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Understanding Systemic Risks in the Canadian Financial System

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Abstract

This paper reviews recent efforts to monitor and assess systemic risk in the Canadian financial system and outlines a framework for future system-wide stress testing. We examine how perceived and actual interconnections—across banks and non-bank financial institutions, domestic and foreign entities, and institutions of different sizes—shape the propagation of financial stress. We then review advances in system-wide stress-testing approaches, including agent-based and equilibrium-based models that capture downside amplification mechanisms and macro-financial feedback. Finally, the paper presents a blueprint for a

*Does not reflect the view of the Bank of Canada. Gabriel Bruneau, Sascha Clazie-Thomson, Ruben Hipp and Kerem Tuzcuoglu were at the Bank of Canada at the time of their contribution to the article. This does not represent the views of the Autorité des marchés financiers, European Central Bank, British Columbia Investment Management Corporation, nor Amazon and its affiliates. The research presented in this paper was conducted independently and does not relate to Kerem Tuzcuoglu's position at Amazon. Correspondence to tduprey@bank-banque-canada.ca. The authors thank Bo Young Chang, Tamara Gomes, and Radoslav Raykov for helpful comments and discussions.

Canadian system-wide stress-testing and reverse stress-testing toolkit designed to support the assessment of financial system resilience.

JEL classification codes: G01, G17, G18, G21, G23, G28.

Themes: financial stability and systemic risk

1 Introduction

Canada has not experienced a major systemic banking crisis in recent decades. International crisis databases (e.g. Laeven and Valencia, 2013, 2020) identify numerous systemic banking episodes across advanced economies since the 1970s, but none for Canada. Previous studies (e.g. Huang and Ratnovski, 2009) attribute this resilience in part to a stable funding structure and a regulatory environment that limits risk amplification.[1]

Historical experience nevertheless shows that systemic risk can re-emerge unexpectedly. Episodes such as the funding stress at Home Trust in 2017,[2] the failures of several U.S. regional banks in 2023, or the failure of a Global Systemically Important Bank also in 2023 underscore how rapidly confidence shocks and liquidity pressures can propagate across institutions and borders.[3] These events highlight the importance of monitoring not only individual institutions, but also system-level vulnerabilities and interconnections.

After the 2008 global financial crisis, central bankers and regulators increasingly turned their attention to the analysis of systemic risks—wide financial system disruptions that spill over to the real economy—and the design of macroprudential policies—safeguarding the financial system by making sure it can absorb rather than amplify systemic shocks.[4] As a result, many new measures of systemic risks have been proposed

[1] Rolling the clock backward, Reinhart and Rogoff (2009, 2011) identified three earlier systemic banking crises: 1838-9 (Bank of Upper Canada and Gore Bank suspended payments), 1866 (Bank in Western Canada suspended payments and Bank of Upper Canada failed), 1873-4 (several bank failures and economic depression). Policy actions taken at the early phases of possible systemic events also limited the risk of financial contagion in Canada. For instance, the banking crisis of 1985–86 with the bailout of the Canadian commercial banks (CCB) and the liquidation of Northland Bank of Canada (NBC) remained a regional banking crisis that did not trigger a recession and spill over to the rest of the economy, in part thanks to the actions of the federal authorities.

[2] Home Trust, an alternative mortgage lender, lost 80% of its market capitalization in April 2017, after the Ontario's securities regulator highlighted falsified loan applications prior to 2015 and misleading statements to investors after 2015.

[3] In the US, the regional banks Silicon Valley Bank, Signature Bank and Silvergate Bank failed in March 2023 due to a bank run given their large interest rate risks. At the same time, Credit Suisse, classified in November 2022 as one of the top 30 most systemic bank worldwide, also collapsed.

[4] For a discussion on recent macroprudential policies in Canada and how it interacts with monetary policy, see Duprey et al. (2024).

by the literature.[5] At the same time, stress-tests became a vital tool among central banks and regulators to assess the resilience of the banking sector.

In this discussion paper, we integrate existing Bank of Canada tools into a coherent system-wide analytical logic. Rather than introducing a new empirical measure or model, the paper clarifies how existing indicators and simulation frameworks can be combined and expanded to assess system-wide vulnerabilities, amplification mechanisms, and resilience across a broad range of scenarios.

We further provide a blueprint for the development of an approach tailored to the Canadian financial system that considers the financial system as a whole, i.e. a system-wide framework. We argue that the current stress-testing framework that relies on assessing banks' resilience to a single severe but plausible scenario needs to evolve in two directions. First, a system-wide stress-testing framework would allow policymakers to conduct "what-if" analyses of the resilience of the entire financial system as it continues to fund the real economy. Second, a reverse stress-testing framework would identify what it would take for the resilience of the entire financial system to be threatened, depending on the combinations of shocks or contagion channels at play.

Over the years, Bank of Canada staff significantly invested in the analysis of systemic risks. In terms of systemic risk measurements, staff developed one of the first measures of systemic stress (Illing and Liu, 2006) later updated with various indicators to monitor financial or banking stress, system-wide spillovers, foreign and non-banks connections, or trust contagion across financial institutions.[6] In terms of stress-testing toolkit, staff developed the Framework for Risk Identification and Assessment (FRIDA) (MacDonald and Traclet, 2018), sketched out on the left panel of Figure 1. Essentially, a severe but plausible scenario is built by one model that feeds into sectoral modules

[5] See the following surveys on systemic risk measures: De Bandt and Hartmann (2000), Bisias et al. (2012), Chinazzi and Fagiolo (2013), Benoit et al. (2017), Silva et al. (2017), Jackson and Pernoud (2021).

[6] See measures of financial stress by Duprey (2020), measures of banking stress by (MacDonald et al., 2016; Oordt, 2023), measures of interconnectedness by Hipp (2020); Hałaj and Hipp (2025); Ojea-Ferreiro (2025, 2026).

for households and corporates, eventually feeding into a bank solvency risk module in a sequential manner.[7]

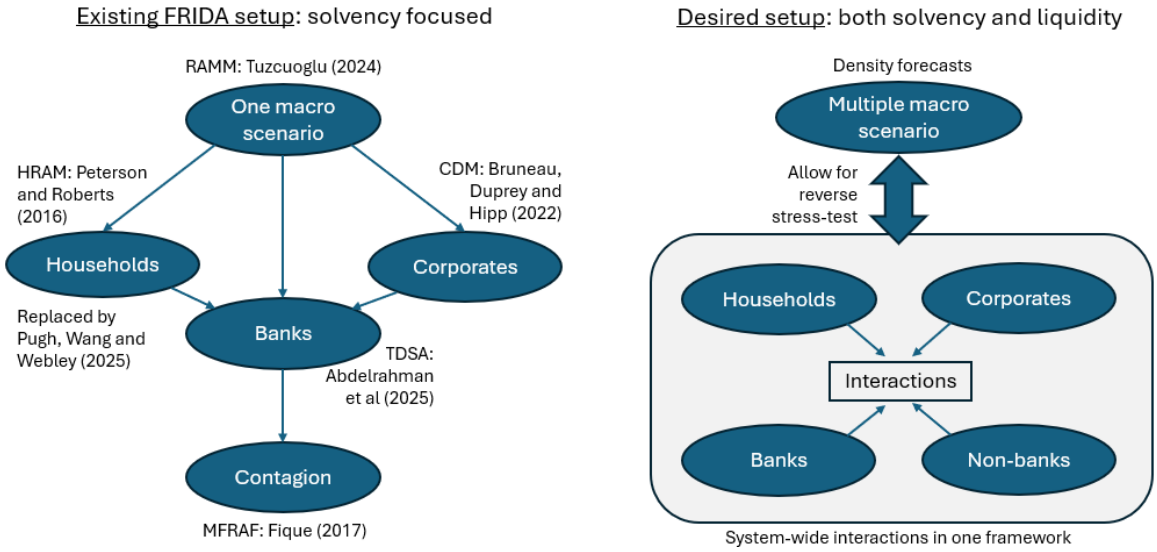

Figure 1: **Evolution of system-wide stress testing at the Bank of Canada**

But as banks became better regulated following Basel III and the global footprint of non-bank financial institutions continued to grow, the emphasis started to shift away from a bank-focused solvency assessment to systemic liquidity concerns and system-wide resilience.

Thus, the alternative system-wide approach we favor in this paper would consider the financial system as a whole, represented on the right panel of Figure 1. It would include a wide range of scenarios and a joint modelling of relevant financial system agents interacting with each other via various channels. The addition of a wider range of non-bank entities and market interactions would allow for the combined analysis of solvency and liquidity stress.[8]

[7]Specifically, the scenario is simulated with the Risk Amplification Macro Model (RAMM) (Tuzcuoglu, 2023, 2024), feeds into defaults for households via the Household Risk Assessment Model (HRAM) (Peterson and Roberts, 2016; Pugh et al., 2026) and firms via the Corporate Default Model (Bruneau et al., 2022). Bank losses are eventually calculated by the Top Down Solvency Assessment (TDSA) model (Abdelrahman et al., 2025), and possible contagion effects in case of bank defaults are calculated by the Macro-Financial Risk Assessment Framework (MFRAF) (Anand et al., 2014, 2015; Fique, 2017).

[8]Recent work by Bank of Canada staff already focused on developing stress-testing models for

Although system-wide stress testing is still in its early stages, significant strides have been made by institutions such as the Bank of England with a bottom-up approach to system-wide stress test (System-Wide Exploratory Scenario, SWES, from Bank of England, 2024) and the European Central Bank with a top-down approach to system-wide stress test (Interconnected System-wide stress test Analytics tool, ISA, from Sydow et al., 2024a,b).[9] Bottom-up approaches can generate new insights about market participants' behaviour that are aggregated up, but it is also a broader endeavor to coordinate. Conversely, the top-down approach is a table-top simulation by the regulator, smaller in scale and more flexible but relying on complex modelling assumptions and a broad access to detailed regulatory data.

Section 2 provides an operational definition of systemic risks and channels. Section 3 highlights the systemic risk toolkit developed to monitor financial system interconnectedness. Section 4 highlights recent developments to assess financial system resilience via scenarios of simulated stress. Finally, Section 5 highlights possible avenues for future work to foster new ideas and collaboration with academics as well as fellow public authorities in charge of systemic risk monitoring.

2 What is systemic risk?

2.1 A definition

Although no single definition is universally accepted, systemic risk usually refers to (i) the risk of a breakdown in the entire financial system, rather than the failure of individual institutions, with (ii) a potential to have serious negative consequences for the real economy (see e.g. IMF-BIS-FSB, 2009). Systemic risk arises when a shock—stemming from external events or internal imbalances—triggers widespread disruption in the functioning of financial institutions or markets. Disruptions can propagate through interconnections within the financial system, creating cascading

funds (Arora et al., 2019) or central clearing counter-parties (Brennan et al., 2025), agent-based models of contagion with non-bank financial intermediaries (Hałaj, 2018; Bruneau et al., 2025) or equilibrium models of banks' strategic behaviour with fire sales (Hipp and Ojea-Ferreiro, 2026).

[9]The Bank of England had also developed simpler top down approaches with representative agents, see Aikman et al. (2019).

failures. Disruptions can also propagate to the real economy, impairing credit provision and the efficient allocation of financial resources, potentially increasing firm defaults, job losses, house price corrections, etc.

The materialization of systemic risk can therefore contribute to an economic downturn. The feedback between the breakdown in the financial system and the real economic downturn can create a macro-financial feedback loop that exacerbates the instability via a financial accelerator channel (e.g. Kiyotaki and Moore, 1997; Bernanke et al., 1999; Catalan and Hoffmaister, 2022). This dynamic is illustrated with Figure 2.

