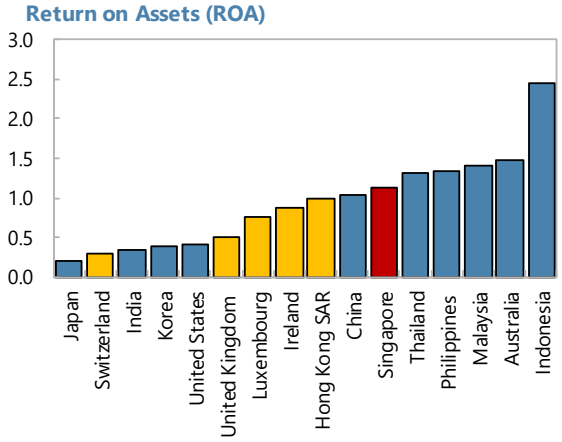
(In percent, latest)

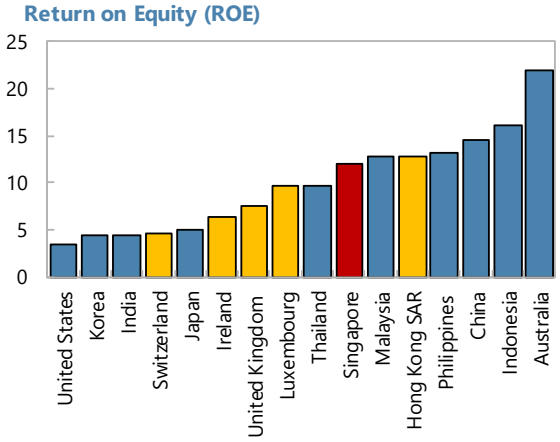
Banks' capital ratios in Singapore are lower than the ones in other similar-sized financial centers but compare well with those of neighbors and other international banks, reflecting conservative risk-weighted asset calculation.



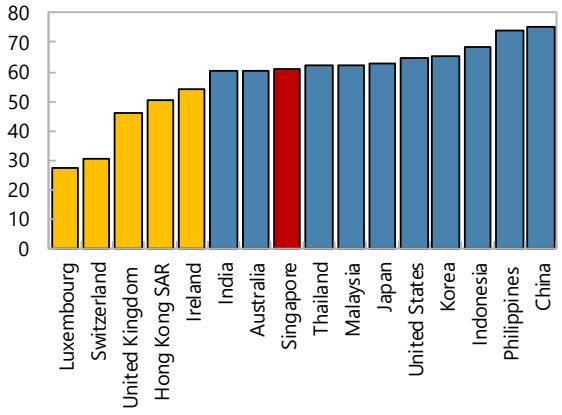


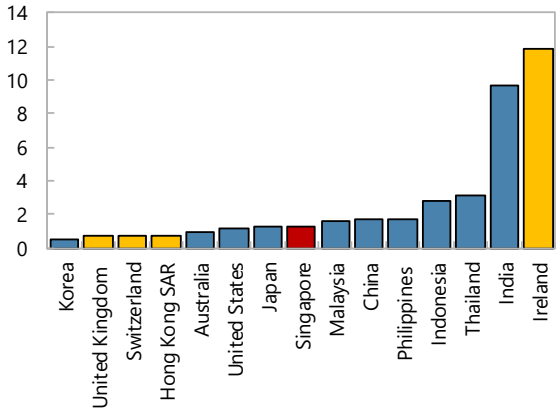
Profitability of local banks has been stronger than that of other financial centers, thanks to high fee and commission income.





Interest margins are also high, and NPL ratios are at a low level but have increased recently.

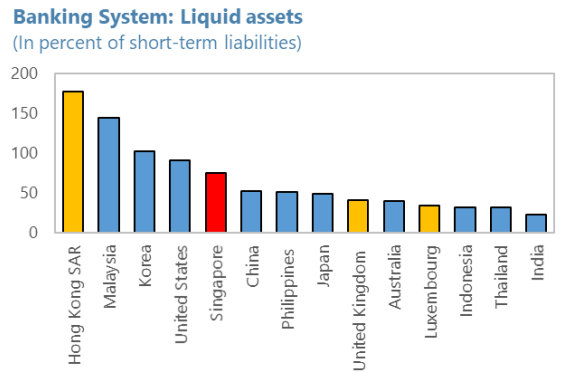




Sources: IMF Financial Soundness Indicators; national authorities' websites; and Haver Analytics.
Note: Yellow bars refer to Singapore's peer group of financial centers and economies with financial sectors that account for a large share of GDP.

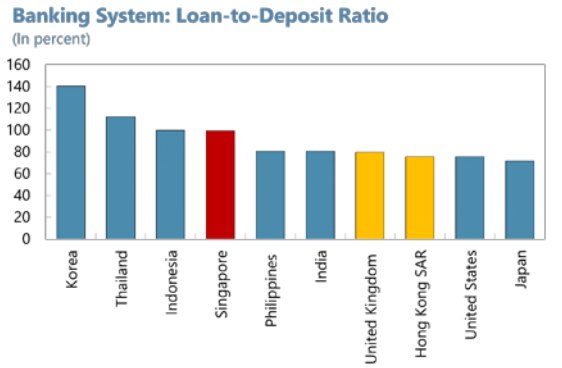
Figure 5. Singapore and Selected Countries: Bank Liquidity Indicators

Singapore's banks have similar liquid assets to banks in peer countries



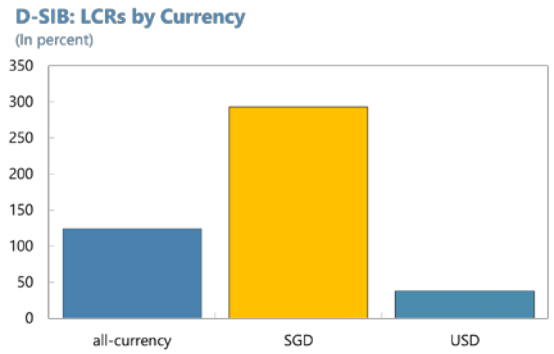
Source: FSI database.
Note: data as at 2018Q3, except for Luxembourg and Indonesia (2018Q4), China, Philippines and United Kingdom (2018Q2), and Korea (2016Q4).

Loan-to-deposit ratios are high but in a large part because of foreign banks



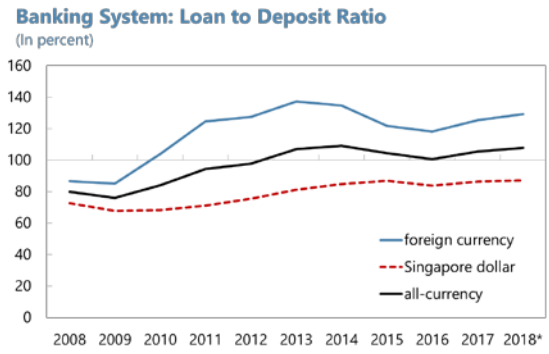
Sources: FSI database; Singapore from MAS.
Note: data as at 2018Q2, except for Japan and UK (2018Q1), and Korea (2016Q4).

LCRs in foreign currency are low



Sources: MAS; and IMF staff calculations.
Note: bars show the average LCR for D-SIBs in 2018Q2, weighted by total assets and using the country-group level of consolidation for Citi and HSBC.

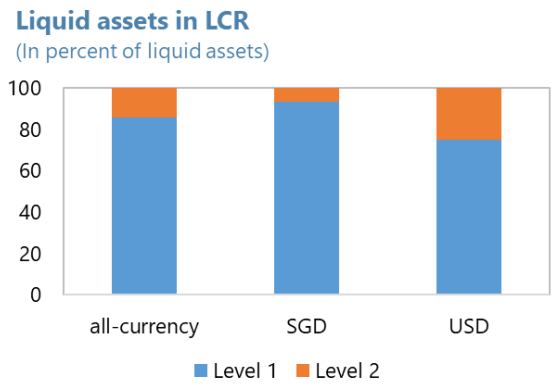
And loan-to-deposit ratios in foreign currency are on the rise



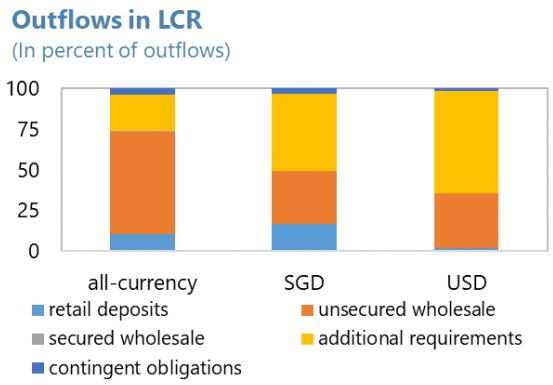
Source: MAS 2018 Financial Stability Review.
Note: The data show the ratio of non-bank loans to non-bank deposits for the banking system. (*) Data for 2018 refer to September.

Figure 6. Composition of D-SIBs' Liquidity Coverage Ratios (LCRs)

Liquid assets are concentrated in Level 1 instruments, which are of higher quality.



Outflows are driven by requirements for derivatives and margin calls.



Sources: MAS; and IMF staff calculations.
Notes: Liquid assets refer to the HQLA numerator in the LCR and outflows refer to the gross outflows in the denominator of the LCR. The aggregation across D-SIBs is achieved by summation across individual entities, using submissions at the country-level group where available. Each outflow is calculated as an outstanding balance multiplied by its LCR weight under MAS Notice 649. Each color shows a category of cash outflow, according to the categorization in that notice. For example, "additional requirements" includes derivatives and margin calls.

15. However, the foreign currency liquidity position is vulnerable to stress. The banking system's loan-to-deposit ratio in foreign currency has risen some 12 percentage points over the past two years, to 128 percent, which is driven by non-DSIBs. Since the last FSAP, D-SIBs successfully reduced their foreign currency loan-to-deposit ratios from these levels to 90 percent, which means that they do not rely on FX swaps to fund normal foreign currency lending. D-SIBs' U.S. dollar LCR is 48 percent, which suggests a shortfall (relative to a 100 percent LCR) of liquid U.S. dollar assets of some 20 percent of GDP in an adverse scenario (Table 4).[16] The adverse scenario implicit in the computation of the U.S. dollar LCR includes assumptions of stress in the FX swap market. This shortfall is split relatively evenly between domestic and foreign D-SIBs, and for foreign D-SIBs is driven by their branches (rather than subsidiaries). Analysis of banks' liquidity planning processes reveals that banks count on the FX swap market for foreign currency funding in the event of liquidity stress. There are safety nets in U.S. dollars, including the fact that the parent banks of large foreign bank branches are largely located in countries with access to U.S. dollar credit facilities. MAS provides U.S. dollar funding through the FX swap market as part of its daily money market operations. MAS' foreign exchange reserves are significant (at 80 percent of GDP), but the primary purpose of these reserves is to implement monetary policy.

[16] This 48 percent is an asset-weighted average across D-SIBs at the entity level. Using the group level (including the country-level group that some banks use for LCR compliance) leads to a lower asset-weighted LCR of 38 percent and a slightly lower liquid asset shortfall of 17 percent of GDP.

Table 4. U.S. Dollar Liquidity Shortfalls at D-SIBs. /1

	All D-SIBs	Domestic D-SIBs	Foreign D-SIBs
USD LCR (In percent) 2/	48	40	74
HQLA needed for 100% LCR (In millions of Singapore dollars)	88,329	40,093	48,236
In percent of GDP	*20*	*9*	*11*
HQLA needed to meet same requirements as all-currency LCR (In millions of Singapore dollars) 3/	53,203	40,093	13,110
In percent of GDP	*12*	*9*	*3*

Sources: MAS; and IMF staff calculations.

Notes:

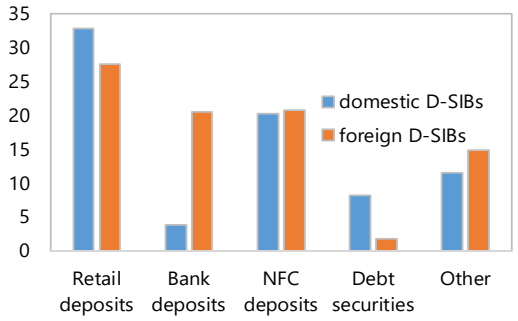
1/ This table shows the additional high-quality liquid assets that would be needed to meet hypothetical requirements for projected one-month liquidity in USD.

2/ Average of USD LCRs at the entity level, weighted by total assets. If we use the country-group level of consolidation for those banks that report it, we obtain a USD LCR of 38 percent for all D-SIBs.

3/ This assumes an LCR requirement of 100% for domestic banks and 50% for foreign banks. The requirements are imposed at the same level of consolidation as those for the all-currency LCR.

16. Banks' funding structure relies primarily on deposits, but also reflects the openness and sophistication of the economy. Some 73 percent of D-SIBs' liabilities come from deposits, of which 20 percent are deposits of non-financial firms. Local D-SIBs rely relatively more on retail deposit funding and foreign D-SIBs rely relatively more on interbank funding, which is mostly intragroup (Figure 7). The significant reliance of branches on intragroup funding results in loan-to-deposit ratios of 145 percent. The openness of Singapore also drives high shares of foreign currency (61 percent) and non-resident (71 percent) liabilities. Some 37 percent of D-SIBs' liabilities are denominated in U.S. dollars and 27 percent are denominated in other foreign currencies. The complexity of banks' funding is evident from the fact that "other" liabilities, including derivatives, make up 12 percent of liabilities.[17]

Figure 7. D-SIBs' Funding
(In percent of liabilities)



Source: MAS.
Notes: Bank deposits include funding from repurchase agrements. Other liabilities include derivatives.

17. Since the last FSAP, MAS has strengthened the regulatory framework for bank capital and liquidity. It amended regulatory capital requirements (Notice 637) to introduce the minimum leverage ratio for locally incorporated banks (3 percent) and loan loss provisioning rules (Notice 612), known as the SFRS 109, to encourage timely recognition of credit losses. MAS has also

[17] Banks also have corresponding large asset positions in derivatives.

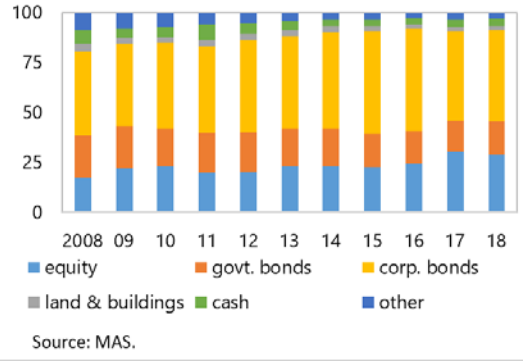
introduced minimum LCR and NSFR requirements for D-SIBs in all currencies and in Singapore dollars (Notice 649 and Notice 652). [18] It also monitors LCRs in significant foreign currencies, but there is no minimum requirement for foreign currency liquidity specifically. Other banks remain subject to the minimum liquid asset requirement. It conducts regular stress tests of bank solvency and liquidity.

Insurance Sector Soundness

18. Insurers have strong buffers over minimum capital requirements. Regulatory capital amounted to 247 percent of risk-based regulatory capital requirements in 2018. Profits have been strong but were weighed down in falling asset prices in 2018 (Table 3). Competition in the direct general insurance sector has driven down its profits recently. Some three-quarters of the regulatory capital of the four largest life/composite insurers comes from yet undeclared discretionary benefits (Box 2).

19. Market risks in the life insurance sector have trended up in the last decade. Given their large portfolios of marketable securities, the main risk to life insurers is of falls in asset prices. Life insurers have increased their share of assets allocated to equity securities over time (Figure 8), as their participating policies have shifted to those with greater emphasis placed on terminal (rather than reversionary) bonuses. Life insurers are also notably exposed to corporate bonds, making them particularly vulnerable to widening credit spreads. Insurers in Singapore need corporate bonds to match their liability cashflows because life insurance liabilities are almost as large as the market for bonds issued by the Singapore government and statutory boards. However, more than 90 percent of rated corporate bonds are investment grade. The share of assets allocated to corporate bonds has remained constant over time, but the credit quality has shifted very slightly toward lower-rated investment grade bonds.

Figure 8. Life Insurers' Asset Allocation
(In percent of total assets)



Source: MAS.

[18] The minimum LCR requirements apply to D-SIBs and any other banks that opt in. The minimum requirement is set at 100 percent in Singapore dollars. For all currencies, the minimum requirement is set at 100 percent for the three domestic banks and 50 percent for foreign banks. The minimum all-currency NSFR requirements apply to D-SIBs. The minimum requirement is set at 100 percent for domestic banks and 50 percent for foreign banks.

Box 2. Insurance: The Allowance for the Provision of Non-Guaranteed Benefits (APNGB)

The loss absorbing capacity of undeclared discretionary benefits from participating policies is difficult to determine and comprise a large share of regulatory capital in Singapore. Participating policies are popular in Singapore, representing some 80 percent of insurers' liabilities. The assets of these policies exceed their guaranteed liabilities. In principle, this excess will need to be shared in future between the insurer and its policyholders, the latter in the form of discretionary benefits (bonuses) to be declared. A portion of these excess assets is recognized as regulatory capital. The amount of capital from such discretionary benefits that insurers are eligible to recognize under the regulatory capital calculation is known as the allowance for the provision of non-guaranteed benefits (APNGB). About three-quarters of regulatory capital of the four largest life/composite insurers comes from this source, given their sizable portfolios of participating policies.

The current capital regulations therefore include safeguards to prevent insurers from over-relying on this source of capital. Given the need to share these excess assets with policyholders, some of this excess would not be available to absorb losses in an adverse scenario. In principle, the undeclared discretionary benefits are not guaranteed, and insurers can refuse to declare them if necessary. Furthermore, the APNGB applies two limits on the extent to which undeclared discretionary benefits can be recognized as eligible capital for the purposes of meeting minimum capital requirements. First, the capital of participating policies is also measured separately from other capital, and only 50 percent of the value of future discretionary benefits can be recognized toward regulatory capital of participating policies. This turns out to be the binding condition in most cases. It can be interpreted as allowing insurers to take credit for a hypothetical cut to future bonuses by one-half. Second, the capital of participating policies is ringfenced in the sense that it is not allowed to be used to offset any capital shortfalls among other insurance policies. These safeguards were assessed to be in observance of the Insurance Core Principles (IMF, 2013).

The safeguards seem reasonable given historical experience and the stress tests. The first safeguard in the APNGB credits insurers with a cut of discretionary benefits by 50 percent. This was not exceeded under the GFC—insurers needed to cut discretionary benefits by only 24 percent in 2008. It is also not exceeded in the bottom-up stress tests discussed below, where selected insurers report that they would need to cut discretionary benefits by up to 40 percent. The extent of reduction to discretionary benefits depends on the severity of the stressed situation.

These safeguards will be revised as part of the enhanced risk-based capital framework (RBC 2). The revised framework will introduce new safeguards (against overreliance on the APNGB) in the form of minimum requirements for CET 1 and Tier 1 capital. These minimum requirements will ensure that capital requirements will be met by high quality capital. The revised framework will also remove the 50 percent limit, which authorities view as consistent with the lower risk appetite (1-in-200 years) that is built into the revised framework.

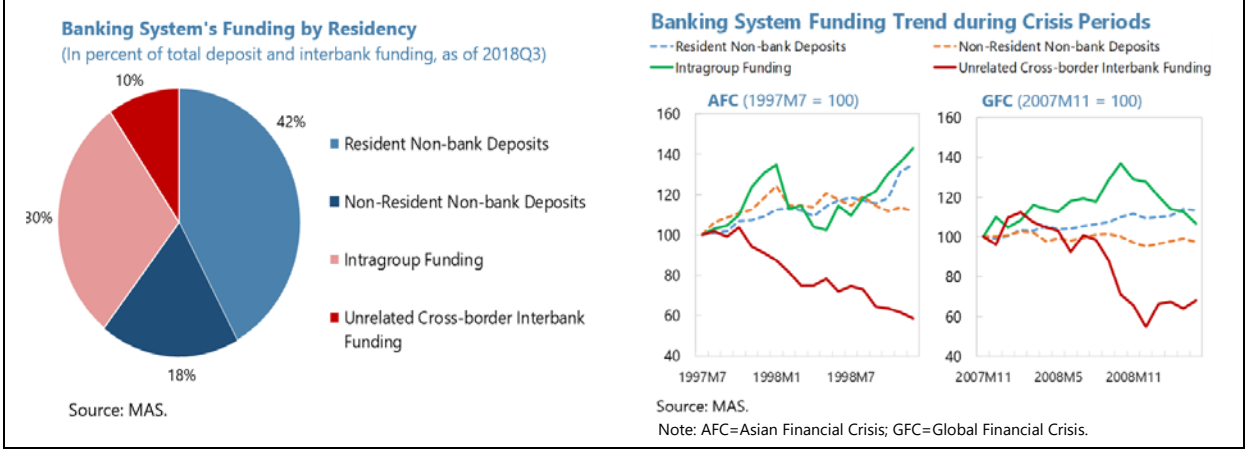
20. Since the last FSAP, regulations have evolved to enhance the soundness of the sector. Requirements came into force in 2014 for insurers to adopt formal capital planning and risk assessment processes. The authorities have recently revised the risk-based capital regime (RBC 2) to make several technical improvements and this is expected to come into force in 2020. Large insurers that staff met are prepared for this new regime and do not expect it to change their capital positions materially. International Financial Reporting Standard (IFRS) 17 was recently adopted by the

Singaporean accounting standard-setting body, to come into force at the same time proposed by the International Accounting Standards Board. Insurers are evaluating its implications group-wide, which could be significant. Larger insurers that are part of internationally active insurance groups are also involved in field-testing of the Insurance Capital Standards being developed by the International Association of Insurance Supervisors.

Interconnectedness

21. Singapore's financial sector has extensive direct cross-border linkages. Singaporean banks have large cross-border exposures amounting to about 60 percent of total loans, as they heavily engage in cross-border lending especially to East Asia (China, Hong Kong SAR, Japan, Korea, Taiwan PoC, and ASEAN). Being a financial hub, there is also a large presence of foreign banks, some of which are systemically important to domestic system. On the funding side, this contributes to the fact that interbank funding is mostly driven by cross-border flow, especially intragroup funding which functioned as a stabilizing factor for some foreign branches and subsidiaries during the past crises (MAS, 2015; Figure 9). As noted above, there can be other sources of cross-border connections including common exposures and ownership links, which are beyond the scope of this note.

Figure 9. Banking System's Funding



22. Financial institutions within Singapore, however, have limited direct interlinkages among each other.[19] The gross bilateral exposures within the domestic financial system amounted only to 29 percent of GDP at 2018Q2 (Table 5), very small relative to total assets of financial institutions and those in other countries (e.g., 230 percent of GDP in Ireland at 2015Q2). Three quarters of the exposures are between banks. As shown in the 2013 FSAP, bank liabilities to nonbank financial institutions (NBFIs), including asset management firms, are small at about 4 percent of GDP (1.1 percent of D-SIBs' liabilities) and banks also have very small lending exposures to NBFIs (only 1 percent of GDP, 0.3 percent of D-SIBs' assets). Furthermore, excluding intra-group

[19] Financial institutions could connect to each other via other channels, such as common exposures and cross-holdings of equities, which are not covered in this note.

and cross-border interbank exposures, interbank exposures among the 118 banking groups stood only at 0.8 percent of total banking system assets and about 5 percent of GDP.

Table 5. Financial Network Matrix within the Domestic Financial System
(Gross Bilateral Position, as of 2018Q2)

Unit: Percent of GDP		Liabilities							
		Bank	Finance Company	Insurer	Pensino Funds	Broker-Dealer	CMS License Holder	Rest	Total
Assets	Bank	21.5	0.0	0.0	0.0	1.0	0.0	0.0	22.6
	Finance Company	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
	Insurer	1.5	0.0	0.1	0.0	0.9	0.0	0.0	2.6
	Pensino Funds	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	Broker-Dealer	1.1	0.0	0.0	0.0	0.3	0.0	0.1	1.5
	CMS License Holder	1.0	0.0	0.0	0.0	0.3	0.0	0.1	1.4
	Rest	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.3
	Total	25.7	0.0	0.1	0.0	2.8	0.1	0.2	28.8

Unit: Percent of domestic liabilities in each sector		Liabilities							
		Bank	Finance Company	Insurer	Pensino Funds	Broker-Dealer	CMS License Holder	Rest	Total
Assets	Bank	84	0	22	0	37	48	0	78
	Finance Company	1	0	0	0	0	0	0	1
	Insurer	6	40	78	0	34	44	0	9
	Pensino Funds	0	2	0	0	0	0	0	0
	Broker-Dealer	4	28	0	33	12	0	53	5
	CMS License Holder	4	25	0	33	11	0	47	5
	Rest	1	4	0	33	6	8	0	1
	Total	100	100	100	100	100	100	100	100

Unit: Percent of domestic assets in each sector		Liabilities							
		Bank	Finance Company	Insurer	Pensino Funds	Broker-Dealer	CMS License Holder	Rest	Total
Assets	Bank	95	0	0	0	5	0	0	100
	Finance Company	100	0	0	0	0	0	0	100
	Insurer	59	0	4	0	36	1	0	100
	Pensino Funds	100	0	0	0	0	0	0	100
	Broker-Dealer	71	0	0	0	22	0	6	100
	CMS License Holder	71	0	0	0	22	0	6	100
	Rest	49	0	0	0	49	2	0	100
	Total	89	0	0	0	10	0	1	100

Sources: MAS; and IMF staff calculation.

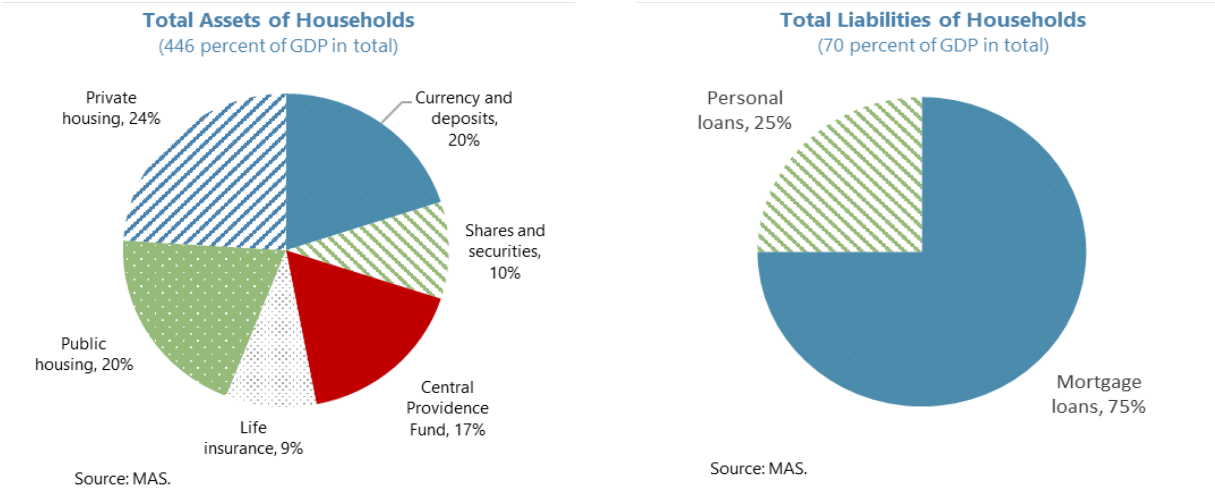
C. Developments in the Private Sectors

Household Sector Soundness

23. Households have a strong financial position. Total household assets amount to 446 percent of GDP at end-2017 (Figure 10). The household sector's balance sheet has strengthened further thanks to rising financial asset and housing asset amid the recent increase in real estate prices, with the growth of housing assets outpacing the growth of household debt. Household debt

has stabilized around 70 percent of GDP since 2013 and the average debt-to-income ratio is low at 2.1. The ratio of debt outstanding to total assets stood at only 15.6 percent at end-2017. Liquid financial assets (including currency, deposits, shares, and securities) are almost twice the size of total household debt, reflecting the resilience of household balance sheets. NPL ratio of household loans is low at less than 0.5 percent as of 2018Q2.

Figure 10. Total Assets and Liabilities of Households as of end-2017



24. Households are sensitive to house price fluctuations. House prices have contributed the most to developments in household assets, with about 44 percent of assets comprising residential property. A panel data analysis with 17 countries from Asia and other advanced economies by MAS (2017) found that property prices have contributed to about half of the change in household debt-to-GDP ratio after the GFC. Other factors, such as stock prices, interest rates, income, and macroprudential policies, have also played a role in driving the changes in household debt.

