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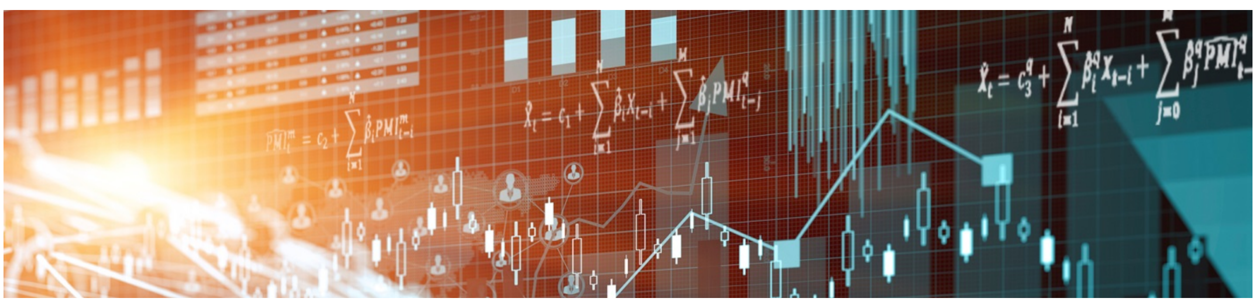
Implementing Market-Based Indicators to Monitor Vulnerabilities of Financial Institutions



by Cameron MacDonald, Maarten van Oordt and Robin Scott

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by

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Abstract

This note introduces several market-based indicators and examines how they can further inform the Bank of Canada's vulnerability assessment of Canadian financial institutions. Market-based indicators of leverage suggest that the solvency risk for major Canadian banks has increased since the beginning of the oil-price correction in the second half of 2014. This is in contrast to accounting-based leverage measures, which indicate a stable or improving trend. Similarly, measures of insolvency risk contingent on severe financial stress (i.e., market-based stress tests) indicate that the major banks are currently more vulnerable to a sudden adverse shock than they were in the summer of 2014. Finally, a measure of financial system interconnectedness and common exposures suggests a strong link between the major banks and the rest of the financial system, as expected. In other financial subsectors, the degree of interconnectedness has exhibited an upward trend over the last two decades.

JEL classification: G10; G21
Bank classification: Financial stability; Financial institutions

Résumé

Cette note analytique présente différents indicateurs de marché et examine en quoi ils peuvent contribuer davantage à l'évaluation, par la Banque du Canada, des vulnérabilités des institutions financières canadiennes. D'après les indicateurs de marché mesurant le levier financier, le risque de solvabilité des grandes banques canadiennes s'est accru depuis le repli des prix du pétrole amorcé au second semestre de 2014. Cette observation tranche avec la tendance à la stabilité ou à l'amélioration dont témoignent les indicateurs comptables. Dans le même ordre d'idées, les mesures du risque d'insolvabilité en cas de graves tensions financières (à savoir les tests de résistance appliqués aux marchés) montrent que la vulnérabilité des grandes banques à un choc défavorable inopiné est plus forte aujourd'hui qu'à l'été 2014. Enfin, à en juger par une mesure des interdépendances et des expositions à des facteurs de risque communs dans le système financier, il existe un lien étroit entre les grandes banques et le reste du système financier, comme on pouvait s'y attendre. Dans d'autres segments du système financier, le degré d'interdépendance a eu tendance à augmenter ces vingt dernières années.

Classification JEL : G10; G21
Classification de la Banque : Stabilité financière; Institutions financières

Introduction

The interpretation of market data in the context of monitoring the stability of financial institutions has become the subject of a rapidly developing academic literature.[1] Developments in this field have been further fuelled by the interest of numerous national and international bodies that are concerned with financial stability issues.[2] This literature has resulted in several new market-based indicators that can be used to monitor the vulnerabilities of financial institutions. These indicators are referred to as market-based because they rely to a large extent on market data (i.e., the prices of financial instruments such as stocks and derivative contracts).

The Bank of Canada regularly evaluates vulnerabilities in the Canadian financial system using the approach set out by Christensen et al. (2015). The basis of the Bank of Canada's vulnerability assessment incorporates a variety of quantitative and qualitative sources of information across several potential vulnerabilities. While market data and intelligence can inform the assessment in a more qualitative manner, market-based indicators may help to process such information in a structural manner in order to improve the assessment. In particular, market-based indicators can inform the Bank of Canada's vulnerability assessment in such areas as the solvency of financial institutions, their expected solvency in potential stress scenarios and structural vulnerability from interconnectedness and common exposures.

