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Australia: Addressing Systemic Risk Through Higher Loss Absorbency—Technical Note

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FINANCIAL SECTOR ASSESSMENT PROGRAM UPDATE

AUSTRALIA

ADDRESSING SYSTEMIC RISK THROUGH HIGHER LOSS ABSORBENCY

TECHNICAL NOTE

NOVEMBER 2012

INTERNATIONAL MONETARY FUND
MONETARY AND CAPITAL MARKETS DEPARTMENT

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GLOSSARY

APRA	Australian Prudential Regulation Authority
BCBS	Basel Committee on Banking Supervision
CDS	Credit Default Swap
D-SIB	Domestic Systemically Important Bank
EDF	Expected default frequency
GDP	Gross Domestic Product
GFC	Global Financial Crisis
G-SIB	Global Systemically Important Bank
HLA	Higher loss absorbency
IMF	International Monetary Fund
RWA	Risk Weighted Assets

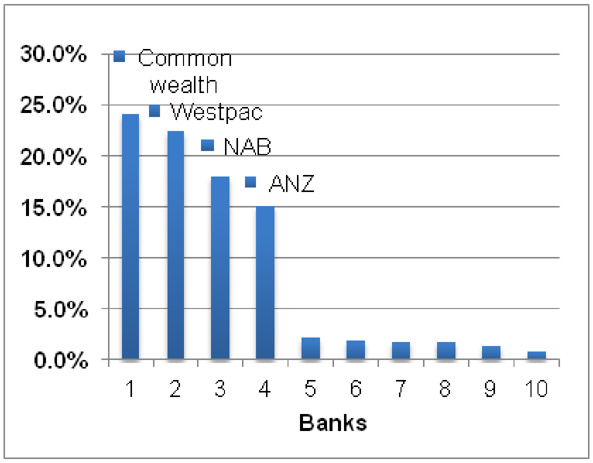
I. Executive Summary

Australia's four largest banks can be considered domestically systemic. They make up the lion's share of the banking system, use similar business models, and are interconnected. The top four banks are relatively similar in terms of systemic importance, partly reflecting the authorities' "four pillar" policy, which aims at preventing the number of large banks from falling below four. To deal with systemic risks, the authorities deploy a multi-pronged approach consisting of risk-based supervision, recovery and resolution planning, and conservative risk weights and definitions of loss-absorbent capital. Most countries that have already identified strategies to deal with their systemic institutions incorporate higher loss absorbency for systemic institutions in their approach. Market based methodologies using the expected default frequency for systemic institutions can gauge the amount of additional capital—higher loss absorbency—required to reduce the probability of failure of systemic institutions to an acceptable level. Alternatively, the implied funding cost advantage can indicate the degree of systemic importance and be used to define higher capital requirements to offset this implicit subsidy. Application of these methods to Australian banks provides a range of estimates of higher loss absorbency requirements for systemic institutions and a transparent framework for discussion and selection of these requirements.

II. Defining Systemic Importance

1. **Defining domestic systemic importance for financial institutions is relatively straightforward in Australia.** Banks dominate the financial system and the four largest banking groups stand head and shoulders above the rest (Figure 1). Australia's top four institutions hold assets close to 200 percent of GDP, putting the country in the middle in an international comparison (Figure 2). However, Australia's banking system is much more concentrated than that of other countries, with the top four institutions accounting for almost 80 percent of resident assets (Figure 3).

Figure 1. Top Ten Banks (share of resident assets, March 2012)



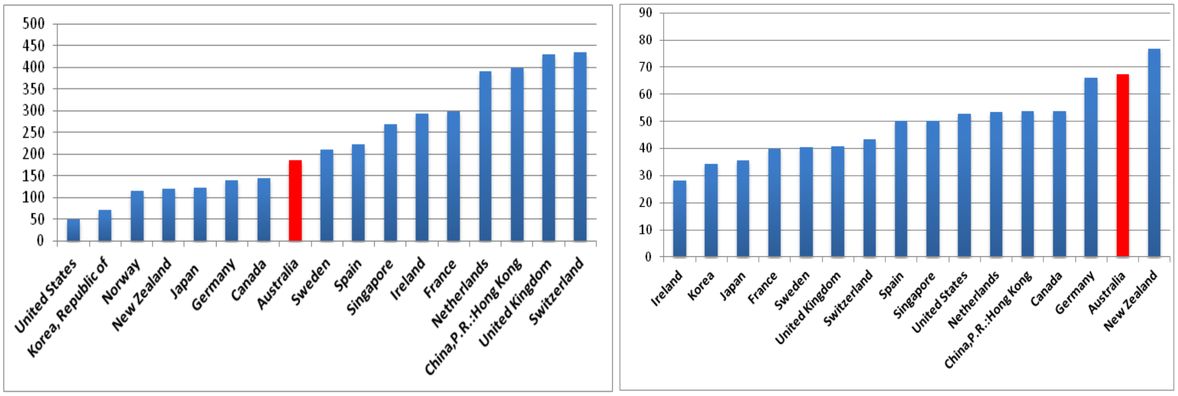
Source: APRA.

2. **Size is not the only criterion to determine systemic importance.** At the global level, systemically important banks (G-SIBs) have been identified using an indicator methodology that also includes interconnectedness, substitutability/infrastructure, complexity and cross-jurisdictional activity. None of the Australian banks were found to be systemically important from a global perspective.

3. **The Basel Committee on Banking Supervision (BCBS) is consulting on a framework to identify domestic systemically important banks (D-SIBs).** While the proposed approach is principle based and emphasizes the need to allow for national discretion in determining systemic importance, it suggests that the framework for D-SIBs be complementary to that of G-SIBs and take into account externalities and the need to maintain a level playing field.

Figure 2. Bank Concentration: Assets of the Largest Four Banks

As percent of GDP, 2011 **As percent of Total Banking Assets, 2010**



Source: IMF. Source: SNL.