25. House prices are expected to remain stable, but the upcoming housing supply could pose a downside risk to the prices. Real estate prices recovered strongly since the second half of 2017, but the growth rates have since stabilized with the latest tightening of property market measures.[20] Private residential property prices experienced a strong turnaround (+8.3 percent, y-o-y) between 2017Q3 and 2018Q2 after a gradual decline of about 12 percent between 2013Q3 and 2017Q2. Following the tightening of macroprudential measures in July 2018, however, the pace of house price inflation has started to moderate. An upcoming increase in the supply of new housing units may pose a downside risk to property prices (see Technical Note on Macroprudential Policy).

26. Sound household sector financial conditions and stable property price developments are crucial for financial stability. Households allocate their funds into deposits, insurance

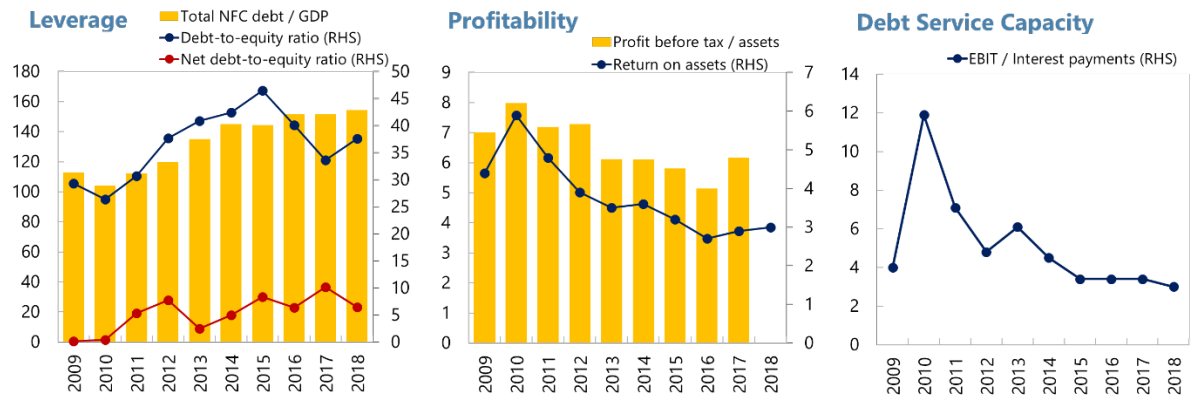
[20] MAS together with other government agencies have been proactive in mitigating systemic risk through prudential measures such as limits on total debt servicing ratios and loan-to-value (LTV) ratios, as well as stamp duties and supply-side measures. In the second half of 2017 and after four years of decline, private residential prices began to rise rapidly. The authorities responded by raising stamp duties and lowering LTV limits in July 2018, proactively muting the potential build-up of financial risk.

products, equities or debt securities, and borrow from financial institutions to finance consumption and investment. Household loans, including residential mortgages and loans to professional and private individuals, account for about 30 percent of total bank lending. Thus, household sector financial vulnerabilities, which can lead to higher NPLs and deposit withdrawal, have important implications on banks' solvency and liquidity and financial stability overall. Also, as mentioned above, property-related loans accounts for about 30 percent of total bank lending, exposing banks to risks stemming from property price movements (see the bank solvency stress tests below).

Non-Financial Corporate Sector Soundness

27. Corporate leverage is high, but corporates maintain ample cash buffers. Corporate debt increased steeply from 104 percent of GDP in 2010 to over 148 percent in 2015Q3 in a persistently low interest environment post-GFC (Figure 11). It has stabilized since then and stood at 148 percent of GDP as of 2018Q2. Such high level of debt relative to the size of domestic economy to some extent reflects the presence of large foreign owned companies and Singapore corporate's large overseas activities in general. The balance sheet leverage ratios do not stand out as much, with the median debt to equity ratio falling in recent years to below 40 percent. In addition, corporates hold significant amount of liquid assets with a median cash-to-debt ratio of 50 percent. The leverage on a net basis is much lower.

Figure 11. Financial Indicators of Non-Financial Corporates
(In percent)



Sources: Monetary Authority of Singapore, Singapore Department of Statistics, IMF staff calculations.

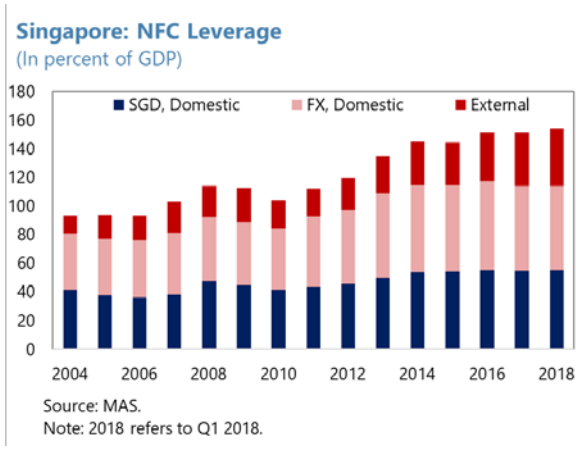
28. Corporate debt service capacity appears healthy at the aggregate level. Corporate profitability, return on assets, gradually declined post-GFC until 2016. Deteriorating profitability together with the increasing leverage weighted on healthy corporate debt service capacities, and ICR (EBIT divided by interest expense) fell from the high level of 12 to below 4. Since 2016, however, profitability, as well as the leverage, have started to level off, stabilizing the debt service capacity at a still-healthy level of about 3.

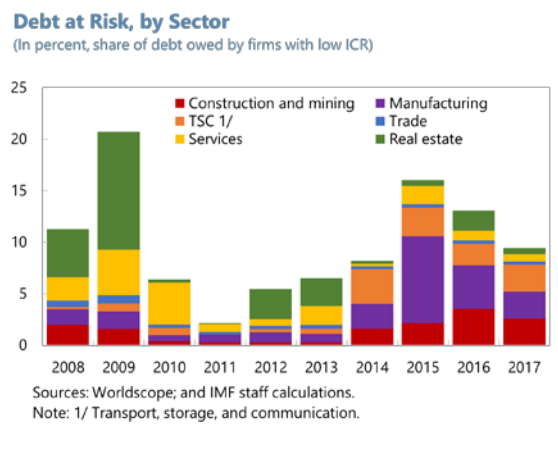
29. Corporate sector health is important for financial stability. Corporates in Singapore rely heavily on bank loans for financing (90 percent of domestic corporate debt). Deposits from corporates are also important source of bank funding. Corporate sector soundness thus has

important implications on banks' asset quality and financial stability overall. A potential area for risks is the large and increasing share of foreign-currency denominated corporate debts (64 percent as of 2018Q2, Figure 12). While this may reflect the international nature of Singapore's corporates as mentioned earlier, given the potential currency risks, the authorities monitor hedging strategies of large companies based on their financial reports and notes that most companies employ natural hedging and/or foreign exchange derivatives (MAS, 2018).

30. Corporate debt vulnerabilities have improved in recent quarters. The share of debt-at-risk (i.e., the share of debt owed by firms with ICR below one) peaked recently in 2015, as the low oil prices and slow global trade put a strain on companies especially in marine and offshore engineering (captured in TSC in Figure 12) and manufacturing sector. It has improved since then in light of strong external demands and the recovery of oil prices, especially among large corporates in manufacturing sector. Corporate NPL ratio also fell to 2.4 percent in 2018Q3 from the latest peak of 2.8 in 2016Q4. Currently, while some weakness continues in construction and TSC sector especially among medium-sized corporates, the overall debt-at-risk is at a moderate level (e.g., below the average levels seen among emerging market firms (GFSR, 2016)).

Figure 12. Corporate Debt Vulnerabilities

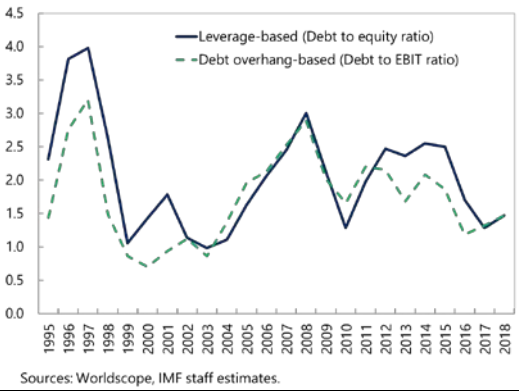




31. The riskiness of credit allocation does not seem to have risen significantly despite easy credit conditions in 2017. The riskiness of credit allocation index captures the evolution of relative vulnerabilities among those firms that are leveraging up fast; that is, the average vulnerabilities (e.g., high debt ratios) among the firms that are accumulating debt fastest, compared to those reducing debt fastest (GFSR, April 2018). If it rises over time, it indicates the relative vulnerabilities among the top issuers are rising, thus credit allocation is becoming riskier. In Singapore, it rose during the periods of easy

Figure 13. The Riskiness of Credit Allocation

(Index, two-year moving average)



financial conditions,
for instance, during the run-up to the GFC and recently in 2010-11. They are then followed by de-risking periods as financing condition subsequently tightens (Figure 13). Despite easy financing conditions in 2017, the indices do not yet show a significant uptick in the riskiness of credit allocation.

D. Scenarios and Scope of Financial Stability Analyses

Risks and Vulnerabilities

32. The main macrofinancial vulnerability relates to Singapore's extensive linkages to the region and the rest of the world (Risk Assessment Matrix, Appendix I). The financial system is exposed to global and regional macrofinancial shocks through significant trade and financial channels. Particularly, a sharp economic slowdown in China would have a large impact via the extensive trade, investment, and financial linkages, and via regional second-round spillover effects. A disorderly normalization of monetary policies in advanced economies would also have an important impact transmitted through financial and property markets. A sharp fall in house prices and a widening of credit spreads would impair balance sheets of financial institutions as well as private sectors.

33. Cyber risk is a growing risk to financial stability and the expansion of fintech poses challenges to financial oversight. Financial innovation has increased the exposure to cyber-attacks, which could adversely affect banks and nonbank financial institutions through disruption of business, damages to data and systems, explicit and implicit cyber exposures, and loss of confidence within the financial system.

Macrofinancial Scenarios

34. Two tail scenarios underpin the systemic risk assessment. Against the background of the macrofinancial developments and structural features of the financial system described above, MAS and the FSAP mission designed two severe but plausible scenarios as the basis for the financial stability analyses (Table 6).[21] The scenarios are driven mainly by external shocks and their initial impacts are amplified by existing vulnerabilities (e.g., legacy loans to transportation firms, vulnerable foreign currency liquidity, households' sensitivity to property prices, high corporate leverage). The scenarios have a duration of five-and-a-half years and start at the reference date of 2018Q2. The first half-year of the adverse scenarios matches the baseline scenario, so their downside events only occur from 2019 onward. These scenarios are mainly used in the bank and insurer solvency stress tests[22] and corporate sector analyses. Bank liquidity stress tests use tailor-made scenarios to capture short-term dynamics. The following narratives underpin the scenarios:

[21] The baseline and adverse scenarios are generated in collaboration between MAS and the IMF FSAP team, using MAS' Monetary Model of Singapore and IMF's Global Macrofinancial Model (Vitek, 2015).

[22] The insurer solvency stress tests only use the first two years of the five-year adverse scenario, as explained in Box 5.

Table 6. Detailed Stress-Test Scenarios

	2018[P]	Stress Horizon				
		2019	2020	2021	2022	2023
Real GDP growth rate (In percent)						
Baseline scenario	2.9	2.7	2.7	2.6	2.6	2.6
Adverse scenario 1	2.9	-3.1	-0.8	4.3	5.2	4.1
Adverse scenario 2	2.9	-2.5	-3.3	0.5	6.8	6.4
Output gap (In percent of potential output)						
Baseline scenario	0.9	0.7	0.6	0.4	0.2	0.0
Adverse scenario 1	0.9	-5.0	-8.4	-7.1	-5.0	-3.8
Adverse scenario 2	0.9	-4.4	-10.2	-12.3	-8.8	-5.7
Real GDP (2018 = 100)						
Baseline scenario	100.0	102.7	105.6	108.4	111.2	114.1
Adverse scenario 1	100.0	96.9	96.1	100.2	105.5	109.7
Adverse scenario 2	100.0	97.5	94.3	94.7	101.2	107.6
Unemployment rate (In percent)						
Baseline scenario	2.9	2.9	2.9	2.9	2.9	2.9
Adverse scenario 1	2.9	3.5	5.8	6.2	4.9	3.9
Adverse scenario 2	2.9	3.2	5.8	8.9	8.8	6.5
Interest rate: 3-month SIBOR						
Baseline scenario	1.8	2.3	2.8	2.6	2.6	2.6
Adverse scenario 1	1.8	3.8	4.3	3.6	2.8	2.3
Adverse scenario 2	1.8	2.8	3.8	4.3	4.3	4.3
Property prices (Change in percent)						
Baseline scenario	8.0	0.0	0.0	0.0	0.0	0.0
Adverse scenario 1	8.0	-30.0	-15.0	5.0	5.0	5.0
Adverse scenario 2	8.0	-20.0	-25.0	0.0	3.0	5.0
Exchange rate (SGD/USD, Change in percent)						
Baseline scenario	2.0	2.0	1.0	0.0	-1.0	0.0
Adverse scenario 1	2.0	20.0	5.0	-10.0	-10.0	-5.0
Adverse scenario 2	2.0	10.0	10.0	5.0	-10.0	-10.0
Commodity prices (Change in percent)						
Baseline scenario	31.4	-2.7	-5.9	-4.0	-2.8	-1.9
Adverse scenario 1	31.4	-40.0	-5.0	20.0	20.0	5.0
Adverse scenario 2	31.4	-20.0	-20.0	-5.0	20.0	20.0
Equity prices (Change in percent)						
Baseline scenario	1.0	3.0	2.0	2.0	2.0	2.0
Adverse scenario 1	1.0	-35.0	-5.0	20.0	15.0	6.7
Adverse scenario 2	1.0	-20.0	-15.0	-5.0	20.0	15.0

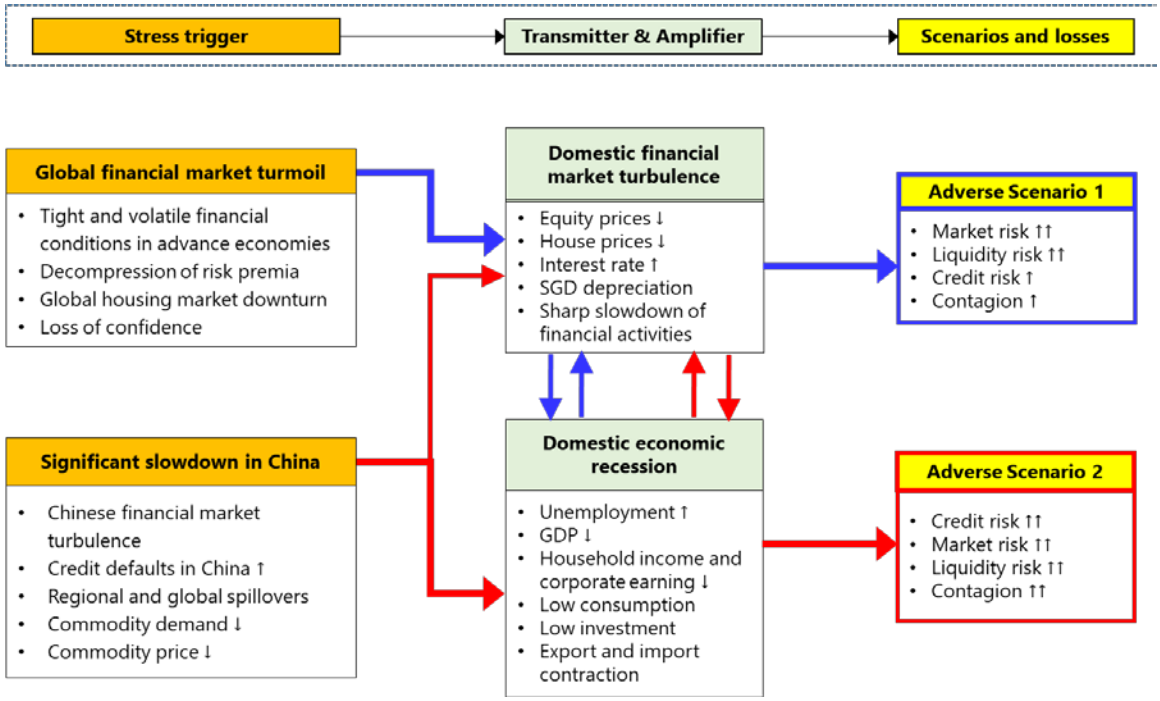
Sources: MAS; and IMF staff estimates.

- ***Baseline scenario*** is based on the July 2018 World Economic Outlook (WEO) projections. Some of these variables, such as house prices and equity prices, are not part of the WEO projections; as a result, these variables are projected by the FSAP team using a simple VAR model with real GDP growth rate and the Singapore Interbank Offer Rate as additional endogenous variables.

- ***Adverse scenario 1*** features large-scale global financial market turmoil, precipitating financial cycle downturns in Singapore (text figure). It causes falling asset prices, which then propagate to the real economy. Equity and house prices drop by 40-45 percent, and short-term interest rates rise by 250 basis points in the first two years.

- ***Adverse scenario 2*** involves a major slowdown and macrofinancial stress in China with a persistent impact on Singapore via its extensive linkages to the ASEAN region (Figure 14). It would lead to rising NPLs, a decline in investor sentiment, and pullback of funding from the region. The interbank spread rises 250 basis points over the stress horizon. Unemployment rise dramatically. The economy would recover only in the fourth and fifth years, but unemployment remains high at the end of the stress test horizon.

Figure 14. Transmission Channels of Adverse Shock



Source: IMF staff.

35. The adverse scenarios are severe enough to ensure that stress tests are rigorous (Figure 15). The output gap opens to -12.3 percent and cumulative declines of real GDP growth peak at 2.3 standard deviations in 2021 under *Adverse Scenario 2,* more severe than both the Asian Crisis and the GFC. Detailed path of key variables under the scenarios can be found in Table 6.

Scope of Financial Stability Analyses

36. Staff simulated the impact of these and other scenarios to assess contagion, solvency, liquidity, and cyber risks as well as private sector financial soundness. The impact of the scenarios is assessed with a wide-ranging set of analyses (Figure 16). For banks, the exercise covers the seven D-SIB groups (a total of 10 banks, including both branches and subsidiaries of foreign D-SIBs), which account for about 75 percent of non-bank loans to private sectors.[23] For insurers, the

[23] Maybank operated as a branch but had not been incorporated at 2018Q2, which is the reference date for the stress test.

exercise focuses on the big four insurers, which represent 80 percent of total assets of the sector. The contagion analyses cover domestic interbank exposures, interlinkages within the domestic financial system, and cross-border bank networks. For private sectors, the FSAP team assesses the impact of adverse shocks on their debt servicing burden. Detailed information of each analysis can be found in Appendix II.

- ***Domestic and cross-border Interconnectedness analyses.*** Following Espinosa-Vega and Solé (2010), the FSAP simulates the impact of a hypothetical bank failure on the domestic interbank market. This model is also applied to cross-border interbank network. A complementary analysis is conducted based on the methodology by Diebold and Yilmaz (2014) using the volatility of bank equity return indices as proxy for bank stress. Further, the FSAP explores how stress in the dollar funding market may signal downside risk to the banks' health, using the arbitrage pricing theory and an efficient market hypothesis.

- ***Private sector financial soundness analyses.*** MAS, in close collaboration with the FSAP team, simulates mortgage debt servicing ratio under *Adverse Scenario 2* and identifies segments of households that are particularly susceptible to negative shocks. The FSAP team's corporate vulnerability exercise quantifies the share of firms under financial distress (those with inadequate debt servicing capacity, with ICR below one or two) and the debt owed by these firms (i.e., debt-at-risk).

- ***Bank stress tests.*** The tests project the solvency positions of banks under the scenarios explained above. The FSAP performs top-down stress tests that are cross-checked against bottom-up stress tests performed by banks (and administered by MAS). They are complemented by sensitivity analyses, which project banks' solvency positions under simpler scenarios of single-variable changes in the economic environment, including the impact of fintech on fee and commission income. Concentration risk is assessed by assuming default of the largest private borrowers in the banking system. The bank liquidity stress tests project the liquidity positions of banks under adverse scenarios. Complementary stress tests assess liquidity positions in absolute terms and relative to minimum regulatory requirements. They are complemented with analyses of the drivers of stable funding and concentration of deposit funding.

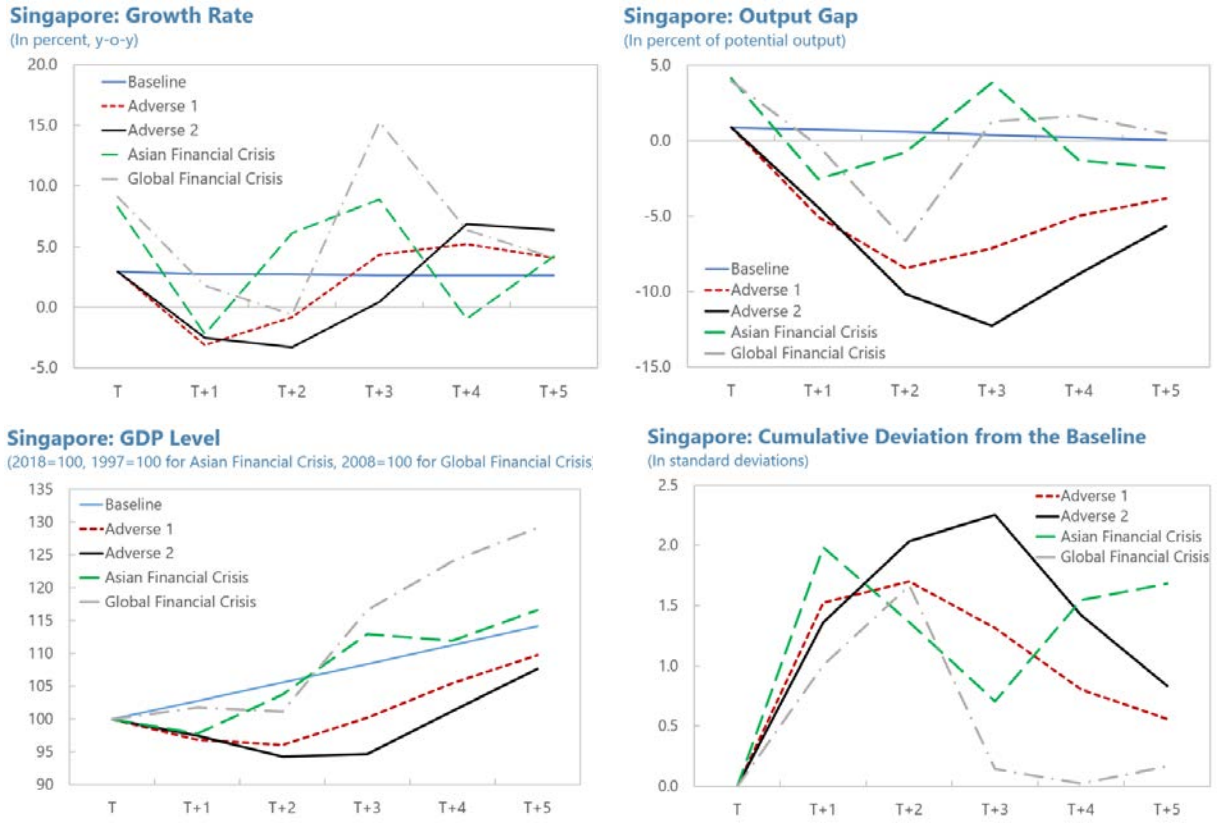
- ***Insurer stress tests.*** The assessment of insurers' solvency draws on bottom-up stress tests by insurers and top-down stress tests undertaken by MAS and the FSAP team. In addition, the bottom-up tests include scenarios for catastrophe risk from extreme flooding.[24] Given their importance for insurers, term structures of interest rates are modelled, in greater detail than in the bank solvency stress tests.

- ***Cyber risk analysis.*** It involved a bottom-up survey of 18 banks and 17 direct general and composite insurers regarding their exposures to cyber-attacks. Banks are asked to describe cyber events that they would be most vulnerable to and mitigating measures, to conduct

[24] The extreme flooding scenario is motivated by climate change considerations and the desire of MAS to raise awareness of its effects among insurers.

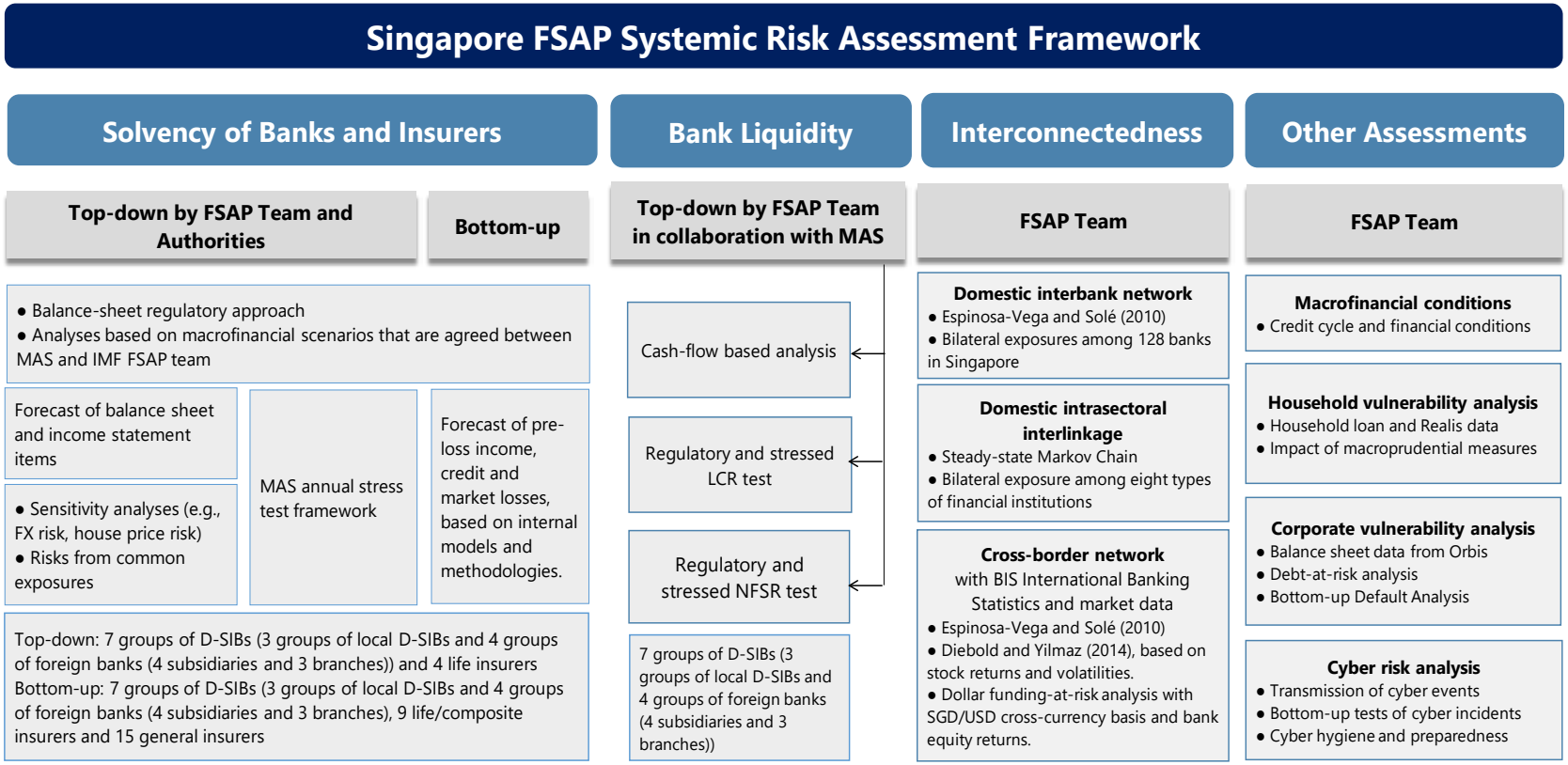
qualitative analysis of transmission channels of cyber events, and to provide quantitative estimates of potential losses. Insurers on the other hand are asked to calculate their exposures arising from claims on insurance policies that (explicitly or implicitly) cover such incidents.

Figure 15. Economic Growth under Baseline and Adverse Scenarios



Sources: MAS; IMF WEO database; and IMF staff calculation.

Figure 16. FSAP Systemic Risk Assessment Framework



Source: IMF staff.