Pros and Cons

An advantage of market-based indicators is that they provide a forward-looking and almost real-time view since market prices are quick to reflect the changing expectations of market participants. In comparison, most accounting-based indicators are backward-looking and released with a significant time lag. The recording of accounting-based data is costly and sometimes requires methodological choices and expert judgment. Moreover, frequent changes in statistical definitions may result in challenges for cross-sectional comparisons or comparisons over time. In contrast, market data are usually easily accessible and relatively inexpensive and can also provide coverage of financial institutions for which we may lack comparable accounting-based data.

That being said, market-based indicators also have their disadvantages. As a result of random signals in market data and uncertainty inherent in the methodologies used to estimate them, market-based indicators may provide relatively noisy signals, which implies that small differences are often meaningless. Market-based indicators may also provide a false sense of safety because potential policy reactions can be incorporated in market prices. For example, low funding costs may not only be the result of creditworthiness but could also be the result of market participants' expectation of government support. Moreover, it is almost impossible to infer the direction of shock transmission when relying solely on market data; for example, correlated prices movements may be the result of either

[1] For two literature surveys, see De Bandt, Hartmann and Peydró (2012) and Bisias et al. (2012). The indicators discussed in this note are based on the work of, among others, Merton (1974), Hartmann, Straetmans and De Vries (2007), Acharya, Engle and Richardson (2012), Acharya et al. (forthcoming), Brownlees and Engle (forthcoming), Adrian and Brunnermeier (forthcoming), and Van Oordt and Zhou (2014).

[2] Many institutions with responsibilities that involve financial stability monitoring apply some of the market-based indicators discussed in this note; see, for example, Bank of Japan (2015, chart VI-1-7), European Central Bank (2015, chart 1), International Monetary Fund (2015, figure 3.16) and the Financial Stability Oversight Committee (2015, figure 7.8.5).

common exposures or may stem from interconnectedness. Finally, some accounting-based indicators used in the Bank of Canada's vulnerability assessment are based on confidential information and may provide a more detailed picture than is available to market participants.[3]

In summary, accounting- and market-based indicators both have their advantages and disadvantages. The usefulness of information obtained from a given indicator depends on the particular policy question and the situation at hand. In many situations, accounting- and market-based indicators may provide complementary views.

Scope of Indicators

The remainder of this note presents a synopsis of a selection of market-based indicators. These descriptions will be supplemented by concrete illustrations of potential applications of these indicators to Canadian financial institutions. The table in Appendix A provides computational details.

Table 1 classifies these indicators into three types based on how they may inform vulnerability assessments. The first type of indicators is related to leverage (e.g., the market-based capital ratio and the distance to default). These indicators provide insight into the stand-alone *leverage* or solvency of institutions. The second type of indicators covers the impact of a systemic stress scenario on the solvency of financial institutions (e.g., marginal expected shortfall [MES], systemic risk [SRISK] and exposure ΔCoVaR). These measures are essentially *market-based stress tests* that consider the expected performance of institutions in relation to the rest of the financial system suffering an extremely adverse shock. The third type of indicators focuses on the *interconnectedness* of the financial system (e.g., systemic linkage), that is, the strength of the relationship between an institution and the rest of the financial system in case of extremely adverse shocks, regardless of whether this relationship stems from potential common exposures or contagion.

Table 1: Vulnerabilities and Indicators

Vulnerability	Indicator
Leverage	- market-based capital ratio - distance to default
Leverage, interconnectedness (market-based stress test)	- marginal expected shortfall - SRISK - exposure ΔCoVaR
Interconnectedness	- systemic linkage

All of these indicators rely on data related to stock prices,[4] which is advantageous because this information is readily available for many institutions. However, these indicators are merely a subset of those covered by the literature; additional measures that rely on the market prices of options and other derivatives are available. Moreover, there is an emerging literature on market-based indicators that measure funding and liquidity vulnerabilities. Further exploring the use of other market-based indicators to gain a better understanding of vulnerabilities in the Canadian financial system is part of the continuous process to innovate the Bank of Canada's vulnerability assessment.

[3] From a communications perspective, this can also be considered as an advantage of market-based indicators.

[4] The stock price data for the results presented in this report have been collected using Thomson Reuters Datastream.