4. **Similar indicators to global systemic importance have been proposed to assess domestic systemic importance but with the domestic economy as the reference system:** size, interconnectedness, substitutability/financial institution infrastructure (including consideration on the concentrated nature of the banking system), and complexity (including the additional complexities from cross-border activity). The BCBS proposes that the authorities provide an outline of the methodology used to assess domestic importance.

5. **Applying various metrics for these indicators to the case of Australia unambiguously establishes the four largest banks as systemically important.** Some smaller banks may be regionally important, but as the recent case of the acquisition by the Commonwealth Bank Group has shown, their activities can relatively easily be taken over by the rest of the banking system, subject to competition policy requirements. One smaller institution provides payments infrastructure services to a large number of credit unions, but its size means it is unlikely to be systemic.

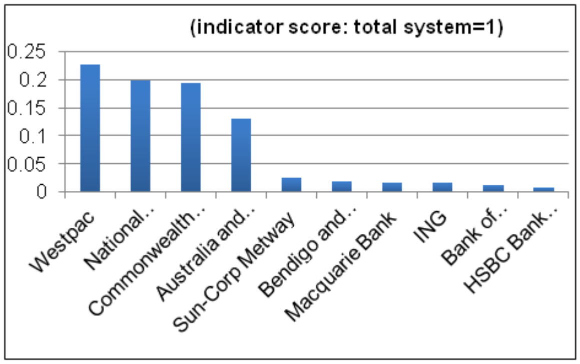
6. **Braemer and Gischer (2012) use publicly available indicators to establish the domestic systemic importance of Australia's banks.** They translate the G-SIB approach to D-SIBs by substituting a measure of the impact of a bank on domestic sentiment for cross-jurisdictional activity and use the bank's market share of loans to various sectors of the economy as an indicator of non-substitutability (Table 1). These indicators are highly correlated with others used in their analysis, and the indicator for non-substitutability is of especially doubtful quality. Removing them only slightly modifies the relative systemic importance of banks (Table 2, Braemer-Gischer-3 column).

Table 1. Indicator Approach to Systemic Importance

Category	**G-SIBs**	**D-SIBs**			
	BCBS approach (1/5 each)	Braemer-Gischer approach-5 (1/5 each)	Braemer-Gischer-3 (1/3 each)	IMF-BCBS Approach (1/3 each)	IMF-BCBS + Qualitative information (1/3 each)
Size	*Total exposures as defined for use in the Basel III leverage ratio*	Total resident assets			
Interconnectedness	Intra-financial system assets Intra-financial system liabilities Wholesale funding ratio	Loans to financial corporations Deposits from financial corporations		Investment securities Wholesale funding Loan deposit ratio Intra-group exposures	
Non-Substitutability	Assets under custody Payments cleared and settled through payment systems Values of underwritten transactions in debt and equity markets	Loans to households Loans to non-fin. corporations Loans to the general government Loans to community service and non-profit organizations	*not included*		
Complexity	OTC derivatives notional value Level 3 assets Held for trading and available for sale	Investment securities Trading securities		Trading book	Trading book + qualitative information
Cross-jurisdictional activity	Cross-jurisdictional claims Cross-jurisdictional liabilities	*not included*			
Domestic sentiment	not included	Deposits from households	*not included*		

Sources: Braemer and Gischer 2012, IMF Staff calculations.

Figure 3. Relative Systemic Importance of Domestic Banks



Source: IMF Staff Calculations (Table 2, last column).

7. **Non-substitutability, interconnectedness, and complexity are characteristics that are subject to judgment and likely to differ across financial systems.** In the case of Australia, varying the indicators used for these features changes the relative ranking of systemic importance of the institutions to some degree, but does not alter the finding that the same four institutions are systemically important (Table 2, IMF-BCBS column, which emphasizes wholesale funding and loan-to-deposit ratios for interconnectedness and the trading book for complexity). A more accurate assessment is likely to require the use of information that is not publicly available as well as non-quantifiable elements of systemic importance (as an illustration see Table 2, IMF-BCBS + Qualitative information[1]). Nonetheless, there is little doubt that the four large banks are systemic for the domestic economy (Figure 3).

8. **An alternative way to judge systemic importance is to rely on rating agencies' views about the likelihood of government support.** Support ratings (Fitch) and uplift (Moody's) broadly confirm the assessment reached on the basis of the other indicators, but they are not fully identical, allow limited differentiation, and assign higher systemic relevance to certain other banks (Table 3). Moreover, ratings are available only for a minority of financial institutions.

[1]As an illustration, a rating from 1 to 5 (squared) is added to the complexity indicator. For banks rated by rating agencies, the inverse of the Fitch support rating was used; unrated banks were assigned the lowest support rating.

Table 2. Indicators of Systemic Importance for Banks

Name	Braemer-Gischer-5	Braemer-Gischer-3	IMF-BCBS	IMF-BCBS +Qualitative information
Westpac	0.236	0.241	0.238	0.228
Commonwealth Bank	0.234	0.209	0.194	0.193
National Australia Bank	0.182	0.193	0.249	0.199
Australia and New Zealand Bank	0.146	0.141	0.126	0.130
Suncorp Metway	0.023	0.021	0.024	0.026
Macquarie Bank	0.020	0.027	0.010	0.017
ING	0.019	0.013	0.015	0.016
Bendigo and Adelaide	0.018	0.012	0.016	0.018
Bank of Queensland	0.015	0.010	0.015	0.013
HSBC Bank Australia	0.008	0.008	0.005	0.008
Other	0.098	0.126	0.109	0.152
Total	1.000	1.000	1.000	1.000