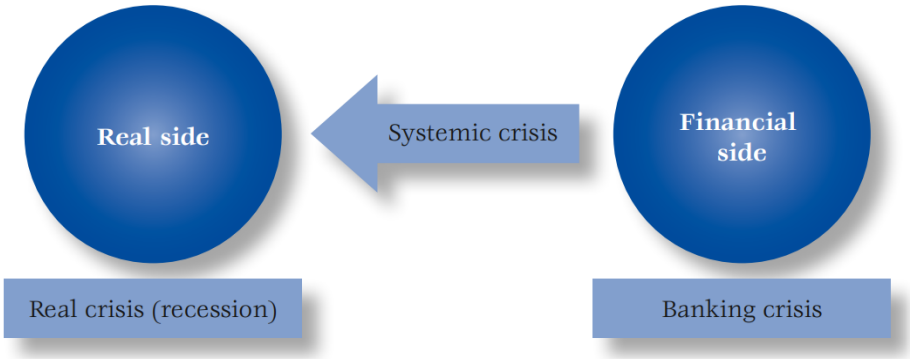

Figure 2: **Stylized definition of a systemic crisis**

Source: Bennani et al. (2014).

2.2 Decomposing systemic risks into contagion channels

The literature provides several decompositions of systemic risks. For instance, one common approach defines systemic risk as a tail Beta, i.e. the realization of institutions' losses conditional on extreme aggregate outcomes (De Jonghe, 2010; Acharya et al., 2016; Adrian and Brunnermeier, 2016). This concept helps understanding the bilateral connection between the aggregate and individual institutions, yet it ignores the complex entanglement of individuals. Thus, in this discussion paper we use a conceptual framework based on literature that views systemic risk as arising from two elements: (1) the underlying shocks—both idiosyncratic and systematic—and (2) the mechanisms through which these shocks spread across the financial system.

We conceptually decompose systemic risk below to guide the distinction between

additive and multiplicative effects.

$$\text{Systemic Risk} = \text{Contagion} * (\text{Idiosyncratic Risk} + \text{Systematic Risk}) \tag{1}$$

For example, not all contagion is destabilizing: spreading risks across institutions can facilitate absorption rather than amplify it. In this representation, a contagion value of 1 represents the no-amplification baseline: greater than 1 amplifies underlying risks, while a value below 1 implies absorption. Throughout the paper, we use this decomposition to anchor our toolkit choices and identify gaps in our framework. The three terms are:

Idiosyncratic risk refers to vulnerabilities specific to individual institutions or sectors. These risks may stem from flawed governance, unsound business models, operational inefficiencies, or concentrated exposures to particular assets. Although runs on fragile institutions can occur (Diamond and Dybvig, 1983), in a well-functioning financial system, idiosyncratic risks are generally diversifiable—meaning that distress at a single institution does not necessarily threaten system-wide stability.

Systematic risk refers to the unavoidable, non-diversifiable hazard inherent to an entire market or economy, rather than a specific individual institution. It simultaneously impacts multiple institutions, markets, and asset classes, conditional on a market-wide downturn (Acharya et al., 2016). It often originates from broad-based shocks such as macroeconomic downturns, geopolitical instability, or widespread asset price corrections.

On its own, idiosyncratic risks or systematic risks do not need to trigger systemic risks. However, when an individual institution's risks become correlated (Acharya, 2009), for instance because it is systemically important or highly interconnected through complex asset and liability exposures, its failure can propagate disruptions across the financial system, especially if critical regulatory thresholds such as capital adequacy or liquidity buffers are breached. Also, exposure to systematic risks may be amplified throughout the system, for instance if institutions exposed to a similar asset class all

have to readjust their portfolio at the same time, amplifying the market impact of the initial shock.

Contagion risk captures the potential for financial distress at one institution to spread to others, amplifying the initial idiosyncratic or systematic shock, and creating systemic instability. Contagion can operate through balance sheet linkages, behavioural responses, and price mechanisms. It can manifest in several forms:

- **Contractual-based contagion**: It transmits through existing bilateral contractual exposures—such as interbank loans, derivatives, or repos—where the solvency of one institution directly affects the valuation of others' assets or liabilities (Eisenberg and Noe, 2001). This can result in cascades of defaults. Interbank exposures, intended to share liquidity risk, can also become channels for contagion (Allen and Gale, 2000) depending on the characteristics of the network of connections (Amini et al., 2012; Acemoglu et al., 2015).
- **Rollover risk contagion**: It arises when institutions cannot renew short-term funding due to deteriorating counterparty fundamentals, reflecting liquidity dependencies in interbank markets. Financial institutions may also manage their roll-over risks strategically without considering the externality onto others, possibly triggering contagion (Brunnermeier and Oehmke, 2013). Deteriorating market liquidity and shorter debt maturity can worsen rollover risks even if fundamentals are solid (He and Xiong, 2012).
- **Market-based contagion (or information contagion)**: It occurs through investor perceptions and expectations. If markets perceive two institutions with similar businesses to be closely linked, a loss of confidence in one can raise funding costs or restrict market access for the other—even without direct contractual exposures (e.g. due to incomplete information frictions and beliefs, King and Wadhwani, 1989; Morris and Shin, 2000; Vives, 2014).
- **Price-mediated contagion**: It results from fire sales of mark-to-market assets. When institutions simultaneously liquidate assets to meet liquidity needs, prices

decline, eroding the value of similar holdings across the system and triggering further losses (e.g. Shleifer and Vishny, 1992; Cont and Schaanning, 2019).

2.3 Decomposing systemic risks into agents and links

As idiosyncratic and systematic risks spread to the financial system via multiple contagion channels, it is important to understand how those interactions can propagate risks and disrupt different agents. The financial system could be seen as a network of heterogeneous agents interacting through credit, funding, investment, and risk-sharing mechanisms. Each agent type fulfills a distinct economic function, shaping the flow of funds, risk allocation, and maturity transformation. These interactions create complex interdependencies that influence liquidity conditions, market dynamics, and systemic vulnerabilities.

The agents and interactions outlined in Tables 1 and 2 show how systemic risk arises from both the agents' balance sheet positions and the flow of funds between them.[10] Each agent's balance sheet composition determines its sensitivity to shocks. The flow of funds, i.e., who funds whom, is the main creator of channels that transmit those shocks. For example, households' role as net savers and banks' reliance on short-term wholesale funding establish dependencies that can amplify liquidity stress when savers withdraw their funds. Similarly, the flow of funds through securities markets links non-bank financial intermediaries (NBFIs) via common asset holdings, so that the price adjustments after asset sales can lead to price-mediated contagion.

The NBFI sector is a heterogeneous group of agents that is less well understood. It is composed of all non-bank financial entities that engage in some form of financial intermediation (e.g. investment funds, insurance corporations, or finance companies.). Their activities are often associated with financial leverage and are generally less regulated than banks. Consequently, they represent an important channel through which risk can spread across the financial system. Figure 3 shows the relative importance of banks and NBFIs in the Canadian financial system as a share of total financial

[10] For a fuller breakdown of agents interacting in the financial system see Table A.1.

Table 1: Main Financial Agents: Assets, Liabilities, and Economic Function

Agent Type	**Assets**	**Liabilities**	**Economic Function**
Households	Deposits, housing, mutual fund shares, equity	Mortgages, private loans	Net savers optimizing asset allocation based on expected returns
Firms	Deposits (liquidity buffer)	Bank loans, private credit	Production using capital and labour
Banks	Loans to households and firms, securities, cash, repos	Deposits, wholesale funding	Central intermediaries clearing deposits and supplying credit
NBFIs	Securities, loans, deposits	Shares, obligations with policy holders	Efficient reallocation of capital in the system

Table 2: Flow of funds between agents

Agent	**Receives funds from**	**Provides funds to**
Households	Income (exogenous)	Banks, NBFIs
Firms	Banks, private credit	Banks (via deposits), NBFIs
Banks	Households, NBFIs (funding)	Households and firms (loans), NBFIs
NBFIs	Households, institutional capital	Firms, households, banks, other NBFIs

assets.[11] According to Gomez Navas Acevedo and Thorn (2025), NBFIs represent more than 60% of total financial assets in the Canadian financial system in 2023.

Eventually, interdependencies across agents and their behavioural responses mean that distress originating in one segment—whether idiosyncratic or systematic—can propagate through funding, credit, and market linkages.

[11] Definition used by Financial Stability Board (2023) (page 3). Fisher and Walsh (2024) and Gomez Navas Acevedo and Thorn (2025) provide yearly updates on the prevalence of the NBFI sector in Canada as part of an initiative of the Financial Stability Board to collects annual data from 29 jurisdictions to monitor NBFIs.

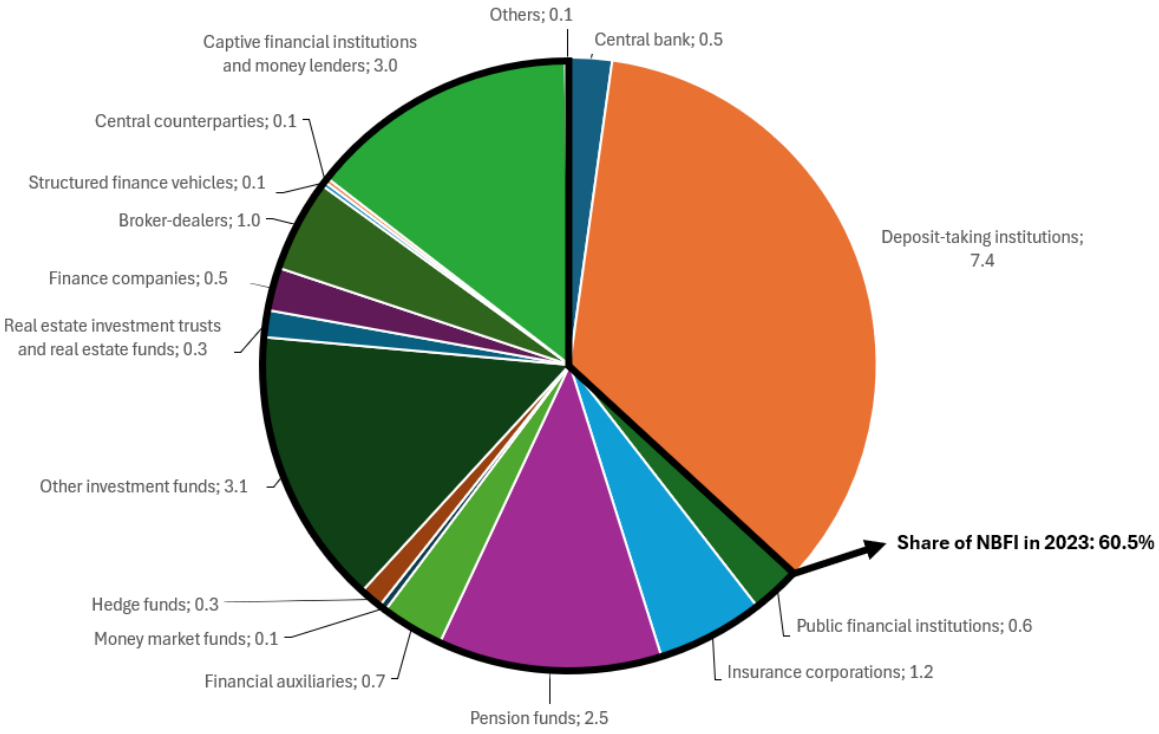

Figure 3: **Non-bank financial institutions landscape in Canada**

Source: Combination of Chart 1 and 2 of Gomez Navas Acevedo and Thorn (2025), expressed as a share of total financial assets in Canada. The non-bank financial intermediation (NBFI) sector includes insurance corporations, pension funds, financial auxiliaries, money market funds, mutual funds, exchange-traded funds, finance companies, structured finance vehicles, hedge funds, real estate funds, broker-dealers, captive financial institutions, etc. Last observation: December 2023.