Leverage

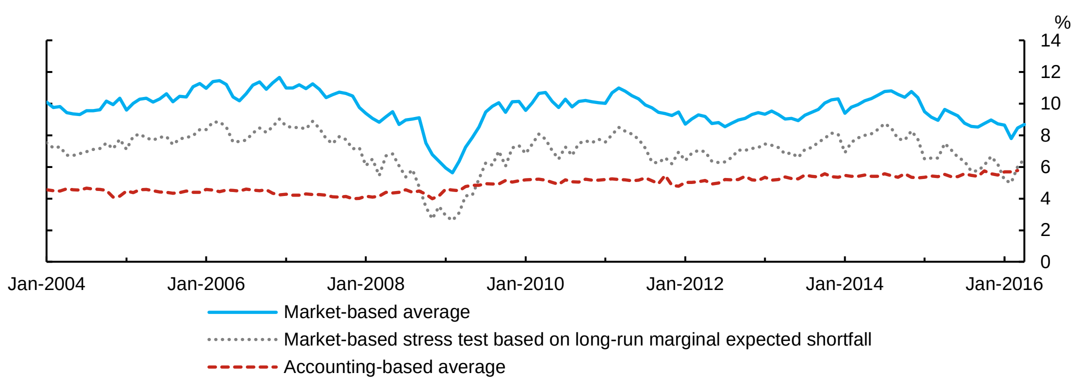
Market-based measures of solvency may simply provide a market equivalent of existing accounting-based measures of leverage (for example, the market-based capital ratio). Additionally, there are market-based solvency measures that do not have an accounting-based counterpart (such as the distance to default) but may nevertheless shed light on the insolvency risk of a given institution, at least from the perspective of market participants.

Market-based capital ratio

The market-based capital ratio is a measure of the size of a firm's capital buffer according to market valuations. A smaller buffer implies greater leverage and a higher degree of insolvency risk. More precisely, the market-based capital ratio is defined as the level of common equity as a percentage of total assets, both in terms of market values. The market value of total assets is calculated as the sum of the market value of common equity and the book value of total debt.

The solid line in **Chart 1** shows the average market-based capital ratio across the Big Six banks. The dotted line shows a stressed market-based capital ratio, which serves as an input to the SRISK calculation, as explained in the next section. Over the past decade the market-based capital ratio has been moving steadily within the range from 8 to 11 per cent, with a major exception during the financial crisis. In October 2008, the same month that the Bank of Canada announced exceptional liquidity measures, the ratio dropped from 9.1 to 7.5 per cent, reaching its deepest trough of 5.6 per cent in February 2009. In contrast, the accounting-based capital ratio (dashed line) shows remarkably little of the underlying concerns in this period. Since the start of the recent slide in oil prices in July 2014, the solvency of the Big Six banks has deteriorated somewhat by moving from the top to the lower end of the 8 to 11 per cent range.

Chart 1: Leverage: The capital ratio of the Big Six banks



Sources: Datastream and staff calculations

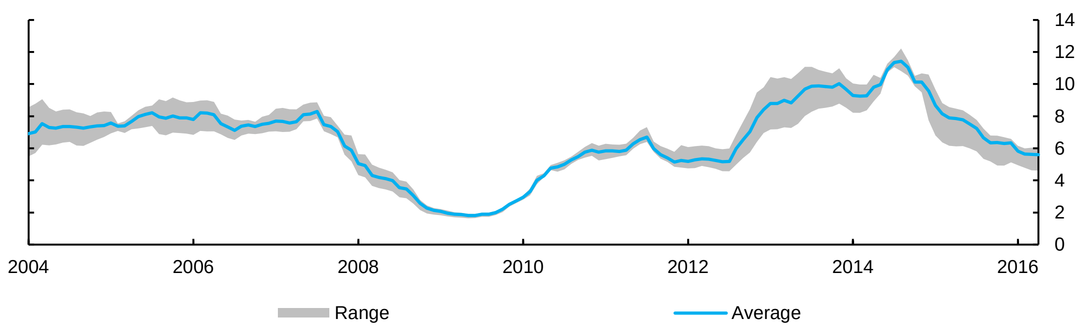
Last observation: April 2016

Distance to default

The distance to default is a proxy for the number of standard deviations in the value of a financial institution's assets that could erase its capital. A smaller distance to default indicates that a less extreme shock could potentially eliminate the institution's capital, which suggests a higher probability of default. Roughly, the distance to default is calculated as the difference between the market value of assets and the face value of debt, expressed as a ratio of the annualized volatility of the asset value. This measure relies on estimating the Merton model (Merton 1974).