FINANCIAL STABILITY ANALYSES

A. Contagion Risk

Cross-border Banking System Contagion

37. Banks in Singapore are most connected, through direct balance sheet exposures, with banks in major advanced economies like Japan, the U.K., and the U.S. and regionally with Hong Kong SAR, China and Malaysia. The analysis simulates the cross-border transmission of credit and funding shocks based on the methodology by Espinosa-Vega and Solé (2010), using the country-level interbank exposure data from the BIS Locational Banking Statistics (Figure 17). It shows banks in Singapore, including foreign branches and subsidiaries, are tightly connected with banks in Japan, reflecting the exposures through Japanese banks in Singapore. In addition, credit events in banks in major advanced economies such as the U.S. and the U.K. and regionally in Hong Kong SAR, China and Malaysia would have significant impact on banks in Singapore. For the rest of countries in Asia, Singapore banks have more outward rather than inward spillover effects.

Financial Market Evidence for Cross-border Spillover

38. The analysis using equity return data further highlights Singaporean banks' regional interconnectedness especially with China and Hong Kong SAR. In order to capture the interconnectedness of bank stress beyond balance sheet exposures, a complementary analysis is conducted based on the methodology by Diebold and Yilmaz (2014) using the volatility of bank equity return indices as proxy for bank stress (see Appendix III for methodological details and Figure 18 for results). It shows that Singapore is one of the most connected banking systems in Asia, together with China and Hong Kong SAR. The market data also show that Singaporean banks' inward connection to the U.S. and the U.K. However, regional connectedness comes out more strongly when using market data than balance sheet data. Singapore banks are tightly connected with China and Hong Kong SAR, while the connectedness with Japan appears much smaller. It also reaffirms that Singaporean banks' outward spillover is felt mostly by countries in Asia.

Cross-border Spillover from U.S. Dollar Funding

39. Dislocations in FX derivative markets can disrupt bank business activities and signal risk to bank value. Quantile regressions show that the SGD/USD cross-currency basis is strongly associated with the lower tail of the distribution of bank equity returns, although the magnitude is small. Specifically, a more negative five-year SGD/USD cross-currency basis is associated with a lower value of the left tail of residual returns of Singaporean banks, the idiosyncratic component of bank return (Figure 19).[25] This suggests that dislocation in the FX derivative market is correlated with the downside risk to bank value. Moreover, the basis is also predictive about near-term (five days

[25] The residual return is computed as the residual component of daily stock returns based on a standard Fama-French three factor model. The residual return is the idiosyncratic component of stock returns excluding the effects of market fluctuation and other standard systematic risk factors.

ahead) downside risk to the value of bank equity. This indicates that FX derivative market dislocation can forecast a larger near-term bank return volatility, especially the downside risk to bank value.

40. Stress conditions in FX derivative markets can provide useful insights on bank riskiness, although causality is not straightforward. While Singaporean banks generally do not rely on these markets for structural funding needs, FX derivative markets are used by banks to close US$ funding gaps and are highly relevant for banks' funding cost in general. It is possible that the measured dollar funding stress indicator is influenced by liquidity and other market factors. This concern is alleviated by the analysis including standard known (Fama-French) factors as well as VIX and Libor-OIS spread as additional factors. The goal of this analysis is to understand how stress conditions in dollar funding market can provide useful insights on bank riskiness and signal downside risk to bank value.

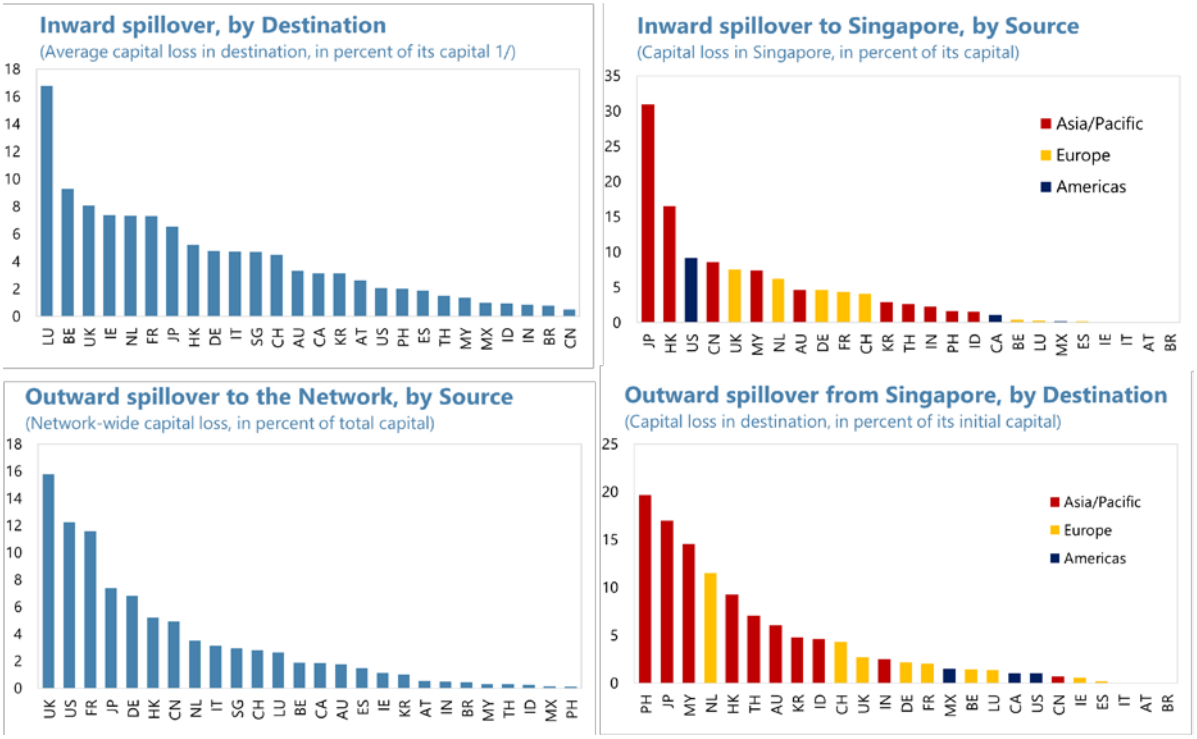
Domestic Interbank Contagion

41. The domestic interbank network analysis, following Espinosa-Vega and Solé (2010), reveals that contagion risks stemming from interbank exposures are limited (Figure 20). Even in the most conservative case, the hypothetical solvency event of a banking group—failing to meet the minimum regulatory requirement (10 percent of RWAs for total capital adequacy ratio)—would have a limited impact on other banking groups, inducing domino solvency events of up to three more banking groups and reducing system-wide total capital ratio by 0.8 percentage points at most.[26] Three local banking groups are not vulnerable to the solvency event of foreign banks in Singapore, but their solvency events would make a few small non-DSIB foreign banks to face a solvency problem. On contrary, twelve and four small foreign branches have a significant share (more than 10 percent) of assets and liabilities in the form of interbank lending and borrowing, respectively. On average, they are four times more vulnerable to the event than other banks in Singapore.

[26] The analysis uses a matrix of gross interbank exposures among all the 118 banking groups in Singapore as of 2018Q2. This analysis includes not only D-SIBs but also all other non-DSIB foreign branches. Following Espinosa-Vega and Solé (2010), it assesses the direct and indirect contagion impact on capital arising from a hypothetical solvency event of a banking group: if a banking group fails to meet the hurdle rate of total capital ratio (10 percent of RWAs), the failure triggers not only direct credit losses of other banks but also the subsequent fire sales caused by funding losses. If the failure of any given bank on its interbank obligations leads to the default of another bank in the system, a subsequent round is calculated to assess the impact of the second bank's solvency event on all other banks, and so on (i.e., "cascade effects"). To calculate the impact on capital, it assumes the capital adequacy ratio of foreign branches to be at the weighted average of locally-incorporated banks.

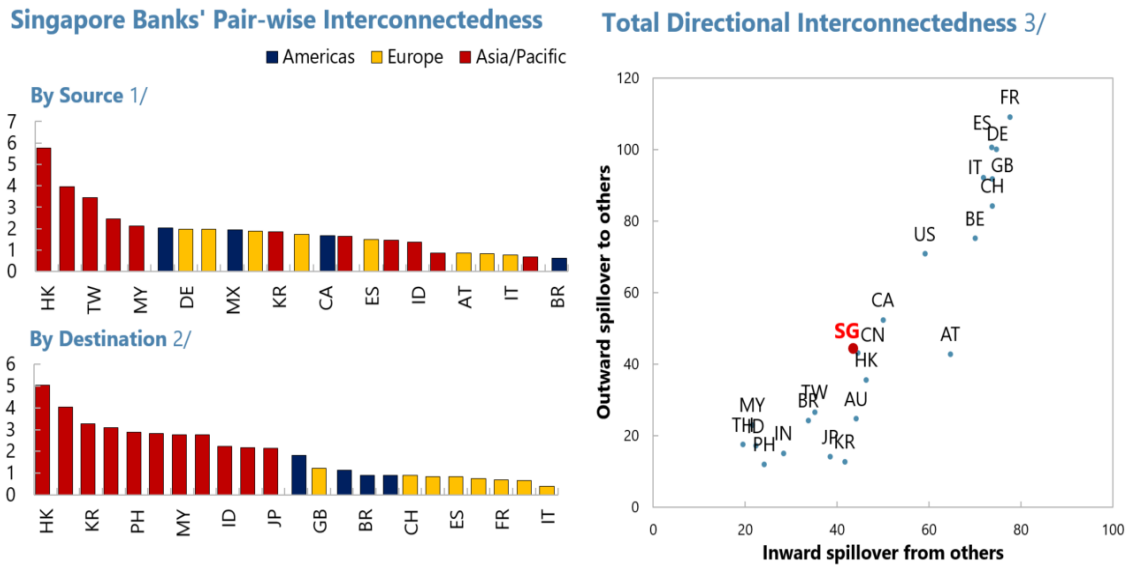
Figure 17. Spillover of Credit and Funding Shocks through Cross-border Interbank Exposures

(Locational Banking Statistics, unconsolidated)



Sources: BIS Locational Banking Statistics; MAS; and IMF staff estimates.
Notes: The analysis measures spillover through aggregate, unconsolidated cross-border bank flows using the BIS Locational Banking Statistics, based on the methodology by Espinosa-Vega and Sole (2010). As a benchmark case, this assumes that banks need to absorb 50 percent of loss given defaults of another banking system and unable to source 50 percent of lost funding thus leading to fire sale of assets at 50 percent discount. The size of spillover measured by capital impairment varies depending on assumed parameters, but relative order across countries remain largely the same.
1/ The average over individually triggered failure of all other countries.

Figure 18. Cross-border Spillover of Bank Equity Return Volatility



Source: Worldscope, IMF staff estimates

Notes: Full sample interconnectedness during January 2016 and December 2018 based on the methodology by Diebold and Yilmaz (2014). Pair-wise spillover measures the percent of a country's forecast error variance explained by shocks to another country.

1/ Percent of Singapore banks' forecast error variance explained by shocks from another country

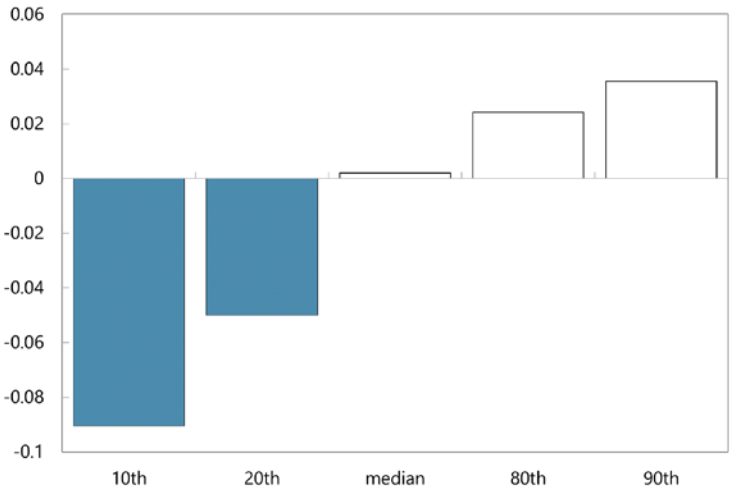
2/ Percent of the forecast error variance of the country explained by shocks from Singapore

3/ Total directional interconnectedness is the sum of inward spillover to the country from all other countries (inward) or outward spillover from the country to all other countries (outward).

Figure 19. Dollar Funding-at-Risk Analysis Results

Effect of Negative Cross-Currency Basis on Contemporaneous Bank Equity Returns at Different Quantiles

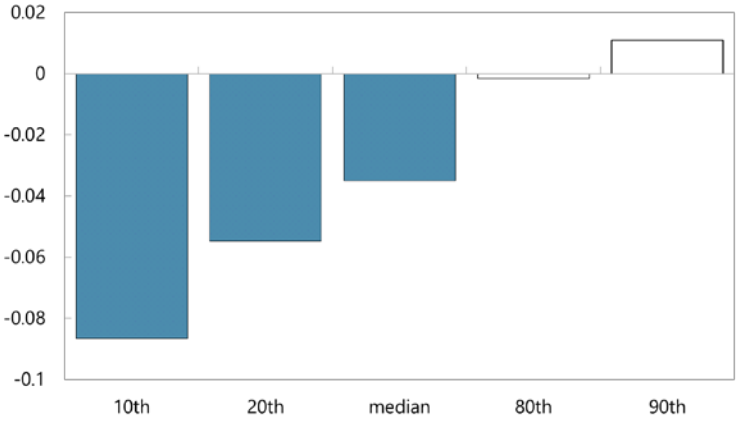
Unit: coefficient



Note: This figure plots the relationship between the deviation from CIP (negative basis) and the contemporaneous bank equity return at different quantiles. Equity returns are the residual return excluding the effects of Fama-French (ex-Japan) factors. Demeaned (annually) five-year cross-currency basis is used. Sample is from 2010 to 2018 at the daily frequency. The figure plots the average of coefficients for three Singaporean banks where solid bars represents statistical significance at 5 percent.

Effect of Negative Cross-Currency Basis on Near-Term Bank Equity Returns at Different Quantiles

Unit: coefficient

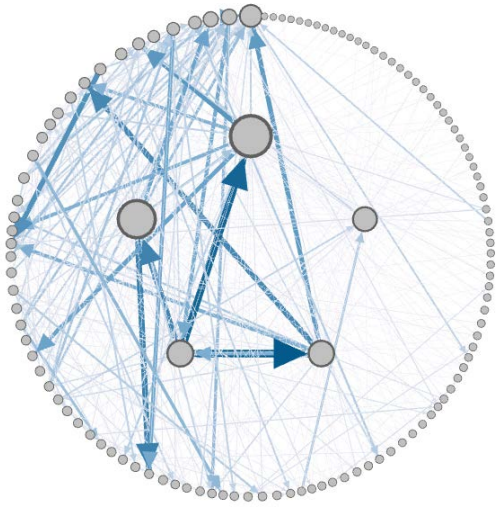


Note: This figure plots the relationship between the deviation from CIP (negative basis) and the one-week-ahead bank equity return at different quantiles. Equity returns are the residual return excluding the effects of Fama-French (ex-Japan) factors. Demeaned (annually) five-year cross-currency basis is used. Sample is from 2010 to 2018 at the daily frequency. The figure plots the average of coefficients for three Singaporean banks where solid bars represents statistical significance at 5 percent.

Sources: Bloomberg; Kenneth R. French's website; and IMF staff calculations.

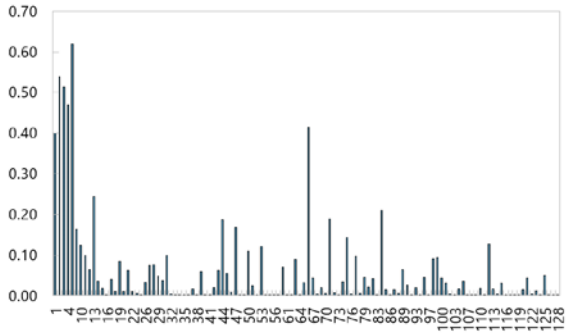
Figure 20. Interbank Network Analysis Results[1/]

Gross bilateral lending and borrowing, as of 2018Q2[2/, 3/]



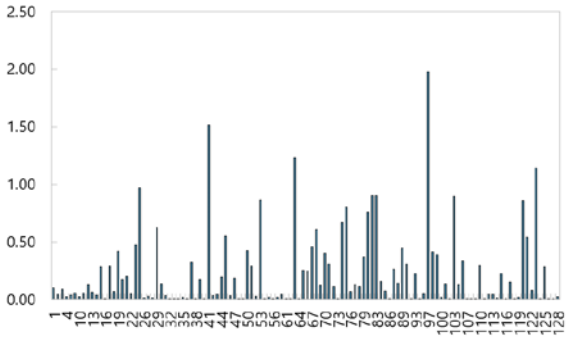
Index of Contagion

(In percentage point of total capital impairment in the banking system due to the failure of a bank)



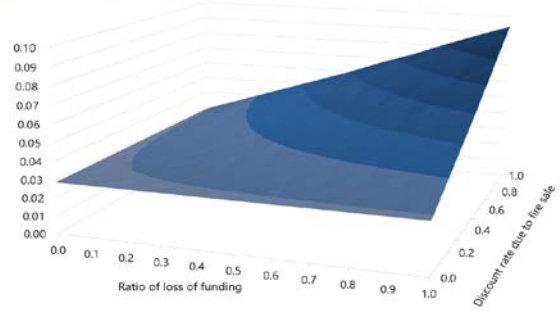
Index of Vulnerability

(In percentage point of avearge capital impairment of a bank due to the failure of other banks)



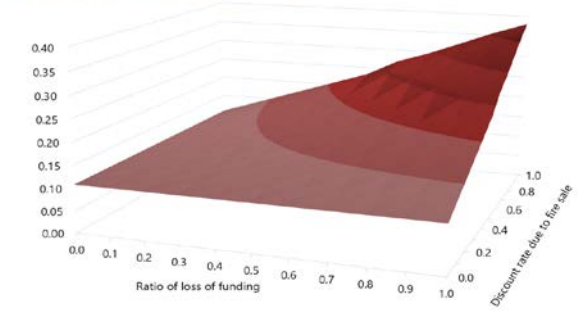
Index of Contagion

(In percent, average in the banking system)



Index of Vulnerability

(In percent, average in the banking system)



Source: IMF staff calculation.

Notes: 1/ The size of each vertex represents its degree (the sum of in-degree and out-degree). The thickness of an arrow depicts the volume of a relative bilateral exposure from a bank to another.

2/ Index of contagion is the percent of total capital losses in the system due to the failure of each bank, while index of vulnerability shows the average of capitla losses of each bank due to the failure of all other banks.

3/ There are three parameters: LGD ratio for interbank lending (λ), loss of funding ratio (ρ), and the discount rate (δ). In the middle two charts, these parameters are set at the most conservative level, λ =0.45, ρ=0.5, and δ=1, while the bottom two charts show the system-wide average of the index of vulnerability and contagion for all possible ρ and δ value.

B. Household Sector Resilience[27]

42. Household sector soundness analysis is based on simulations of the effect of interest rate and income shocks on household debt service ratios. Mortgage debt service simulations are carried out by shocking the Total Debt Servicing Ratio (TDSR) income and the interest rate for each individual loan account, and by assessing the corresponding increase in borrowers' mortgage debt servicing ratio (based on adjusted monthly mortgage payment as a share of the total adjusted TDSR income). Shocks correspond to those of *Adverse scenario 2*, in which the interbank interest rate increases by 250 basis points and nominal GDP drops by more than 20 percent in cumulative terms over the stress horizon. The associated drop in disposable income (10 percent) is computed by estimating the elasticity of the growth rate of household income to nominal GDP growth, using two different definitions of household income (the household gross income and the earnings per worker) in the absence of a national accounting variable of household income that would perfectly match the definition of the TDSR income, and computing the average elasticity according to a meta-analysis principle.

43. Simulations use account-level information of new housing loans granted in 2018 by the 12 largest mortgage lending banks in Singapore, which collectively provide the vast majority of outstanding housing loans by financial institutions. The account-level data includes information on the loan profile (the period of borrowing, the mortgage loan amount, the monthly mortgage repayments, the loan tenure, and the interest rate), the borrower profile (the age and the total debt-servicing ratio), and the property profile (the value of transaction and the type of property).

44. The simulations entail a set of conservative assumptions. Loans are assumed to have been fully disbursed, even though a significant share of borrowers get only partial disbursement at the time the loan is granted.[28] Second, the income used in the simulation and in the computation of the TDSR include only income of the main borrowers, so that for joint applications (about one-third of mortgage loans), only one of the borrowers' income is considered though the loan account would be serviced by a dual- or potentially triple-income household.[29] Third, the rise in the SIBOR interest rate is assumed to be fully and immediately passed through to the actual mortgage interest rate for all loan accounts, despite the fact that the majority of borrowers are on non-floating rate packages

[27] This analysis has been carried out in collaboration with MAS.

[28] Some borrowers purchase private residential properties before issuance of Certificate of Statutory Completion (CSC) and do not make full payment to the developer, but instead provide progressive payments upon purchase and completion of development milestones. As such, banks only disburse mortgage loan amounts in accordance with payment schedules for project development. These partial disbursements concern a significant share of borrowers as about 70 percent of outstanding mortgage loans from banks are for the purchase of private residential properties, and half of the property transactions are based on purchase of a unit directly from a developer before the issuance of the CSC.

[29] More generally, the TDSR income is a conservative estimate of household income, as it excludes CPF contributions from the employer (which account for 17 percent of income for the majority of working adults and can in practice be used to service mortgage repayments) and includes a 30-percent haircut on variable income (e.g., bonuses or rental income).

(and could take further steps to mitigate risks from rising mortgage rates by refinancing to non-floating mortgage rates). Finally, simulations assume a higher likelihood of default should the debt servicing ratio breach a 60-percent threshold, while according to the latest household expenditure survey, the average household typically spends 40 to 45 percent of its income on non-mortgage living expenses and households purchasing private property are likely to have lower expenditure-to-income ratios.[30]

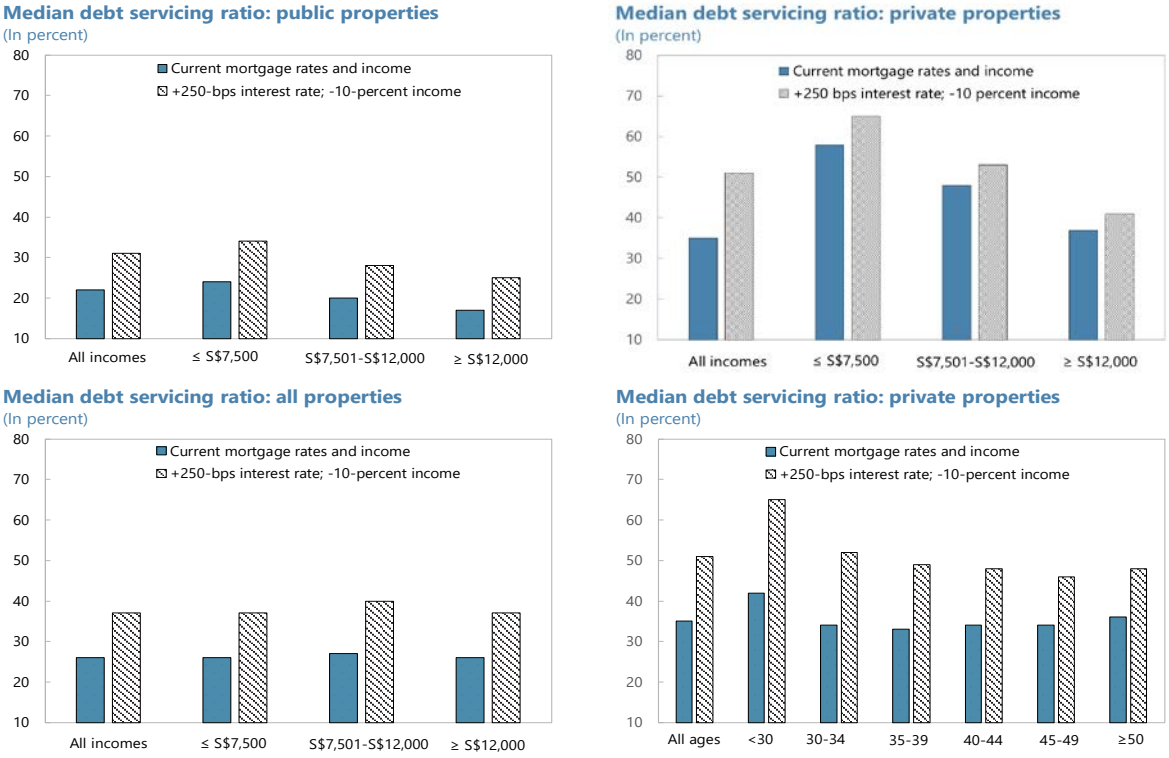
45. Using newly issued mortgage loans provides a conservative estimate of the actual outstanding amount of debt of borrowers but can also lead to underestimate risks. Given that the outstanding loan amount of existing loans decreases as mortgages are paid down over time, the debt service ratio at the point of loan inception is higher than the one of the average borrower. Conversely, as the credit risk profile of borrowers improved over time thanks to the implementation of credit-based macroprudential measures, using new loans rather than the total stock of existing loans could possibly exclude riskier loans of the simulation sample.[31] This latter concern is however somewhat attenuated by refinancing practices that progressively eliminate older loans of the current stock of household debt. Mortgage refinancing represented in 2018 about 15 percent of the outstanding amount of housing loans, in line with anecdotal understanding from banks suggesting that almost all of their housing loan portfolio is replaced within 7 to 8 years.

46. Results indicate that a significant proportion of borrowers remains resilient under severe stress scenario, although a small segment of highly-leveraged, low-income households as well as younger borrowers could face repayment difficulties (Figure 21). Simulations on bank-extended mortgage loans are carried out for two types of borrowers based on whether the latter purchased public or private residential properties. A significant proportion of households remains resilient under the stress scenario, especially public housing owners as the latter have low debt service-to-income ratios initially, reflecting lower prices of public housing and the imposition of the 30-percent Mortgage Servicing Ratio (MSR) on top of the TDSR limit. However, on the private housing market, a small segment of highly-leveraged households with income below S$7,500 (comprising less than 10 percent of the mortgage borrowers from financial institutions in 2018) could face repayment difficulties. Likewise, some younger borrowers would see their TDSR increasing beyond 60 percent. These younger borrowers are however likely to be professionals, managers, executives, and technicians enjoying higher potential income growth, improving their debt servicing capacity in the years following the shocks. Also, they tend to take up smaller loans, so their individual defaults would pose less risk to the banking system as compared to other loans. The reduction in mortgage LTVs across the board in July 2018 will also further improve the mortgage servicing risk profiles of borrowers.

[30] While a threshold of 100 percent would be more indicative of a technical default situation, the simulations conservatively assumes an increased likelihood of default should mortgage servicing burden breaches the 60 percent mark as borrowers would have to cut back on living expenses or rely on savings to continue their mortgage repayments.

[31] Nonetheless, some of the legacy loans might have higher financial buffers if the buyer has transacted in a period of lower property prices, relative to the amount of loan taken up.

Figure 21. Households' Mortgage Servicing Ratio under Baseline and Adverse Scenarios



Source: MAS.

Notes: This figure shows median debt servicing ratios under baseline scenario and *Adverse Scenario 2* for borrowers purchasing public and/or private properties, by income and age ranges. The stress test covers new property loans granted in 2018.

C. Corporate Sector Resilience

47. Financial resilience of non-financial corporates is assessed based on the sensitivity analysis of debt-at-risk under adverse macroeconomic scenarios. The debt-at-risk level is assessed based on the ICRs recalculated under two different scenarios, which are chosen with reference to the stress test scenarios above.

- ***Baseline scenario*** assumes the increase in borrowing costs by 1 percentage points and currency depreciation of 2.5 percent, without earnings shocks.

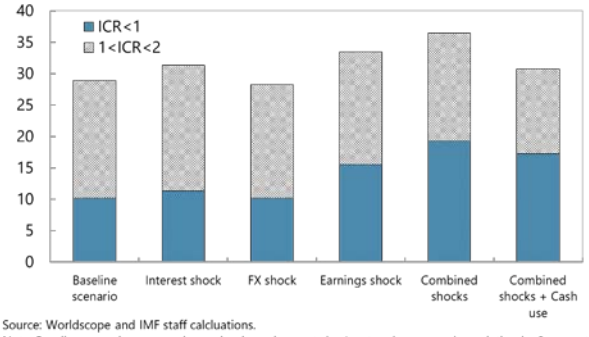
- ***Adverse scenario*** assumes the increase in borrowing costs by 2.5 percentage points and currency depreciation of 20 percent, consistent with the peak interest and currency impact under bank stress tests adverse scenarios. It also assumes the fall of earnings by 20 percent, commensurate to the magnitude seen during the GFC.