Source: IMF Staff Calculations

Rising relative ranking compared to first column

Declining relative ranking compared to first column

Table 3. Support Ratings for Banks

	Fitch support rating	Fitch rating floor	Moody's uplift	Moody's standalone
Australia & New Zealand Banking Group	1	A	2	A1
Commonwealth Bank of Australia	1	A	2	A1
National Australia Bank Limited	1	A	2	A1
Westpac Banking Corporation	1	A	2	A1
Bendigo and Adelaide Bank Limited	3	BB	1	A3
Macquarie Bank Ltd.	3	BB	2	Baa1
Suncorp-Metway Limited	3	BB+	1	Baa2
Bank of Queensland	3	BB	1	Baa1

Source: Fitch and Moody's 2012

III. Systemic Importance and Higher Loss Absorbency

9. **On a comparable basis, total Tier 1 capital of Australia's major banks is about average among a peer group of systemically important banks (Figure 4).** This group consists of 47 universal and commercial banks (excluding investment banks) from 16 countries. Data for Australia's major banks has been adjusted (upward) to reflect APRA's conservative approach to risk weights compared to Basel II. This may still underestimate the conservatism in capital ratios given APRA's approach to capital deductions.

10. **Most countries that have already identified strategies to deal with their systemic institutions incorporate higher loss absorbency for systemic institutions in their approach (Table 4).** The "Swiss finish" establishes a total capital requirement for the two very large Swiss G-SIBs of 19 percent of risk weighted assets (RWA), of which up to 9 percent can be contributed in the form of contingent capital. The Swiss justify their

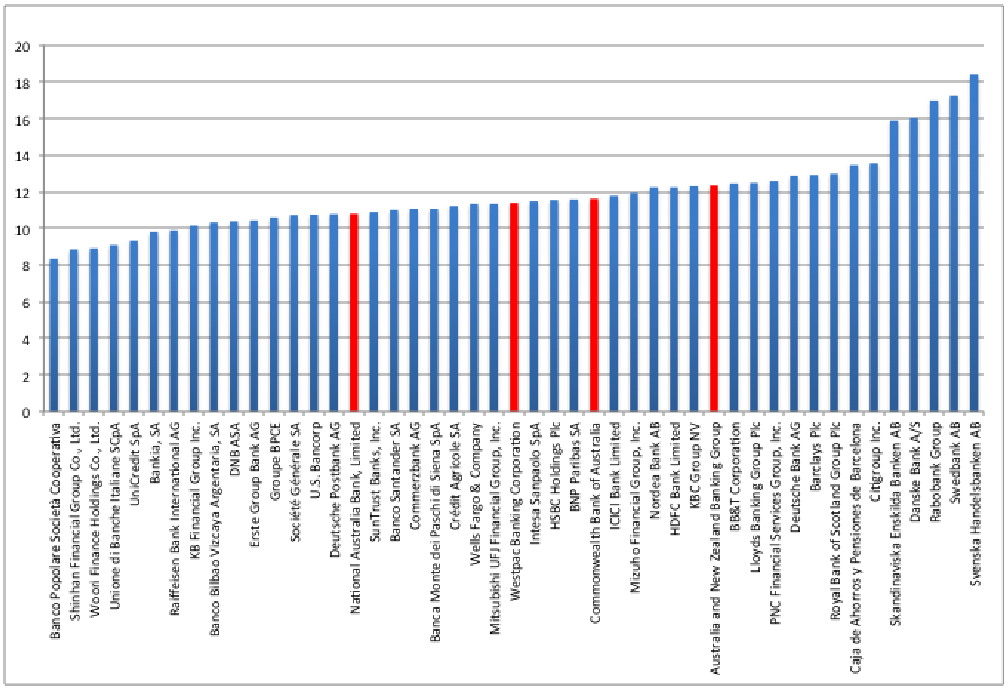
approach by the need to "prevent an insolvency of these banks or at least ensure the possibility of orderly resolution of the bank in question, including the continuation of systemically important functions."

Table 4. Cross-Country Comparison of Approaches to D-SIBs

Country	***HLA***	***Special Supervision***	***Structural Measures***	***Recovery and Resolution Planning***	***Other Measures***
Austria	Adoption of Basel III by January 2013; additional 3 percent by 2016	Monitor loan to local stable funding ratio	No	Yes	
Canada	No, but accelerated implementation of the CET1 standard of 7 percent: January 2013	Additional reporting requirements	No	Yes	
Korea	Additional capital for D-SIBs likely				
Singapore	2 percent additional by 2015				
Sweden	Accelerated adoption of Basel III; plus 3 percent by 2013; 5 percent by 2015				Accelerated adoption of liquidity requirements
Switzerland	19 percent of RWA total capital, of which up to 9 percent cocos, by 2016		Caps on interbank claims and counterparty exposures	Yes	Progressive requirements in terms of absolute size and market share
United Kingdom	Proposal: 3 percent additional to Basel III and up to 17 percent of RWA loss absorbency for the largest institutions and ring-fenced entities		Proposed: ring fencing of retail deposit taking	Yes	
United States	Supplementary Tier 1 of 3 percent of RWA for complex institutions		Separation of proprietary trading; leverage ratios	Yes	Progressive requirements related to size

Source: Country authorities

Figure 4. Comparison of Tier 1 Capital with Peer Banks (percent of RWA)



Source: IMF LCFI database, Australian banks adjusted to equivalent risk weights, but not for other factors such as differences in capital quality or deduction regime.

11. **Countries focusing on D-SIBs have also established HLA requirements, albeit at lower levels:** Austria, Singapore, and Sweden have set supplementary capital requirements of 3 percent, 2 percent, and 5 percent, for domestically important institutions. Sweden's systemic banks already carry much higher capital levels than their peers (Figure 4). Other jurisdictions (e.g., Korea, United Kingdom, and United States) are contemplating higher capital requirements for systemic institutions, in some cases in addition to structural measures and scaled to size and complexity.