The narrow range in **Chart 2** demonstrates that the movements in the distance to default have been very similar for each of the Big Six banks over the past decade. The distance to default confirms some deterioration in the solvency of Canadian banks since the start of the slide in oil prices. With a current average distance to default of 5.5, however, the distance to default is substantially higher than the average of 3.0 in September 2008.[5] Therefore, in terms of standard deviations, a shock triggering a potential default must now be more extreme. Judging from the distance to default, there is now less concern about the solvency of the Big Six banks, even though the market-based capital ratios are at similar levels to those in September 2008. (This is because the current level of volatility—the denominator of the distance to default—is lower.) Nevertheless, the downward trend in both the market-based capital ratio and the distance to default emphasize the importance of monitoring these developments in the near future.

Chart 2: Distance to default of the Big Six banks



Sources: Datastream and staff calculations

Last observation: April 2016

Market-Based Stress Tests

The measures mentioned above provide a market-based assessment of the solvency based on current market conditions. The question of solvency under alternative scenarios—such as a severe shock to the financial system—can be addressed by the following three measures. These measures can be considered as market-based stress tests.

Marginal expected shortfall

The MES is the expected loss of an institution on a day that the financial system[6] suffers a sudden adverse shock. The long-run marginal expected shortfall (LRMES) is a measure of an institution's expected cumulative loss of equity over a prolonged period conditional upon a large shock in the financial system. The higher the MES (or LRMES), the greater the expected loss in a systemic event. The MES can be estimated non-parametrically from daily equity returns (Acharya et al. forthcoming). Estimating the LRMES typically requires modelling the relationship between the institution and the rest of the financial system while allowing for time-varying volatility and correlations. The LRMES can

[5] At the end of April, the average distance to default of the Big Six banks in Canada was also relatively high when compared with the weighted average of a selection of international peers in Australia (4.0), the euro area (2.5), Japan (2.7), the United Kingdom (3.4) and the United States (3.9).

[6] In this note, when computing measures for an institution, the financial system is defined as all other listed deposit-taking institutions, life insurers and property and casualty insurers. See Appendix B for more details.

subsequently be obtained from simulating future return paths for the institution and the system (Acharya, Engle and Richardson 2012; Brownlees and Engle forthcoming).

The dotted line in **Chart 1**, which reports the stressed capital ratio of the Big Six banks, is based on LRMES. The stress scenario is calibrated as a 1 per cent worse shock to the Canadian financial system occurring over the next six months. The most recent observation suggests that the scenario is associated with an expected reduction in the market capitalizations of the Big Six banks by roughly 2 per cent of total assets.

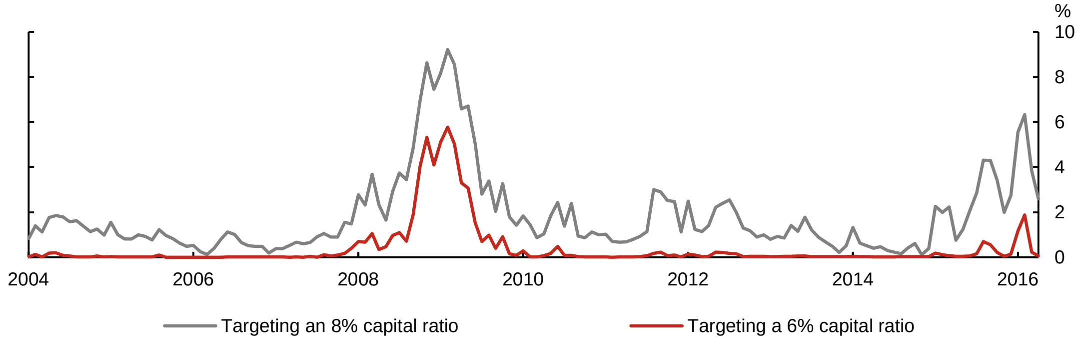
SRISK

SRISK is a measure of an institution's expected capital shortfall relative to a target ratio, conditional upon a market-based stress scenario. In the context of the financial system as a whole, the aggregate SRISK is the total expected sum of money that would be needed to restore the capital ratio of all institutions to the target ratio. Thus, a higher SRISK level implies that a greater capital injection is necessary to restore confidence in financial institutions. The level of SRISK depends on the amount of total assets and the level of the LRMES (described above) (Acharya, Engle and Richardson 2012); Brownlees and Engle forthcoming).