In both scenarios, it is assumed that the interest shock applies to 45 percent of total debt that are being rolled over (55 percent are on fixed rates), and the currency shock applies to 65 percent (referencing the share of FX debt) of total debt.

48. Corporate debt-at-risk would rise significantly under the adverse scenarios, but cash reserves can provide some buffer. The debt-at-risk is expected to rise from the current level already in baseline scenario due to the expected tightening of financing condition. The further severe interest and currency shocks, and most of all the earnings shock, under the adverse scenario would have a sizable impact on firms' balance sheet and significantly raise the debt-at-risk level beyond the levels seen in the global financial crisis in line with the projected NPL ratios in the bank solvency stress tests, before considering mitigating factors (Figure 22). However, the fact that corporates generate significant revenue from foreign sales provide natural hedging mitigating currency shocks. Further, corporates' ample cash reserve can mitigate the adverse impacts, even as we assume limits on cash use for debt service in consideration of honoring other current liabilities. (see bank liquidity analysis below for deposit concentration risk).

Figure 22. Sensitivity Analysis, Debt at Risk

(In percent, share of debt owed by firms with low ICR)

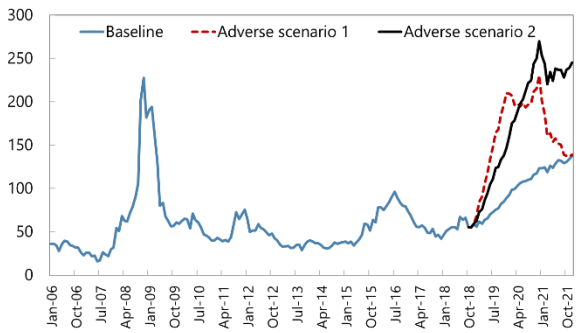


Source: Worldscope and IMF staff calcluations.
Note: Baseline scenario assumes increasing borrwing costs by 1 ppt and currency depreciation by 2 percent. Interst shock assumes increasing borrwing costs by by 2.5 ppt on non-fixed rate debts (50 percent of total); FX shock assumes currency depreciation of 25 percent, increasing interst burden by 25 percent on FX debts (50 percent of total) while increasing the earnings from foreign sales by 25 percent in local currency (natural hedging); Earnings shock assumes the fall of EBIT by 20 percent. Use of cash is limited to keep quick ratios above 1--somewheat conservative assumption limiting the depleting of liquid assets.

49. Corporate probability of defaults projections point to higher stress on corporates as the economy slows down. The analysis projects the corporate probability of defaults (PD) based on the Bottom-up Default Analysis (Duan, Chan-Lau, and NUS CRI team, 2018), under the baseline and two adverse scenarios (Figure 23). Given the already expected tightening of financial conditions and slowdown of the economy, the model projects gradually increasing PDs even under the baseline scenario. Under adverse scenarios, default risk is expected to rise steeply in the first two years and weigh on banks and insurers as shown in the stress tests below. Broadly mirroring the pace and the severity of assumed stress test scenarios, stress is more severe and persistent under the second adverse scenario. The PDs among the firms under higher distress (75 percentile) are expected to rise beyond the level seen during the GFC, especially in *Adverse Scenario 2*, which is in line with the projected NPL ratios in the bank solvency stress tests.[32]

Figure 23. Corporate Probability of Defaults

(In basis points, 75 percentile, 12-month horizon)



Sources: Haver Analytics, MAS, Risk Management Institute at National University of Singapore, IMF staff estimates.
Note: Estimates based on Bottom-up Default Analysis by Duan, Chan-Lau and NUS CRI team (2018). The data base covers 412 NFCs that are listed and domiciled in Singapore, drawn from Bloomberg and Thomson Reuters Datastream and compiled by Credit Research Initiative at the Risk Management Institute, National University of Singapore.

[32] Note that the PD projections shown here differ slightly from those generated in the bank solvency stress tests, due to differences in data sources, definitions and methods.

D. Bank Solvency Resilience

IMF's Top-down Solvency Stress Test

50. The solvency stress test follows a balance sheet approach broadly aligned with the MAS regulatory framework. Based on the Basel III capital standard in Singapore (MAS Notice 637), which is now fully phased in, the solvency test assesses if banks would have adequate capital buffers (existing capital and forthcoming after-tax net income) to absorb potential credit and market losses if economic conditions deteriorate from the beginning of 2019 (Box 3).

Box 3. Methodology of Bank Solvency Stress Tests

The bank solvency stress test is carried out under a passive balance sheet assumption. Growth of gross exposures, such as total loans and gross holding of debt securities, is identical to overall credit growth, with the balance sheet composition unchanged. Overall credit growth equals to nominal GDP growth when the GDP growth rate is positive and zero otherwise. This assumption prevents banks from deleveraging under the adverse scenario, which imposes some conservatism and avoids the need to model second-round effects on the economy. At the beginning of the adverse scenarios, total assets increase as a small portion (5 percent) of off-balance sheet exposures (non-cancelable credit guarantees and commitments) are drawn. Banks are not allowed to raise new capital during the stress test horizon. Given the evolution of total assets and equity, total liabilities are adjusted accordingly, with banks raising additional funding, as needed (see Appendix VI for other assumptions for balance sheet projections). Banks are allowed to pay dividends if their net income after taxes are positive, with limits on dividend payout rate as per the MAS regulatory requirement.

The transmission of macrofinancial shocks to NPL ratios, point-in-time PDs, and point-in-time LGDs is assessed by estimating satellite credit risk models. The models use macrofinancial scenarios of five countries where D-SIBs have significant credit exposures, including Singapore, China, Malaysia, Indonesia, and Thailand. In the models, the logit-transformed NPL ratios are determined by real GDP growth rates, short-term interest rates, house prices, equity prices, and nominal (bilateral) exchange rates in a non-linear fashion. Because of the unavailability of historical point-in-time PDs, the FSAP uses historical NPL ratios as a PD proxy. Besides the logit transformation, non-linear effects are introduced with the square of real GDP growth rate as an explanatory variable, so that NPLs rise at an increasing rate as economic conditions exacerbate further. The FSAP team estimates several credit risk models with different panel estimation methods and combinations of explanatory variables to test their robustness, projects the NPL path by averaging results across the models, and then applies the path to the latest point-in-time PD estimates to produce the PD dynamics over the stress test horizon. LGDs for residential mortgages and corporate income producing real estate assets are scaled up with property price deflation in the adverse scenarios (-45 percent in 2020-2021) through a decline of collateral value. The FSAP team conservatively assumes a full pass-through of the price changes to LGDs (see Appendix VII for the detailed calculation). Following Schmieder and others (2011), LGDs also increase by 2.15 percentage points as PDs rise by 1 percentage point. Not only point-in-time LGDs but also regulatory LGDs are calculated in this way, imposing another conservatism.

Market losses correspond to changes in key financial variables, such as interest rates, foreign exchange rates, and equity prices. These losses (or gains) are due to the existence of "open

Box 3. Methodology of Bank Solvency Stress Tests (concluded)

positions" in banks' balance sheets (e.g., currency, maturity, time-to-repricing mismatches between assets and liabilities). The valuation changes corresponding to holdings of debt securities are measured through changes in yields leading to re-pricing based on a modified duration approach. By tracking the shifts in sovereign and corporate bond yield curves over time, changes in yields are obtained for any given (modified) duration and are applied to calculate haircuts and re-price bond portfolios in available-for-sale and held-for-trading accounts. Risk related to equity investments is considered for completeness, even if equity positions make up a small part of assets.

The changes in RWAs reflect the evolution of balance sheets, credit risk, and foreign exchange risk. First, the size of total assets increases as a portion of non-cancellable off-balance sheet exposures: second, the RWAs for credit risk under the standardized approach increase proportionately with balance sheet growth for all D-SIBs; third, for the exposures under the internal ratings-based approach, the stress test uses the Basel II formula to translate credit risk parameters (e.g., through-the-cycle PDs, LGDs, correlation, maturity, and scaling factors) into stressed RWAs. Conservative parameters are used to convert point-in-time PDs to through-the-cycle PDs: $\Delta PD_{TTC} = 0.8 * \Delta PD_{PIT}$ for retail exposures and $\Delta PD_{TTC} = 0.5 * \Delta PD_{PIT}$ for all other exposures; and lastly, RWAs are adjusted to reflect changes in the value of exposures in foreign currencies.

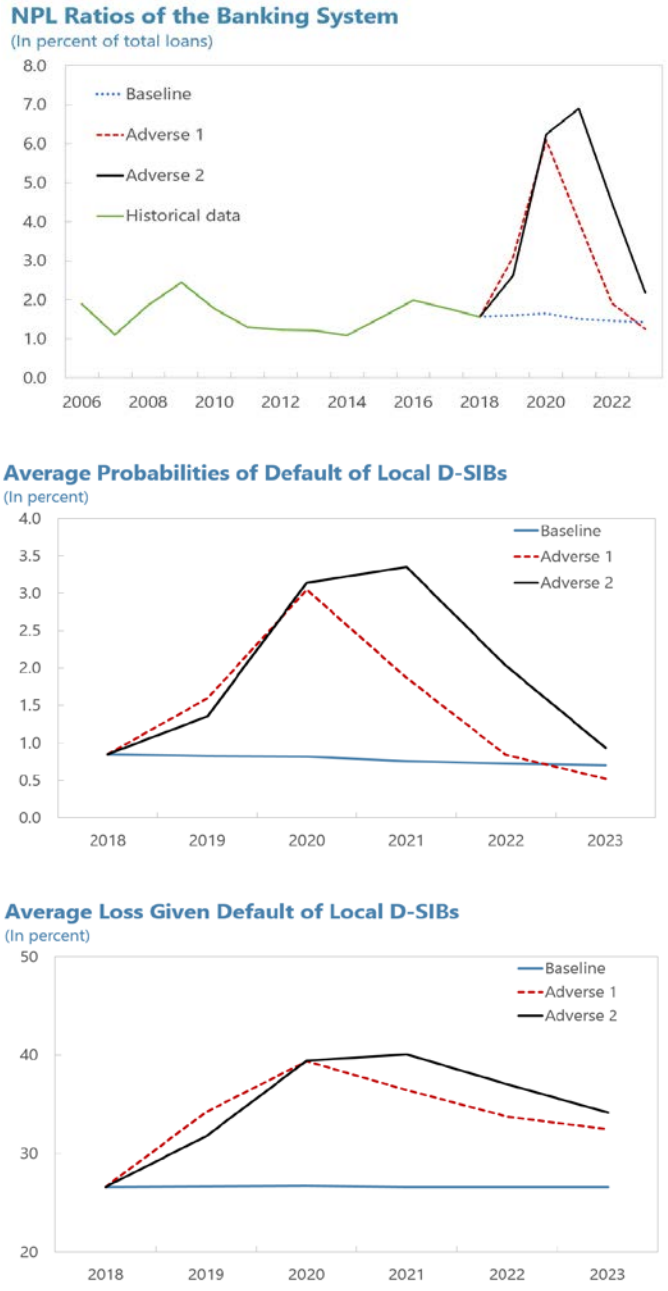
51. Credit risk constitutes the largest risk factor for D-SIBs on the asset side. Total loan portfolios constitute 67 percent of total assets, while debt securities (sovereign bonds) account for 13 (8) percent. Three local banks use both the standardized approach and the internal ratings-based approach to measure the credit risk of loan portfolios, while foreign D-SIBs use only the standardized approach. Regardless of the approach, the FSAP calculates loan-loss provisions of all D-SIBs according to the SFRS 109, which became effective in January 2018 (Appendix IV). It allows the top-down stress tests to be easily compared with the bottom-up stress tests based on the SFRS 109. Write-back of provisions are not allowed during the stress test horizon.

52. Estimates from the credit risk models suggest that NPL ratios, point-in-time PDs, and point-in-time LGDs would rise sharply under adverse scenarios (Figure 24). NPL ratios are sensitive to both economic developments and financial conditions, such as interest rate spikes, a sharp house price decline, and exchange rate depreciation, in the countries that D-SIBs are exposed to (Appendix V). At the beginning of the stress test horizon, the negative effects pass mostly through financial channels. But, as the economic conditions deteriorate further, GDP growth slowdown affects debt service capacity of borrowers and increases credit losses for banks. In *Adverse Scenario 1* and *2*, system-wide NPL ratios increase 4 and 4.4 times as high as the starting level (1.6 percent) in 2020 and 2021, respectively. In line with corporate sector analysis above, corporate sector would make a significant contribution to the rise of NPL ratios,[33] In contrast, the NPL ratios remain flat under the baseline scenario. In line with the NPL path, local D-SIBs' point-in-time PD increases fourfold from the starting level (0.8 percent in 2018), peaking at 3.0 percent and

[33] The FSAP team considers quantitative and qualitative information from the household and corporate sector simulation analyses when designing the bank credit risk model. However, PDs generated here differ from those produced in the analysis of private sector financial soundness due to differences in data sources and definitions.

3.3 percent in 2020 and 2021 under *Adverse Scenario 1* and *2*, respectively. Local D-SIBs' LGDs rise from 27 percent in 2018 to 40 percent in 2020 and 2021 under *Adverse Scenario 1 and 2*, respectively, driven by falling property prices and rising PDs.

Figure 24. Projection of Credit Risk Parameters under Baseline and Adverse Scenarios



Source: IMF staff calculation.

53. Credit losses significantly affect D-SIBs' solvency under adverse scenarios. On average, the annual loan loss stays at about 0.3 percent of system-wide risk-weighted assets (RWAs) during 2019-2021 under the baseline scenario, as economic conditions moderate and domestic interest

rates gradually rise. However, in *Adverse Scenario 1* and *2*, the accumulated credit losses amount to 2.6 percent and 4.1 percent of RWAs during the first two and three years, respectively. The results revealed that credit loss allowance is more preemptive under the SFRS 109 than the old standards (the incurred credit loss model), due to the cliff-effect on loan loss provisioning between Stage 1 and 2 (Figure 25).

Figure 25. Loan Loss Provision of Local D-SIBs: Adverse Scenario 2

(In billions of Singapore dollar)

Source: IMF staff calculation.

54. D-SIBs are also exposed to market risk. Under *Adverse Scenario 1* and *2*, potential valuation losses due to a decline in the price of debt securities in the available-for-sale and held-for-trading portfolios amount to S$6 billion and S$13 billion, equal to 0.7 and 1.4 percent of system-wide RWAs in 2019-21. Two factors contribute to this result: first, the sizable exposure of D-SIBs to debt securities, with an average exposure of 13 percent of total assets; and the substantial increase in credit spreads for corporate bonds under the adverse scenarios (e.g., 350 basis points for Singapore manufacturing firms during 2019-21 under *Adverse Scenario 2*), resulting in large haircuts on bond prices. In addition, D-SIBs are exposed to a large equity price shock under adverse scenarios, equivalent to 0.2 percent of RWAs. However, the expected losses on interest income, computed as the product of the time-to-repricing gap and the changes in the interest rate, are projected to be 0.9 percent of system-wide RWAs in 2019-21 under *Adverse Scenario 2*. Losses on banks' net foreign exchange positions are small, because D-SIBs' net open positions in U.S. dollar amount to S$5 billion as of end-2018, equivalent to about 0.3 percent of total assets.[34]

55. RWAs of D-SIBs are projected to grow considerably under the adverse scenarios. During the first three years, RWAs are expected to grow about 6 percent and 10 percent under *Adverse Scenario 1* and *2,* while they would grow only 2 percent under the baseline scenario. Note that MAS does not require foreign branches to calculate RWAs and capital in Singapore and thus RWAs and the impact on capitalization are calculated only for D-SIBs that are locally incorporated.[35]

56. The hurdle rates are set according to the minimum regulatory requirements (Table 7). In adverse scenarios, they are the sum of the minimum regulatory requirements and D-SIB capital surcharges: 10 percent for total capital, 8 percent for Tier 1 capital, and 6.5 percent for CET1 capital, respectively. In the baseline scenario, D-SIBs should maintain a capital conservation buffer of 2.5 percent and countercyclical capital buffers introduced by jurisdictions outside of Singapore. They can use the two buffers under the adverse scenarios. The 3 percent leverage ratio is also set as an

[34] While the supervisory data on net open foreign currency positions carries information of directions, i.e., positive or negative, the FSAP team takes the most conservative approach to calculate the maximum impact.

[35] The Asset Maintenance Ratio requirement for foreign branches is put in place to strengthen depositor protection, given that a resolution of cross-border bank insolvencies is often complex and slow, not as a measure for solvency.

additional hurdle for both baseline and adverse scenarios. The stress test is based on the minimum capital ratios under Pillar I and do not consider any individual requirement under Pillar II.

Table 7. Hurdle Rates for Bank Solvency Stress Test under Adverse Scenarios
(In percent)

	Total capital ratio	Tier 1 capital ratio	Common Equity Tier 1 capital ratio	Leverage ratio
Baseline scenario	12.5+CCyB[1/]	10.5+CCyB	9+CCyB	3.0
Adverse scenarios	10.0	8.0	6.5	3.0

Sources: MAS; and IMF staff calculation.
Note: 1/ Countercyclical Capital Buffer.

57. The top-down stress tests show that D-SIBs are resilient to severe shocks described in the adverse scenarios (Figure 26). Despite large credit losses and a significant increase in RWAs, there would be no D-SIBs with capital shortfalls relative to the hurdle rates.[36] The resilience largely stems from their large initial capital buffers, high initial asset quality (e.g., low point-in-time PDs for IRBA assets) and strong profitability, which allow them to absorb sizeable credit and market losses. Existing capital buffers (above total regulatory requirements) equal, on average, about 7 percentage points of RWAs. The key results from the FSAP top-down solvency stress test are:

- ***Baseline scenario.*** The system-wide total capital adequacy ratio (CAR) and CET 1 ratio (17.0 and 14.1 percent at the end of 2018) would go up to 18.3 and 15.5 percent by 2021, respectively. Profits would be more than enough to cover credit and market losses as well as the increase in RWAs and would provide room for D-SIBs to beef up their capital buffers.

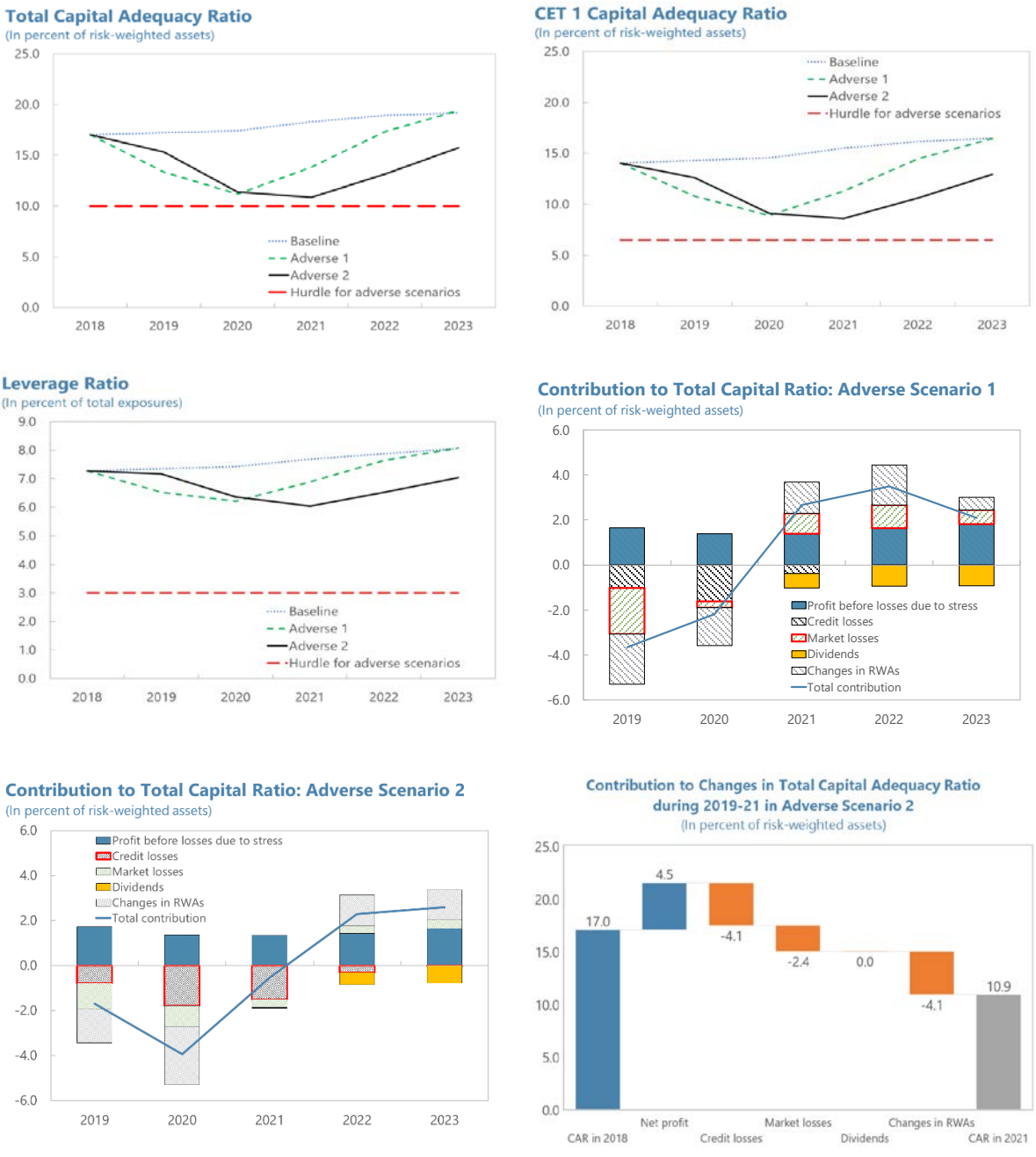
- ***Adverse scenario 1.*** The large-scale global financial market turmoil precipitates stresses in Singapore's financial and property markets and results in significant market losses in the first two years (2.3 percent of RWAs). D-SIBs' total CAR would decline to 11.2 percent in 2020. As financial markets start recovering sharply from 2021, the total CAR would go back to the starting level (17 percent) rather quickly.

- ***Adverse scenario 2.*** As the marked growth slowdown and macrofinancial stress in China spill over to Singapore and the Asian region, NPL ratios sharply increase from 1.6 percent to nearly 7 percent. D-SIBs' total and CET 1 capital ratios would decline to 10.9 percent and 8.6 percent in 2021 (text figure). But, no bank would fail to meet the hurdle. The main drivers of the change in capitalization for the first three years are the following: (i) loan loss provisions (-4.1 percentage points of RWAs); (ii) market losses related to financial market prices (-2.5 percentage points); and (iv) the change in RWAs (-4.1 percentage points).

[36] Because of the resilience of D-SIBs to adverse shocks, the FSAP assesses the domestic interbank contagion in a stand-alone hypothetical analysis, instead of combining it with the bank solvency stress tests.

58. D-SIBs can maintain the leverage ratio above the minimum requirement in adverse scenarios. In the adverse scenarios, the leverage ratio of D-SIBs, measured as Tier 1 capital to total exposures, remains above 6.0 percent, comfortably above the 3 percent minimum requirement. It shows that their RWA calculations based on internal ratings-based models are suitably conservative with risk-weight density of IRBA assets being 36 percent on average among local D-SIBs.

Figure 26. Bank Solvency Stress Test Results



Source: IMF staff calculation.

IMF's Top-down Sensitivity Analyses

59. The sensitivity analyses consider three single risk factors—foreign exchange rate, interest rate, and house prices—as well as name concentration risk, risk of common exposures, and the impact of fintech. The sensitivity analysis is static unlike the scenario analysis: it assesses the instantaneous impact of the risk factors on capitalization of D-SIBs as of end-2018. Each shock is calibrated to be larger than the accumulated change of each risk factor in the most severe adverse scenario. The sensitivity analysis captures the following transmission channels:

- ***Interest rate risk.*** The impact of a sudden increase in interest rates (300 basis points) encompasses three channels: market losses due to the increase in bond yields; a reduction of net interest income following the re-pricing of adjustable deposit and lending rates; and credit losses as a result of diminished debt-servicing capacity.

- ***Foreign exchange rate risk.*** A sensitivity test assesses how banks would be affected by market losses with foreign currency depreciation against U.S. dollar (40 percent) due to existing net open foreign exchange positions.

- ***House price risk.*** A decline in the property prices (50 percent) increases credit losses via higher PDs and LGDs.

- ***Name concentration risk.*** This analysis calculates credit loss generated by default of the largest private borrowers and the impact on capitalization, incorporating the haircut on collateral values due to a 30 percent decline of property prices. Loans to one and five largest private borrowers account for 4-19 percent and 11-70 percent of Tier 1 capital of individual D-SIBs, respectively.

- ***Risk of common exposures.*** It assesses the impact of defaults of the largest (top one, five, ten, and fifteen) private borrowers. The single largest common exposure is equivalent to 2.5 percent of total capital and 0.2 percent of total assets as of 2018Q2, while the twenty largest common exposures amount to 25 percent of total capital and 2.1 percent of total assets.

- ***Potential impact of fintech.*** Banks could lose part of non-interest income due to the expansion of fintech firms, particularly in business segments related to transaction and payment services, wealth management, investment banking, and trade finance that are responsible for 75 percent of fee and commission income.

60. A sharp movement in interest rates would have considerable effects on D-SIBs' capitalization, but the current capitalization provides them a buffer to avoid undercapitalization (Table 8). Market losses with holdings of debt securities to a 300 bps increase in interest rates lead D-SIBs' Tier 1 ratios to decline by 2.6 percentage points. Higher interest rates could also generate additional credit losses of S$4.3 billion by deteriorating borrowers' repayment capacity and lower net interest income by S$1.4 billion due to banks' maturity mismatch. All in all, total costs of the interest rate shock amount to 3.4 percentage points of Tier 1 capital ratio.

This shock, however, would not cause undercapitalization in any of D-SIBs, because of their sizable capital buffers.

Table 8. Results of Sensitivity Analyses

		Decrease in Tier 1 Capital Adequacy Ratio			
		Total	Due to		
			Credit Loss	Market Loss	Changes in net interest income
		Percentage points	Percentage points	Percentage points	Percentage points
Interest rate risk (300bps increase)	Locally incorporated banks	-3.4	-0.6	-2.6	-0.2
	Domestic banks	-3.5	-0.6	-2.7	-0.2
	Foreign subsidiaries	-1.7	-0.7	-1.1	0.2
FX rate risk (40 percent depreciation)	Locally incorporated banks	-1.6	-	-1.6	-
	Domestic banks	-1.6	-	-1.6	-
	Foreign subsidiaries	0.0	-	0.0	-
House price risk (50 percent decline)	Locally incorporated banks	-2.0	-2.0	-	-
	Domestic banks	-2.0	-2.0	-	-
	Foreign subsidiaries	-2.5	-2.5	-	-
Name concentration risk (10 largest borrowers' default)	Locally incorporated banks	-2.2	-2.2	-	-
	Domestic banks	-2.2	-2.2	-	-
	Foreign subsidiaries	-3.0	-3.0	-	-
Impact of FinTech (Loss of 75 percent of fee and commission income)	Locally incorporated banks	-0.8	-	-	-0.8
	Domestic banks	-0.8	-	-	-0.8
	Foreign subsidiaries	-1.8	-	-	-1.8

Source: IMF staff estimates.

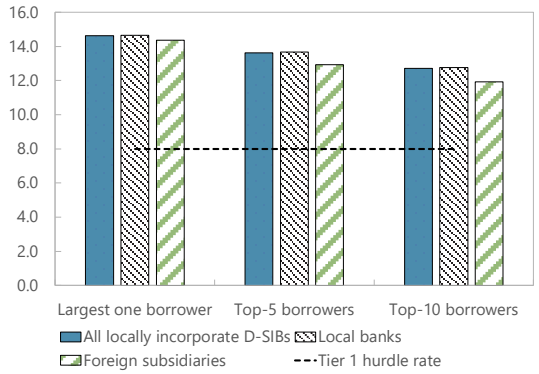
61. The impact of sharp movements of foreign exchange rates would be moderate. A 40 percent depreciation of foreign currencies against US$ would cause market losses of S$12 billion, so that Tier 1 ratio of D-SIBs drops by 1.6 percentage points.