A. Capital, Insolvency Risk, and Funding Cost

12. **The desired level of loss absorbency depends on the degree of risk tolerance of the taxpayer.** The higher the amount of loss-absorbent capital relative to risk weighted assets, the less likely a bank will become insolvent and the lower the potential need for public support.[2] Countries like Sweden, Switzerland, and the United Kingdom are looking to set very high capital requirements precisely to minimize this risk and the amount of potential taxpayer support ultimately needed to be met by taxpayers should default occur. Conversely, the greater the likelihood a bank will receive public support (from a credible and sound

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[2]For this to hold, it is crucial that higher capital requirements do not induce banks to take more risk and thus that supervisors maintain a constant intensity of supervision regardless of capital levels.

sovereign); the lower will be its cost of funding. In both cases, investors perceive the institution to be equally safe, but in the first the burden is internalized through higher private capital, whereas in the second much of it is borne implicitly by the taxpayer.

13. **Using the relationship between market capitalization, funding costs, and the expected probability of default, there are at least two ways to internalize systemic risk through higher private capital.** First, one could define a level of risk appetite, i.e., an acceptable amount of dislocation from the failure of a financial institution, and use this level to equate the expected impact of failure between a systemic and a non-systemic institution. Because systemic institutions have a much higher impact upon failure, it becomes essential to ensure that they have a much lower probability of failure than non-systemic institutions. Second, an alternative is to estimate the funding cost advantage enjoyed by the institutions perceived to be implicitly supported by the public sector, and compute the additional capital required to offset this advantage.

14. **Moody's KMV's expected default frequency (EDF™) can be used for the purpose of gauging the desired level of capital to be held by a financial institution.** The methodology is based on the Black-Scholes-Merton contingent claims analysis (see Annex 1 for an exposition based on Bohn and Crosby 2003). The EDF is the estimated probability that a company will default within a given time horizon, where default means the failure to make a scheduled payment. The EDF depends on a firm's asset value, its volatility, and the distress barrier from the book value of liabilities (i.e., the point at which the value of assets of a company falls below the present value of promised payments on debt).[3] The exact methodology for the computation of the EDF is confidential, but it is based on a large real world database of default events and has a proven track record (Korablev and Qu, 2009).

15. **Relations between market capitalization and EDFs and CDS spreads, respectively, were computed for Australian banks, both individually and in a pooled sample.** The computations were based on daily data from June 22, 2011 through June 25, 2012 obtained from Moody's CreditEdge database. The EDF used is the one-year ahead default frequency (i.e., the likelihood of a missed payment within the next 12 months). The relationship between EDFs and market capitalization of the four largest banks is more robust than that between CDS spreads and market capitalization. CDS spreads are inherently more volatile, reflecting also general shifts in risk appetite that are unrelated to individual institutions.

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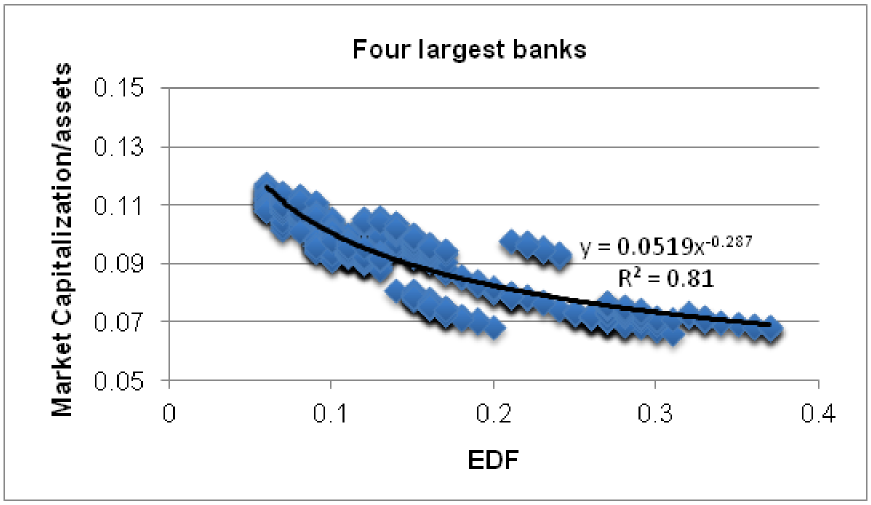
[3]Equity values and equity return volatility are actually used to represent the unobservable asset value and asset volatility.

Figure 5. Relationship between Market Capitalization and EDF (in percent)