The aggregate SRISK of listed deposit-taking institutions (DTIs) in Canada is shown in **Chart 3**. The level is interpreted as the expected aggregate amount of capital necessary to restore the market-based capital ratio of all listed DTIs in Canada to a target ratio of both 6 per cent and 8 per cent[7] after the stress scenario. The differences between these two lines show the sensitivity of the indicator to different levels of the target ratio. The general pattern is that the SRISK has increased since August 2014. This rise reflects the decline in the stressed capital ratio resulting from a decline in the current market-based capital ratio and an increase in the level of volatility (see the dashed line in **Chart 1**). Moreover, the growth in banking system assets in recent years (60 per cent since 2008) has also contributed to higher levels of SRISK, even when expressed as a percentage of gross domestic product (GDP).

[7] Market-based capital ratios are not directly comparable with capital requirements. To account for a higher reported level of total assets as a consequence of the transition from Canadian generally accepted accounting principles to International Financial Reporting Standard, the target capital ratios have been adjusted downward with a multiplication factor of 0.942 from November 2011 onward. For illustrative purposes we use two target capital ratios: The 8.0 per cent is the standard percentage used in the literature for US institutions, while the 6.0 per cent is in line with the standard percentage of 5.5 per cent used in the literature for European institutions after downward adjustment due to the transition to IFRS (Acharya, Engle and Richardson 2012; Acharya, Engle and Pierret 2014).

Chart 3: **SRISK: Additional capital needed in 1 per cent systemic event**
Aggregate for all listed deposit-taking institutions, per cent of GDP



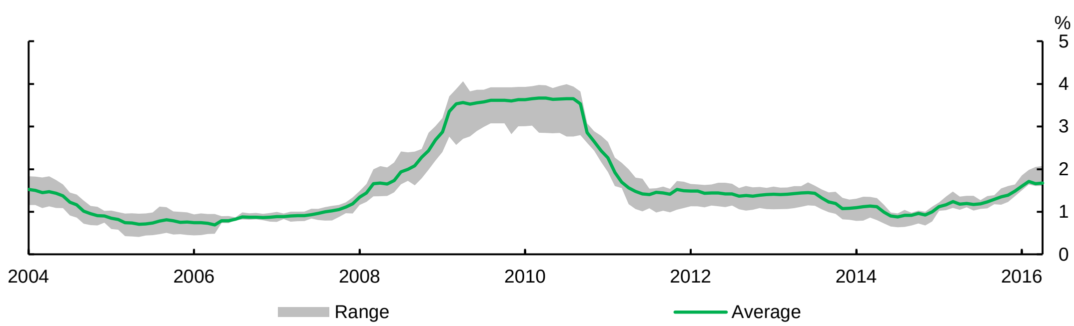
Sources: Datastream and staff calculations
Last observation: April 2016

Exposure ΔCoVaR

The MES and SRISK both focus on the *expected loss* conditional upon a stress scenario. In contrast, *exposure ΔCoVaR* focuses on the increase in downside tail risk conditional upon a stress scenario. Its level not only depends on the level of expected losses but also on how risk distributions evolve in a potential stress scenario.[8] A larger exposure ΔCoVaR therefore indicates a higher degree of sensitivity in a firm's individual distress to shocks in the financial system. Exposure ΔCoVaR is computed as the increase in the daily value at risk of an institution conditional upon the system suffering a loss equal to its value at risk (Adrian and Brunnermeier forthcoming).

The exposure ΔCoVaRs of several banks are reported in **Chart 4**. The increased levels of the exposure ΔCoVaRs to the right of the chart reflect the elevated level of tail risk that has coincided with the decline in oil prices since mid-2014. Nevertheless, the degree of sensitivity of individual institutions to shocks to the system is still well below the levels observed in the financial crisis.

Chart 4: **Exposure ΔCoVaR: Increase in daily value at risk conditional on the 5 per cent worse shock to the system**



Sources: Datastream and staff calculations
Last observation: April 2016

[8] This measure is referred to as "ΔCoVaR" rather than "exposure ΔCoVaR" if it is computed in reverse, i.e., as the level of risk in the system conditional on observing a shock to the institution. However, a change in the directionality does not imply causality in the sense that an adverse shock to the institution is causing a higher level of downside tail risk in the system; see Adrian and Brunnermeier (forthcoming) for details.