Building on Equation (1) and the overview provided in Tables 1 and 2 and Figure 3, a comprehensive understanding of systemic risk extends beyond individual FIs' resilience and requires two complementary elements: the network of connections among individual institutions to understand how contagion propagates, and the condition of the financial system as a whole to assess its overall resilience. Accordingly, we employ two complementary approaches to monitor systemic vulnerabilities.

- **Interconnectedness**: We examine how links among financial market participants can amplify or absorb shocks, highlighting the channels through which risks may spread.
- **System-wide stress**: We assess the financial system's robustness by exploring how broad market indicators and aggregate measures help gauge the resilience

of the financial system as a whole.

Both the interconnectedness and system-wide stress approaches rely on two broad types of underlying information sources:

- **Market-based**: Captures real-time pricing, liquidity, and volatility dynamics, reflecting investor sentiment and funding stress. These indicators provide early signals of shifts in risk perception.
- **Book-based**: Offers a more stable view of institutions' fundamentals, including solvency, leverage, and maturity mismatches. These metrics help assess structural vulnerabilities.

Building on this framework, we now describe our systemic risk monitoring toolkit.

3 Monitoring interconnectedness

The indicators presented in this section are designed to monitor the contagion term in Equation (1): they track features of the market, such as linkages and spillovers, that are related to the propagation of risk. This interconnectedness is usually visualized as a network among financial agents, whose complexity makes monitoring challenging. At a granular level, correlated stress across markets often reflects the degree of interconnectedness—whether perceived or actual—among financial actors.

Interconnections are typically thought of as structural vulnerabilities but are not inherently undesirable. They can enhance resilience by dispersing shocks across the system. However, they can also serve as amplifiers of stress, particularly when they involve concentrated exposures or operate within opaque and complex structures. In such cases, the same linkages that facilitate risk-sharing and the efficient allocation of liquidity under normal conditions can become channels for contagion, accelerating the transmission of shocks and magnifying systemic vulnerabilities.

3.1 Market-based interconnectedness

Market participants may perceive that some entities are strongly interconnected, adjusting the price of risk accordingly. This approach typically relies on decompositions

of the co-movement in the stock prices of financial institutions.

We consider, in particular, three types of market-based interconnections: cross-border risks from interconnections between the Canadian and U.S. banking system, interconnections between banks and less regulated non-bank financial intermediaries, and domestic interconnections between larger and smaller banks.

Market-based interconnections perceived across the border. In 2023, the share of Canadian banks' foreign assets and liabilities amounted to around 50% (Friedrich et al., 2025). Thus, risks to Canadian and U.S. financial institutions can be tightly connected.

Figure 4 decomposes tail risks (low-probability, high-impact events) derived from stock prices (Ojea-Ferreiro, 2025). The black line is the weighted-average expected shortfall for Canadian deposit-taking institutions. The expected shortfall is decomposed into idiosyncratic, domestic, and global components. About half of the variation in the systemic risk metric for Canadian banks appears to be linked to cross-country exposures.

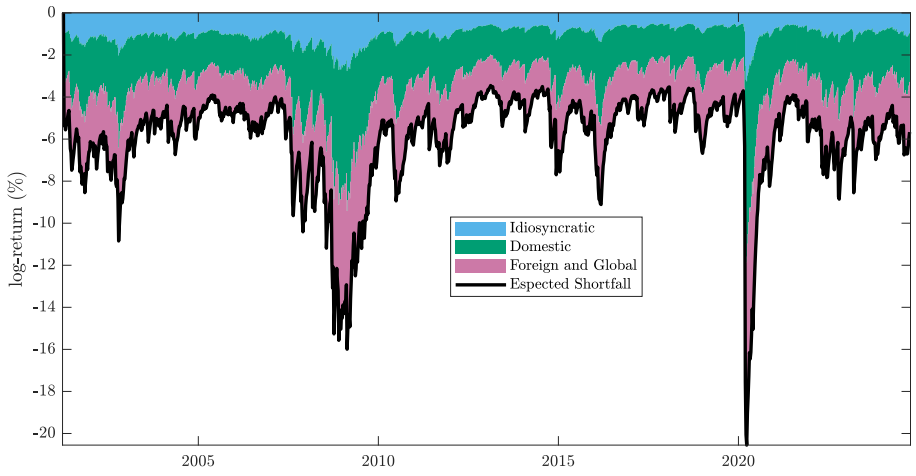

Figure 4: **Cross-border connections worsen market-based contagion risks in Canada**

Note: This expected shortfall of Canadian deposit-taking institutions stock returns is decomposed into components reflecting whether adverse returns are happening (i) in isolation for the institutions (idiosyncratic risk), (ii) in conjunction with tail losses in other Canadian institutions (domestic risk), (iii) in conjunction with tail losses for foreign institutions (global risk). Source: Figure 26a from Ojea-Ferreiro (2025).

Market-based interconnections perceived between banks and non-banks. The share of non-banks financial institutions (NBFI) assets in the Canadian financial system is around 60% in 2023 (Fisher and Walsh, 2024). Thus NBFIs represent an important channel through which risk can spread across the financial system.

Figure 5 relies on stock prices to infer Canadian NBFIs and banks perceived contributions to tail risks. The figure highlights that interconnections between tail risks of Canadian banks and non-banks financial institutions are increasingly tight. This is a similar pattern to the U.S. (Acharya et al., 2024; Fernandez et al., 2024). Of note, the liquidity stress in Home Capital Group (HCG)—a Canadian mortgage company—during 2017 may have been partly idiosyncratic, thereby reducing the correlation with other entities.[12]

[12]An alternative explanation is that the announcement of a secured credit line to address liquidity concerns may have helped prevent broader market concerns from escalating, thereby decreasing tail risk co-movements with banks.

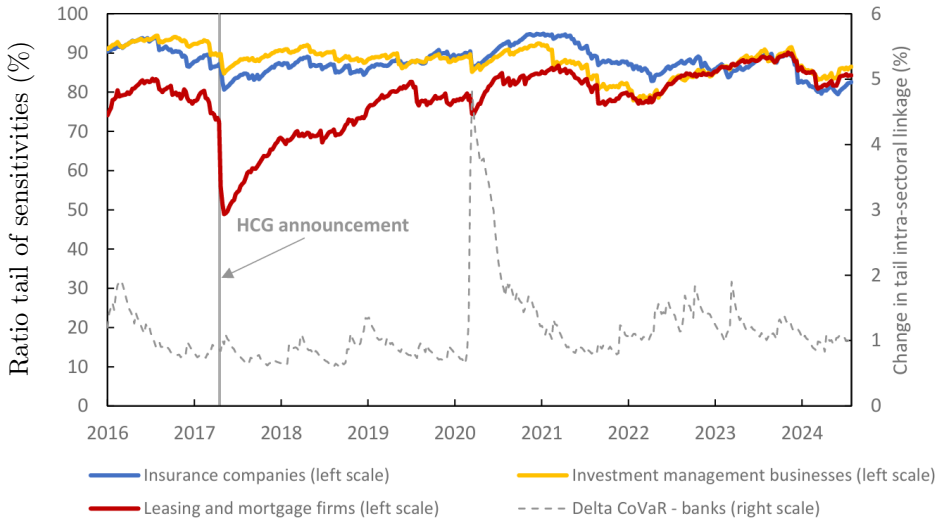

Figure 5: **Perceived banks-NBFI connections increase market-based contagion risks in Canada**

Note: The dashed line represents the evolution of bank losses conditional on a shock hitting the banking sector, i.e. interbank market linkages (so called Delta conditional value-at-risk, or Delta CoVaR). The solid lines show the banking sector losses conditional on a shock to one type of Canadian NBFI, as a ratio to the banking sector losses conditional on a shock to banks. A value of 100 means that the magnitude of losses in the banking sector is similar whether the stress scenario is driven by NBFIs or banks, so values closer to 100 imply tighter banks-NBFI interconnections. HCG is Home Capital Group, the parent company of Home Trust, which experienced severe funding stress in 2017 followed by the announcement of a secured credit line. Source: Chart 2 of Ojea-Ferreiro (2026).

Market-based interconnections perceived between small and large banks. The failure of the Silicon Valley Bank (SVB) in March 2023 reignited the fear of a contagion effect across financial institutions. Although the U.S. bank was relatively small, it raised concerns about the viability of other regional U.S. banks—with the failure of New York's Signature Bank—or the stability of large systemically important banks—with the failure of Credit Suisse. Around that time, the stock returns of Canadian banks were increasingly more explained by spillovers from U.S. stock returns (Figure 6.a).

Using the method of Hipp (2020), this can be decomposed into a network of directional stock price spillovers to track the daily evolution of contagion dynamics (Figure 6.b). The figure shows the direction of effects between critical financial market segments. On the one hand, SVB had a strong impact on U.S. regional banks and, in turn, on

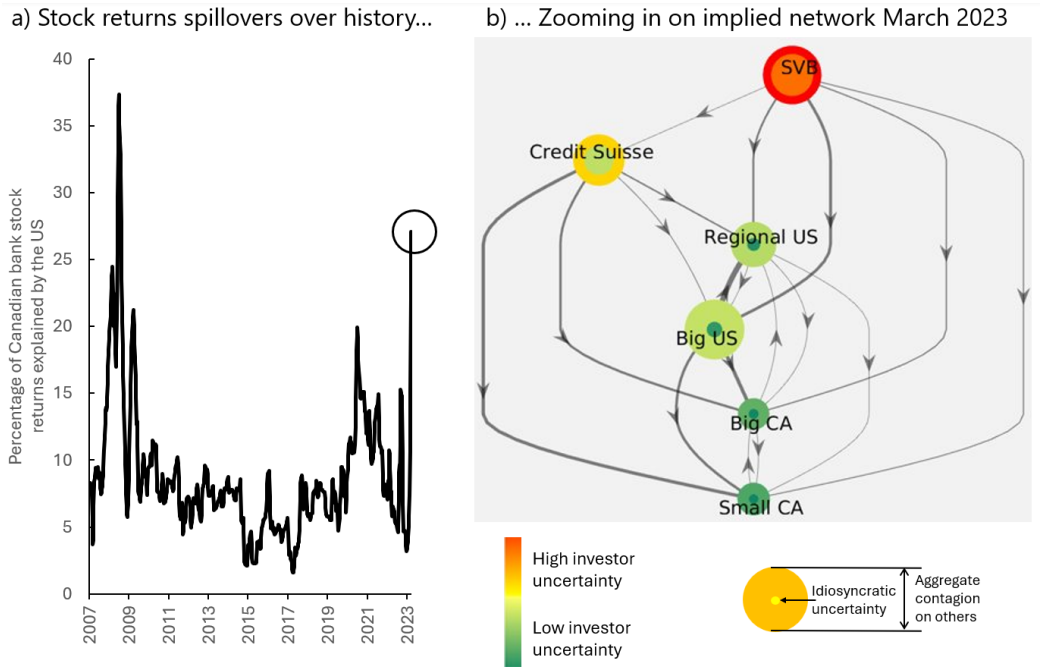

Figure 6: **Spillovers to Canada around the Silicon Valley Bank failure**

Note: On the right chart, one node shows either an index or a single bank, while the colors indicate the level of uncertainty in that respective stock or market. The inner part of the node represents idiosyncratic risk while the outer part represents the contagion onto others. Arrows indicate how much of that uncertainty can be explained by other stocks movements. Source: Bank of Canada calculations based on Hipp (2020). Last observation: 17th March 2023.

large U.S. banks. But on the other hand, SVB had a much more muted impact on the banking sector in Canada (either large or small Canadian banks), with investor uncertainty and spillovers remaining relatively low. While the fallout of this event remained mostly foreign to Canada, it was a reminder that Canadian banks can take indirect effects from failing institutions, large or small, via informational contagion, even if not directly exposed.