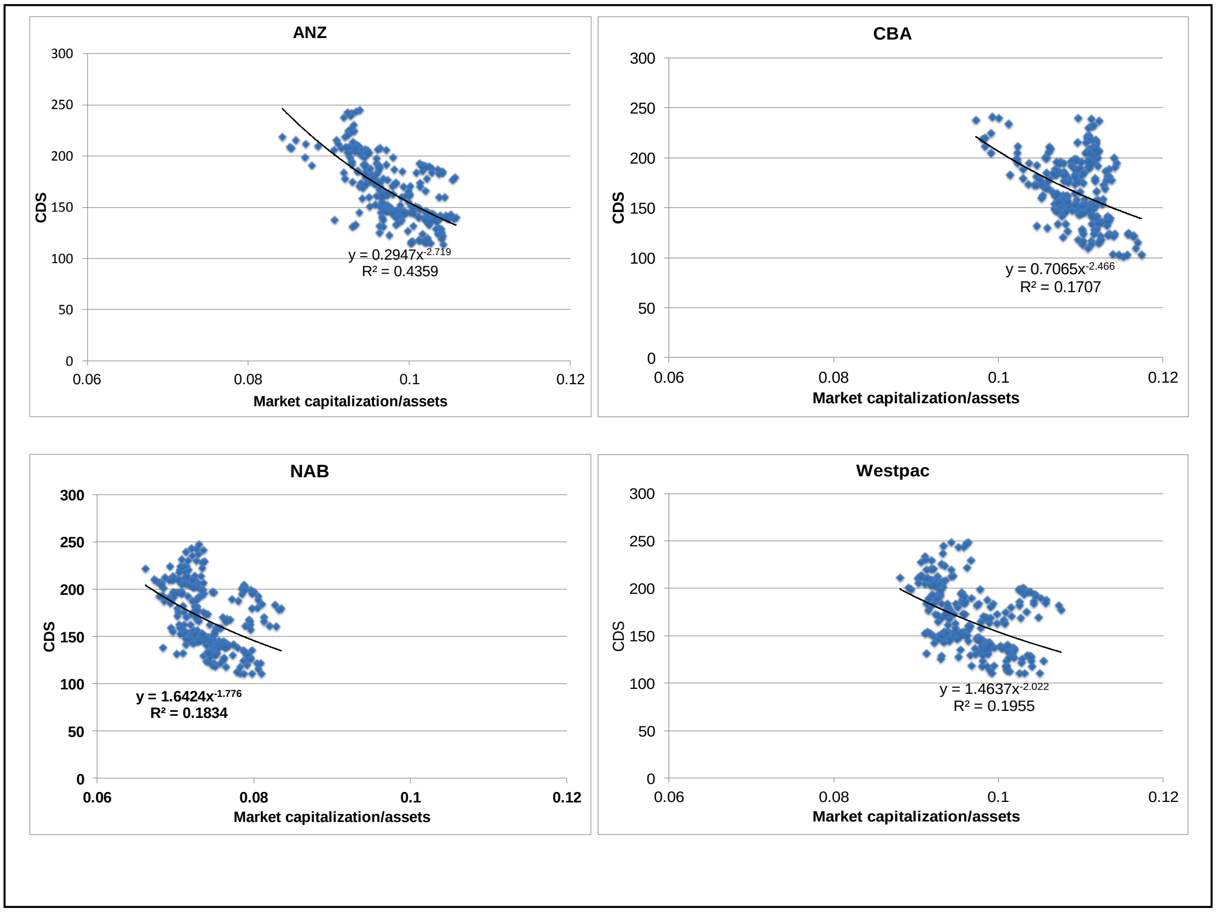


Source: Moody's CreditEdge and IMF staff calculations
Note: Sample period June 24, 2011-June 25, 2012, pooled sample

16. **The key is to find a relatively robust relationship among the variables of interest, consistent with theory.** Because the relationship between EDFs and market capitalization is highly non-linear, a power function was chosen. Its fit turns out to be relatively robust for the pooled sample over the full sample period with an R^2 of 0.81 (Figure 5). Removing outlying episodes improves the R^2 to 0.88 without significantly altering the estimated coefficients.[4] The robustness of bank-specific estimations is lower and varies considerably, with the R^2 ranging from 0.33 to 0.53 over the full sample and from 0.53 to 0.71 when outlying episodes are removed (Figure 6). Coefficients also change significantly for some banks with different sample periods. As expected, the inverse holds for the relationship between CDS spreads and market capitalization: here, pooling the data does not yield meaningful results, though panel estimates with fixed effects could remedy this drawback. Fits are also less robust for individual banks, but can be improved by removing outlying episodes with the R^2 ranging from 0.39 to 0.45 (Figure 7). These findings point to the need to interpret the data carefully and conduct further robustness tests, or alternatively specify more comprehensive models

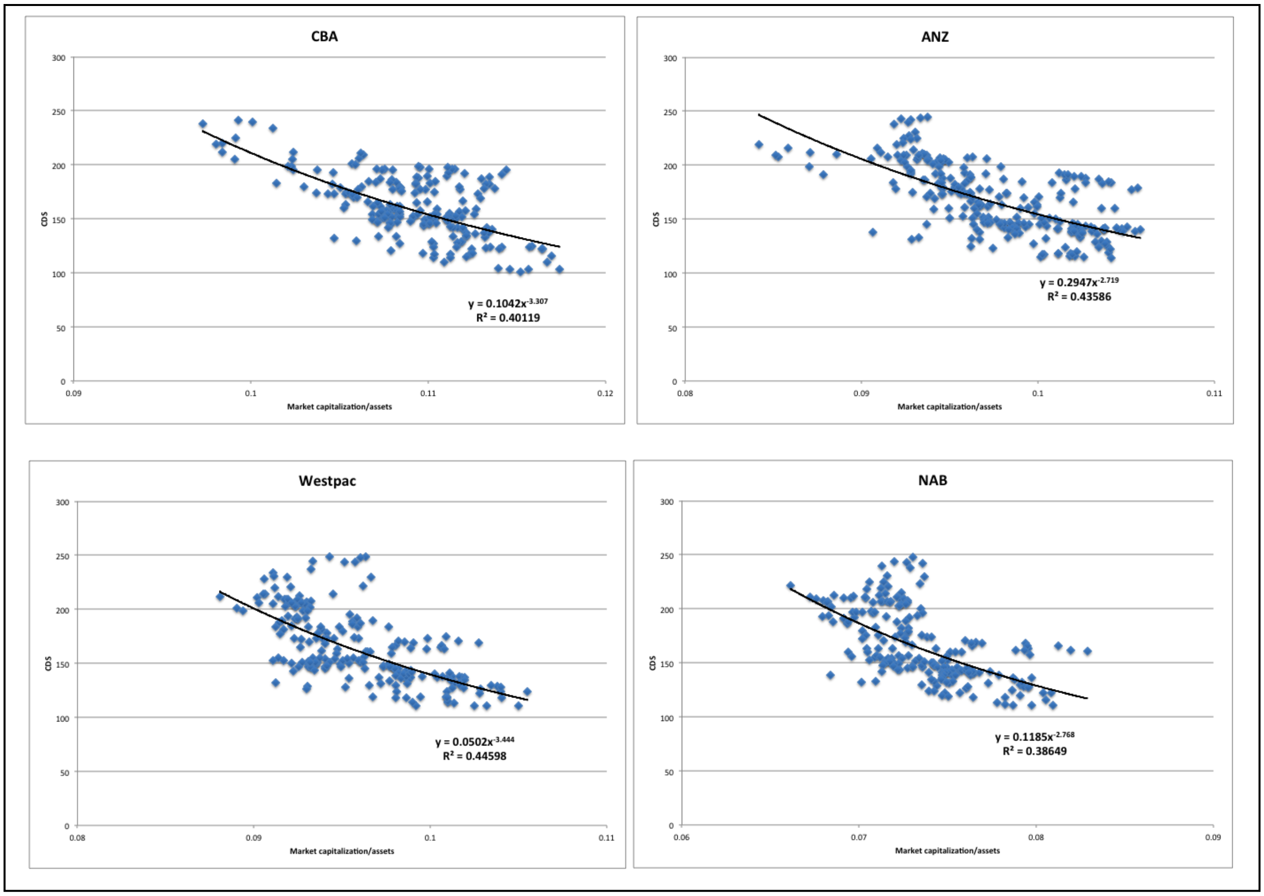
[4]Those where the intercept of the function is shifted significantly with respect to the sample median—the power function does not estimate an intercept.