Interconnectedness

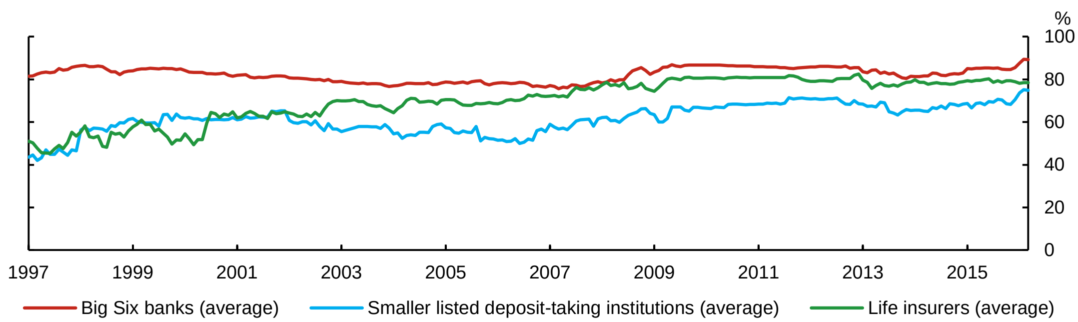
Any institution interacting with a financial system is capable of either initiating or transmitting a shock. A full understanding of the links within the system is rarely possible to achieve, especially in cases of limited or nonexistent regulatory data. Market-based measures of interconnectedness and common exposures may help to fill in such gaps.

Systemic linkage

The systemic linkage of an institution is the proportion of a firm's overall downside tail risk that is associated with severely adverse shocks to the financial system. The greater the systemic linkage, the stronger the connection between an institution's extreme losses and systemic events. Computation of the systemic linkage relies on two quantities: the level of tail dependence between the institution and the financial system, which can be estimated by applying extreme value theory approach (Hartmann, Straetmans and De Vries 2007), and the behaviour of the tail distribution reflecting extremely adverse shocks to the financial system (Van Oordt and Zhou 2014).

The average systemic linkage of various financial subsectors is shown in **Chart 5**. Compared with other indicators, this measure is fairly stable over time, reflecting the structural nature of interconnectedness within the financial system. As expected, the systemic linkage of domestic systemically important banks (D-SIBs) is consistently high, suggesting a strong link with the rest of the financial system during episodes of stress. For life insurers and, to a lesser extent, small banks, we observe an increase in systemic linkage over the previous two decades. This trend could be the result of either rising common exposures or greater interconnectedness within the system.

Chart 5: Interconnectedness: Fraction of tail risk due to large shocks in the Canadian financial system



Sources: Datastream and staff calculations

Last observation: April 2016

Conclusion

This note introduces several market-based indicators and examines how they can further inform the Bank of Canada's vulnerability assessment of Canadian financial institutions. Market-based indicators of leverage suggest that the solvency risk for major Canadian banks has increased since the beginning of the oil price correction in the second half of 2014. This is in contrast to accounting-based leverage measures that indicate a stable or improving trend. Similarly, measures of insolvency risk contingent on severe financial stress (i.e., market-based stress tests) indicate that the major banks are currently more vulnerable to a sudden adverse shock than they were in the summer of 2014. Finally, a measure of financial system interconnectedness and common exposures suggests a strong link between the major banks and the rest of the financial system, as expected. In other financial subsectors, the degree of interconnectedness has exhibited an upward trend over the past two decades.

Appendix A: Guide to Data, Computational Details, Formal Definitions and Literature