62. A sharp decline in property prices would increase loan loss provisions sizably. A 50 percent drop in property prices results in a rise of D-SIBs' PDs by three times (from 1.3 percent to 4 percent) in addition to a sharp increase in LGD. This would increase aggregate loss provisions from S$3 billion to S$15 billion. The loss of Tier 1 capital ratio among D-SIBs would be equivalent to 2 percentage points.

63. D-SIBs have well diversified loan portfolios in general, but the concentration risk of a foreign subsidiary warrants a close monitoring. The value of an exposure of D-SIBs to any single largest private counterparty does not exceed 25 percent of Tier 1 capital. All the D-SIBs have enough Tier 1 capital buffers to withstand simultaneous defaults of top-10 largest borrowers (Figure 27) and no bank become undercapitalized until top-15 largest borrowers default at the same time. However, relatively speaking, a foreign subsidiary is more severely exposed to concentration risk than other banks: the defaults of five largest borrowers would cause its Tier 1 capital to drop by 6 percentage points, compared to 2 percentage points for other D-SIBs on average.

Figure 27. Tier 1 Ratio after Concentration Risk Analysis

(In percent of risk-weighted assets)



Source: IMF staff calculation.

64. The impact of the simultaneous default of large common borrowers is manageable (Table 9). Due to the large capital buffers in the banking system (about 7 percentage points of RWAs) and well diversified portfolios, the simultaneous default of the top twenty largest common borrowers would cause D-SIB's Tier 1 ratio to drop by 2.7 percentage points but no D-SIBs fails to meet the FSAP hurdle.

Table 9. Impact of Hypothetical Default of Largest Common Borrowers

Default of common borrowers	Exposures		Decrease in total capital adequacy ratio
	(In percent of total capital)	(In percent of total assets)	(In percentage points)
Top one largest borrower	2.5	0.2	-0.3
Top 5 largest borrowers	10.6	0.9	-1.2
Top 10 largest borrowers	15.3	1.3	-1.7
Top 20 largest borrowers	24.6	2.1	-2.7

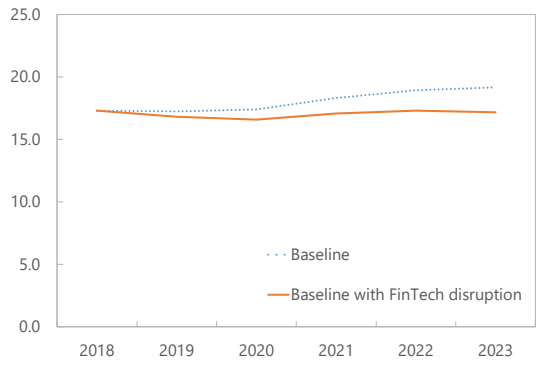
Source: IMF staff estimates.

65. At the current stage, financial innovation does not pose a significant risk to the banking sector. It is difficult to incorporate the impact of the expansion of fintech within a macrofinancial scenario because of high uncertainty at its embryonic stage. Fintech may not be disruptive because of the focus on partnership with existing financial institutions ("business-to-bank solutions") in Singapore. However, there are no grounds for complacency. Banks could lose a substantial portion of their non-interest income due to fintech disruption, particularly in business segments relating to transaction and payment services, wealth management, investment banking, and trade finance. The FSAP assumes a hypothetical scenario in which banks lose all the income

from these business segments (75 percent of fee and commission income) due to the fintech disruption over the stress test horizon. Then, D-SIBs would experience a decline of total capital adequacy ratio by 2.0 percentage point of CAR (Figure 28).

Figure 28. Impact of Fintech Disruption on Total Capital Adequacy Ratio

(In percent of risk-weighted assets)



Source: IMF staff calculation.

66. However, financial institutions' risk appetite may change when fintech development changes the market structure of financial services and when there is uncertainty surrounding the benefits of financial innovation. When serving as pure solution providers to banks, fintech can improve banks' efficiency and capacity to manage risk without changing the market structure of the banking system. However, if a fintech firm provides complementary services to those provided by incumbents and quickly and successfully acquires a large retail customer base, incumbents would need to compete with each other for business with the fintech firm. Intensified competition lowers the franchise value of incumbents and can lead to greater risk-taking behavior. Uncertainty surrounding the benefits of financial innovation could also change the market structure and result in a "winners-take-all" situation. Such uncertainty in technology will increase banks' risk appetite ex-ante. This is because, with limited liability, banks only care about the upside—and disregard the costs of a potential failure—and will benefit more from the new technology if they buy more risky assets. This is tantamount to an ex-ante increase in risk appetite and higher systemic risk in the financial sector (see Technical Note on Fintech).

Solvency-Funding Cost Interaction

67. The interaction between solvency and funding costs is not acute, as banks relies primarily on deposits in Singapore. A decline in capital adequacy ratio during the stress test horizon translates into higher funding costs, which in turn weakens solvency further through reduced profits. The FSAP mission derived the relationship between solvency and funding costs from a linear panel regression model (Table 10) and computed the second-round impact on solvency via the funding cost channel. The second-round impact resulted in a drop of the aggregated CAR by 0.3 percentage points in 2021 (from 10.9 percent to 10.6 percent) under Adverse Scenario 2 and caused failure of a D-SIB to meet the hurdle rate. Capital shortfalls, however, were small at 0.1 percent of GDP.

Table 10. Estimation Results of Interaction between Solvency and Funding Cost

Panel regression model with bank fixed effects

Variables	Coefficients	P-value
Dependent variable: $Funding\ cost_t = \left(\frac{\text{Interest expense}}{\text{Total assets}}\right)_t$		
$Funding\ cost_{t-1}$	0.8568	0.027
$SIBOR_t$	0.0479	0.012
$Real\ GDP\ growth\ rate_t$	0.0108	0.039
$Total\ CAR_{t-1}$	-0.0069	0.060
$NPL\ ratio_{t-1}$	0.0719	0.074
Constant	0.0923	0.562

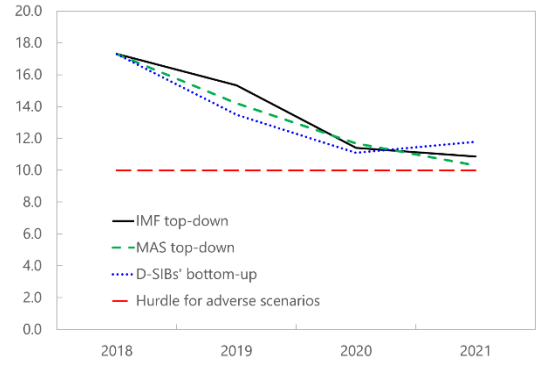
Source: IMF staff estimates.
Note: Within R^2=0.7397, Between R^2=0.7397, and Overall R^2=0.7397.

MAS' Top-down and D-SIBs' Bottom-up Solvency Stress Test

68. MAS' top-down and D-SIBs' bottom-up stress tests reveal similar resilience.[37] The authorities' top-down tests confirmed the findings from the FSAP top-down stress tests. Decline in total CAR was mainly driven by increases in credit RWAs and loan loss allowances. MAS projected that the impact of adverse shocks on pre-loss income would be relatively milder, while RWAs increased more than those of the IMF top-down stress test. Therefore, the overall solvency impact would be similar. The authorities' tests showed that, in *Adverse Scenario 2*, one D-SIBs failed to meet the hurdle rates, but the capital shortfalls are small at 0.5 percent of GDP. Two top-down stress test results were more conservative than D-SIBs' bottom-up results (Figure 29). The difference was mainly driven by D-SIBs' higher profit projections than two top-down stress tests.

Figure 29. Total Capital Adequacy Ratio

(In percent of risk-weighted assets)



Sources: MAS; and IMF staff calculation.

69. Some risks remain and warrant closer monitoring by further enhancing surveillance tools. While maintaining capital ratios above the regulatory minima, D-SIBs experience sizable credit

[37] D-SIBs conducted a bottom-up stress tests over a three-year horizon (2019-2021).

losses and their capital buffers erode under adverse scenarios. It could lead to a credit crunch domestically if they were to deleverage to re-build capital buffers. To avoid negative consequences for the real economy, it would be important to continue monitoring exposures to property price volatility, legacy loans to transportation sector, and name concentration risk in the banking system.[38] MAS has been improving the bank solvency surveillance tools. However, there is some room for further development. MAS should explore alternative approaches to estimate the credit-to-GDP gap, recognizing changes in credit cycles and improve the bank solvency stress testing model by adopting the full aspects of the Singapore Financial Reporting Standards 109 (e.g., projection of a transition matrix of Stage 1, 2, and 3 assets with granular data and calculation of loan loss provision of foreign D-SIBs by asset class). These efforts will support timely and appropriate macroprudential policy actions.

E. Bank Liquidity Resilience

70. This section analyzes the drivers of liquidity metrics and simulates them under severe yet plausible counterfactual scenarios (Appendix VIII).[39] This section investigates the drivers of the NSFR and measures of deposit concentrations. It also simulates liquidity positions under severe yet plausible counterfactual ('adverse') scenarios using stress tests, as outlined in Box 4.

Box 4. Methodology of Bank Liquidity Stress Tests[1/]

Staff conduct two types of complementary liquidity stress tests that simulate banks' liquidity positions under adverse scenarios. Liquidity stress tests simulate banks' liquidity positions under severe yet plausible counterfactual ('adverse') scenarios. There are two types of stress tests considered here: LCR-based and cashflow-based. In addition to the LCR for regulatory purposes that is reported above, the LCR-based stress tests assess the adequacy of the *buffer* of liquid assets relative to regulatory requirements by simulating the LCR under adverse scenarios.[2/] The cashflow-based stress tests assess the adequacy of banks' liquid assets in *absolute* terms (i.e., not relative to requirements) by simulating them under adverse scenarios.

The analyses cover D-SIBs at multiple levels of consolidation, in multiple currencies and at two reference dates. The analyses cover D-SIBs, which hold 76 percent of the deposits of resident individuals and firms. Domestic banks are analyzed at the level of their consolidated global operations and at the level of their Singapore activities only. Foreign D-SIBs are analyzed at the entity level, which separates the branch and subsidiary, and at the level of their combined Singapore operations (the so-called country-level group). Since they depend on regulatory minima, simulations of LCRs are conducted on contracts denominated in all currencies and separately on just those contracts that are denominated in Singapore dollars. By contrast, cashflow-based simulations of liquid assets are also conducted in U.S. dollars. The LCR- and cashflow-based stress tests are applied at multiple levels of

[38] Considering these aspects, property market measures in Singapore have been important to contain macrofinancial feedback mechanisms of house price fluctuations and contain the risk of disruptions to the provision of financial services (see the technical note on macroprudential policy for more details on the effects of property market measures).

[39] In this note, the liquidity position of a bank should be understood to mean the degree to which the bank would be able to meet its near-term obligations as they fall due.

Box 4. Methodology of Bank Liquidity Stress Tests (continued)

consolidation, but the greatest emphasis is placed on the highest level of consolidation, given that banks have regulatory approval to manage liquidity at this level. Liquidity positions can change quickly over time, so simulations are run using data as of both 2018Q2 and 2018Q3 for robustness.

The LCR stress test simulates banks' LCRs under two scenarios:

- *Retail scenario*. This scenario is sparked by increased liquidity demand and risk aversion among individual and non-financial firms. The scenario manifests in widespread withdrawals of deposits of individuals and non-financial firms, repayment difficulties on loans (including increased customer demand for roll-over of maturing loans) and rising government bond yields. Parameters are calibrated to produce a withdrawal of up to 15 percent of deposits of individual and SMEs (an increase of 5 percentage points over the parameters used in domestic regulations), a refinancing by the bank of 65 percent of its customers' maturity loans (an increase of 15 percentage points) and a 2 percent reduction in the value of government bonds that banks hold.

- *Wholesale scenario*. This scenario is sparked by increased liquidity demand and risk aversion among financial firms and a depreciation of the Singapore dollar. The scenario manifests in widespread withdrawals of deposits of financial and non-financial firms (including some withdrawal of parent funding), delays in receiving payments from financial firms, margin calls on derivatives and delays in receiving payments on derivative contracts. In addition, a depreciation of the Singapore dollar increases the Singapore dollar value of foreign currency outflows. Parameters are calibrated to produce a withdrawal of up to 55 and 70 percent of operational and non-operational deposits respectively (an increase of 30 percentage points over parameters used in domestic regulatory requirements), calls for 30 percent more margin on derivatives contracts (an increase of 10 percentage points), and a refinancing by the bank of 50 percent of the maturing loans that it has extended to other financial institutions (an increase of 50 percentage points).

The cashflow-based stress tests consider short- and long-term stress scenarios. The short-term scenario concentrates the stress on liquid assets in the first week, while the long-term scenario applies stress over six months and concentrates its effects in the first three months. Parameters are calibrated, with reference to the first year of the first adverse scenario in the bank solvency stress tests, to a two-standard deviation historical episode. **The criteria for passing the stress tests vary with the purpose of the tests.** Banks were assessed to pass the LCR-based test under a given scenario if their LCR under that scenario remains above regulatory requirements.[3/] For contracts denominated in Singapore dollars, the minimum LCR is 100 percent, and for contracts denominated in all currencies, the minimum LCRs are 100 and 50 percent for domestic and foreign banks respectively. Banks pass the cashflow-based test if their liquid assets are not depleted after three months. The amount by which failing banks fail the stress tests are aggregated to calculate liquidity shortfalls. Numbers of failing D-SIBs are counted out of the seven D-SIB groups. In the scenario horizon, banks are not allowed to take management actions like deleveraging.

One caveat of the cashflow-based stress test results is that the test uses repurposed data sources. The cashflow-based stress test relies on banks' reports of their amounts contractually receivable and payable, by maturity and currency. The templates for these reports, which follow the structure of the tables of run-off and roll-off rate assumptions in Appendix VIII, were designed to analyze banks' business models rather than to conduct liquidity stress tests. Therefore, they lack some

Box 4. Methodology of Bank Liquidity Stress Tests (concluded)

detail for stress testing purposes, like a distinction between insured and uninsured deposits.

1/ Appendix VIII explains the liquidity stress test methodology further.

2/ The standard LCR is already a stress test. The purpose LCR-based stress test is to project the LCR under an adverse scenario, which indicates whether minimum LCR requirements would be breached under an adverse scenario. The purpose of this test is therefore to examine the adequacy of liquid asset buffers over minimum regulatory requirements. It is likely that the LCR would not be enforced for a period of time under an adverse scenario, so the interpretation of any shortfalls is at a longer-term horizon when the LCR would be enforced again.

3/ The interpretation of this pass/fail criteria is given in footnote 2.

71. Cashflow-based stress tests confirm that D-SIBs' liquidity is broadly adequate overall, but reveal vulnerabilities in U.S. dollars. D-SIBs have broadly adequate liquidity in all currencies and in Singapore dollars, with some weaknesses at specific banks and at longer maturities. However, U.S. dollar liquidity is vulnerable to stress conditions. Taken together, these results suggest that the all-currency liquidity of D-SIBs is vulnerable to depreciations of the Singapore dollar against the U.S. dollar. These conclusions stem from the following stress test outcomes, which are shown in Figure 30.

- ***All currencies.*** In an environment of no significant exchange rate movements (i.e., at prevailing exchange rates), D-SIBs have sufficient liquid assets to withstand significant stress over one week and one month, but 1-2 banks do not have sufficient liquid assets to withstand stress between one and three months.[40] The shortfalls are, however, limited at below 1.3 percent of GDP.[41]

- ***Singapore dollars.*** Six of seven D-SIBs have sufficient liquid assets in Singapore dollars to withstand significant stress over one week and to withstand significant stress over up to three months. The one failing D-SIB generates shortfalls of 2.2 and 2.9 percent of GDP under the short- and long-term scenarios respectively. The results for this bank are affected by the quality of the data inputs (Box 4). Staff estimate that these shortfalls could be 1.5 percentage points lower if some adjustments are made for how the bank reports its intragroup liabilities and depreciation.

- ***U.S. dollars.*** A significant number of D-SIBs (between four and seven) have insufficient liquid assets in U.S. dollars to withstand one-week and three-month stresses.[42] These failures lead to system-wide shortfalls of 8-10 percent of GDP under the short-term scenario and 11 percent of GDP after the first three months of the long-term scenario.

[40] Two banks have insufficient liquid assets using data as of Q2. Using data as of Q3, one of these two banks has sufficient liquid assets, but only at the group level (and not at the level of its Singapore operations alone).

[41] Specifically, shortfalls are 1.3 percent of GDP using data as of Q2 and 0.1 percent of GDP using data as of Q3.

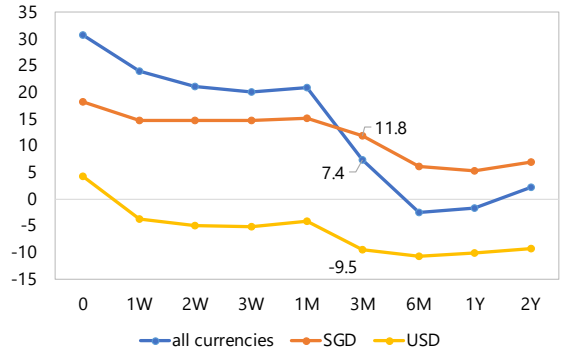
[42] Specifically, 4-5 banks fail the short-term scenario and 4-7 banks fail within the first three months of the long-term scenario. The numbers of failing banks are expressed as ranges because tests were done using data as of Q2 and as of Q3. Fewer banks fail the U.S. dollar tests using Q2 data.

Figure 30. Cashflow-based Stress Test Results

(In percent)

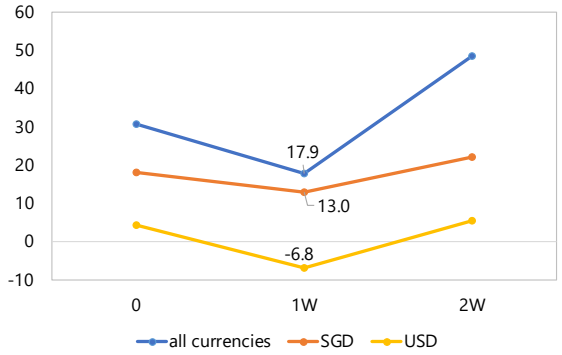
Liquid assets of the banking system deteriorate continuously under the long-term adverse scenario…

Liquid assets: long-term scenario



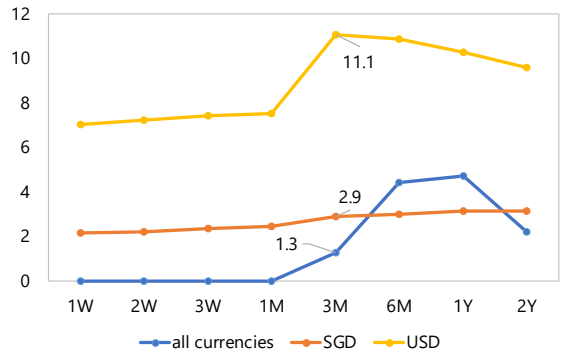
… but rebound quickly under the short-term adverse scenario.

Liquid assets: short-term scenario



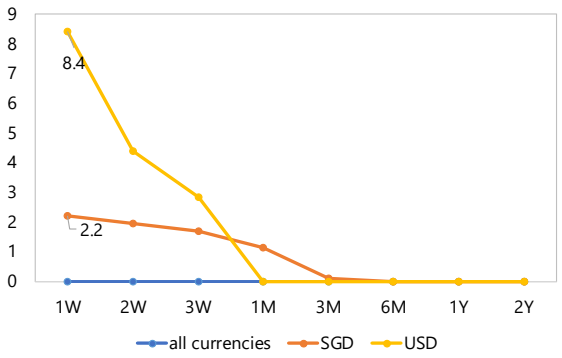
In the long-term adverse scenario, liquid asset shortfalls of individual banks are large in foreign currency but manageable in domestic currency.

Long-term stress scenario



The short-term adverse scenario produces a similar pattern.

Short-term stress scenario



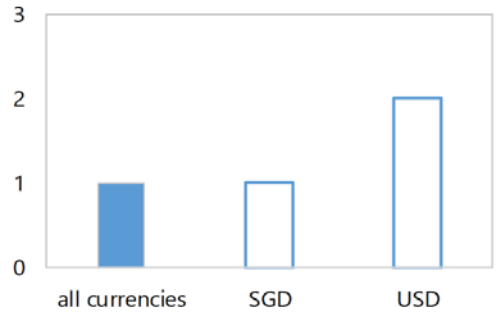
Source: IMF staff calculations.

Notes: W denotes weeks, M denotes months and 1 denotes years. The top two charts show the result of the cashflow-based stress tests applied to the aggregate data of all D-SIBs. Liquid assets represent the remaining value of liquid assets after receiving stressed contractual cash inflows and paying stressed contractual cash outflows, where the stress assumptions account for contract renewal. Negative liquidity denotes a shortfall. The bottom two charts show the results of the cashflow-based stress tests applied to data for each D-SIB individualls. Shortfalls are the sum, across all D-SIBs at their highest level of consolidation, of the amount by which cash outflows exceed the sum of liquid assets and cash inflows.

- **The cashflow-based stress tests reveal a reliance on the transferability of liquid assets within groups (Figure 31).** For example, in the first three months of the six-month stress scenario, one entity within a banking group shows insufficient liquid assets even though the group as a whole has adequate liquid assets (in all currencies). This suggests that the entity relies on other entities in the same group for liquid assets in adverse scenarios. This kind of cross-subsidization is evident in all currencies combined, but less clear in Singapore and U.S. dollars individually.

Figure 31. Cross-subsidized Liquidity

(Number of failures)



Source: IMF staff calculations.
Notes: The bars show the number of groups (out of 5 for which we have data) that pass the liquidity stress test at the group level but fail the test at the level of an entity within the group. Failures within a banking group that do not occur for the group as a whole suggest that some entities implicitly rely on others for liquidity support. Failures here refer to failure under the the first three months of the long-term adverse scenario of the cashflow-based stress test. The test is based on data as of 2018Q2. The unfilled bars indicate currencies where a similar result is not obtained using data as of 2018Q3.

72. The LCR-based stress tests reveal that demand for high quality liquid assets would increase substantially over the medium term under an adverse scenario. The LCR-based stress tests reveal that the liquid asset buffers over the minimum all-currency LCR requirements would fully deplete under the adverse scenarios (Table 11). This shows that even an apparently healthy 30 percentage point buffer (over regulatory requirements) among domestic banks can quickly erode under stress. These buffers have shrunk over the years as minimum requirements have been phased in. By contrast, the buffers in Singapore dollars are preserved under stress. The resilience of buffers in Singapore dollars suggests that these (all-currency) shortfalls of liquid assets are driven by foreign currency activity. However, exchange rate effects seem small.[43] Domestic banks are the main source of these shortfalls, to a large extent because they face higher minimum all-currency LCR requirements. D-SIBs appear equally exposed to the retail and wholesale scenarios. To restore all-currency LCRs to regulatory minima, D-SIBs would need to raise liquid assets equivalent to an additional 11 and 14 percent of GDP under the retail and wholesale scenarios respectively. However, the LCR is volatile, and the shortfalls are reduced by one-half if a moderately higher starting LCR is used.[44]

[43] The stress tests of the all-currency LCR explicitly model the effects of an exchange rate depreciation under the wholesale scenario. Under the wholesale scenario, the currency composition of LCR components leads all-currency LCRs to fall by modest 3 percentage points under the scenario's exchange rate depreciation of 10 percent. The 3 percentage points is an asset-weighted average across D-SIBs.

[44] Specifically, the volatility of year-on-year changes in the LCR of D-SIBs is 12 percentage points. To check for the effect of volatility in the pre-stress LCR, staff added a buffer of 12 percentage points to each D-SIBs' LCR before calculating shortfalls under the adverse scenarios.

Table 11. Results of the LCR-Based Liquidity Stress Test

	retail scenario						wholesale scenario					
	all currencies			Singapore dollar			all currencies			Singapore dollar		
	LCR /1	no. failures	shortfall (% GDP)	LCR /1	no. failures	shortfall (% GDP)	LCR /1	no. failures	shortfall (% GDP)	LCR /1	no. failures	shortfall (% GDP)
D-SIBs	83	3	11	153	0	0	75	4	14	174	0	0
domestic	76	3	11	150	0	0	72	3	14	185	0	0
foreign	101	0	0	162	0	0	84	1	0	143	0	0

Source: MAS and IMF staff calculations.

Notes:

1/ Asset-weighted average.

Numbers of failures and value of shortfalls are measured relative to regulatory requirements, which are at 100 percent for the Singapore dollar LCR, 100 percent for the all-currency LCR for domestic banks, and 50 percent for the all-currency LCR for foreign banks.

73. Banks set prudent internal limits on their recourse to FX swap market funding. Banks tend to rely on the FX swap market for foreign currency funding in stress episodes, but they set internal limits to prevent overreliance on the FX swap market. These limits are expressed as a share of the lowest FX swap market turnover observed in recent years. The share is chosen by each bank to be similar to or smaller than its typical share of turnover.

74. Domestic banks draw more of their stable funding at shorter maturities than foreign banks. Examining the components of the NSFR by maturity reveals a surplus of stable funding with up to six months' maturity and a corresponding shortage of stable funding with greater than one years' maturity (first panel of Figure 32). This is consistent with normal maturity transformation. However, the pattern is less pronounced for foreign D-SIBs than for domestic banks (second panel of Figure 32).

75. Deposits are more concentrated among corporate deposits and at foreign D-SIBs. D-SIBs' corporate deposits are more concentrated than their deposits from individuals. The largest single corporate deposit and the largest five corporate deposits make up on average 1.9 and 5.8 percent of liabilities respectively, but the same numbers are only 1 and 3 tenths of a percent for deposits of individuals. D-SIBs' largest twenty corporate deposits closely follow a power law, and the exponent of 0.9 also suggests excess concentration (second panel of Figure 33).[45] Deposits are slightly more concentrated in foreign D-SIBs than in domestic D-SIBs, with Herfindahl indices of 14 and 11 basis points, respectively. A simple stress test that simulates the withdrawal of each D-SIB's largest depositors suggests that deposit concentration would not cause distress, because the largest deposits are covered by liquid assets (first panel of Figure 33).[46] However, there is some concentration risk within the Singapore operations of domestic banks, in the sense that, for two domestic banks, the five largest corporate deposits within their Singapore operations exceed those

[45] Specifically, this statement is based on the median, across D-SIBs, of the share of the k^{th}-largest corporate deposits to the bank's liabilities, for $k = 1, \ldots, 20$. The power law exponent can be compared with those of other economic phenomena in Gabaix (2016).

[46] Liquid assets include are defined as high quality liquid assets under the LCR reporting standard.

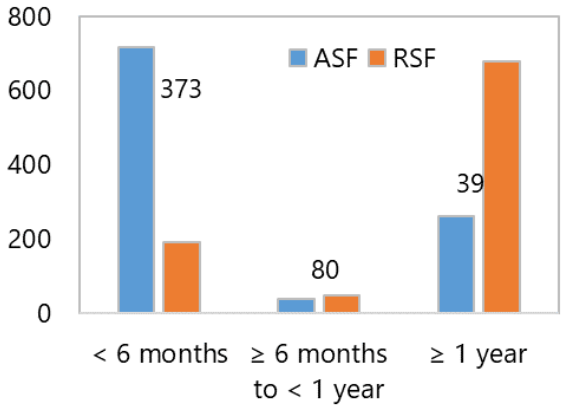
operations' high-quality liquid assets. From a systemic risk perspective, the concentrations of corporate deposits should be read alongside the reliance of corporates on their liquid asset buffer to offset their gross debt.

Figure 32. Analysis of D-SIBs' Net Stable Funding Ratios (NSFRs)

Stable funding is concentrated in short-term obligations…

ASF and RSF /1

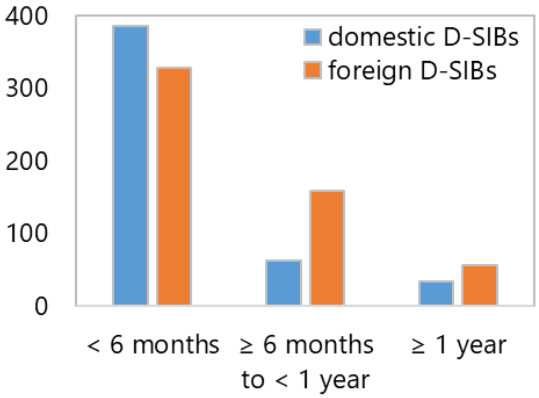
(In billions of Singapore dollars)



…and this pattern is accentuated for domestic D-SIBs relative to foreign D-SIBs.