Figure 6. Individual Banks Market Capitalization and EDFs (percent)



Source: Moody's CreditEdge and IMF staff calculations.
Note: Sample is daily data for ANZ June 24, 2011-May 18, 2012 and June 13-25, 2012; CBA June 24, 2011-April 18, 2012; NAB September 19, 2011-June 25, 2012; and Westpac June 24, 2011-June 25, 2012.

Figure 7. Individual Bank Market Capitalization and CDS Spreads (percent and basis points)



Source: Moody's CreditEdge and IMF staff calculations

Note: Sample daily data ANZ, June 24, 2011- June 25, 2012; CBA June 24, 2011-November 23, 2011 and January 27, 2012–June 25, 2012; NAB and Westpac June 24, 2011-September 16, 2011 and November 7, 2011–June 25, 2012.

B. Reducing Default Frequencies Through Higher Capital

17. **The link between market capitalization and expected default frequency can be used to compute the capital required to meet targeted default frequencies.** The choice of the tolerable default frequency or probability of survival depends on the risk appetite of the country and the supervisor.

18. **The desired probability of survival can be set in absolute or relative terms.** In the exercise below, 99.9 and 99.95 will be used to compute the capital required to meet these survival probabilities. The first is consistent with the threshold chosen for the capital requirements under the Basel agreements (from Basel II onward). The second is simply to illustrate much stricter requirements consistent with a lower risk appetite. An alternative is to set relative probabilities based on comparing systemic and non-systemic institutions. One

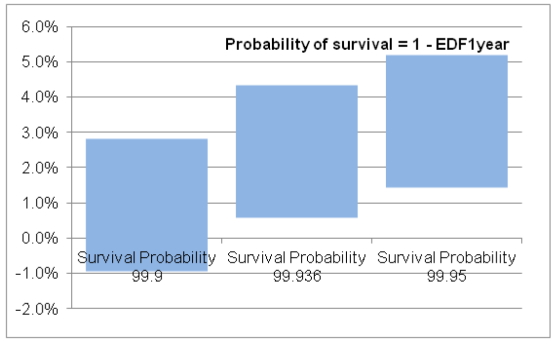
could, for example, assume that the impact of systemic failure is ten times that of a non-systemic bank and then require that the probability of failure of the systemic bank be no more than one-tenth of that of a non-systemic institution. Based on the estimated one-year ahead EDF of a small, representative non-systemic Australian financial institution, this would imply a desirable survival probability of 99.937, which falls between the two absolute values selected.

19. **Finally, it is necessary to relate market capitalization to regulatory capital requirements.** Market capitalization and total Tier 1 capital ratios turn out to be very similar in the case of the large Australian banks. This holds true if the supervisor's view of risk weights coincides closely with the market's view and Tier 1 capital is perceived to be of high quality. At the end of 2011, reported total Tier 1 capital averaged 10.1 percent of RWA whereas the ratio of market capitalization to the market value of assets averaged 9.4 percent. The ratio between these two was used to compute the total Tier 1 equivalent of market capitalization.

20. **Reflecting the non-linear relationship between market capitalization and EDFs, capital requirements become increasingly higher as the desired probability of meeting all payments rises (Figure 8).** Based on market data between June 2011-June 2012, accounting data of end-2011, and the pooled sample, all but one of the large four banks pass or nearly pass the lower hurdle (i.e., 99.9). However, in the most stringent case (i.e., 99.95) none of the banks would meet the requirement and additional HLA in terms of Tier 1 capital ranging from 1.4 percent to 5.2 percent of RWA would be needed. For the middle-case, HLA requirements would range from 0.6 percent to 4.3 percent of RWA.

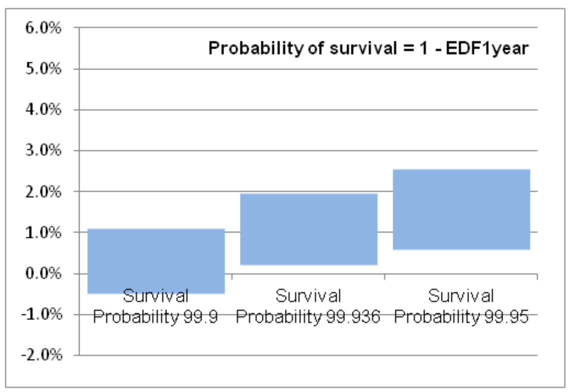
21. **It may be preferable to allow the relationship between market capitalization and EDFs to vary across systemic institutions (Figure 9).** This permits some idiosyncratic structural risk characteristics to be reflected in the supplementary capital requirements. The results of this exercise are qualitatively similar to the pooled sample, but the range of supplementary capital requirements is narrower. The most stringent case now yields a range of additional Tier 1 HLA between 0.6 percent and 2.5 percent of RWA, while in the middle case, using the relative comparator; one bank's additional requirements are small (0.2 percent) while for the other three, additional capital lies in the range of 1.5 to 2.0 percent of RWA.