Measure	Data and Computation	Key Equation(s), Variables
Market-based capital ratio (MBCR)	Market value of equity as a ratio of the book value of debt and the market value of equity.	$\mathbf{MBCR} = \frac{E_t}{D_t + E_t}$
Distance to default[9] (DD)	Estimates based on one year of daily equity returns; T corresponds to the number of weekdays each year. The future debt (D_{t+T}) is set to the current value (D_t).	$\left\{ \mathbf{DD} = \frac{\log(A_t/D_t) + r_{t+T} - {\sigma_A}^2 T/2)}{\sigma_A \sqrt{T}} \quad , \quad \sigma_A = \frac{\sigma_E E_t}{\Phi(\mathbf{DD} + \sigma_A \sqrt{T})} \right\}$, where $\Phi(\cdot)$ denotes the standard normal CDF.
Long-run marginal expected shortfall[10] (LRMES)	Estimated from simulations based on a GJR-GARCH-DCC[11] model, using 10 years of daily equity returns; p = 0.01.	$\mathbf{LRMES} = -\mathbb{E}[\, r_{i,t+1:t+h} \mid r_{s,t+1:t+h} \leq -VaR_s^{t+h}(p)\,]$
SRISK[12]	Based on LRMES estimates (above); k = 0.08; h = 130, which corresponds to half a year.	$\mathbf{SRISK} = \mathbb{E}[\, k(D_t + E_{t+h}) - E_{t+h} \mid r_{s,t+1:t+h} \leq -VaR_s^{t+h}(p)\,]$ $= (k-1)\, E_t\, (1 + \mathbf{LRMES}) + k\, D_t$
Exposure ΔCoVaR[13]	Estimated using quantile regression, with two years of daily equity returns; p, q = 0.05.	$\mathbb{P}\left(r_{i,t+1} \leq -\mathbf{CoVaR}_p^q \mid r_{s,t+1} = -VaR_s^{t+1}(q) \right) = p$ $\Delta\mathbf{CoVaR}_p^q = \mathbf{CoVaR}_p^q - \mathbf{CoVaR}_p^{0.50}$
Systemic linkage[14] (SL)	Estimated using extreme value analysis, on four years of daily equity returns; p = 0.05.	$\mathbf{SL} = \lim_{p \to 0} \tau_i(p)^{1/\varsigma_s}$; $\tau_i(p) = \mathbb{P}(r_{i,t+1} < -VaR_i^{t+1}(p) \mid r_{s,t+1} < -VaR_s^{t+1}(p))$

Variable definitions: D_t: total debt (book value); E_t: market capitalization; r_{t+T}: One-year Canada Treasury Bill interest rate; $r_{i,t+h}$: h-day cumulative return on the firm's stock; $r_{s,t+h}$: h-day cumulative return on a market cap weighted financial index constructed from the returns of listed deposit-taking insitutions, life insurers, and property and casualty insurers (see Appendix B), excluding firm i; k: prudential target capital ratio; $VaR_X^{t+h}(p)$ is the h-days ahead value-at-risk of firm (or system) X. For the distance to default, the remaining variables (the daily volatility of assets (σ_A) and the current asset value (A_t) are not observable; the model solves for their values based on the structural credit model to obtain the distance to default.

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9 See Merton (1974) for more details.

10 See Acharya, Engle and Richardson (2012) and Brownlees and Engle (forthcoming) for more details.

11 See Glosten, Jagannathan and Runkle (1993) for more details on the GJR-GARCH model, and see Engle (2002) and Capiello, Engle and Sheppard (2006) for details on the DCC model.

12 See Brownlees and Engle (forthcoming) for details.

13 See Adrian and Brunnermeier (forthcoming) for details.

14 See Van Oordt and Zhou (2014) for details.

Appendix B: List of Institutions Included in the Analysis

Name	Classification (comment)
Bank of Montreal	Big Six banks
Scotiabank	Big Six banks
CIBC	Big Six banks
National Bank	Big Six banks
Royal Bank	Big Six banks
TD Bank	Big Six banks
Laurentian Bank	smaller listed DTIs
Canadian Western Bank	smaller listed DTIs
VersaBank	smaller listed DTIs
Home Capital Group	smaller listed DTIs (Holdco for Home Trust)
MCAN Mortgage Corporation	smaller listed DTIs
Equity Financial Holdings	smaller listed DTIs (Holdco for EFTC)
Equitable Group	smaller listed DTIs (Holdco for Equitable Bank)
Sun Life Financial	life insurance
Manulife Financial	life insurance
Industrial Alliance	life insurance
Great West Lifeco	life insurance
E-L Financial	life insurance
Fairfax Financial Holdings	P&C insurance
Kingsway Financial Services	P&C insurance
Intact Financial	P&C insurance
Echelon Financial Holdings	P&C insurance
Till Capital	P&C insurance

Notes: The classification is based on the main activities of the entities listed. DTI means "deposit-taking institution." P&C insurance means "property and casualty" insurance.

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