NFSR by maturity /2

(In percent)



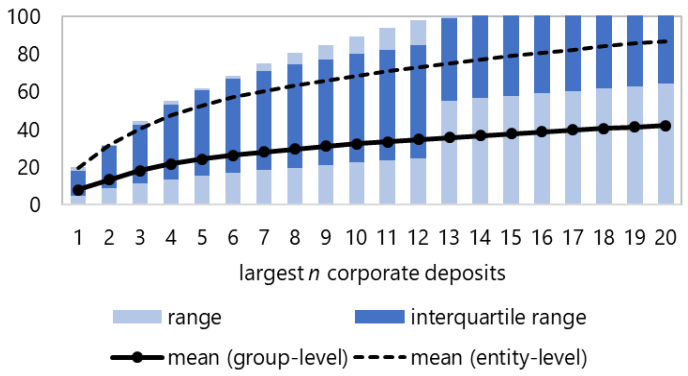
Sources: MAS and staff calculations.

1/ ASF denotes available stable funding and RSF denotes required stable funding, as defined in MAS Notice 652. The values shown are the sums of values across D-SIBs at the highest level of consolidation. The amounts reflect contracts denominated in every currency, and reporting banks convert amounts in foreign currency to Singapore dollars using their internal exchange rates. The annotated numbers at each maturity show the NSFR (in percent) obtained as the ratio of ASF to RSF at that maturity.

2/ The numbers at each maturity show the NSFR obtained as the ratio of ASF to RSF at that maturity, where ASF denotes available stable funding and RSF denotes required stable funding, as defined in MAS Notice 652. The underlying ASF and RSF are calculated as the sum, across all domestic D-SIBs or foreign D-SIBs, of the bank-level ASFs and RSFs at the highest level of consolidation. The amounts reflect contracts denominated in every currency, and reporting banks convert amounts in foreign currency to Singapore dollars using their internal exchange rates. Dashed lines show the minimum NSFRs for domestic and foreign D-SIBs of 100 and 50 percent respecively.

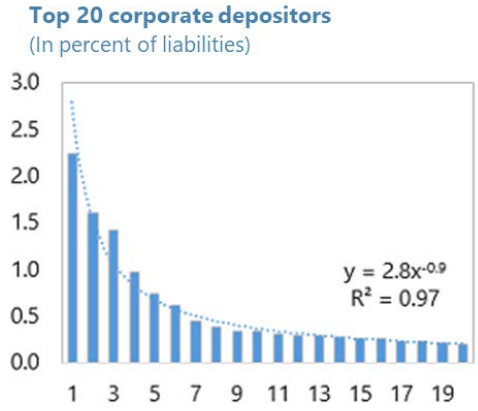
Figure 33. Analysis of Concentration of Corporate Deposits

For most banks, liquid assets are sufficient to cover the largest corporate deposits.



Source: MAS and IMF staff calculations.
Note: The data underlying this chart apply to D-SIBs only, based on data at 2018Q2. The chart shows the distribution, across banks, of the cumulative share of corporate desposits in liquid assets. Each bar represents a distribution across banks. The black lines trace the size of all the largest deposits relative to liquid assets for the average bank. Averages are weighted by total liabilities. The solid black line shows the average across banking groups, while the dotted black line shows the average across banking entities. Liquid assets are defined here as high quality liquid assets from LCR reports. For a given bank, a share of 100 percent at the 13th largest depositor means that the bank's 13 largest deposits equal its liquid assets. A share of 24 percent for the average bank at the 5th largest deposit means that the 5 largest deposits of the average bank amount to 24 percent of liquid assets.

Corporate deposits follow a power law with exponent 0.9.



Source: MAS and IMF staff calculations.
Note: The kth bar shows the median, across D-SIBs, of the share of corporate deposits of the the kth largest borrower in total liabilities.

F. Insurer Solvency Resilience

76. This section assesses insurers' solvency positions by modelling regulatory capital and capital requirements under adverse scenarios. It draws on top-down stress tests undertaken by staff and MAS, and on bottom-up stress tests performed by insurers. The scenarios are aligned to the bank solvency stress tests. The coverage and modelling details appear in Box 5.

Box 5. Methodology of the Insurer Solvency Stress Tests

Top-down and bottom-up stress tests model regulatory capital and capital requirements under adverse scenarios. Top-down stress tests are undertaken by both the IMF and MAS, and bottom-up stress tests are administered by MAS. Both tests use financial data on insurers as of 2018Q2. The top-down stress test covers the four largest direct life/composite insurers, which hold 80 percent of the assets of the direct life insurance sector. The tests cover all life insurance activities but exclude investment-linked business.[1/] The bottom-up tests cover the 9 largest direct life/ composite insurers and the 15 largest direct general insurers. Insurers pass the test if their regulatory capital exceeds minimum risk-based capital requirements under the adverse scenario (in other words, the CAR remains above 100 percent). Otherwise, insurers breach minimum capital adequacy requirements, and the amount by which they breach is the capital shortfall. In addition to capital projections, the bottom-up tests include single-factor stress tests that model the impact on claims of a natural catastrophe

Box 5. Methodology of the Insurer Solvency Stress Tests (continued)

event and cyber-attacks on clients.[2/]

The top-down insurer solvency stress test uses a static regulatory balance sheet approach under the first adverse scenario of the bank solvency stress tests. The top-down stress test uses a single adverse scenario, calibrated to the cumulative effects of years 2019 and 2020 under Scenario 1 of the bank solvency stress tests.[3/] Regulatory capital is projected by modelling the values of assets and liabilities, which requires specifying the falls in asset prices and changes in statutory liability discount rates. Capital requirements are derived from the falls in asset values using regulatory risk weights. Regulatory risk-based capital ratios are projected separately for participating and non-participating policies, because the ratio for the insurer prevents the capital of participating policies to offset any capital shortfalls among other policies.

In the top-down stress tests, staff model the asset side of insurers' balance sheets by repricing contracts under the adverse scenario. Haircuts on government and corporate bonds are calibrated by revaluing them at the higher interest rates specified by the government bond yield curves and credit spreads in Table 6. Staff calibrated haircuts as the simple average of haircuts produced under two methods, which turned out to be similar. The first method explicitly revalues the bonds by maturity, coupon and country, assuming a semi-annual coupon frequency. The second method uses the modified duration approach to revalue the bonds by maturity and country, to allow for potentially hidden pricing characteristics of the underlying bonds. Underlying both these methods for revaluing bonds are semi-annual government and corporate bond yield curves. Government bond yield curves at selected maturities for Australia, China, European countries, South Korea, Singapore, Thailand and the U.S. appear in Table 6. From these, staff estimated government bond yield curves for Canada, Japan, Mexico, Switzerland and the UK by least squares.[4/] These yield curves were then interpolated to semi-annual maturities by cubic splines. Staff derived corporate bond yield curves by assuming an initial global credit spread of 2 percent in 2018Q2 and then applying the year-on-year credit spread changes given in Table 6.

In the top-down stress tests, staff model the liability side of insurers' balance sheets by discounting expected cashflows at rates consistent with regulatory specifications under the adverse scenario. Staff revalued technical reserves on liabilities by discounting insurers' projected cashflows at statutory yield curves. Staff converted the government bond yields in the scenarios (Table 6) to statutory yield curves under the risk-based capital regulations for insurers (Figure 34). Under these regulations, yield curves for statutory reserving are market-consistent up to an initial maturity, almost insensitive after another specified maturity, and linearly interpolated in between. All liabilities that are not denominated in SGD or USD are treated as if they are denominated in the Australian dollar, which is the next most significant currency for liabilities. Insurers provided monthly projected liability cashflows, net of reinsurance recoveries, by currency. Monthly cashflows are a luxury that are not available for stress testing in other jurisdictions; they were found to improve the accuracy of the liability revaluation by about one-half of a percent.[5/]

The authorities' top-down stress tests and insurers' bottom-up stress tests differ in scenario and methodology, in addition to the differences in coverage. The authorities' top-down stress tests match the IMF stress tests in insurer coverage and are nearly identical in adverse scenario. The bottom-up stress tests cover the largest nine direct life/composite insurers and the largest fifteen direct general insurers and consider both adverse scenarios of the bank solvency stress tests. Under the first adverse

Box 5. Methodology of the Insurer Solvency Stress Tests (concluded)

scenario of the authorities' stress tests, yields on Canadian, Japanese and U.K. government bonds behave the same as those on U.S., Chinese and European bonds respectively.[6/] Insurers' bottom-up stress tests draw on their policy-level data, and they use standard actuarial projection models to model the balance sheet dynamically. Staff and authorities' top-down stress test models are similar. Staff and the authorities' top-down stress tests both make use of a duration-based approximation to revalue bonds. However, staff's approximation is more granular because it is calculated by maturity. As explained above, staff also combine the result of this approximation with the result of an exact discounted cashflow revaluation.

1/ For the purposes of mark-to-market losses on assets, the analysis excludes investment-linked business because such losses are passed on directly on to policyholders. For the purposes of revaluing liabilities under the adverse scenario, the analysis further excludes non-participating term life and non-participating accident and health business. These contracts would require policy-level data to model correctly, because they often generate negative technical reserves and the current risk-based capital system requires these reserves to be set to zero policy-by-policy.

2/ The results from bottom-up cyber risk stress tests of banks and insurers appear in the next section.

3/ Scenario 1 simulates financial stress, which is the biggest near-term risk for insurers. Scenario 1 is therefore more appropriate than Scenario 2 for the insurer stress test.

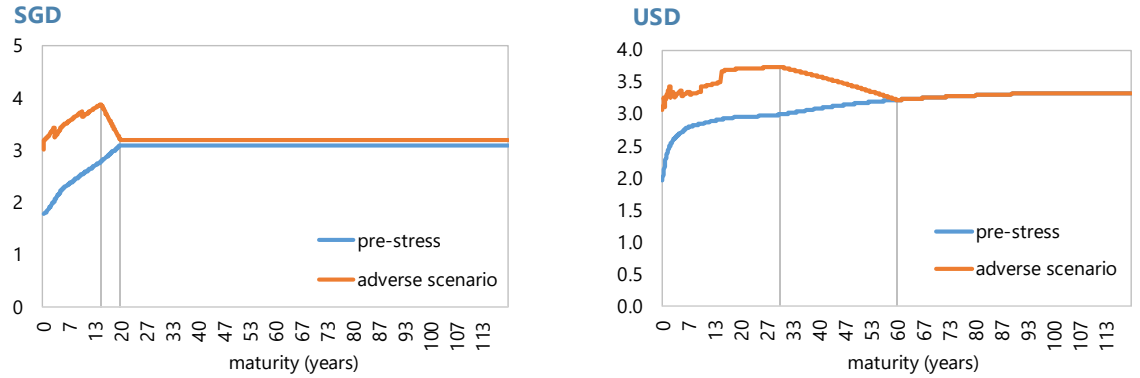
4/ Staff considered a range of ridge regression models alongside least squares, but the scenarios produced by least squares were ultimately judged to be more plausible.

5/ In other words, if technical liabilities with yearly cashflows would be devalued by 6.5 percent under a scenario of rising yield curves, then they would be devalued by only 6 percent with monthly cashflows. This reduction in interest rate sensitivity is a simple consequence of eliminating the assumption that all yearly cashflows occur at year-end.

6/ Staff model these yield curves separately, as discussed above.

Figure 34. Solvency Stress Tests: Statutory Discount Rates for Discounting Policy Liabilities

(In percent, per year)



Source: IMF staff calculations.
Notes: The charts show statutory zero-coupon yield curves for discounting insurers' technical liabilities based on the methodology prescribed in Risk Based Capital regulations. Pre-stress is the reference date of 2018Q2 and the adverse scenario matches the cumulative change in 2019 and 2020 under Adverse Scenario 1 of the bank solvency stress tests.

77. The top-down stress test shows the vulnerability of solvency positions, but these do not lead to a systemic risk. Two of the four largest direct life/composite insurers breached their minimum risk-based capital adequacy requirements in the solvency stress test, due to mark-to-market losses within both participating and non-participating funds. However, the capital shortfalls amount to a moderate 1.3 percent of GDP, which does not suggest a macroprudential concern.

78. Losses in the stress tests are driven by market risk, given sizeable equity and corporate bond holdings. The top-down stress tests reveal losses of S$33bn due to asset price falls over the two-year scenario horizon, relative to regulatory capital (i.e., adjusted financial resources) of S$36bn. Asset losses are concentrated in equities and corporate bonds (Figure 35), due to insurers' large holdings (see paragraph 19). Most bonds are in practice held to maturity to meet long-term liabilities. Therefore, corporate bond devaluations would only have a temporary effect on solvency, provided that the bonds remain fully performing.[47] The four largest life/composite insurers tend to gain from a depreciation of the Singapore dollar, given their holdings of foreign currency assets and limited foreign currency liabilities.[48]

79. The authorities' stress tests of life insurers also show these vulnerabilities, but MAS assesses capital recovery plans to be adequate. The bottom-up stress tests administered by the authorities showed that three of the four largest direct life/composite insurers that were tested, and four of the five smaller direct life/composite insurers that were tested, breached their minimum capital adequacy requirements.[49] The authorities' top-down results aligned closely with the bottom-up results. They were slightly weaker than those of staff, due to the authorities' more conservative modified duration method and their inclusion of losses from floating rate bonds. As part of the bottom-up stress tests, insurers prepared plans to recover their capital positions to meet minimum regulatory requirements. These plans were deliberated by insurers' executive boards and senior managements. In order of size, the management actions included capital injection from the parent, cuts to bonuses of participating policies, reinsurance arrangements and other actions like portfolio de-risking (Figure 35). In each case, the authorities assess that the parent would be willing and able to provide the capital injection.[50] The capital injections are similar to previous capital injections and are to be deliberated by the executive boards of the parents. The authorities' models suggest that the extent of bonus cuts in the bottom-up stress tests are similar to those observed in 2008 if the credit spread widening in the adverse scenario is adjusted to match that observed in 2008.

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[47] Staff model these yield curves separately, as discussed above.

d at market value for regulatory capital purposes.

[48] Nevertheless, profits from depreciations of the Singapore dollar are limited, given that most insurers hedge the currency risk in foreign bond holdings. Data limitations made it difficult to model exchange rate revaluation effects accurately.

[49] The quantitative results were similar under adverse scenarios 1 and 2.

[50] MAS assesses that each capital injection is small relative to the insurer's turnover, its regulatory capital and its parent's capital. For two insurers with foreign parents, their Singapore operations are deemed as significant operations in Asia within their respective insurance groups, so it is likely that they would receive parent support.

80. The authorities' stress tests showed the resilience of general insurers to market risk and to the risk of extreme flooding. All 15 direct general insurers passed the bottom-up stress tests under the first and second adverse scenarios. The extreme flooding scenario required direct general insurers to estimate the impact of flooding in Singapore at an average depth of 600 millimeters.[51] Under the flood scenario, CARs fall by a small 8 percentage points and no insurers breach their minimum CAR requirement.

81. Large insurers' exposures to banks and non-banks show limited concentration risk. Staff analyzed the concentration of the exposures of the four largest life/composite insurers. For participating and non-participating funds, insurers' top five bank exposures are less than 60 percent of capital buffers.[52] More than half of large bank exposures take the form of equity holdings because banks have non-negligible weights in the stock market. Only 21 percent of these exposures take the form of deposits.[53] Concentration by bank is also limited, with the largest exposure to any single bank, across all participating and non-participating funds, equivalent to 20 percent of the fund's capital buffer. Insurers' largest exposures to banks are less concentrated than their largest exposures to non-banks. In the case of one insurer, its large exposures to non-banks exceed capital buffers for the non-participating fund, and the exposures of this fund take the form of unsecured and subordinated bonds.

82. The riskiness of insurers' asset allocation requires close monitoring. Insurers have buffers greatly in excess of capital requirements. These buffers erode under a severe but plausible adverse scenario, but the capital shortfalls are modest. To some extent these are an artifact of the capital regime, where assets are valued at market value, but liabilities are stable. Under the revised risk-based capital framework, the so-called matching and illiquidity premium adjustments will keep capital more stable by making liabilities more sensitive to market conditions. In other words, the reduction in liability value from higher discount rates will offset some of the mark-to-market losses on fixed income assets. Nevertheless, signs of search for yield among life insurers should continue to be monitored closely. MAS plans to include this topic in its briefings to the industry on the results of the bottom-up stress tests. MAS could also enhance its measurement of market risk from corporate bonds by modelling the revaluation effects of an adverse scenario using a cashflow projection method. Such a method explicitly models the timing of bond cashflows and therefore accounts for the effects of the full shape of the yield curve on bond prices. The current approach is based on modified duration, which is more conservative, but less precise, for the large movements in yields that are typical of stress tests.

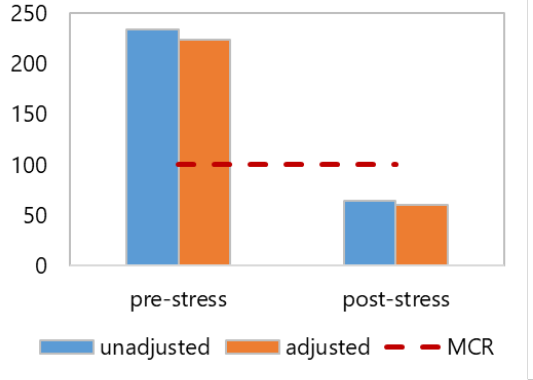
[51] This is far above the average flood depth.

[52] Here, capital buffers should be understood as the excess of (unadjusted) available capital over total risk requirements at the level of the participating or non-participating insurance fund.

[53] The remainder take the form of unsecured and subordinated bonds.

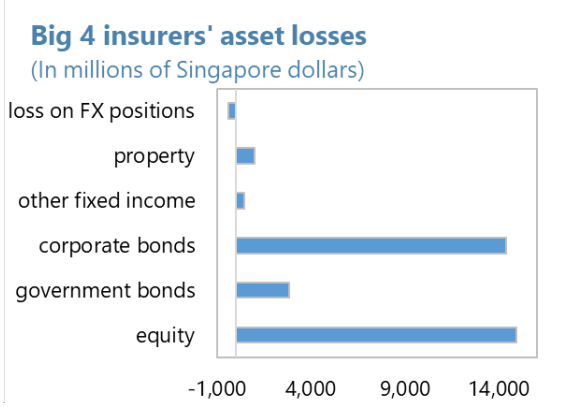
Figure 35. Insurer Solvency Stress Test Results

Capital buffers of large insurers are eroded under the adverse scenario.



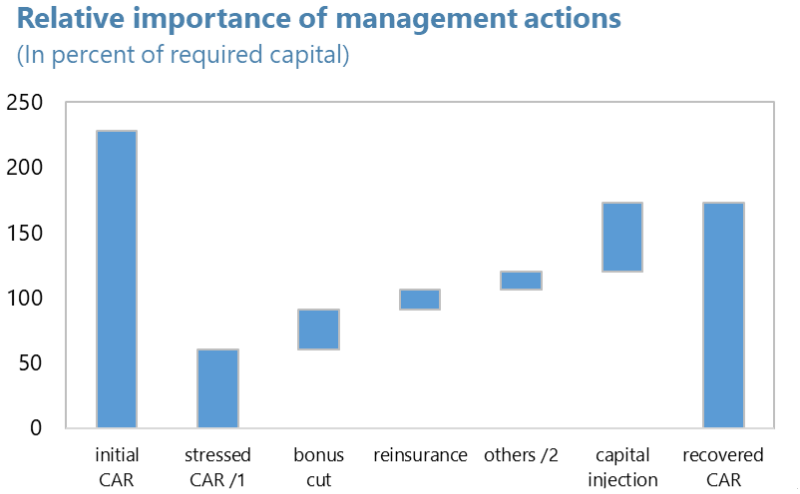
Source: IMF staff calculations.
Notes: The capital adequacy ratio is defined as available capital over required capital. This chart shows the aggregate available capital for the four largest direct life insurers over their required capital. For each insurer, the unadjusted capital ratio aggregates all funds, including the participating fund, while the adjusted capital ratio excludes the participating fund. The MCR denotes the Minimum Capital Adequacy Requirement of 100 percent.

Losses are primarily driven by falls in the prices of equity and corporate bond assets.



Source: IMF staff calculations.
Notes: The solid blue bars represent losses in asset values under the stress scenario. A negative loss represents a gain.

The bottom-up stress tests included management actions to restore capital, which MAS assessed to be systemically feasible.



Source: MAS.
Notes:
1/ Denotes CAR after application of asset losses but before earning any profits through normal business operations. The asset losses here refer to those in the first year of the projection horizon of adverse scenario 1 of the bank solvency stress tests.
2/ Includes deleveraging actions where insurers do not hold a large share of the whole market.

G. Cyber Risk

83. Cyber risk is an emerging risk to financial stability and exposures grow with the digitalization of the financial system. The authorities and financial institutions regard cyber-attacks as severe threats, and the expansion of financial innovation poses challenges to financial oversight. To gather information of the potential impact of cyber-attacks, MAS conducted a bottom-up cyber risk survey and collected responses from 18 banks and 17 direct general and composite insurers as part of the 2019 FSAP.

84. The authorities are actively developing a sound institutional framework for cybersecurity in the financial sector.[54] The Cybersecurity Act of 2018 imposes responsibilities on the owners of computer systems that are designated as critical information infrastructures and defines rules for the licensing of cybersecurity service providers. The Cyber Security Agency (CSA) coordinates national policy and responds to incidents in this area. MAS is responsible for overseeing the cybersecurity of the financial sector, and for identifying and securing the sector's critical information infrastructures. MAS monitors threats through its 24/7 financial sector security operations center and shares information with financial institutions. MAS is consulting with financial firms on a set of minimum regulatory requirements for cyber hygiene.[55] MAS has appointed a chief cybersecurity officer with associated responsibilities. MAS employs information technology experts to conduct on-site inspections of financial institutions' cybersecurity practices and is training supervisors to include cybersecurity elements in their regular monitoring of individual financial institutions.

85. All Singapore financial institutions regard cyber-attacks as severe threats and all are taking steps to secure their computer systems. Staff consulted, and MAS meets with systemically important banks and insurers on their cybersecurity issues and developments regularly.[56] Financial institutions' frameworks closely follow that published by the U.S. National Institute of Standards and Technology and SWIFT. Sensors across the network detect unusual activity that is relayed to security operation centers (SOCs). Many events are identified this way, and SOCs use algorithms to filter events for further investigation. More sophisticated financial institutions proactively gather intelligence on potential threat actors. In addition to the minimum cyber hygiene requirements outlined above, some financial institutions indicated that they found disabling Universal Serial Bus

[54] FSB (2018) defines "cyber security" as the preservation of confidentiality, integrity, and availability of information and/or information systems through the cyber medium, "cyber incidents" (also known as cyberattack) as the events that jeopardize the cyber security of an information system or the information the system processes, stores, or transmits; or violates the security policies, security procedures or acceptable use policies, whether resulting from malicious activity or not, and "cyber risk" as the combination of the probability of cyber incidents occurring and their impact.

[55] Minimum requirements for cyber hygiene are motivated by the observation that most successful cyber-attacks globally could have been prevented by basic cybersecurity measures. Such measures include timely system patch updates, network perimeter defense, malware protection, multi-factor authentication and established baseline security standards.

[56] Specifically, staff discussed cybersecurity frameworks with all seven D-SIBs and all four large insurers.

drives, filtering websites and scanning email traffic to be useful. All financial institutions discuss cybersecurity at the level of their board of directors, and they either have a training program in place to educate board members or they have hired external experts to improve the board's understanding of information technology risk. Financial institutions allocate some 0.4-2.0 percent of their staff and about 4-5 percent of their information technology budgets to such defenses.[57] In addition, outsourcing is popular for activities like monitoring the network perimeter and managing website traffic flow. Foreign bank branches rely partially on their parent for cybersecurity. Singapore is also an attractive destination (given the time zone and highly educated workforce) for establishing regional SOCs.

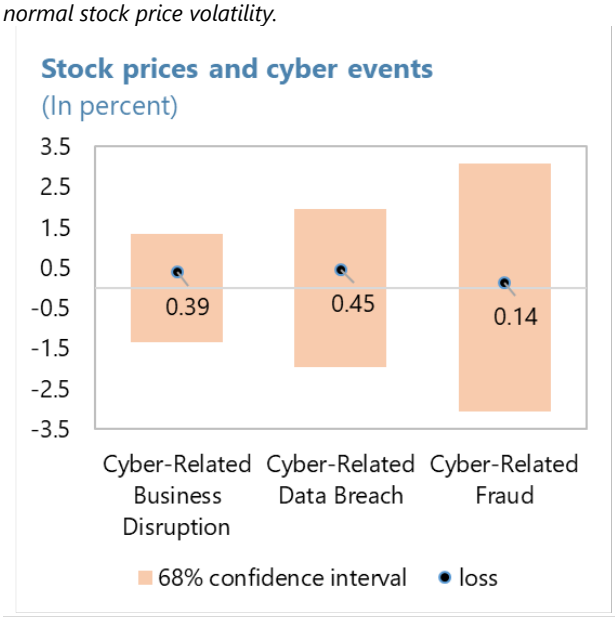
86. So far, successful cyber-attacks in the Singapore financial sector have not caused significant losses. Staff examined confidential data on successful cyber-attacks as part of its assessment and these show an improving trend in recent years. Since 2015, most cyber-attacks were targeted at securities firms and banks. The clear majority of these events were distributed denial of service attacks and other website-targeted behavior. Nevertheless, there have also been incidents of ransomware and attacks on third-party providers (including in cloud computing, productivity applications and marketing).

87. The healthy solvency and liquidity positions of Singaporean banks provide buffers against financial losses from cyber threats. The stress tests above could all be interpreted as analyses of the exposure to a cyberattack. For example, liquidity analyses already simulate a situation where depositors withdraw from an individual bank and that bank is also forced to sell or lend its assets (at discounted prices) to meet such cash requirements. A cyber risk event, possibly including a loss of reputation, could be the source of this liquidity stress. Solvency stress tests already simulate a situation where asset prices decline sharply. A cyber event, particularly a form of fraudulent market manipulation, could be the source of this fall in asset prices. Interbank network analyses already simulate the cascading transmission of credit and liquidity risk between banks. A cyber event, possibly including a loss of reputation, could be the source of the initial bank failure.

[57] These are estimates based on those firms that had them available. Most financial institutions indicated that it is difficult to estimate resource allocation because much cybersecurity activity is outsourced. The CSA has recommended that firms allocate at least 8 percent of their information technology budgets to cybersecurity (CSA, 2017).

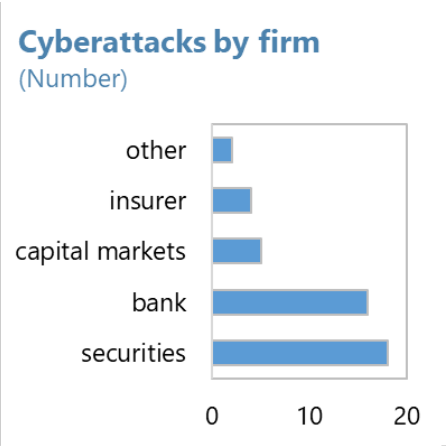
Figure 36. Cyber-Risk Analyses

Data breaches seem to be the most impactful type of cyber-attack, although losses from cyber-attacks are swamped by normal stock price volatility.



Source: ORX, Bloomberg and IMF staff calculations.
Notes: The loss is calculated as the natural logarithm of the fall in the price from the day before the cyber event to the day after it. The 68 percent confidence interval is a one-standard deviation confidence interval, based on the standard deviation of losses across events of a given type.

Cyber-attacks are concentrated in banks and securities firms.



Source: MAS.
Notes: Events refer to the Singapore financial sector. Data cover the period up to November 2018.

88. Analysis of international data suggests that financial firms' stock prices fall by between 39 and 45 basis points on days of cyber-attacks leading to data breach or business disruption (see first panel in Figure 36). An event study of historical cyber-attacks around the world reveals that data breaches have historically had the largest impact on financial institutions' stock prices, followed closely by business disruptions.[58] Stock prices fall by on average 45 and 39 basis points on days of cyber-attacks leading to data breaches and business disruption respectively.[59] The loss on data breaches is similar to the 50 basis points found by Kamiya and others (2018), who use data on U.S. events only and include attacks on non-financial firms.[60]

[58] This analysis is based on a dataset from the Operational Riskdata eXchange Association (ORX), as studied by Bouveret (2018). The data cover 341 cyber-attacks on financial institutions worldwide between 2009 and 2017.