Figure 8. HLA Requirements for Systemic Banks-Pooled Estimate (Tier 1 in percent of RWA)



Source: IMF staff calculations
Note: Range of excess (-)/shortfall (+) of capital to meet desired probabilities for largest four banks

Figure 9. HLA Requirements for Systemic Banks-Bank Specific Estimates (Tier 1 in percent of RWA)



Source: IMF staff calculations
Note: Range of excess (-)/shortfall (+) of capital to meet desired probabilities for largest four banks

C. Compensating the Funding Cost Advantage of Systemic Institutions

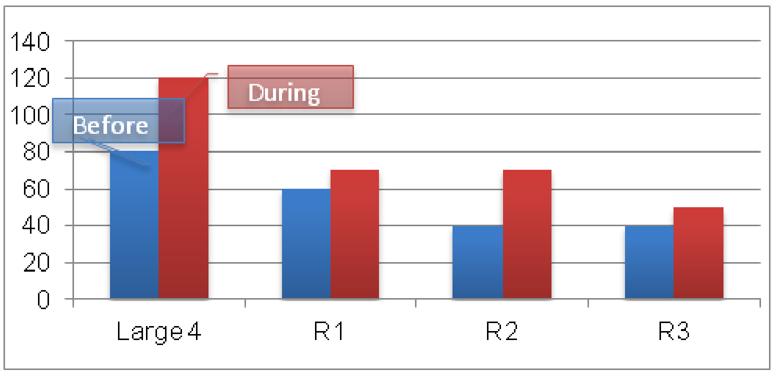
22. **Investors assume that systemic institutions can count on government support, and will therefore accept a lower yield compared with that required for funding non-systemic banks.** This cost difference leads to a competitive advantage for systemic institutions in wholesale funding markets, which provides them with the means and the incentive to become even more systemic. To offset this tendency, one could charge systemic banks a fee to offset this implicit support. Alternatively, if such fees are deemed not to be desirable, one could require systemic banks to hold more capital to the point that their systemic advantage vanishes.

23. **Computing the supplementary capital needed to offset the funding advantage of systemic institutions requires:** 1) an estimate of the funding cost advantage for each

institution; 2) an estimate of the relationship between funding costs and capitalization (see Figure 7); and 3) an estimate or an assumption about the impact of the higher capital requirement on the market structure.

24. **Ueda and Weder di Mauro (2012) use information from rating agencies to estimate the funding cost advantage for systemic banks.** Rating agencies distinguish between overall ratings and unsupported ratings. The difference between the two sets of ratings is a measure of implicit support. Rating agencies also distinguish between support from governments and support from parent institutions. Thus the public support component can be used as a proxy for the implicit support for systemic institutions.[5]

Figure 10. Funding Cost Advantages For Large Banks (basis points)



Source: Ueda and Weder di Mauro (2012) based on Fitch support ratings
Notes: R1-R2 different groups of regional banks

25. **Using this methodology for Australian banks, three different support levels can be identified.** The four large banks are estimated to have a wholesale funding cost advantage of about 80 basis points prior to the global financial crisis (GFC) and 120 basis points in 2009, during the GFC (Figure 10). Two sets of regional banks enjoyed advantages of 60 and 40 basis points before the GFC and 70 and 50 basis points during the GFC, respectively. Compared to international peers, the estimated wholesale funding advantage for Australian banks was about average before the global financial crisis and somewhat above average at the time of the crisis.[6]

26. **Because a funding advantage is relative, charging a fee (or the equivalent higher capital) equal to the difference in funding cost would be unduly severe.** Indeed, as the market share of those subject to a fee diminishes, that of the non-systemic institutions rises.

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[5]There are alternative methods to compute the implicit subsidy enjoyed by systemic banks (see Nuss and Sowerbutts, 2012). All methods involve some degree of subjective judgment.

[6]The sample included all rated Australian institutions. For a complete overview see Ueda and Weder di Mauro (2012).

In the absence of a detailed study on how market shares would evolve in the Australian context, the analysis uses a parameter of 0.7. This means that 70 percent of the fee needs to be imposed to offset the market dominance of the four large banks. However, since this parameter is a scalar, adjusting the estimates to reflect different views about the impact of the additional HLA on market structure is straightforward.

27. **On balance, this exercise yields more uniform results than the previous exercise with similar orders of magnitude of HLA requirements.** At the end-2011 average level of capitalization (10.1 percent of RWA), to offset 80 basis points worth of funding advantage, additional capital in the range of 1.2 percent to 1.6 percent of RWA is required. This rises to a range of 1.8 to 2.4 percent to offset 120 basis points. A drawback of the method is that the level of the required HLA varies inversely and in a non-linear way with the actual level of market capitalization. It is thus prudent to evaluate it near the observed sample average of key variables.

IV. Concluding Remarks

28. **By any metric, Australia's four largest banks appear to be of systemic importance in a domestic context.** With similarities in business models and common exposures, shocks are likely to impact these banks in a similar way. The resolution of one of the large banks following an idiosyncratic shock may increase the importance of the other banks and raise their degree of systemic importance.

29. **An international consensus has developed that systemic risks require heightened attention.** The approach to G-SIBs is being extended to D-SIBs in a manner that leaves authorities the necessary flexibility to adapt their approach to domestic systemically important banks to national circumstances. Essential elements of this approach are: heightened supervision, strong recovery and resolution planning, and higher loss absorbency for systemic institutions.