3.2 Book-based interconnectedness

Markets perceptions of interconnections may differ from the actual interconnections within the system. But quantifying actual interconnections heavily depends on the availability of granular regulatory data.

Book-based interconnections at the sectoral level. Statistics Canada's from-whom-to-whom data[13] maps the specific counterparty relationships between economic sectors (e.g., households, financial entities, government) for financial assets and liabilities. It shows who is funding whom and with what instruments, providing granular detail on financial interdependencies beyond aggregate sector data. This data allows for an analysis of exposures across sectors.

The arrows in Figure 7 show inter-sectoral exposures from creditor to debtor sectors. Unsurprisingly, NBFIs, households, and chartered banks represent the three most central debtor sectors in the Canadian economy. Households have large deposits in chartered banks, but they also have large counter-parties with NBFIs—for instance investment funds. NBFIs, in turn, are significantly connected to non-residents, a possible source of external shocks.[14]

[13] See https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2018015-eng.htm

[14] Note that although the chart shows only the NBFI aggregate sector, NBFIs within the sector would also be connected with each other.

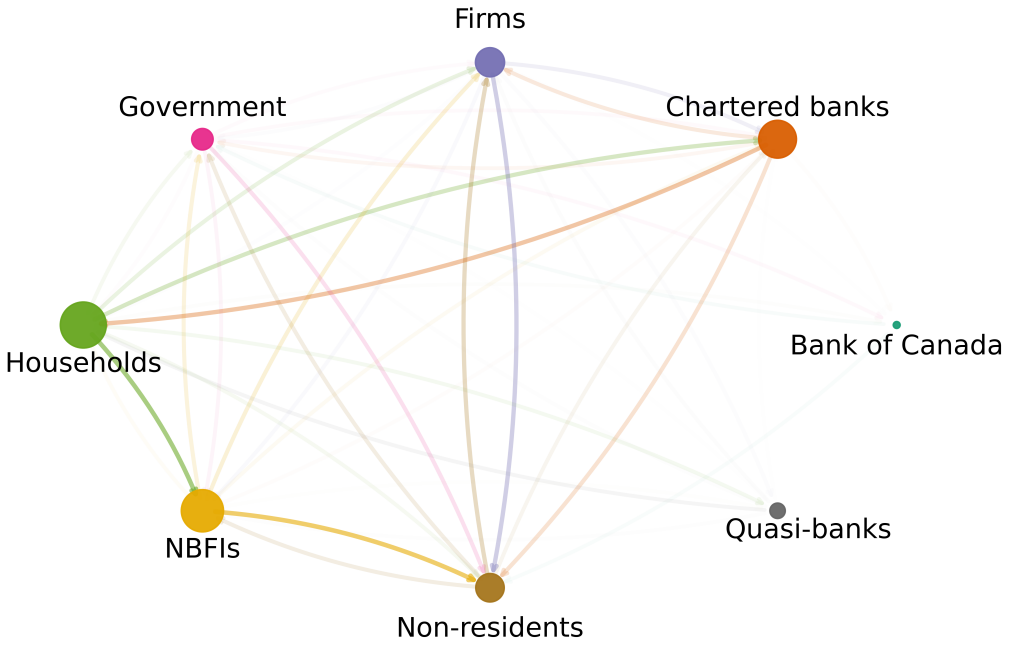

Figure 7: **From-whom-to-whom financial exposures in the Canadian financial system**

Note: The arrows show inter-sectoral exposures from creditor to debtor sectors. The nodes are scaled by the debtor eigenvector centrality (Girón and Matas-Mir, 2017) that measures both the direct connectedness of the sector, but also its indirect connectedness via intermediate counter-parties that may amplify spillover risks. Quasi-banks include credit unions, caisses populaires, trusts and loan companies. NBFIs stand for Non-bank Financial Institutions. The opacity of each arrow is determined by the size of the inter-sectoral connection. Source: Statistics Canada financial accounts on a from-whom-to-whom basis and Bank of Canada calculations. Last observation: 2025Q2.

Book-based interconnections among financial institutions. Regulatory returns allow for a more granular breakdown of actual interconnections. Figure 8 displays connections on the asset side of Canadian Domestic Systemically Important Banks (DSIBs, the black nodes in the middle ring) to other major financial institutions (the outer ring) across different types of instrument (on each layer).[15]

By analyzing the evolution of these interconnections over time, we can get a sense of the concentration of exposures by instruments or entities. Potential exposures can also be relevant, for instance if NBFIs draw on their bank credit lines. This network of potential exposures is represented by the middle layer (lending undrawn).

[15]See Figure 2 of Hałaj and Hipp (2025) for additional layers of the network.

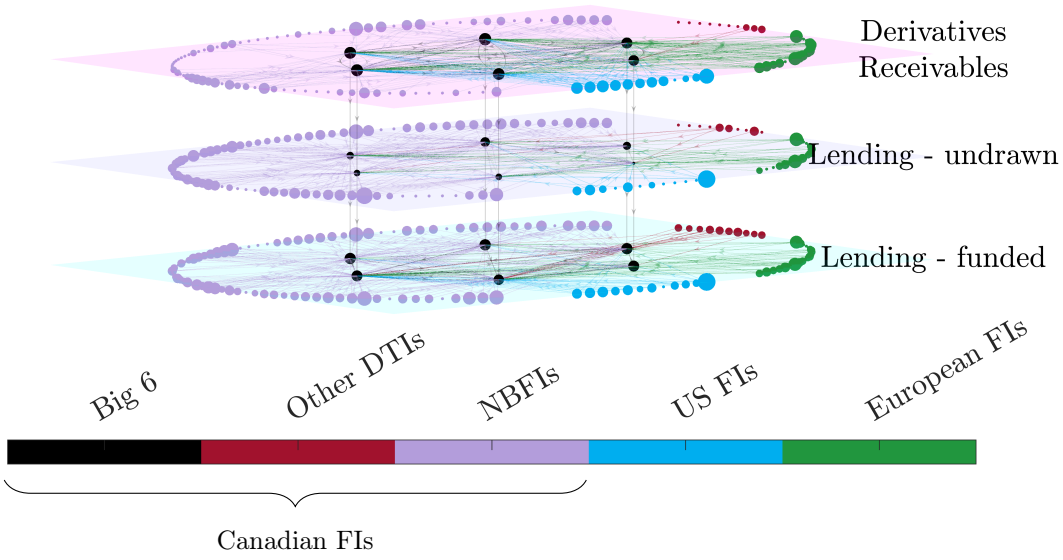

Figure 8: **Contractual obligations from Domestic Systemically Important Banks to other financial institutions**

Note: Each financial institution is represented by a dot, scaled by the institution's size. Each layer represents a different type of instrument. For a given layer, at the center, each black dot represents one of the Big 6 banks in Canada (the Domestic Systemically Important Banks reporting the data). The Big 6 banks are connected to each other on the inner ring, or to other financial institutions on the outer ring. The other financial institutions are grouped by color. Source: EB/ET-2A, Bank of Canada calculations. Last observation: 2024Q4.

Book-based interconnections between banks and firms. If several large banks lend to the same firm, it can be a sign of common exposure to the same source of risk, but it could also ensure access to liquidity should the firm be hit by an idiosyncratic shock.

Figure 9 represents the bank lending relationships between each big Canadian bank (the black dots) and large corporations in Canada (the small dots). Essentially, many financial firms (red dots) or non-financial firm (blue dots for real estate or construction related) have multiple banking relationships.[16]

[16]For firms borrowing from a syndicate of multiple banks, we may observe only one of the syndicate members. Thus firms on the outside connected to only one of the large banks have in fact other lending relationships with banks not observed in our dataset.

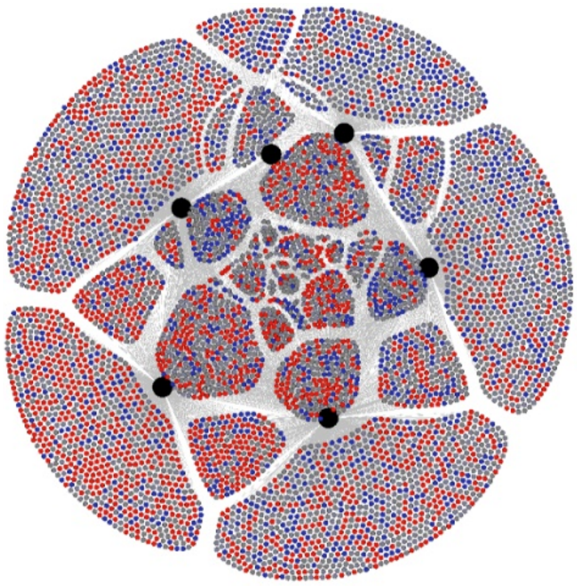

Figure 9: **Network of firms borrowing from multiple banks**

Note: Each large black dot represents one of the big Canadian bank. Each small dot is a large financial firm (e.g. red dots for funds) or non-financial firm (e.g. blue dots for real estate or construction related). Source: Duprey et al. (forthcoming), and Bank of Canada calculation using IRB Credit Data Wholesale Transaction (BF). Last observation: 2022Q4.

3.3 Combining market and book-based interconnectedness

Both market and book-based interconnections eventually reflect different possible channels of contagion that may interact with each other. Hałaj and Hipp (2025) combine both elements for Canada in one framework to incorporate revaluations from contractual book-based interconnections and intangible channels, such as information contagion from market-based interconnections. They decompose the sources of banks' capital ratio variations into contagion across channels and market segments, and systematic risks from common exposures.

Figure 10 displays how different contagion channels have contributed to the variation in the Canadian banking system's capital ratio over time. Consistent with the representation from Equation (1), contagion risk acts as an amplifier for variations due to systematic risks caused by common exposure and idiosyncratic risks. Taking the 2008 financial crisis as an example, contagion amplified idiosyncratic or systematic risks in the variation of banks' capital ratio by 140%. That is, the initial risk in the

system got multiplied by 2.4 across all the contagion channels considered.[17]

Contagion driven by contractual book-based obligations (i.e., all channels except market-based and price-mediated contagion, some of those layers being represented in Figure 8[18]) remains relatively stable at around 40% throughout the sample period, up until the exceptional monetary policy interventions in 2020. This stability suggests that liquidity sharing practices in Canada maintained a healthy level of diversification during both normal and stressed periods. Derivative receivables were particularly significant during the lead-up to the GFC in 2007 but became less dominant thereafter, potentially reflecting the post-crisis reforms promoting the use of central counterparties.

Conversely, market-based (encompassing the data from Figure 6) and price-mediated contagion spike during stressful periods. During the 2008 global financial crisis, market-based contagion (dark brown) peaked, in line with the lack of trust among market participants at the time. The associated reshuffling of portfolios created large asset price movements reflected by the price-mediated contagion (light brown). Moreover, when Home Trust experienced difficulties around 2017, contagion related to trust (market-based) and fire-sales (price-mediated) peaked again.

[17] Note that this representation treats contagion symmetrically, i.e. positive as well as negative contagion following a decrease or increase in risk.