[59] The stock price falls are measured on the day in which the cyberattack was first made public.

[60] The authors use a sample of 188 cyber-attacks that lead to data breaches on U.S. financial and non-financial firms between 2005 and 2014. The underlying data are published by the Privacy Rights Clearinghouse. The authors find a median effect of 50 basis points and a value-weighted average effect of 76 basis points, both of which are statistically

Incidents of cyber-related fraud have had much smaller effects. Nevertheless, the effect of these losses is difficult to distinguish from normal stock market volatility.

89. MAS conducted a bottom-up cyber risk survey as part of the 2019 FSAP assessment and collected answers from 18 banks on the following topics: (1) description of cyber-attacks that they would be most vulnerable to; (2) qualitative analysis of transmission channels; (3) quantitative estimates of potential losses; and (4) description of mitigating measures.[61] As noted above, the top-down and bottom-up stress tests with scenarios could be interpreted as those related to cyber events. Therefore, the cyber risk survey provided commonalities in terms of the mode, target, and types of the attacks instead of another prescribed scenario and banks were allowed to calibrate the impact based on the well-known historical cyber-attacks around the world and their own intelligence, so that the survey can help understand banks' own views on cyber risk.

90. Banks envisage that they would be mostly affected by money theft and business disruption but can weather the impact with ample capital and liquidity buffers. Responses from 18 banks on a bottom-up cyber risk survey show that the potential losses from cyber-attacks would amount to about [50] percent of their quarterly profits and cause the CAR and the LCR to drop by 0.4 and 16 percent, respectively. They think adequate measures are in place to mitigate the impact, including multiple layers of security controls and strong data encryption and access controls, regular cyber security simulations, and disaster recovery sites. However, the responses suggest that some banks do not fully consider the negative impact arising from loss of confidence on the bank and the spillover effects from contagion within the financial system. Table 12 shows the cyber risk scenarios that banks identified as most impactful, banks' assessment of their likelihood, and banks' security measures in place to guard against them.

significant. The authors also control for other asset pricing factors, but it is unclear whether these are correlated with incidents of data breaches.

[61] MAS (2018) categorizes the cyber-attacks into theft, disruption, or damage: (1) theft is an incident that extract items are valuable to the perpetrator, such as funds/monies using ATM malwares and data (e.g., intellectual property or market-valuable information); (2) disruption is an event that can temporarily disrupt business functionality or degrade the availability of transactions or communications (e.g., a distributed denial of service attack); and (3) damage is an attack that affect data integrity (e.g., corruption of customer account balance and transaction data) or damage system hardware or software or other equipment.

Table 12. Cyber Risk Assessment Matrix for Banks /1

Scenario	Likelihood /2	Security measures
Corruption of data from data service provider	0% of respondents	• Due diligence e.g., on service provider
Theft of data or money For example, ATM jackpotting: malware causes ATMs to dispense cash. Especially if malware is delivered to the centralized ATM software delivery system.	60% of respondents	• Access control • Multiple security devices (e.g., firewalls, intrusion prevention systems) • Regular security testing • Encryption
Disruption of a bank's IT systems For example, DDOS attack: disruption to websites prevents customers from accessing internet and mobile banking applications. Customers would still have access to banking services at bank branches. A more severe example would be a disruption of a bank's own payment processing system.	60% of respondents	• Disaster recovery systems, including alternate site • Incident response plans
Corruption of customer data: a bank discovers that its customer data has been corrupted for three days. The affected data include demographics, transactions and account balances. Banking services are disrupted until data can be recovered.	20% of respondents	• Regular tape backups to enable data restoration
Disruption of third-party services Most important providers include: payments and clearing systems (public and private), telecommunications, utilities, printing	n.a.	• Due diligence • Third parties' contractual cybersecurity obligations • Business continuity measures, like alternate service providers

Source: D-SIBs' responses to bottom-up stress test exercise.

1/ This table is an application of the "Risk Assessment Matrix", as an analytical tool, to assess cyber risk in the banking sector. This table should not be confused with the Risk Assessment Matrix of this FSAP, which appears in Appendix I, and which covers all risks to the whole financial system.

2/ The likelihoods reported in this table are based on the fraction of banks that identified the scenario as a significant risk to themselves, rather than staff's assessment of the likelihood of occurrence of each scenario.

91. Direct insurers expect the claims from affirmative and silent cyber coverage[62] to be manageable, mainly due to reinsurance arrangements in place. MAS surveyed 17 direct general/composite insurers on the claims that would arise if their ten largest clients of affirmative cyber coverage and their 10 largest clients of Property & Casualty insurance were victims of cyber-attacks. Together, insurers report exposures of S$600 million and S$3.4 billion for affirmative and silent cyber coverage, respectively. Claims arising from these exposures amount to S$1.8 billion, which are shared between the direct insurers and their reinsurers and may be offset against a release of technical reserves. The net losses reduce the aggregate CAR of these insurers by only 3 and 2 percentage points for affirmative and silent cyber coverage, respectively. Moving forward, insurers with exposures to silent cyber coverage intend to include appropriate exclusion clauses in their contracts.

92. The authorities should make an effort to develop a cyber network map and continue to monitor cybersecurity risks from third party service providers.[63] MAS has been monitoring interconnectedness via financial exposures and cyber-interdependences in the financial system separately. Taking a holistic approach will help MAS better understand the financial and Information Technology and Communication (ICT) connections between firms (including financial market infrastructures and third-party service providers) to identify interconnectedness, potential risk concentrations and common dependencies. The concept builds on traditional supervisory approaches to identify concentration risks in the financial network at a system level and adds the cyber network. The authorities already supervise third party providers that are financial firms, and they have a framework for engaging with non-financial third-party providers that are separately regulated. Nevertheless, the stress tests showed banks' vulnerability from this source, which MAS should enhance monitoring.

[62] Affirmative cyber coverage refers to any insurance policy that explicitly covers cyber risk in the policy wording. Silent cyber coverage refers to any insurance policy that could lead to a claim due to a cyber-attack and where 'cyber' is not mentioned in the policy wording (e.g., fire insurance, where a fire could be triggered by a cyber-attack).

[63] This topic is covered in more detail in the accompanying technical notes on financial technologies and banking supervision.

CONCLUSIONS AND RECOMMENDATIONS

93. The FSAP systemic risk assessment finds that the Singapore's financial system is broadly resilient to severe adverse shocks, but foreign exchange liquidity is a key weakness. D-SIBs do not show any shortages of capital in the adverse macroeconomic scenario, although some banks are relatively more exposed to legacy loans, property price volatility, and concentration risk. Many banks do not pass the liquidity stress tests in U.S. dollars, suggesting that overall liquidity is reliant on a stable value of the domestic currency. Insurers show vulnerability to asset prices, but do not suggest a systemic risk. The contagion analyses reveal that severe distress in major advanced economies could inflict significant losses on banks in Singapore and Singapore could cause significant outward spillovers in the regional neighbors. Households remain resilient under stress except a small segment of highly leveraged, low income, and younger borrowers. Non-financial corporates remain resilient in stress tests thanks to large cash reserves that offset their high gross debt. Cyber-attacks have not led to significant losses to financial firms in Singapore, but financial institutions should fully consider the negative impact arising from loss of confidence and the spillover effects from contagion within the financial system.

94. Systemic risk assessment results should be interpreted with caution. They are subject to methodology, coverage, and data constraints. The analyses do not fully capture the macrofinancial second-round effects. Bank stress tests estimate satellite credit risk models with historical data only after 2004 (excluding the Asian Financial Crisis) and are subject to estimation uncertainty. Bank and insurer stress tests cover D-SIBs and the four largest direct life/composite insurers. The FSAP risk analyses are based on supervisory and market data that are collected at a specific point in time. Furthermore, economy is affected by a combination of external and domestic shocks that (ex-ante) have a low probability of realization.

95. The authorities should seek to strengthen U.S. dollar liquidity among D-SIBs. Foreign currency liquidity is important in Singapore because it facilitates trade and investment. Staff find banks' U.S. dollar liquidity positions to be vulnerable, given that the U.S. dollar LCR suggests shortfalls of liquid U.S. dollar assets of some 20 percent of GDP (Table 4) and the stress tests above reveal shortfalls of 8-11 percent of GDP. The adverse scenarios underlying these liquidity risk analyses assume deteriorating liquidity conditions in foreign currency swap markets. The authorities have the capacity to provide U.S. dollars to banks through money market operations, but it is important for banks to self-insure more of their foreign currency liquidity risk. There are several ways that this could be achieved. MAS has chosen to use the supervisory process to encourage banks to improve their foreign currency liquidity positions. This approach seems feasible, given that the supervisory process has been successful in reducing banks' reliance on the FX swap market for funding normal U.S. dollar lending activity. Other jurisdictions have found it useful to introduce minimum requirements for foreign currency LCRs.[64] MAS should therefore keep this option open if

[64] Such jurisdictions include Sweden, Norway, Korea and Iceland.

improvement is not achieved through the supervisory process. Any actions should be undertaken gradually to avoid disrupting banking or foreign exchange activity.

96. The authorities should strengthen surveillance by closing data gaps and developing additional analytical tools. Further data collection and enhancement in the following areas will help MAS' surveillance: (i) domestic interlinkages; (ii) total stock of household mortgage debt at the borrower-level over time; and (ii) direct life insurers' liability cashflow projections and the underlying asset allocation of the collective investment schemes in which they invest. MAS needs to explore alternative approaches to estimate credit gap, recognizing changes in credit cycles, which will support timely and appropriate macroprudential policy actions. MAS should continue to enhance the bank solvency monitoring by adopting the full aspects of the SFRS 109. MAS should revise its contractual and behavioral cashflow-reporting templates to make them more useful for stress testing purposes. MAS should develop a cyber network map that takes into account both financial linkages and Information and Communications Technology connections and use it for cyber risk surveillance.

97. It would be beneficial to Singapore to explore the possibility of extending swap line arrangements with other central banks. The Asian dollar market in Singapore is an important channel for intermediating funds from advanced economies to Asia, and therefore regional spillovers are significant. The authorities have established swap lines for financial stability purposes with the People's Bank of China and the Bank of Japan, and Singapore also participates in regional liquidity arrangements. Nevertheless, extending Singapore's network of bilateral swap arrangements would improve its ability to withstand global liquidity events.

Appendix I. Risk Assessment Matrix (RAM)

Source of Risk	Transmission Channels	Relative likelihood	Potential impact
Tighter global financial conditions and retreat from cross-border integration	An abrupt change in global risk appetite (e.g., due to higher-than-expected inflation in the U.S.) could lead to sharp increases in interest rates, tightening of financial conditions, and reduction of cross-border capital flows. Higher debt service costs and a sharp decline in economic activity could increase private sector's delinquency and deteriorate banks' capital. Heightened financial volatility and refinancing costs would also affect financial institutions through market risk and liquidity risk with tighter dollar funding conditions. A decline in financial sector activity—an important driver of the economy—could slow growth further through feedback channels.	Medium/High	High
Weaker-than-expected global growth, especially China	Singapore's position as a financial center and a trading hub would imply large spillovers from global lower growth. Especially, a significant slowdown in China would have both direct effects on Singapore and indirect impacts via a sharp slowdown in the region and a severe decline in commodity prices. Financial stress in China would lead to rising NPLs and a decline in investor sentiment, pullback of funding from the region, deteriorating further the quality of regional exposures of banks in Singapore. High corporate and household leverage and property price corrections could exacerbate a slowdown in economic activity, leading to a deep recession with substantial credit risk.	Medium	Medium/High
Cyber-attacks	Given Singapore's role as a financial hub, cyber-attacks on interconnected financial systems that trigger systemic financial instability or widely disrupt socio-economic activities could significantly impact the financial sector–an important driver of growth. Liquidity and operational risk would be the main channels.	Medium	Medium/High

Appendix II. Stress Testing Matrix (STeM)

Domain		Assumptions		
		Bottom-up by financial institutions	Top-down by authorities	Top-down by FSAP Team
Banking Sector: Solvency Stress Test				
1. Institutional Perimeter	Institutions included	• All seven D-SIBs (10 banks).	• All seven D-SIBs (10 banks).	• All seven D-SIBs (10 banks).
	Market share	• 75 percent of total loans to private residents.	• 75 percent of total loans to private residents.	• 75 percent of total loans to private residents.
	Data and starting position	• Bank proprietary data. • Starting position: 2018Q2 and projected to end-2018 under the baseline scenario. • Bank consolidated level data for banks having their headquarters in Singapore and unconsolidated data for foreign bank subsidiaries and branches.	• Supervisory data (balance sheet and income statements). • Starting position: 2018Q2 and projected to end-2018 under the baseline scenario. • Bank consolidated level data for banks having their headquarters in Singapore and unconsolidated data for foreign bank subsidiaries and branches.	• Supervisory data (balance sheet and income statements). • Starting position: 2018Q2 and projected to end-2018 under the baseline scenario. • Bank consolidated level data for banks having their headquarters in Singapore and unconsolidated data for foreign bank subsidiaries and branches.
2. Methodology	Overall framework	• Balance sheet approach • Banks' own internal stress testing methodology.	• Balance sheet approach. • Satellite models and stress testing methodology, developed by the MAS.	• Balance sheet approach. • Satellite models and stress testing methodology, developed by the FSAP team.
	Satellite models for macro-financial linkages	• Banks' own internal models to translate macrofinancial conditions into pre-loss net income, credit and market losses, and regulatory capital. • Three local banks use both standardized approach and internal ratings-based approach to measure the credit risk of their loan portfolios, while foreign D-SIBs use only the standardized approach. For example,	• MAS' satellite model to estimate PD and LGD dynamics and credit losses • SFRS9 framework to calculate loan loss provisioning needs. • Market losses from bottom-up submission. • Method to integrate credit and funding losses from interbank cross-exposures into the solvency stress test. • Method to calculate risk-	• FSAP team's own model for credit losses from banks' lending portfolios. • SFRS9 framework to calculate loan loss provisioning needs. • Method to calculate market losses from holdings of debt instruments (sovereign and other issuers). Haircuts are calculated based on a modified duration approach. • Method to integrate

		the average EAD for residential mortgages under the internal ratings-based approach as a proportion of total credit EAD/exposures for residential mortgage is 88 percent among three local banking groups.	weighted assets. • Model to estimate pre-loss net income as a sum of net interest income and non-interest income. • No accrued income on NPL loans.	credit and funding losses from interbank cross-exposures into the solvency stress test. • Method to calculate risk-weighted assets. • Model to estimate pre-loss net income as a sum of net interest income and non-interest income. • No accrued income on NPL loans.
	Stress test horizon	• 3-years (2019-2021).	• 5-years (2019-2023).	
	Assumption	• Banks' own internal stress testing methodology.	• Passive balance sheet assumption: (i) the balance sheet growth is identical to the overall credit growth, which is linked to nominal GDP growth; (ii) the balance sheet composition remains constant throughout the stress test horizon; (iii) banks build capital only through retained earnings; and (iv) maturing capital instruments are not renewed. • Banks can pay dividends only if net income after taxes are positive, with limits on dividend payout rate as per the MAS regulatory requirement.	
3. Type of analyses	Scenario analysis	• Three macrofinancial scenarios, agreed with the authorities. • The scenarios include domestic macrofinancial variables (e.g., GDP, inflation, interest rates, unemployment rate, exchange rate, equity and house prices), and global variables (global GDP, interest rates, and commodity prices). • All the scenarios are generated in collaboration between the MAS and the IMF FSAP team, using MAS' Monetary Model of Singapore and IMF's Global Macrofinancial Model. • Baseline scenario based on the July 2018 WEO projections. • Two adverse scenarios reflect macrofinancial risks in the Risk Assessment Matrix. All of them are triggered by external factors but amplified by domestic vulnerabilities. - Scenario 1. Large-scale global financial market turmoil. - Scenario 2. Protracted recession centered on a major slowdown in China and trade tensions. • Under the two adverse scenarios, the Singaporean economy sets to suffer a recession, with the output gap being -8.4 percent and -12.3 percent and the cumulative decline of real GDP growth being 1.7 and 2.3 standard deviations over the first two and three years, respectively. These shocks are unprecedently in Singapore. • The SGD/USD bilateral exchange rate would depreciate by 20 percent in 2019 under the adverse scenario 1, equal to 3.7 standard deviation of the annual exchange rate movement (y-o-y).		
	Sensitivity analysis	N.A.	• Sensitivity analyses will also be conducted in the top-down exercises. • They evaluate impacts of different risk factors on	• Sensitivity analyses will also be conducted in the top-down exercises. • They evaluate impacts of four different single risk

			NPL and capital ratios: - GDP and unemployment - Property prices - Commodity prices - Exchange rates Interest rates	factors on the existing capital buffers: - Exchange rate risk - Interest rate risk - Hypothetical decline of non-interest income due to Fintech development - Concentration risk from default of largest private borrowers
4.Risks and Buffers	Risks	• Credit loss captures all exposures in on-balance sheet's loan portfolios and off-balance sheet credit commitments. • Market loss from valuation adjustments of banks' holding of debt securities and exchange rate risk on the net open foreign exchange positions.		• Credit loss captures all exposures in on-balance sheet's loan portfolios and off-balance sheet credit commitments. • Market loss from valuation adjustments of banks' holding of debt securities and exchange rate risk on the net open foreign exchange positions. • Credit and funding losses from interbank cross-exposures.
	Buffers	• Existing capital buffers. • Internal capital generation from net income after taxes. • No new capital injection.		
5. Regulatory Standards	Regulatory Standards	• National regulatory framework: MAS Notice 637 and 612. • Fully loaded Basel III.		
6. Reporting Format for Results	Output presentation	• System-wide capital shortfalls from macroprudential perspectives. • Hurdle rates – Baseline scenario: the sum of regulatory minimum (CET1, Tier1, and total capital), D-SIB surcharge, capital conservation buffer, and countercyclical capital buffer. – Adverse scenarios: the sum of regulatory minimum and D-SIB surcharge.		
Banking Sector: Liquidity Stress Test				
			Top-down by the authorities and FSAP team jointly	
1. Institutional Perimeter	Institutions included	N.A.	• All seven D-SIBs (10 banks)	
	Market share	N.A.	• 76 percent of total deposits of private residents.	
	Data and Starting position	N.A.	• Starting position: 2018Q2. Robustness will be investigated using data for 2018Q3. • Supervisory data.	

			• Bank consolidated level data for banks having their headquarters in Singapore and unconsolidated data (i.e., Singapore operations only) for foreign bank subsidiaries and branches.	
2. Methodology	Overall framework	N.A.	• Stress test of the LCR, by applying higher rates of cash outflow, lower rates of cash inflow, and haircuts to liquid asset values. This simulates the liquidity position, as measured by the LCR, in a stress scenario. • The all-currency and Singapore dollar LCRs will be stressed.	• The FSAP liquidity stress test comprises two types of tests: (i) LCR-based stress test and (ii) cashflow-based test. • The LCR-based test will be aligned with that of the authorities, using the authorities' calculation software. • The cashflow-based test projects the bank's liquid asset position under stress conditions of up to six months, based on the contractual maturity profile of assets and liabilities. • The cashflow-based test will be applied to liquid assets in all currencies, Singapore dollars and U.S. dollars separately. • The NSFR and U.S. dollar LCR will be inspected, without being stressed. There is no minimum requirement for the U.S. dollar LCR.
3. Type of analyses	Scenario analysis	N.A.	• The LCR-based stress tests consider retail and wholesale scenarios separately. They are designed to be similar to those used in other FSAPs but are elaborated to emphasize features and potential vulnerabilities of the Singapore context. They include delays in cash inflows from derivatives and margin calls on derivatives. They explicitly model the effects of a depreciation of the Singapore dollar on the all-currency LCR. These scenarios are agreed with the authorities. • The cashflow-based stress tests consider 1-week and 6-month stress scenarios. • The parameters of the scenarios are calibrated with reference to the first year of Scenario 1 in the bank solvency stress tests, international experience of bank liquidity stress episodes and past FSAP practices. Run-off rates on deposits are calibrated to a two-standard	

			deviation fall in historical supervisory data on deposit balances. Run-off and roll-off rates on FX swaps are also calibrated to a two-standard deviation scenario, but since trade volumes in FX swaps are not observed, liquidity in the FX swap market is proxied by bid-ask spreads on FX forwards.	
4. Risks and Buffers	Risks	N.A.	• Contraction in the supply of funding to the bank (so-called "funding liquidity stress") • Increased demand by the bank's clients for renewal of maturing loan contracts • Reduced ability of the bank's clients to repay the bank on time • Falling asset prices, possibly due to fire sales (so-called "market liquidity stress"). For the LCR-based test, some depreciation of the Singapore dollar is included.	
	Buffers	N.A.	• The buffer in the LCR-based test is the excess value of high-quality liquid assets over the regulatory requirement (which varies by currency and bank type). High quality liquid assets are as defined in the domestic implementation of the LCR. • The buffer in the cashflow-based test is the value of liquid assets (so-called "counterbalancing capacity"). This buffer includes notes and coins, deposits at the central bank, deposits at commercial banks, and securities. Securities may be monetized before their maturity. • The cashflow-based test is agnostic about the use of standing facilities or markets to monetize high quality assets, but it precludes the use of emergency liquidity facilities or liquid assets backing reserve requirements.	
5. Regulatory Standards	Regulatory standards	N.A.	• National regulatory framework. The LCR is defined as in MAS Notice 649. • The hurdle is set at a Singapore dollar LCR of 100 percent for all banks, an all-currency LCR of 100 percent for local banks, and an all-currency LCR of 50 percent for foreign branches. • The hurdle for the cashflow-based test is zero Singapore dollars.	
6. Reporting Format for Results	Output presentation	N.A.	• The authorities will share headline results in their industry briefings and Financial Stability Review.	• System-wide LCR and liquid asset shortfalls under the LCR stress scenarios • System-wide liquid asset value under the cashflow-based stress scenarios.
Insurance Sector: Solvency Stress Test				
1. Institutional Perimeter	Institutions included	• 9 largest life/composite insurers and 15 largest	• The 4 largest life/composite insurers	• The 4 largest life/composite insurers

		general insurers		
	Market share	• At least 80 percent of total assets (life insurers) • At least 80 percent of gross written premiums (general insurers)	• 80 percent of total assets	• 80 percent of total assets
	Data and starting position	• Starting position: 2018Q2 • Each insurer's own data	• Starting position: 2018Q2 • Supervisory data • Only life insurance activities of these insurers will be included • Investment-linked business is excluded for market risks • The liabilities of investment-linked business, non-participating term life and non-participating accident and health are not revalued (7 percent of liabilities in the sector, measured using guaranteed liabilities and a provision for uncertainty).	• Starting position: 2018Q2 • Supervisory data • Only life insurance activities of these insurers will be included • Investment-linked business is excluded for market risks • The liabilities of investment-linked business, non-participating term life and non-participating accident and health are not revalued (7 percent of liabilities in the sector, measured using guaranteed liabilities and a provision for uncertainty).
2. Methodology	Overall framework	• Projection of the regulatory capital position under several scenarios • Each insurer's own internal methodology	• Projection of the regulatory capital position under a severe yet plausible macroeconomic stress scenario • The capital position is modelled by revaluing assets and liabilities under the scenario • Static balance sheet approach, where the impact of the entire scenario is evaluated in one step	• Projection of the regulatory capital position under a severe yet plausible macroeconomic stress scenario • The capital position is modelled by revaluing assets and liabilities under the scenario • Static balance sheet approach, where the impact of the entire scenario is evaluated in one step • A satellite model is used to estimate the impact on government bond prices by maturity, for those currencies where yield curves are not projected under the bank solvency scenario

3. Type of analyses	Scenario analysis	• There will be macroeconomic and non-macroeconomic scenarios. The macroeconomic scenarios have horizons of 2.5 years and the non-macroeconomic scenarios have horizons of one year. • There will be three macroeconomic scenarios, matching the baseline and two adverse scenarios used under the bank solvency stress tests above. • One climate-related scenario tests the impact on general insurers of severe but plausible rainfall. • A cyber risk scenario tests the impact on general insurers of claims on direct (affirmative) and indirect (silent) cyber insurance policies.	• There will be one adverse scenario only. • The scenario will have a two-year horizon, based on the combined impact of 2019 and 2020 under "Scenario 1" of the agreed bank solvency scenarios. • Risk-free discount rates under the adverse scenario will follow the Singapore regulatory regime, where longer-term discount rates are less sensitive to interest rate movements. This insensitivity will change under RBC 2.	• There will be one adverse scenario only. • The scenario will have a two-year horizon, based on the combined impact of 2019 and 2020 under "Scenario 1" of the agreed bank solvency scenarios. • Risk-free discount rates under the adverse scenario will follow the Singapore regulatory regime, where longer-term discount rates are less sensitive to interest rate movements. This insensitivity will change under RBC 2.
4. Risks and Buffers	Risks	• Falls in asset prices, possibly due to fire sales ("market risk") • Catastrophe risk • Cyber risk	• Falls in asset prices, possibly due to fire sales ("market risk") will be modelled in more detail than in the bank solvency stress tests	• Falls in asset prices, possibly due to fire sales ("market risk") will be modelled in more detail than in the bank solvency stress tests • Default by largest counterparties
	Buffers	• Buffers are as specified in the top-down analyses to the right. • In addition, insurers may recognize future profits as they are earned (e.g., interest income from bonds) as buffers. • Insurers also model the effects of their recovery plans on their regulatory capital positions.	• The buffers are regulatory capital in excess of regulatory capital requirements. • The fall in asset values will result in an automatic relaxation of capital requirements for market risk • Falls in liability values, due to rising sovereign yields, will also improve the solvency position.	• The buffers are regulatory capital in excess of regulatory capital requirements. • The fall in asset values will result in an automatic relaxation of capital requirements for market risk • Falls in liability values, due to rising sovereign yields, will also improve the solvency position.
5. Regulatory Standards	Regulatory standards	• Current RBC regulations ("RBC 1"). • Insurers specify hurdle	• Current RBC regulations ("RBC 1"). • The stress tests will use a	• Current RBC regulations ("RBC 1"). • The stress tests will use a

		rates according to their internal targets, which are higher than their regulatory requirement. • Insurers' own regulatory requirements include industry-wide and firm-specific requirements.	hurdle Capital Adequacy Ratio based on confidential, insurer-specific capital requirements.	hurdle Capital Adequacy Ratio of 100 percent. • In addition, a higher Capital Adequacy Ratio will be considered, based on an indicative and confidential capital surcharge for high-impact insurers. However, such quantitative results will not be published, to maintain confidentiality.
6. Reporting Format for Results	Output presentation	• The FSAP team will have access to a summary of insurers' stress test results. • Attribution analysis will assist in identifying the drivers of risk • As much sector-wide detail as possible will be included in the technical note, while preserving insurer—supervisor confidentiality.	• Sector-wide regulatory capital position and capital shortfall.	• Sector-wide regulatory capital position and capital shortfall.
Financial System: Interconnectedness Analysis				
1. Institutional Perimeter	Institutions included	N.A.		• Interbank network: all banking groups (119). • Common exposure: All seven D-SIBs. • Intra-financial network: 8 groups of financial institutions. • Cross-border bank network: the banking system of selected countries.
	Data and Starting position	N.A.		• Starting position: 2018Q2 • Supervisory and market data. • Scope of consolidation – Interbank and common exposure: individual banks. – Intra-financial: groups of financial institutions. – Cross-border: banking system.

2. Methodology	Overall framework	N.A.	• Interbank: Espinosa-Vega and Solé (2010). • Common exposure: balance sheet approach. • Intra-financial network: Steady-state Markov Chain probability. • Cross-border network: Espinosa-Vega and Solé (2010) and Diebold and Yilmaz (2014).
3. Risks and Buffers	Risks	N.A.	• Credit and funding losses related to interbank exposures, intra-financial exposures, and cross-border banking exposures. • Default of large common borrowers in the banking system. • Fire-sale of assets following sizeable withdrawals of deposits.
	Buffers	N.A.	• Interbank network: banks' own capital and liquidity buffers. • Cross-border bank network: capital buffers of a banking system.
4. Reporting Format for Results	Output presentation	N.A.	• Interbank network: a network chart, index of vulnerabilities. • Common exposure: system-wide capital shortfalls. • Intra-financial network: bilateral exposure matrices, a chart of steady state Markov Chain probability, • Cross-border network: index of vulnerabilities and contagion, a heatmap of bank distress, and spillover charts.