30. **HLA requirements for systemic institutions can be determined in different ways. Two potential ways explored in this paper are:** to set a desirable survival probability for systemic institutions that is more stringent than for other institutions given the larger impact of failure of a systemic institution; and to offset any funding advantage enjoyed by systemic institutions. The first approach—based on targeting an expected default probability—is more robust, requires no judgment other than setting the desired EDF and modeling its behavior, and can allow for institution specific characteristics within the group of the four large banks. The second method requires more steps, a judgment about the impact of HLA on market structure, and cannot differentiate between institutions beyond the differentiation made by rating agencies in terms of implicit public support. Both methods allow variations over time and states of the world, and permit adjustments based on supervisory judgment.

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Annex 1. Contingent Claims Analysis

Contingent claims analysis is a generalization of the option pricing theory pioneered by Black-Scholes (1973) and Merton (1973). Since 1973, the option pricing methodology has been applied to a wide variety of contingent claims. Contingent claims analysis is used to construct risk-adjusted balance sheets and is based on three principles: (i) the values of liabilities (equity and debt) are derived from assets; (ii) liabilities have different priority (i.e., senior and junior claims); and, (iii) assets follow a stochastic process. Assets (present value of income flows, proceeds from assets sales, etc.) are stochastic and over a horizon period may be above or below promised payments on debt, which constitute a default barrier. Uncertain changes in future asset value, relative to the default barrier, are the driver of default risk. Default occurs when assets decline below the barrier.

The CCA model assumes that the total market value of assets, A, at any time, t, is equal to the sum of its equity market value, E, and its risky debt, D. Asset value is stochastic and may fall below the present value of promised payments on debt, which constitute a default barrier, B. The value of risky debt is equal to default-free debt minus the present value of expected loss to creditors due to default. Default occurs when $A<B$. Equity value is the value of an implicit call option on the assets, with an exercise price equal to default barrier. The expected loss to bank creditors can be calculated as the value of an implicit put option, P, on the assets with an exercise price equal to B. The equity value, E, can be computed as the value of a call option:

$$E(t) = A(t)N(d_1) - Be^{-rT}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{A}{B}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \text{ and } d_2 = \frac{\ln\left(\frac{A}{B}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

where r is the risk-free rate, □ is the asset return volatility, and N(d) is the cumulative probability of the standard normal density function below d. In its basic concept, the model assumes that the implicit options are of the European variety, and set the time until expiry, T equal to the time horizon of interest, usually between one and five years.

The formula for the implicit put option is:

$$P_E(t) = Be^{-rT}N(-d_2) - A(t)N(-d_1)$$

Several widely-used techniques have been developed to calibrate the CCA models using a combination of balance sheet information and forward-looking information from equity markets. The market value of assets of financial institutions cannot be observed directly but can be implied using financial asset prices. From the observed prices and volatilities of market-traded securities, one can estimate the implied values and volatilities of the underlying assets in financial institutions. In the traditional Merton (1974) model, the calibration requires knowledge about value of equity, E, the volatility of equity, σ_E, and the distress barrier as inputs into equations $E = A_0 N(d_1) - Be^{-rT} N(d_2)$ and $E\sigma_E = A\sigma_A N(d_1)$ in order to calculate the two unknowns, the implied asset value A and implied asset volatility σ_A.

Once the asset value and asset volatility are known expected losses to bank creditors can be calculated. Asset value and asset volatility, together with the default barrier, time horizon, and the discount rate r, are used to calculate the values of the implicit put option, P_E, which is the expected loss to bank creditors. The expected loss to bank creditor's formula can be broken down into its key components. The formula for the implicit put option can be rearranged and decomposed into the (i) risk-neutral default probability (RNDP), (ii) loss given default (LGD), and (iii) the value of the default-free value of debt (B).

$$\boldsymbol{P_E = \underbrace{N(-d_2)}_{RNDP} \underbrace{\left(1 - \frac{N(-d_1)}{N(-d_2)} \frac{A}{Be^{-rT}}\right)}_{LGD} Be^{-rT}}$$

We can use the equations above to see that the spread can also be written as a function of the risk-neutral default probability (RNDP) and LGD, i.e.,

$$s = -\frac{1}{T} \ln\left(1 - RNDP \times LGD\right).$$

The yield to maturity on the risky debt, y, is defined by: $D = Be^{-yT}$.

The credit spread is defined as s = y – r, (r is the risk-free rate of interest), thus

$$\frac{D}{B} = e^{-yT} = e^{-sT} e^{-rT}$$

and hence

$$e^{-sT} = \frac{D}{Be^{-rT}} = \frac{Be^{-rT} - P_E}{Be^{-rT}} = 1 - \frac{P_E}{Be^{-rT}}$$

so the credit spread $s = -\frac{1}{T}\left(1 - \frac{P_E}{Be^{-rT}}\right)$.

In the 1990s a company called KMV adapted Merton's CCA approach for commercial applications to estimate Expected Default Frequencies (EDF^{TM}). The exact methodology is confidential, but the EDF credit measure is calculated using an iterative procedure to solve for the implied asset volatility (Bohn and Crosby, 2003). It uses an initial guess of volatility to determine asset value and de-lever the equity returns. The volatility of the asset returns are used as an input into the next iteration of asset values and asset returns until a convergence is obtained. In essence, the model used equity return volatility, equity values, distress barrier from book value of liabilities, and time horizon to get a distance-to-distress. This distance-to-distress was then mapped to actual default probabilities, called EDFs (expected default frequencies), using a database of detailed real world default events for many firms. Robustness checks show the model to be quite accurate and it is a leading indicator for default (see, e.g., Korablev and Qu, 2009).