[18] Or see the full set of layers in Figure 2 of Hałaj and Hipp (2025).

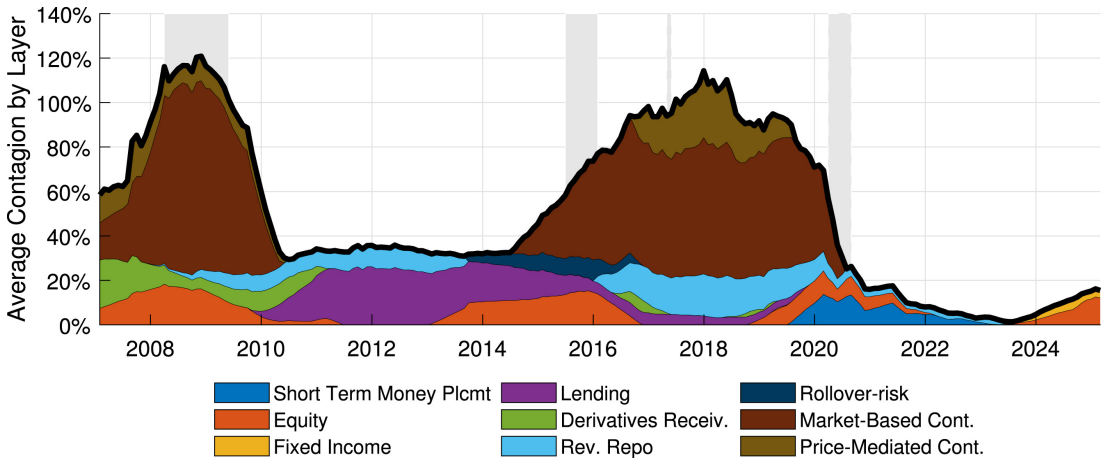

Figure 10: **Decomposition of contagion by book- or market-based channels**

Note: Recession periods are shaded in grey. Source: Hałaj and Hipp (2025). Last observation: 2024Q4.

4 Monitoring system-level stress and resilience

While interconnectedness explains how shocks propagate, assessing the resilience of the financial system as a whole is equally critical. This section introduces system-level stress indicators and simulation tools used by the Bank of Canada. Thus, the tools described in this section directly target the operationalization of the left side of Equation (1).

4.1 Market-based system-level stress

4.1.1 Financial stress

Systemic stress occurs when sharp corrections happen simultaneously across major markets—such as housing, bonds, and equities—leaving investors with no safe haven. This interconnected turmoil can amplify risk transmission throughout the financial system and may signal the onset of a financial crisis.

To monitor systemic stress, the Bank staff uses the Canadian Financial Stress Index (CFSI, Figure 11 from Duprey et al., 2017; Duprey, 2020)[19,20] which aggregates stress

[19]Updated data available for download on the public dashboard of financial stability indicators https://www.bankofcanada.ca/rates/indicators/financial-stability-indicators/

[20]Illing and Liu (2006) built the first index for Canada, initiating the literature on those indices.

indicators across seven markets: equities, government bonds, money markets, banking, corporate credit, currencies, and housing. The index accounts for both the magnitude of stress relative to the U.S. and the degree of co-movement among Canadian markets.

Stress in a single market is not necessarily systemic unless it spreads to others. When markets are highly correlated, overall stress exceeds the sum of individual stresses—similar to how portfolio risk rises when asset returns are correlated. The CFSI captures this amplification by weighting correlated sectors more heavily. During episodes like the 2008 global financial crisis or the COVID-19 pandemic, stress across individual markets increased (blue area), but the index rises even more once interdependencies across markets (orange) are factored in. This illustrates a key feature of systemic crises: financial linkages accelerate risk propagation, leaving no sector immune.

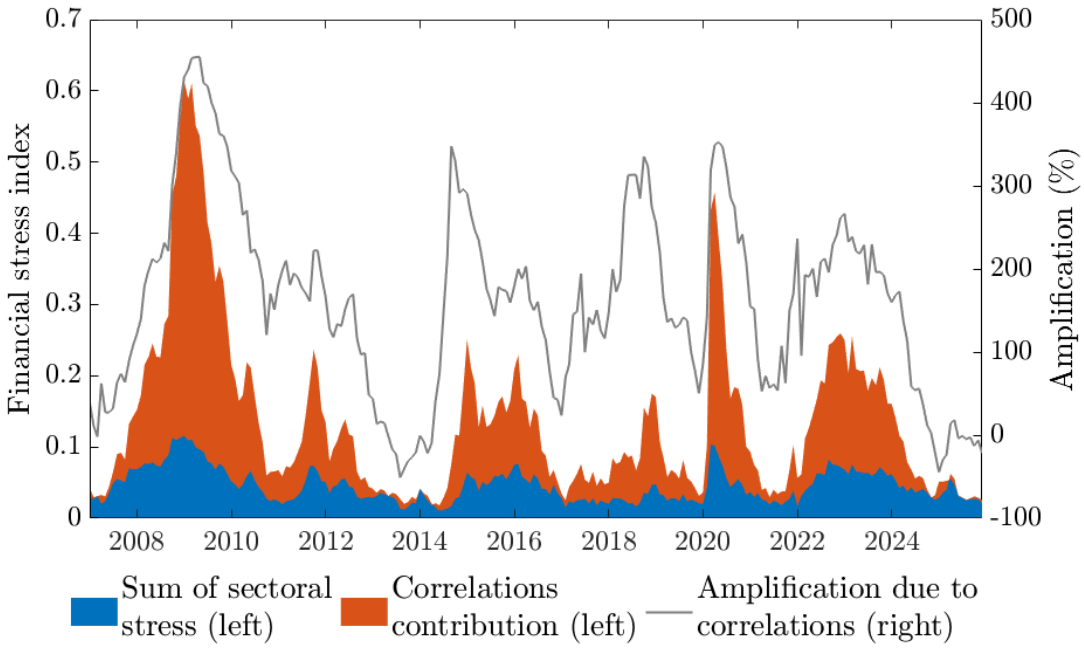

Figure 11: **The evolution of financial stress index in Canada is mostly driven by correlation**

Note: The CFSI ranges from 0 to 1, with higher values indicating greater systemic stress. Source: Duprey et al. (2017); Duprey (2020), Bank of Canada calculations. Last observation: December 2025.

Financial stress indices are most useful at quantifying the intensity of stress in the economy at a given point in time, and the materialization of systemic stress is usually associated with painful real economic impacts (Adrian et al., 2019 or in the Canadian context see Duprey and Ueberfeldt, 2020).[21] However it is less forward looking and justifies exploring scenario as a complement.

4.1.2 Liquidity stress

Liquidity stress differs from solvency stress primarily in its speed and transmission channels. Solvency stress typically builds over longer horizons as credit losses accumulate and capital buffers erode, whereas liquidity stress can materialize abruptly when funding becomes unavailable or funding markets become impaired, forcing institutions to liquidate assets or secure liquidity quickly. Deteriorating market liquidity can trigger price-mediated contagion: falling asset prices erode the balance sheets of other holders, inducing further asset sales (e.g. via margin calls), reducing dealers' willingness to lend, eventually tightening funding conditions further. In particular, liquidity stress is salient for NBFIs, which often combine liquidity transformation, leverage, and reliance on market-based funding, and can therefore both experience and amplify these price- and funding-liquidity spirals. For instance, Gorton and Metrick (2012) and Gorton et al. (2020) highlight that during the 2008 global financial crisis, liquidity concerns led to increased repo haircuts, ultimately leading to solvency concerns for U.S. financial intermediaries.

In Canada, the share of NBFIs in total financial system assets has remained high and broadly stable over time (Figure 12).[22] During the market turmoil in March 2020, Bédard-Pagé et al. (2021) document how the largest Canadian public pension funds

[21] However, episodes of systemic stress are notoriously difficult to predict in real-time. For instance, prior to the 2008 global financial crisis, leading indicators like the credit-to-GDP ratio would not have provided a statistically robust signal of impending systemic stress. This is only once the 2008 global financial crisis is included in the data that traditional leading indicators of crises like debt servicing, credit-to-GDP ratios or house price ratios become valid statistical predictors of systemic stress (Duprey and Klaus, 2022).

[22] Globally, over recent years, non-bank financial institutions, including hedge funds, have increased their reliance on core funding markets. This led to discussions among international regulators to evolve the policy toolkit to address liquidity risks.

managed liquidity during that episode, highlighting their reliance on core funding markets. In times of stress, if the potential demand from insurance companies or asset managers for market liquidity exceeds dealers' intermediation capacity, this could trigger a precautionary, and potentially disruptive, dash for cash, prompting central bank intervention (Aldridge et al., 2024; Cimon et al., 2025).

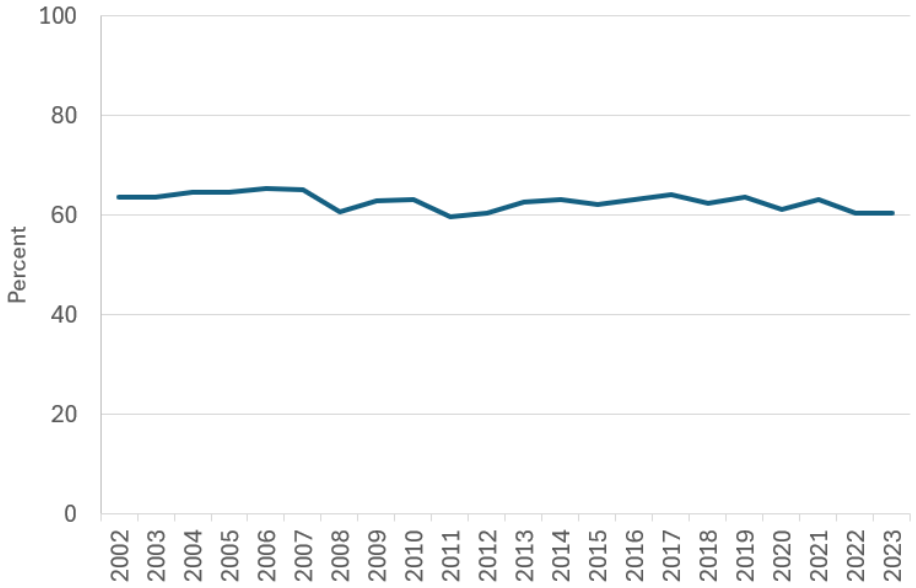

Figure 12: **The prevalence of non-bank financial institutions in Canada is elevated but remains stable**

Note: Percentage as a share of total financial assets. Source: Chart 1 of Gomez Navas Acevedo and Thorn (2025). Last observation: 2023.

Several strands of Bank of Canada staff research explore NBFI-related liquidity risks, derived from market data. First, Arora et al. (2019) build a liquidity stress test model for investment funds that invest in corporate bonds. It quantifies how asset sales from investment funds could amplify a sudden decline in asset prices through the liquidity risk premium, accounting for the investor's responses to fund performance, the portfolio manager's liquidity-management decisions in response to redemption demands, and the provision of liquidity by broker-dealers. Second, Uthemann et al. (2025) estimate that a sale of 1% of the available supply of Government of Canada bonds lowers bond prices by 0.2%. They find that quarterly fluctuations in bond prices

are driven primarily by changes in demand from large institutional investors, such as foreign investors and Canadian pension funds. Third, Brennan et al. (2025) develop a stress-testing methodology applied to Canadian central clearing counterparties, capturing the risk of low-probability tail losses using extreme value theory. Raykov (2024) estimate that the normality assumption for margin calls was associated with an under-margining on the Canadian futures market of about $1.6 billion during the 2008 global financial crisis.