Appendix III. Cross-border Network Analysis Using Market Data

Singaporean bank's cross-border interconnectedness is examined based on the methodology developed by Diebold and Yilmaz (2014) using the volatility of bank equity return indices as proxy for bank stress. Diebold and Yilmaz (2014) build connectedness measures from a forecast error variance decomposition. It first estimates a vector autoregression model (VAR) with stock market return volatility:

$$A(L)Y_t + B(L)X_t = \varepsilon_t,$$

where Y_t denotes a vector of monthly log volatility of the FTSE bank equity return indices of 24 countries with which Singapore has significant financial and trade linkages, for the period from January 2016 to December 2018. It also includes Volatility Index (VIX), X_t, to control for common global factor (the control does not materially change the results).

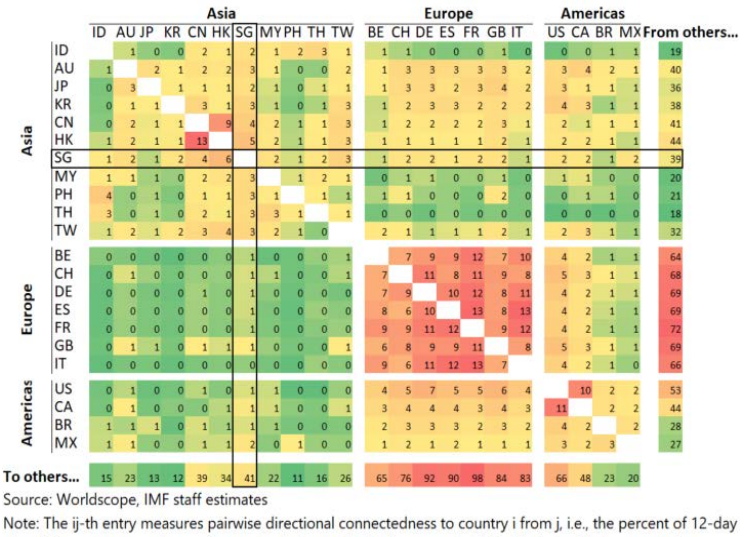
The connected measure is then derived from the H-step Generalized Variance Decomposition matrix (Pesaran and Shin, 1998) of the above VAR:

$$D^H = \left[d_{i,j}^H\right],$$

where each entry $d_{i,j}^H$ captures ij-th pairwise directional connectedness, i.e., the percent of 12-day-ahead forecast error variance of a country i due to shocks from country j. It quantifies how much variation in log volatility of equity return in country i can be attributed to shocks to equity volatility in country j. Connectedness is directional, i.e., $d_{i,j}^H \neq d_{j,i}^H$. Total directional measure can be also constructed by summing up the off-diagonal elements of D^H. The sum of off-diagonal elements in row i measures total directional connectedness from others to i; the sum of off-diagonal entries in column j measures total directional connectedness to others from j.

Appendix Figure III.1. Pairwise Directional Connectedness

(Based on monthly log volatility of bank equity return indices, 2006-2018)



Source: Worldscope, IMF staff estimates

Note: The ij-th entry measures pairwise directional connectedness to country i from j, i.e., the percent of 12-day ahead forecast error variance of a country i due to shocks from country j. Red indicates high connectedness.

The results show clear regional clustering. In terms of pairwise connectenedss countries tend to be connected wit countries in the same region. European banks in particular are very connected with each other, which makes European banks the most interconnected banks within the network. Outside Europe, US and Canadian banks are highly connected with each other and also with the rest of the system. The pair with the strongest pair connection in the entire network is in fact from China to Hong Kong SAR. Singapore is also most connected to these two economies.

Appendix IV. SFRS 109

The GFC highlighted the systemic costs of delayed recognition of credit losses. The incurred loss model in the International Accounting Standards 39 prevented banks from provisioning appropriately and preemptively for credit losses likely to arise from emerging risks. It was criticized as having contributed to procyclicality by spurring excessive lending during the boom and forcing a sharp reduction in the subsequent bust.

In July 2014, the International Accounting Standards Board issued the final version of a new accounting standards (the IFRS) to reflect changes in the credit risk of financial assets timely and appropriately. The IFRS 9 aims to measure the credit risk of financial assets over their lifetime as a product of lifetime PDs, loss given default, and exposure at default. For performing assets (Stage 1), banks would report a 12-month expected credit loss provisioning as done in the old standards. However, for assets with a significant increase in credit risk (Stage 2), they should set aside loan loss provisions in anticipation of lifetime expected credit losses even though the assets are not impaired. Therefore, the IFRS 9 is considerably more preemptive than the old standards, considering the cliff-effect on loan loss provisioning between Stage 1 and 2.

A local version, the SFRS 109, was introduced on January 1, 2018. MAS requires D-SIBs to maintain the higher of a minimum loss allowance of 1 percent on "non-credit-impaired" exposures (Stage 1 and 2) net of collaterals and loss allowances estimated under SFRS 109. This additional requirement is imposed to ensure prudence as well as to cater for potential uncertainties in the quality of SFRS 109 implementation. The transition to the SFRS 109 had only marginal effects banks' capital levels in January 2018, as their pre-SFRS 109 general provisions were sufficient to fulfill the minimum loss allowance and economic conditions were benign. Any excess allowance beyond the required amount in accordance with SFRS 109 needs to be maintained in a non-distributable regulatory loss allowance reserve account through an appropriation of its retained earnings.

Appendix V. Balance Sheet and Income Statement Projection

Item	Projection
Balance sheet	
Exposures	• Growth of gross exposures by types, such as total gross loans and gross holding of debt securities, identical to overall credit growth, with the balance sheet composition unchanged. • Overall credit growth consistent with GDP growth for a positive GDP growth, and zero for a non-positive GDP growth.
Income statement	
Net interest income	• Combination of interest income and interest expense.
Interest income	• Sum of interest income from lending activity and other activities. • Amount of lending (adjusted for balance sheet growth and existing NPLs) multiplied by adjusted effective lending rate. • Interest rate risk is adjusted with time-to-repricing gaps and changes in interest rates.
Interest expense	• Sum of interest expense from deposit funding and other funding. • Amount of deposits (adjusted for balance sheet growth) multiplied by adjusted effective deposit rate or funding cost. • Average funding cost adjusted with banks' solvency position and asset quality deterioration, incorporating solvency-liquidity nexus.
Net non-interest income	• Net fee and commission income is projected as a function of the growth rate of real GDP and equity price, considering its procyclical behavior and the impact of financial markets. • Other non-interest income growth consistent with GDP growth.
Pre-loss net income	• Sum of net interest income and other pre-loss net income.
Provision/impairment	• Credit losses based on the SFRS 109 that reflects the increase of PDs and LGDs on the back of worsening macro-financial conditions. • Write-back of loan loss provisions is not allowed. • Market loss due to mark-to-market to bond yield movements for the trading account, to exchange rate, equity price, and commodity price movements for the net open foreign-exchange, equity and commodity position.
Net income before taxes	• Sum of pre-loss net income and provision/impairment.
Taxes	• Based on applicable tax rates (17 percent) if net income before taxes is positive, and 0 otherwise.
Net income after taxes	• Sum of net income before taxes and taxes

Dividend payout	• Banks pay dividends only if net income after taxes are positive, with limits on dividend payout rate as per the MAS regulatory requirement.
Profits attributed to capital	• Sum of net income after taxes and dividend payout.
Capital	
Risk-weighted assets	• Adjusted for balance sheet growth, changes in credit risk, and exchange rate movements (for foreign-currency exposures).
Capital	• Affected by retained profits and unrealized gain/loss associated with the available-for-sale portfolio. • No capital injections during the stress test horizon.

Appendix VI. Estimation of Credit Risk Models

The transmission of macrofinancial shocks to probabilities of default (PDs) is assessed by estimating satellite credit risk models using the supervisory data over 2004-2018. Given the D-SIBs' cross-border lending exposures, the NPL projection uses macrofinancial scenarios of five countries where D-SIBs have significant credit exposures, including Singapore, China, Malaysia, Indonesia, and Thailand. In the model, the logit-transformed NPL ratios are determined by real GDP growth rates, short-term interest rates, house prices, equity prices, and nominal (bilateral) exchange rates. Each macrofinancial variable is averaged with the share of aggregated credit exposures to the five countries as a weight to incorporate their relative importance.[1]

The logit-transformed NPLs are modeled as a function of macrofinancial conditions and bank-specific factors. The models can be expressed as:

$$Y_{i,t} = \ln\left(\frac{NPL_{i,t}}{1 - NPL_{i,t}}\right) = (\alpha + \mu_i) + \beta_Y * Y_{i,t-1} + \beta_X * X_{t-s} + \varepsilon_{i,t}, \qquad \text{for } t = 1, \dots, T \text{ and } i = 1, \dots, N$$

Where $Y_{i,t}$ is the logit transformed NPL for bank i at time t, X_t is a vector of macrofinancial variables including real GDP growth rates, the square of real GDP growth rates, short-term interest rates, house prices, equity prices, and nominal (bilateral) exchange rates, s and μ_i denote time lags and bank-specific fixed effects, $\varepsilon_{i,t}$ is an independent and identically distributed error term, and α, β_Y, and β_X are parameters to be estimated. Non-linear effects are introduced in three ways: first, the dependent variable is defined as the logistic transformation of the NPL ratios; second, an autoregressive term leads to a larger subsequent increase in NPLs for exposures that have higher NPLs at the starting point; and third, the models use the square of real GDP growth as an explanatory variable to capture a feature that NPLs rise at an increasing rate as economic conditions exacerbate further. Time lags are determined based on cross-correlation

The estimated coefficients are presented in Appendix Table VI.1. The FSAP team estimates several credit risk models with different panel estimation methods and combinations of explanatory variables to test their robustness. NPL ratios under scenarios are computed according to the following formula which corresponds to the inverse of the logit function:

$$NPL_{i,t} = \frac{1}{(1 + \mathrm{e}^{-Y_{i,t}})} * 100$$

Bank-specific NPL paths are projected by averaging results across the models and accounting for fixed effects, when needed and then applies the paths to the latest point-in-time PD estimates to produce the PD dynamics for all asset classes over the stress test horizon.

[1] The FSAP also estimated the credit risk model by sector and the projected NPL path is similar to the case with the aggregated NPL series.

Appendix Table VI.1. Estimation Results of Credit Risk Models

Credit risk model for the top-down solvency stress test	Logit_NPL								
	With foreign branches but without equity price			Without foreign branches but with equity price			Without foreign branches and equity price		
	Fixed effect	Difference GMM	System GMM	Fixed effect	Difference GMM	System GMM	Fixed effect	Difference GMM	System GMM
AR (1)	0.5664	0.7080	0.6549	0.5912	0.6897	0.6462	0.6252	0.7089	0.6574
Real GDP growth (lag)	-0.1314	-0.1108	-0.0955	-0.0926	-0.0803	-0.0834	-0.0674	-0.0580	-0.0627
Real GDP growth (square, lag)	0.0078	0.0064	0.0060	0.0051	0.0044	0.0043	0.0037	0.0032	0.0032
Short-term interest rate	0.1836	0.1249	0.1214	0.1948	0.1593	0.1751	0.1536	0.1250	0.1402
House price inflation rate	-0.0229	-0.0235	-0.0218	-0.0193	-0.0198	-0.0214	-0.0188	-0.0192	-0.0202
Equity price growth rate (lag)				-0.0038	-0.0036	-0.0039			
Nominal exchange rate growth rate (lag)	-0.0025	-0.0001	-0.0030	-0.0161	-0.0129	-0.0188	-0.0161	-0.0013	-0.0059
Constant		-1.1778	-1.4866		-1.2964	-1.4795		-1.2467	-1.4651
Bank 1 dummy	-1.8712			-1.7439			-1.6294		
Bank 2 dummy	-1.7842			-1.7954			-1.6797		
Bank 3 dummy	-1.8351			-1.8305			-1.7030		
Bank 4 dummy	-1.6954			-1.7077			-1.5936		
Bank 5 dummy	-1.8712			-1.7439			-1.6294		
Bank 6 dummy	-1.6273			-1.6487			-1.5470		
Bank 7 dummy	-1.9096			-1.7439			-1.6294		
Bank 8 dummy	-2.1711			-1.7439			-1.6294		
Bank 9 dummy	-2.1948			-1.7439			-1.6294		
Bank 10 dummy	-1.7518			-1.7439			-1.6294		
R-squared	0.4030	-	-	0.8410	-	-	0.8066	-	-
	0.9552	-	-	0.9861	-	-	0.9867	-	-
	0.4983	-	-	0.8695	-	-	0.8496	-	-
Arellano-Bond AR(1) test	-	0.0000		-	0.0100		-	0.0070	
Sargan test	-	0.0200		-	0.1560		-	0.2240	
Number of observations	103	103	103	51	51	51	51	51	51
Number of groups	8	8	8	4	4	4	4	4	4
F-test probaiblity	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: IMF staff estimation.
Note: Yellow, light blue, and light red colors show 1 percent, 5 percent, and 10 percent significance of estimated coefficients.

Appendix VII. Adjustment of LGDs to Housing Price Inflation

The following numerical example and formula illustrate the approach used to adjust the LGDs of mortgage portfolios to reflect the impact of declining house prices under the adverse scenario:

Case without house price adjustment
House price inflation (ΔHP) = -20 percent
Loan amount = S$100
LGD rate (LGD_1) = 30 percent
Recovery rate = 70 percent
Recovery value = S$70

With the 20 percent drop of house prices, LGD rate increases to 44 percent the following formula:

$$\begin{aligned}(1 - LGD_2) &= (1 + \Delta HP) * (1 - LGD_1) \\ &= (1 - 0.2) * (1 - 0.3) \\ &= 0.56\end{aligned}$$

Appendix VIII. Parameters for Bank Liquidity Stress Tests

LCR-based stress tests

The method and scenarios of the LCR-based stress test are introduced in Box 4. Appendix Table VIII.1 shows the detailed parameter assumptions for this stress test. These are calibrated with reference to recent FSAPs in advanced economies and financial centers. The following ideas motivated the parameter assumptions:

- *Retail scenario.* The two percent fall in government bond prices is based on the average maturity of government bonds held by D-SIBs and the first half of the increase in the government bond yields in 2019 under the first adverse scenario of the bank solvency stress tests.

- *Wholesale scenario.* Intragroup funding is significant in Singapore and it is stressed through operational deposits. The reduction in inflows from financial firms is calibrated to match the rate of withdrawal of operational deposits. The currency depreciation is calibrated as half of the depreciation against the U.S. dollar in the first year of the first adverse scenario of the bank solvency stress tests. The effect of the assumption is bank-specific, based on the U.S. dollar proportions in HQLA, cash inflow and cash outflow under the LCR. The depreciation assumption is intended to capture the importance of the currency market, and potential currency mismatches between inflows and outflows, in Singapore. The margin call assumption is calibrated to be in line with the exchange rate depreciation, because foreign currency swaps are the largest category of derivatives. Committed credit lines are not subject to stress because they are mostly unconditionally revocable.

Appendix Table VIII.1. Specification of stress scenarios for the LCR analysis

Retail stress scenario

(1)	adjustment (2)=(4)-(3)	original weight (3)	stressed weight (4)
Withdrawal of retail and SME deposits *(in percent of initial deposits)*	+5	3, 5 (stable), 10 (unstable)	8, 10 (stable), 15 (unstable)
Withdrawal of non-financial firms' operational *(in percent of initial deposits)*	+20	3, 5, 25	23, 25, 45
Withdrawal of non-financial firms' non-operational *(in percent of initial deposits)*	+20	20, 40	40, 60
Contribution to liquid assets due to the non-refinancing of maturing loans that have previously been extended to individuals, SMEs and non-financial firms *(in percent of amount maturing)*	-15	50	35
Contribution of Level 1 HQLA to liquid assets *(in percent of initial value)*	-2	100	98

Wholesale stress scenario

(1)	adjustment (2)=(4)-(3)	original weight (3)	stressed weight (4)
Withdrawal of operational deposits of non-financial firms, banks and other legal entities *(in percent of initial deposits)*	+30	3, 5, 25	33, 35, 55
Withdrawal of non-financial firms' non-operational deposits *(in percent of initial deposits)*	+30	20, 40	50, 70
Withdrawal of deposits of institutional networks of cooperatives *(in percent of initial deposits)*	+30	25	55
Margin calls to replenish Level 2 collateral securing derivatives transactions *(in percent of the value of such collateral)*	+10	20	30
Contribution to liquid assets due to the non-refinancing of maturing loans and deposits that have previously been extended by this bank to other financial firms *(in percent of amount maturing)*	-50	100	50

Cashflow-based stress tests

The cashflow-based stress tests project the path of liquid assets under an adverse scenario using an inventory model. Each cashflow-based stress test projects the liquid assets of a bank under an adverse scenario.[1] The test uses an inventory-based model, where liquid assets are accumulated as cashflows come in and decumulated as cashflows go out. The dates of the model are indexed by $t = 0, 1, 2, \ldots$, where the start date is $t = 0$, and the dates are irregularly spaced in

[1] Staff conduct the tests in three currencies, for 15 levels of consolidation associated with the seven D-SIBs, using data based on two different starting dates, and under two different adverse scenarios, as explained in the main text.

time so that $t = 1,2,3,4$ denotes weeks 1-4, $t = 5$ denotes 1-3 months, $t = 6$ denotes 3-6 months and so forth as specified in the Appendix Table VIII.2.

Appendix Table VIII.2. Roll-off rates on assets in the long-term scenario of the cashflow-based liquidity stress tests

	units	1W	1-2W	2-3W	3W-1M	1-3M	3-6M	6M-1Y	1-2Y
Interbank claims	*(% flow)*	23	23	23	23	18	20	10	5
Intra-group claims	*(% flow)*	23	23	23	23	18	20	10	5
Securities of									
Banks	*(% flow)*	80	80	80	80	60	60	50	50
Non-financial corporates	*(% flow)*	100	100	100	100	100	100	100	100
Reverse repurchase agreements	*(% flow)*	0	0	0	0	0	0	0	0
Negotiable certificates of deposits held	*(% flow)*	80	80	80	80	60	60	50	50
Other securities	*(% flow)*	0	0	0	0	0	0	0	0
Equity investments	*(% flow)*	100	100	100	100	100	100	100	100
Bills discounted or purchased	*(% flow)*	80	80	80	80	60	60	50	50
Loans to									
Governments	*(% flow)*	100	100	100	100	100	100	100	100
Non-bank financial institutions	*(% flow)*	100	90	90	90	60	50	50	25
Non-financial corporates	*(% flow)*	50	50	50	50	30	30	10	10
Individuals	*(% flow)*	50	50	50	50	30	30	10	10
Other assets on balance sheet /1	*(% flow)*	0	0	0	0	0	0	0	0
Interest rate derivatives	*(% flow)*	100	100	100	100	100	100	100	100
Foreign exchange derivatives	*(% flow)*	70	70	70	70	70	70	0	0
Equity and credit derivatives	*(% flow)*	100	100	100	100	100	100	100	100
Forward asset sales	*(% flow)*	100	100	100	100	100	100	100	100
Other derivative transactions	*(% flow)*	0	0	0	0	0	0	0	0
Other assets off balance sheet	*(% flow)*	0	0	0	0	0	0	0	0

Source: IMF staff calculations and assumptions.
Notes: W denotes weeks, M denotes months and Y denotes years.
1/ Including mark-to-market gains/losses and intercompany balances.

The model defines liquid assets at date t to be

$$LA_t = LA_{t-1} + \sum_i \phi_{i,t} a_{i,t} - \sum_j \chi_{j,t} l_{j,t} - \sum_k \psi_{k,t} L_k,$$

where $a_{i,t}$ is the amount of asset i that is contractually receivable at date t, $l_{j,t}$ is the amount of liability j that is contractually payable at date t, L_k is the value of liability k at the start date ($t = 0$), $\phi_{i,t}$ is the roll-off rate of asset i at date t, $\chi_{j,t}$ is the run-off rate of liability j at date t as a fraction of the amount contractually payable (flow) for that liability at that date, and $\psi_{k,t}$ is the run-off rate of liability k at date t as a fraction of the initial value (stock) of that liability. The interpretation of ϕ is

the fraction of the amount contractually receivable that is actually received as cash inflow, given that a large remaining fraction may be refinanced by the bank (i.e., rolled over) or may face delays in being received under the adverse scenario. The interpretation of χ is analogous. The interpretation of ψ is the fraction of the initial value of the liability that becomes due.[2] The initial liquid assets are further calculated as

$$LA_0 = \sum_h \upsilon_h A_h$$

where A_h is the value of liquid asset h at the start date and $1 - \upsilon_h$ is the haircut of liquid asset h. The interpretation of the haircut is the cash value under the adverse scenario of one dollar of initial value of the asset, given that asset prices may fall in the adverse scenario or that assets need to be pledged to the central bank at a discount in order to secure standing facilities against them. Items A_h and L_k are provided as of the start date in balance sheet data and items $a_{i,t}$ and $l_{j,t}$ are provided as of the start date in contractual cashflow tabular data. The scenario of the stress test is the specification of the υ, ϕ, χ and ψ.

Staff calibrate run-off rates for deposits (including interbank and intragroup deposits) to a two-standard deviation episode in historical data. Given the large number of parameters that must be calibrated and the lack of available data, stress tests typically apply judgement to arrive at parameter assumptions (informed by anecdotal evidence in the literature) and sometimes specify multiple scenarios. However, this technical note advances this methodology by explicitly estimating some run-off rates according to a two-standard deviation episode in historical data. For demand deposits, the run-off rate ψ up to one month (as a fraction of the initial value) is $1 - \exp(-2\sigma)$, where σ is the volatility of month-on-month changes in the natural logarithm of deposit balances. The run-off rates ψ within one month are assumed proportionally, given a lack of higher-frequency data. The run-off rates ψ in the 1-3 month window are similarly calculated as $[1 - \exp(-2\sigma_3)] - [1 - \exp(-2\sigma_1)]$, where σ_n is the volatility of n-month changes in the natural logarithm of demand deposit balances.[3] This method is used to calibrate the run-off rates of demand and 'other' deposits. For fixed deposits, the run-off rates are specified as a fraction of the contractually payable amount χ, so these volatility-based run-off rates (ψ) are scaled by the residual time-to-maturity profile of fixed deposit liabilities. In this way, run-off rates are estimated separately for demand, fixed and other deposits and for the government, statutory boards, non-bank financial institutions, non-financial firms and individuals. Run-off rates are estimated on aggregate deposit balances for all D-SIBs (due to confidentiality) and then applied in the stress test symmetrically to every D-SIB. Since data on deposit balances are only available at the quarterly frequency, the one-month volatility of deposits is estimated from the n-month volatilities ($n = 1,2,3,4$) using the model

$$\sigma_n = \sigma_1 \sqrt{n[1 + (n-1)\rho]}$$

[2] Liabilities are classified into those that receive an outflow rate χ as a fraction of the flow and those that receive an outflow rate ψ as a fraction of the initial value.

[3] Typically, $\sigma_n > \sigma_{n-1}$, but if not, then we set the run-off rate to zero.

where ρ is the correlation between one-month changes in (log) deposit balances. This model arises if we assume that one-month changes in (log) deposit balances are identically distributed with correlation ρ (Catalán and Sher, 2019). Run-off rates for interbank and intragroup deposits at Singapore banks are estimated using quarterly data that other countries report as claims on Singapore in the BIS' Locational Banking Statistics database. This analysis supported the view that intragroup funding is less volatile than interbank funding, and these volatilities can be inferred from the run-off rates of the Appendix Table VIII.3. Roll-off rates on interbank and intergroup deposit amounts contractually receivable are matched to the run-off rates on amounts contractually payable.

Run-off rates for foreign exchange derivatives are calibrated to a two-standard deviation deterioration in liquidity conditions. Run-off and roll-off rate assumptions for foreign exchange derivatives are important given their size. For D-SIBs in aggregate (and in all currencies), amounts contractually payable on foreign exchange derivatives are equivalent to 11 percent of total assets within one week, 23 percent within one month and 35 percent within three months.[4] These amounts are very closely matched to amounts contractually receivable on foreign exchange derivatives, so that liquidity risk is negligible in the aggregate (and in all currencies), but not necessarily for every individual bank in each currency. Given that FX swaps are traded OTC trade volume data are not available. Therefore, staff proxy liquidity conditions using bid-ask spreads in USDSGD FX forward contracts.[5] Staff calibrate the run-off rate on foreign exchange derivatives to a two-standard deviation deterioration in these liquidity conditions using $1 - \exp(-2\sigma)$, where σ is the estimated volatility of week-on-week changes in the natural logarithm of the bid-ask spread. The resulting run-off rate of 70 percent is similar to that used in the 2017 Japan FSAP. The roll-off rate on foreign exchange derivative amounts contractually receivable is set at the same value.

The test assumes limited room for banks to take steps to enhance their liquidity under the adverse scenario. The test allows banks not to refinance about half of the loans that customers repay. After applying haircuts, it allows banks to count their entire portfolio of government bonds toward their liquid assets, even where those bonds mature beyond the horizon of the adverse scenario. The tests make no assumption about the order in which assets are liquidated. Due to data limitations, it is not possible to separate reserve requirements from liquid assets, and therefore banks can use their reserve requirements to meet obligations under the adverse scenario.

[4] Since most foreign exchange swaps are FX swaps (rather than cross-currency basis swaps), settlement at maturity is based on gross notional amounts rather than net changes in market values.

[5] These data are available at a daily frequency from Bloomberg.

Appendix Table VIII.3. Run-off rates on liabilities in the long-term scenario of the cashflow-based liquidity stress tests.

	units	1W	1-2W	2-3W	3W-1M	1-3M	3-6M	6M-1Y	1-2Y
Demand deposits of									
Singapore govt and statutory boards	*(% stock)*	23	11	9	9	2	0	0	0
Other governments	*(% stock)*	16	8	6	6	3	1	0	0
Non-bank financial institutions	*(% stock)*	7	3	3	3	2	2	0	0
Non-financial corporates	*(% stock)*	2	1	1	1	2	3	0	0
Individuals	*(% stock)*	2	1	1	1	5	5	0	0
Fixed deposits of									
Singapore govt and statutory boards	*(% flow)*	100	100	100	100	87	69	35	17
Other governments	*(% flow)*	100	100	100	100	66	66	33	17
Non-bank financial institutions	*(% flow)*	23	23	23	23	18	20	10	5
Non-financial corporates	*(% flow)*	11	11	11	11	10	11	6	3
Individuals	*(% flow)*	10	10	10	10	12	14	7	4
Other deposits of									
Singapore govt and statutory boards	*(% stock)*	44	22	16	16	1	0	0	0
Other governments	*(% stock)*	41	20	15	15	6	2	0	0
Non-bank financial institutions	*(% stock)*	26	13	10	10	6	8	0	0
Non-financial corporates	*(% stock)*	15	7	6	6	9	8	0	0
Individuals	*(% stock)*	10	5	4	4	12	9	0	0
Repurchase agreements	*(% flow)*	5	5	5	5	5	5	0	0
Negotiable certificates of deposits issue	*(% flow)*	80	80	80	80	60	60	50	50
Debt securities issued /2	*(% flow)*	80	80	80	80	60	60	50	50
Interbank obligations	*(% stock)*	10	5	4	4	15	9	0	0
Intragroup obligations	*(% stock)*	7	3	3	3	11	8	0	0
Bills payable	*(% flow)*	80	80	80	80	60	60	50	50
Subordinated debt	*(% flow)*	80	80	80	80	60	60	50	50
Other liabilities on balance sheet /1	*(% flow)*	100	100	100	100	100	100	100	100
Interest rate derivatives	*(% flow)*	100	100	100	100	100	100	100	100
Foreign exchange derivatives	*(% flow)*	70	70	70	70	70	70	0	0
Other derivative transactions	*(% flow)*	100	100	100	100	100	100	100	100
Guarantees /3	*(% stock)*	2	3	2	2	2	2	0	0
Bills for collection	*(% flow)*	100	100	100	100	100	100	100	100
Forward asset purchase	*(% flow)*	100	100	100	100	100	100	100	100
Underwriting commitments	*(% flow)*	100	100	100	100	100	100	100	100
Other liabilities off balance sheet	*(% flow)*	100	100	100	100	100	100	100	100

Source: IMF staff calculations and assumptions.
Notes: W denotes weeks, M denotes months and Y denotes years.
1/ Including mark-to-market gains/losses and intercompany balances.
2/ Excluding certificates of deposit.
3/ Including guarantees, warranties, indemnities, endorsements, unutilised commitments and undisbursed credit facilities.

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