4.2 Book-based system-wide simulations

In order to complement the toolkit, it is crucial to have a system-wide simulation tool to simulate stress scenarios and assess system resilience to these scenarios. Bank of Canada staff have developed two complementary frameworks that incorporate agents, flows of funds (Tables 1 and 2), and contagion channels (Section 2) to simulate stress and identify stress patterns requiring further attention.

4.2.1 Agent-based modelling

Bruneau et al. (2025) introduce an agent-based model (ABM) to analyze how shocks propagate and amplify through interactions among different types of agents—banks, life insurers, pension funds, and investment funds—each defined by balance sheets, regulatory constraints, and behavioural rules. The model captures several of the transmission channels listed in Section 2:

- Contractual-based contagion via cross-holdings (ownership of other institutions' debt or equity transmits shocks directly), and via interbank lending (liquidity constraints propagate through lending networks).
- Information contagion via business similarities (institutions with similar balance sheets face higher funding costs when peers are distressed).
- Price-mediated contagion: via margin calls (from its derivatives position), the performance-flow nexus (investor redemptions in open-ended funds amplifying liquidity pressure), common exposures (correlated losses from similar asset hold-

ings), all together contributing to fire sales.

The ABM shows that modest shocks can be significantly amplified, particularly via fire sales and common exposures. Investment funds emerge as key stress amplifiers due to procyclical behaviour and liquidity vulnerabilities, for instance following redemption shocks. Conversely, pension funds act as stabilizers by purchasing undervalued assets during stress due to their longer-term investment horizons and more stable funding base.

Bruneau et al. (2025) apply the ABM to a climate transition shock in Canada and Figure 13 decomposes the origin of systemic risks by institution. The node size represents the systemic impact on each entity, standardized by the entity's total assets, while the arrows track the impact back to the originating institutions. The results highlight the role of mutual funds as a potential source of stress spreading to deposit-taking institutions.[23]

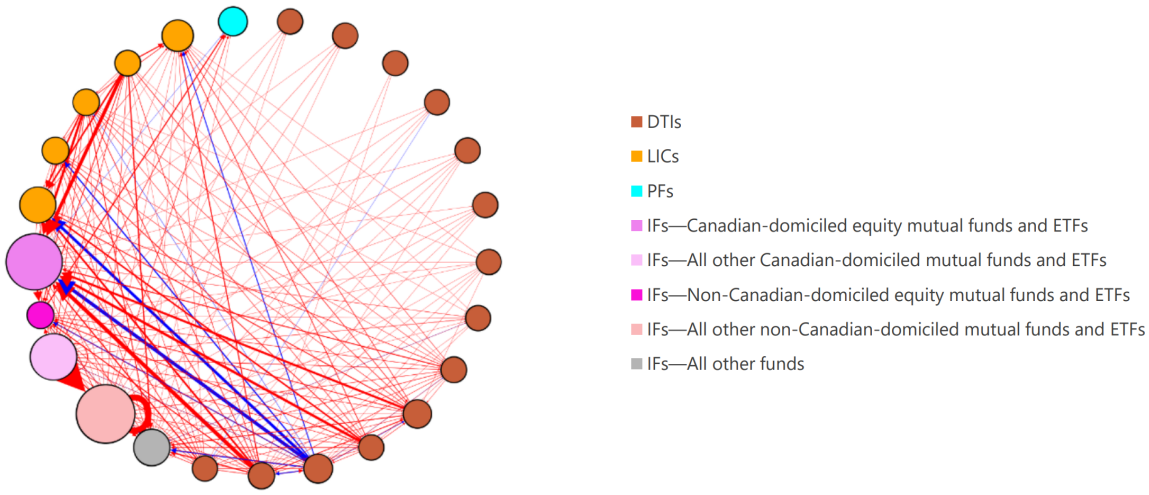

Figure 13: **Origination of systemic effects by entity type**

Note: DTIs are deposit-taking institutions; LICs are life insurance companies; PFs are pension funds; IFs are investment funds. Sources: Office of the Superintendent of Financial Institutions; Autorité des marchés financiers; proprietary data from Canadian pension funds; Lipper, a LSEG Company; Eikon, a LSEG Company; and Bank of Canada calculations. Source: Chart 10b of Bruneau et al. (2025). Last observations: DTIs, LICs, IFs and most PFs, December 2021; remaining PFs, March 2022.

[23] Of note, in that climate scenario, the shock can both depress (red arrows) or amplify (blue arrows) asset valuations of different entities.

A limitation of agent-based modelling is that stressed agents adjust their portfolio with predefined static rules, such as asset sales at a fire-sales price that is calibrated to increase with the volume sold. Put differently, agents do not explicitly optimise their balance sheet, and sold assets are not necessarily bought by another agent. Those are core features of the model described in the next section.

4.2.2 Equilibrium-based modelling

Unlike ABMs, the Bank Strategy Model (BSM) (Hipp and Ojea-Ferreiro, 2026) is a partial equilibrium framework where banks dynamically optimise portfolios under stress, subject to regulatory constraints.[24] Banks maximize their return to equity and compete for assets and liabilities, generating (i) a macroeconomic impact via reduced credit supply to the real economy, and (ii) price-mediated contagion via fire sales that depress the balance sheet of other agents holding the same assets.

The approach differs from traditional models that rely on either static accounting rules (as in standard stress testing, e.g., Abdelrahman et al., 2025) or assumed behavioural rules (as in agent-based models, e.g., Bruneau et al., 2025). It features utility-based optimization of return on equity under stress. As such, it borrows from more structural macro-financial models of banks used in the academic community. The strategic interactions are disciplined through a Nash equilibrium, where each of the six large DSIBs' optimal strategy influences the strategies of the others. This is a reasonable assumption to model the concentrated Canadian banking sector with 6 large banks whose choices may influence the market.

Equilibrium prices are determined endogenously, so that price-mediated contagion emerge within the model. Assets sold under distress are then bought by other banks, resulting in fire-sales if other banks are unable to absorb the volume of assets sold. This is in contrast to other contagion models that do not ensure that assets sold at a firesale price are bought by another agent in the economy.

In this model, changes in regulatory constraints matter even if the constraints are not

[24] It shares some insights with the previous work of Hałaj and Priazhkina (2021).

binding. In practice, Canadian banks hold ample equity and liquidity buffers above the minimum requirements, even though many models assume either that constraints are binding or that amplification is triggered only when constraints are breached. In this model, banks face a tradeoff between holding less capital but being at risk of breaching minimum regulatory requirement, versus holding more capital but diluting their return-on-equity.

The model is estimated on detailed regulatory balance sheet data to match historical patterns, in contrast with many contagion frameworks that are instead calibrated.

Note that the model is not intended as a supervisory forecasting tool, but rather as a way to explore systemic interactions and non-linearities. The model relies on utility functions to model agents such that it is not suited to predict single firms financial outcome.

Simulations illustrate how declining CET1 ratios lead to nonlinear reductions in credit provision to create macro feedback loops that amplify economic downturns. Figure 14 displays one dot per macro-financial scenario after three years, generated by resampling historical shocks. It shows that when all banks remain above regulatory minimums (vertical bar, at 9% for 2020Q2), changes in banks' equity position do not lead to sharp changes in credit provision that largely reflects the demand for loans (blue dots). When one bank breaches the minimum, the aggregate credit provision to the economy deteriorates non-linearly (red dots). As CET1 ratios decline under stress, ailing banks proactively try to preserve their balance sheet and reduce their lending. Lower lending by ailing banks can be compensated by higher lending by healthier competing banks, so it may not severely impact the aggregate provision of credit. This behavioural response creates a wider dispersion of the simulated results (the red dots) and a worsening of the left tail of credit provision to the real economy (skewed distribution of lending outcome).[25]

[25] For an application of the model to assess the impact of tighter capital regulations, see Chart 7 of Duprey et al., 2024.

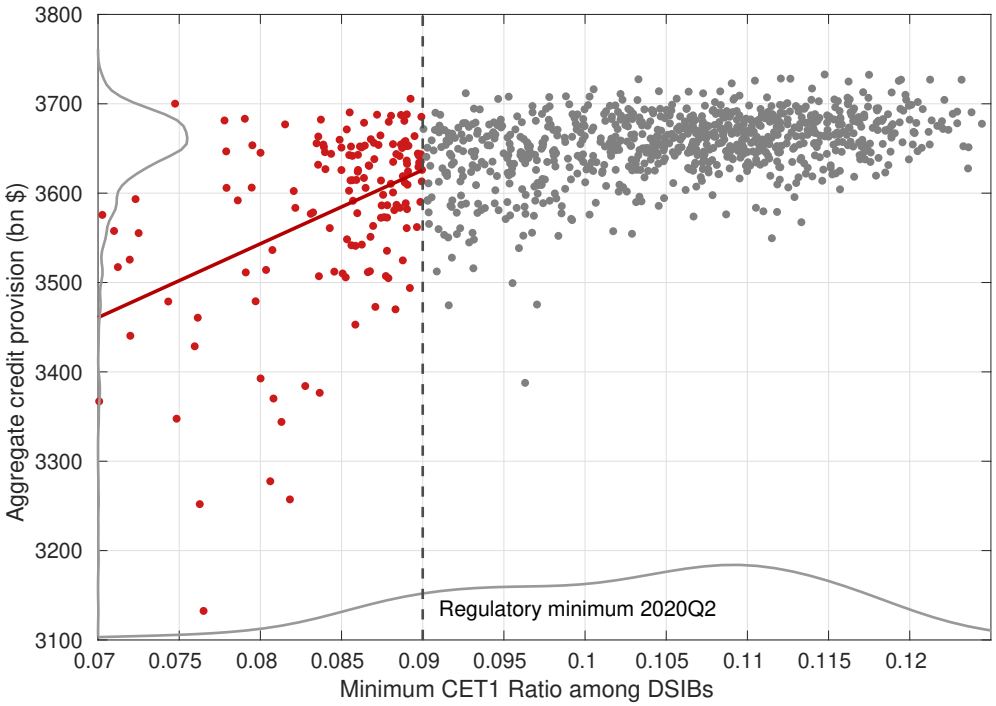

Figure 14: **Financial system stress translates to real economic impacts**

Note: Minimum CET1 ratio among D-SIBs against aggregate credit provision across 1,000 simulated scenarios starting from 2020Q2. Red dots indicate the left tail of the CET1 distribution, corresponding to scenarios of severe capital stress. The nonlinear relationship reflects the collective deleveraging mechanism of the model: above approximately 9.5% CET1, credit provision is relatively stable; below this threshold, simultaneous capital pressure across institutions triggers a self-reinforcing contraction in lending. Source: Bank of Canada calculations using the model of Hipp and Ojea-Ferreiro (2026). Last observation: 2020Q2.

4.2.3 System-wide reverse stress-test modelling

The system-wide risk simulation toolkit lends itself to reverse stress testing. Given the historical resilience of the Canadian financial system, a key question is what type of shocks, macro-financial scenarios or contagion channels could trigger financial stress significantly enough to adversely affect the real economy. The idea is that, instead of looking at the resilience of the financial system under one risk scenario, one would look at which risk scenario could endanger the resilience of the financial system.

This approach is illustrated in Figure 15 using the BSM model. On the left panel, multiple scenarios are simulated and expressed in terms of returns for banks. Each

path is simulated in the BSM model to produce the distribution of possible CET1 ratios on the right panel. Given stress materializing among the big Canadian banks (red part of the histogram on the right panel), one is interested in tracking back what type of macro-financial scenarios can lead to stress (red lines on the left panel).

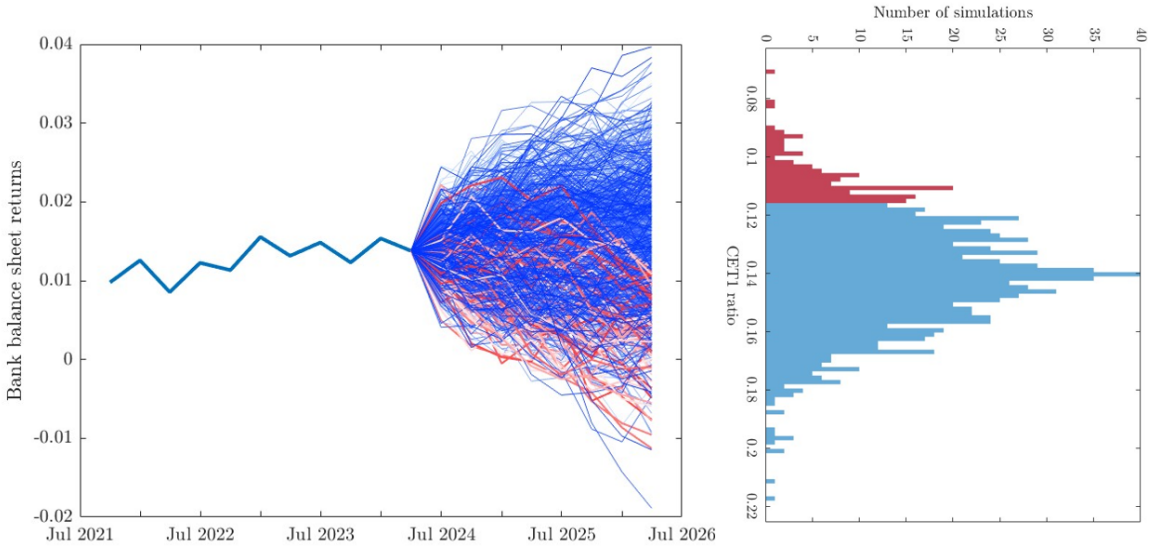

Figure 15: **Example reverse stress-test for the Canadian financial system**

Note: Results of simulating economic scenarios over a two-year horizon, using 2024Q2 initial conditions. Each line on the left panel represents one simulation, and the right panel displays the histogram of each simulation result in terms of the average CET1 ratios for the big Canadian banks using the model of Hipp and Ojea-Ferreiro (2026). Source: Bank of Canada calculations. Last observation: 2024Q2.

5 A blueprint for system-wide stress testing in Canada

The analysis in this paper highlights important limitations of existing financial stability monitoring tools. While banks are well capitalized, systemic risk may still arise through non-bank financial intermediaries, cross-border linkages, and liquidity dynamics that are not fully captured in existing institution-level modelling. Market-based and book-based indicators identify vulnerabilities, but they do not quantify the severity of shocks or configuration of contagion channels required to threaten system-wide resilience.

In this section, we outline the case for a system-wide simulation toolkit that would

allow for system-wide stress testing and reverse stress testing to support financial system and macroprudential policies. We show how Bank of Canada staff's ongoing toolkit development is one step in this direction.

5.1 A new set of questions

The pre-existing stress-testing infrastructure, including the FRIDA framework at the Bank of Canada, is designed to answer a narrowly defined but essential question: whether individual banks remain solvent under a given severe but plausible macroeconomic scenario. System-wide stress testing extends this perspective by asking how distress at one institution or market segment may propagate across the financial system through interconnections, behavioural responses, and market dynamics. Reverse stress testing pushes the analysis further by inverting the problem, starting from a definition of systemic failure and asking under what configurations of shocks and amplification mechanisms such an outcome could arise. Moving from institution-level stress tests to system-wide and reverse stress-testing frameworks therefore does not simply refine existing tools. It fundamentally expands the set of questions that financial stability analysis can tackle.

Shock interaction and amplification. A first set of questions concerns how multiple sources of risk interact and amplify each other. For instance, the economy is simultaneously exposed to geopolitical tensions, structural shifts in global trade, rapid technological change with artificial intelligence, and long-run demographic trends. Each of these developments could affect financial institutions in some way, but their interaction may matter even more. For example, an idiosyncratic failure of a non-bank financial institution may be manageable in isolation. Yet if it occurs in a vulnerable environment with structural shifts and low confidence, trust contagion may start to spill among institutions with similar business models, turning a localized event into potential system-wide disruption.

Propagation channels with NBFIs. A second set of questions concerns the channels through which stress propagates in a heterogeneous financial system with a

strong prevalence of non-bank financial intermediaries. Portfolio reallocations and redemption pressures at investment funds, shifts in insurers' demand for safe assets following large losses, and precautionary deleveraging by market participants can all impair market liquidity and funding conditions. Even in the absence of outright defaults, defensive behaviour can transmit stress across institutions and asset classes, overwhelming dealer intermediation capacity, triggering margin calls and fire sales, and generating price-mediated contagion. A central issue is therefore when and how liquidity stress leads to solvency stress, transforming short-lived funding pressures into persistent system-wide financial instability.

Tipping points. A third set of questions concerns how close the financial system may be to a tipping point. Conventional stress tests assess resilience against a small number of carefully designed scenarios, but they provide little guidance on the severity or combination of shocks and transmission channels required to trigger systemic failure. Identifying the smallest shocks and most prominent channels that could generate outsized effects, or the configurations of risks that push the system beyond its resilience limits, calls for a different approach: one that emphasizes distributions of outcomes and reverse stress testing rather than single scenarios.

Policy effectiveness. A final set of questions relates to the effectiveness of policy interventions in a system-wide context. Stress-testing frameworks have traditionally emphasized capital adequacy and risk-weighted assets, yet the effectiveness of these tools depends on how buffers are used in practice during stress. In addition, broader policy interventions, such as access to central bank liquidity facilities, quantitative easing, or rules shaping competition in the banking sector, can materially influence the resilience of the financial system. Evaluating which policy tools are most effective at breaking macro-financial feedback loops requires a framework that captures behavioural responses across institutions and a wide range of policy tools.

5.2 The current frameworks are not well equipped for those questions

The current stress-testing architecture suffers from a number of structural shortcomings that limit its ability to address this expanded set of questions.

Sequential models without feedback. The typical setup (e.g., FRIDA at the Bank of Canada) passes outputs from one model to another in a predetermined sequence. By construction, this architecture cannot capture the feedback loops that characterise systemic crises: falling asset prices weaken balance sheets, impaired balance sheets reduce credit supply, and tighter credit conditions further depress asset prices. Without explicitly embedding these macro-financial feedback mechanisms, often described as financial accelerator effects, the framework cannot capture how moderate shocks become system-wide events.

Banks without non-banks. Despite NBFI's significant footprint, they have not been systematically integrated into the core stress-testing architecture. Investment funds, pension funds, insurance companies, and private credit vehicles remain largely outside existing toolkit, even though Section 3.1 documents that their perceived connections to banks have tightened over the past decade. In such an environment, a bank-only stress test increasingly provides an incomplete picture of systemic risk.

Solvency without liquidity. The existing toolkit typically assesses solvency over multi-quarter horizons calibrated to historical recessions. Liquidity stress, by contrast, materialises over days or weeks, as illustrated by the March 2020 dash-for-cash episode or the March 2023 failures of U.S. regional banks. A framework that abstracts from the speed at which funding pressures and market dysfunctions propagate cannot credibly assess whether a shock is systemic, nor whether policy intervention must occur before solvency metrics deteriorate.

Gross exposures without hedging. Existing stress-testing frameworks typically focus on gross balance-sheet exposures, giving limited attention to hedging strategies, derivatives positions, and the role of central counterparties. Yet derivatives can both mitigate and amplify stress, depending on margining practices, liquidity demands,

and the distribution of exposures across institutions. Ignoring these mechanisms risks misrepresenting how shocks are transmitted through the system. During periods of heightened volatility, risks might be under-estimated if margin calls are triggered, but risks might also be over-estimated if risky positions are hedged.

Domestic assumptions without global channels. Much of the current toolkit is built around a predominantly domestic set of contagion channels even if macroeconomic stress scenarios include a global dimension. However, Canadian banks hold a large share of their assets and liabilities abroad, and episodes of stress can be transmitted through information channels, market correlations, and funding conditions even in the absence of direct exposures. A framework that treats the financial system as largely closed may therefore understate the scope for cross-border contagion and global amplification.

One scenario without a distribution. Finally, stress tests based on a single, carefully designed scenario provide limited information about how close the financial system is to a tipping point. They cannot identify which combinations of shocks and amplification channels would be sufficient to overwhelm a system that appears resilient under baseline assumptions. As a result, they offer little guidance on the margins of safety surrounding the current state of the financial system, or on the likelihood of tail outcomes.

5.3 The current international state of play

Although system-wide stress testing remains at an early stage of development, international regulatory authorities have already made meaningful progress toward frameworks that go beyond bank-centric solvency analysis. In particular, recent work by the Bank of England and the European Central Bank represents the current frontier, illustrating two complementary approaches to assessing system-wide financial resilience.

- **Bottom-up approach of the Bank of England.**[26] The System-Wide Ex-

[26]The Bank of England has also developed simpler top-down approaches with representative agents;

ploratory Scenario (SWES; Bank of England, 2024) examines how stress may spread across the UK financial system by eliciting responses directly from market participants. Banks, insurers, funds, and other institutions are asked to simulate how they would react to a severe but plausible liquidity stress over a short horizon, typically two weeks. The regulator then aggregates these individual responses to assess how asset sales, funding pressures, and liquidity demands could interact across sectors and potentially amplify instability.

- **Top-down approach of the European Central Bank.**[27] The Interconnected System-wide Stress Test Analytics tool (ISA; Sydow et al., 2024a,b) assesses shock propagation using a regulator-run simulation that links banks, non-bank financial institutions, and financial markets. The framework combines granular balance-sheet and exposure data with market information on asset prices and liquidity conditions. It traces how an initial shock, such as an asset price decline or funding squeeze, affects institutions' portfolios and propagates through common asset holdings, funding linkages, and endogenous price adjustments.

These two approaches involve a clear trade-off. Bottom-up exercises can generate rich insights into institutions' behavioural responses under stress, but they are resource-intensive and require substantial coordination across participants. Top-down approaches are more flexible and scalable to tackle rapidly evolving risks landscapes, but they rely more heavily on modelling assumptions and on the regulator's access to detailed data. Together, they illustrate the range of methodological choices involved in building a system-wide stress-testing capability.

Canada's financial system characteristics make the case for system-wide stress testing less immediately obvious. The banking sector is concentrated, well capitalised, and has historically displayed a high degree of resilience. By contrast, the UK has experienced recent liquidity-driven episodes, such as the 2022 Liability-Driven Investment (LDI)

see Aikman et al. (2019).

[27]The Federal Reserve System is also leveraging top-down modelling, for instance building on the work of Cetorelli et al. (2023).

gilt crisis, in which a sharp rise in yields triggered sudden margin calls and forced asset sales. However, the absence of recent domestic crises does not imply immunity to systemic risk. Instead, it suggests that a system-wide stress-testing framework must reflect the specific structure and fault lines of the financial system.

A system-wide modelling approach would nonetheless be valuable for Canada along several dimensions. First, it would strengthen the assessment of "what-if" scenarios by quantifying how the financial system as a whole would respond to severe macro-financial stress. Second, it would expand risk analysis through system-wide reverse stress testing, helping to identify which combinations of shocks and amplification channels could undermine resilience, even when observed risk indicators are low. This perspective is particularly relevant in an environment of major structural change, including shifts in trade policy, technological adoption such as AI, and geopolitical reconfiguration. Third, it would enhance ex-ante policy analysis by jointly evaluating prudential measures, liquidity facilities, emergency central bank interventions, and balance-sheet policies. As rising global public debt is likely to constrain the scope for large-scale bailouts in future downturns, effective ex-ante regulation becomes an increasingly important first line of defense. In this context, system-wide stress testing should be viewed as a tool for assessing financial resilience rather than supervisory compliance, complementing (rather than replacing) existing regulatory stress-testing frameworks.

5.4 What the new toolkit must contain

A system-wide stress-testing toolkit for Canada should not be a single model, but an integrated architecture: a set of modelling components, data inputs, and analytical protocols that can be combined to answer different classes of policy-relevant questions. Building on the limitations identified above and on emerging international practice, we identify a set of core ingredients that such a toolkit must contain.

Strategic interaction and equilibrium prices. A system-wide framework must allow financial institutions to respond strategically to stress, rather than treating

balance-sheet adjustments as mechanical accounting outcomes. In a concentrated system such as Canada's, where the actions of a small number of large banks can materially affect market conditions, asset prices and funding costs must be determined endogenously. This requires an equilibrium setting in which portfolio rebalancing, fire sales, and funding choices interact, allowing amplification to arise from strategic behaviour rather than imposed shocks. Recent equilibrium-based modelling work by Bank of Canada staff provides a natural foundation on which such system-wide extensions can build.

Explicit inclusion of non-bank financial intermediaries. Non-bank financial institutions play a central role in modern financial systems, both as providers of credit and as key participants in funding and asset markets. A system-wide toolkit must therefore model investment funds, insurers, pension funds, and other NBFIs alongside banks, rather than treating them as passive background entities. This is essential for capturing redemption dynamics, portfolio reallocations, and spillovers to banks and the real economy. Agent-based modelling work by Bank of Canada staff already incorporates several of these institutions, offering a natural platform for broader system-wide integration.

Dynamic liquidity–solvency feedbacks. Systemic crises unfold quickly, often over days or weeks rather than quarters, and are driven by tight feedbacks between liquidity conditions and balance-sheet strength. Funding pressures can force rapid asset sales that erode capital, while weakened solvency can in turn restrict access to liquidity and market funding. A credible system-wide toolkit must therefore capture both the speed and the sequencing of stress propagation. Frameworks that treat liquidity and solvency separately, or that operate only at low frequency, risk missing the nonlinear dynamics that transform localized stress into systemic events.

Hedging, derivatives, and margining mechanisms. Derivatives and hedging arrangements materially shape how shocks propagate through the financial system. While such instruments can mitigate risk exposures in normal times, they can also generate procyclical liquidity demands through margin calls and collateral constraints

under stress. A comprehensive toolkit must therefore account for net exposures, central counterparties, and margining practices, particularly during periods of heightened volatility. Stress-testing work on central counterparties and margin adequacy in Canada highlights the importance of embedding these mechanisms within a broader system-wide framework.

Cross-border and global linkages. Canada's financial system is deeply integrated with global markets, especially the United States. System-wide stress testing must therefore extend beyond a closed-economy perspective to capture cross-border exposures, global asset price co-movements, and informational contagion. Ignoring these channels risks understating tail risks that originate abroad but are transmitted domestically through funding markets and investor expectations.

Scenario distributions and reverse stress testing. A defining feature of a mature system-wide toolkit is the ability to move beyond a small number of predefined scenarios. By generating distributions of outcomes and conducting reverse stress tests, the framework can identify the combinations of shocks (domestic or global), behavioural assumptions, and amplification mechanisms that would be sufficient to overwhelm system-wide resilience. This approach is particularly valuable in environments where observed risk indicators are low but structural vulnerabilities may be building.

Taken together, these ingredients are designed to operationalize Equation (1) in full: a toolkit that can quantify the contagion multiplier endogenously, stress-test all sources of idiosyncratic and systematic risk jointly, and simulate their interaction across institutions, asset classes, and borders.

Bank of Canada staff have already started building prototypes of such a system-wide simulation toolkit and reverse stress-testing framework, drawing directly on many of the ingredients outlined above. Figure 16 illustrates what the new simulation toolkit, STRESS,[28] may look like. At the core, it builds on the BSM equilibrium model of Hipp and Ojea-Ferreiro (2026) focused so far on banks (green square) and several markets

[28] *Systemic Tensions Risk Evaluation via Simulations* in English, or *Simulations des Tensions liées aux Risques Extrêmes Sur le Système* in French, to follow Canada's bilingual diversity.

(green ovals). Ongoing extensions include adding NBFIs, e.g. mutual funds, as well as plans to include households and firms (red squares). Figure 15 illustrates the reverse stress testing using the BSM with our existing multivariate scenario generator and Ojea-Ferreiro (2025) provides a statistical method to label scenarios for reverse stress testing. The goal is to operationalize and expand this framework at the system-wide level, spanning banks and non-banks, domestic and cross-border shocks, solvency and liquidity stress.

Eventually, a system-wide stress-testing toolkit must be embedded within the broader financial stability monitoring and policy framework, rather than operating as a stand-alone modelling exercise. Market-based indicators and balance-sheet metrics should inform scenario design and trigger targeted simulations, while stress-testing outputs should feed directly into policy analysis and decision-making. In this sense, the objective is not supervisory compliance, but a forward-looking assessment of system-wide resilience that complements existing monitoring tools and supports macroprudential, liquidity, and crisis-management policies.

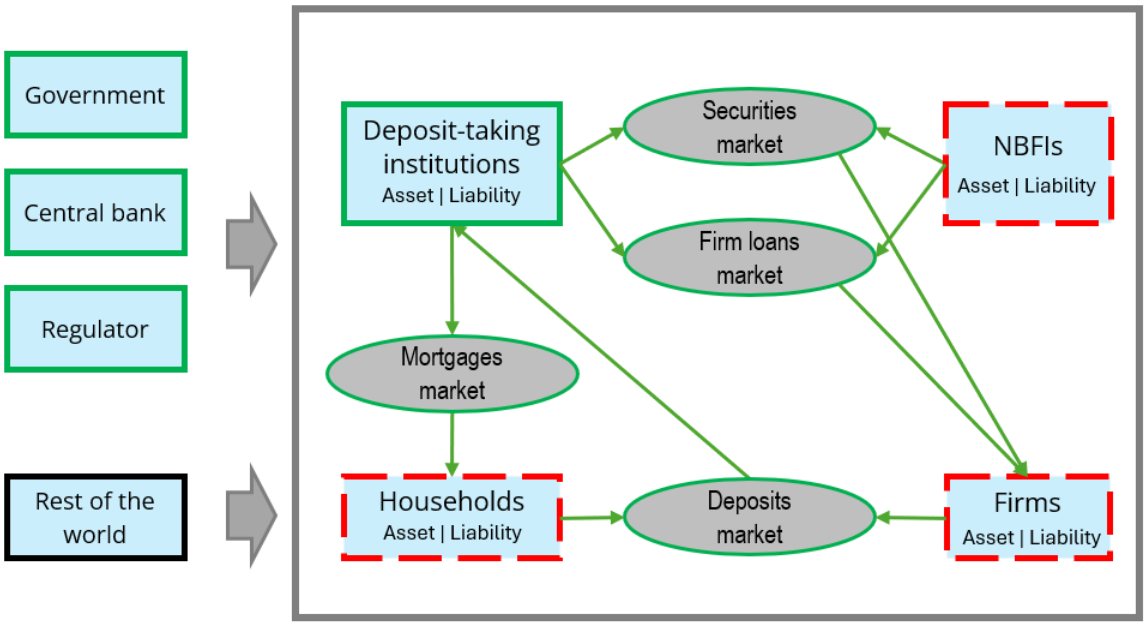

Figure 16: **Outline of the new model, Systemic Tensions Risk Evaluation via Simulations (STRESS)**

Agents with assets and liabilities are simplified with one square per type but may be modeled as individual agents depending on granularity of data available. Markets are oval, and arrows show a simplified set of flows of funds in the system. Green squares and ovals are already included in some form in Hipp and Ojea-Ferreiro (2026). Red squares are ongoing and future work.

6 Conclusion

System-wide stress testing offers a complementary perspective to traditional institution-level solvency analysis by focusing on the resilience of the financial system as a whole. In contrast, traditional solvency-focused frameworks, while still essential, offer limited insight into system-level vulnerabilities, particularly in an environment where banks are well capitalized and non-bank intermediaries play an increasingly prominent role in financial intermediation. A system-wide stress-testing framework would instead allow policymakers to conduct "what-if" analyses of how the financial system continues to fund the real economy under a broad range of scenarios or alternative regulations. Such a framework would also support reverse stress tests, helping to identify combinations of shocks and contagion channels that could threaten system resilience even when individual institutions appear sound.

Despite the analytical advances reviewed here—from market-based and book-based measures of interconnectedness to agent-based amplification models and equilibrium portfolio optimization—important gaps remain on the path toward a fully operational system-wide stress-testing framework. The future toolkit will need to rely on a dynamic equilibrium model that includes financial market participants' behaviour under stress, explicitly models interactions between banks and a broad range of NBFIs, better integrates liquidity with solvency risks to also reflect the growing importance of hedging practices and global interconnections, and accounts for a wide range of scenarios and hypotheses to identify possible fault lines and breaking points. Addressing these challenges will require sustained collaboration between the Bank of Canada, domestic regulatory partners, international institutions, and academic researchers to ensure that system-wide stress testing evolves into a practical and policy-relevant tool for safeguarding financial stability.

Looking ahead, advances in artificial intelligence (AI) present both opportunities and new challenges for system-wide stress testing. On the modelling side, machine-learning techniques may help uncover nonlinear relationships, improve scenario design, and detect early-warning patterns that are difficult to capture using traditional econometric or structural models. AI could also enrich agent-based and equilibrium frameworks by enabling more realistic behavioural responses or by generating synthetic counterfactual data where empirical evidence is limited. At the same time, the growing adoption of AI across financial institutions introduces new sources of systemic risk, including autonomous trading strategies, third-party concentration risk, opaque decision-making processes, and correlated model errors (Global Risk Institute and Government of Canada, 2025). Incorporating AI-driven behaviours and vulnerabilities into future system-wide stress-testing architectures therefore represents a natural and necessary extension of this research agenda.

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A Appendix

Agent Type	Assets	Liabilities	Economic Function
Mutual Funds	Equity, bonds	Shares held by households and firms	Intermediaries channeling household savings into markets
Private Credit Funds	Illiquid loans to households and firms	Investor capital (institutional, high net worth individuals)	Substitute for traditional lending; price in higher risk
Pension Funds	Long-duration assets (gov bonds, equities)	Future obligations to households	Long-horizon savers with low liquidity needs
Insurance Companies	Reserves, investment portfolios	Contingent claims	Risk transformation; hedge tail events
Hedge Funds	Leveraged financial positions	Investor capital, broker leverage	Speculative risk takers; provide market liquidity and volatility
Real Estate Investment Trusts	Real estate holdings	Equity, debt issuance	Real estate exposure vehicle for savers
Securitization Vehicles	Structured finance products (MBS, ABS)	Tranches issued to investors	Pool and repackage loans into tradable assets
Money Market Funds	T-bills, commercial paper, repo	Shares to households/firms	Short-term cash-like exposure for savers
Sovereign Wealth Funds	Diversified portfolios (global equity, infrastructure, bonds)	State capital allocations	Long-term strategic investors

Table A.1: Agent Types, Assets, Liabilities, and Economic Functions