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Simulating the Resilience of the Canadian Banking Sector Under Stress: An Update of the Bank of Canada's Top-Down Solvency Assessment Tool

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Abstract

We present a technical description of the Top-Down Solvency Assessment (TDSA) tool. As a solvency stress-testing tool, TDSA is used to assess the banking sector's capital resilience to hypothetical future risk scenarios.

Topics: Economic model; Financial institutions; Financial stability; Financial system regulation and policies
JEL codes: C, C2, C22, C5, C52, C53, G, G1, G17, G2, G21, G28

Résumé

Nous présentons une description technique de l'outil d'évaluation de la solvabilité selon une approche descendante (modèle TDSA). Permettant de tester la résistance au risque d'insolvabilité, cet outil est utilisé pour évaluer la résilience des fonds propres du secteur bancaire dans des scénarios de risque hypothétiques et prospectifs.

Sujets : Modèles économiques; Institutions financières; Stabilité financière; Réglementation et politiques relatives au système financier
Codes JEL : C, C2, C22, C5, C52, C53, G, G1, G17, G2, G21, G28

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1. Introduction

Since the 2008–09 global financial crisis, stress testing has become a well-established risk management tool that central bankers and bank supervisors can use to assess the resilience of the banking system (Ong and Jobst 2020). One key objective of stress testing is to provide quantitative, forward-looking assessments of the solvency of the banking system under different risk scenarios.

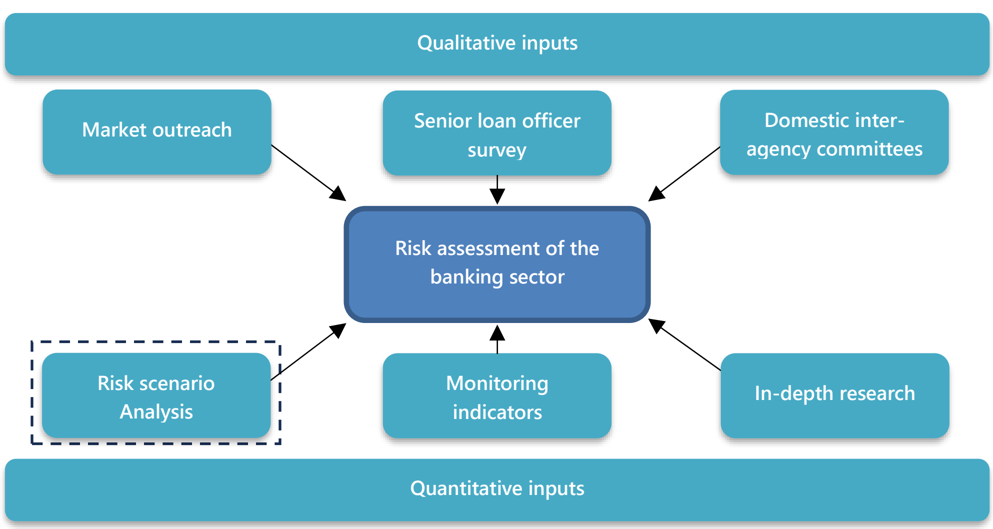
As part of its role in supporting financial stability, the Bank of Canada uses stress testing to identify systemic risks in the Canadian banking sector that could lead to adverse consequences for the financial system and the economy. The Bank focuses on system-wide assessments, rather than on individual financial institutions, primarily because the Bank does not have a mandate to supervise financial institutions that operate in Canada.

This technical report provides a thorough description of the Bank's Top-Down Solvency Assessment (TDSA) tool. Solvency assessments of banks are based on a series of decision rules, econometric models and accounting identities. TDSA quantifies the effects of risk scenarios on revenues, expenses, loan losses and earnings combined with their impacts on balance sheets and capital positions.

TDSA is considered a top-down assessment because it applies a common methodology for a given scenario across all banks. The main advantage of this approach is that it uses the same set of equations and assumptions, which means that results for each bank can only vary based on their financial position at the starting point of the scenario. This makes it easier to compare results across banks to obtain insights about their respective resilience to a given risk scenario.[1]

Overall, TDSA is an important tool that is part of the Bank of Canada's framework for monitoring the Canadian banking sector (**Figure 1**).

Figure 1: Framework for monitoring the banking sector



[1] In contrast, a bottom-up assessment is one in which banks simulate the impact of a common scenario on their own financial position. While banks' own models may be better able to capture the idiosyncrasies of their institutions than a top-down assessment can, differences in modelling assumptions may limit the comparability of results across banks.

This monitoring framework is based on a wide range of qualitative and quantitative inputs that Bank staff incorporate when they conduct a risk assessment of the banking sector. TDSA provides several contributions to this framework. It:

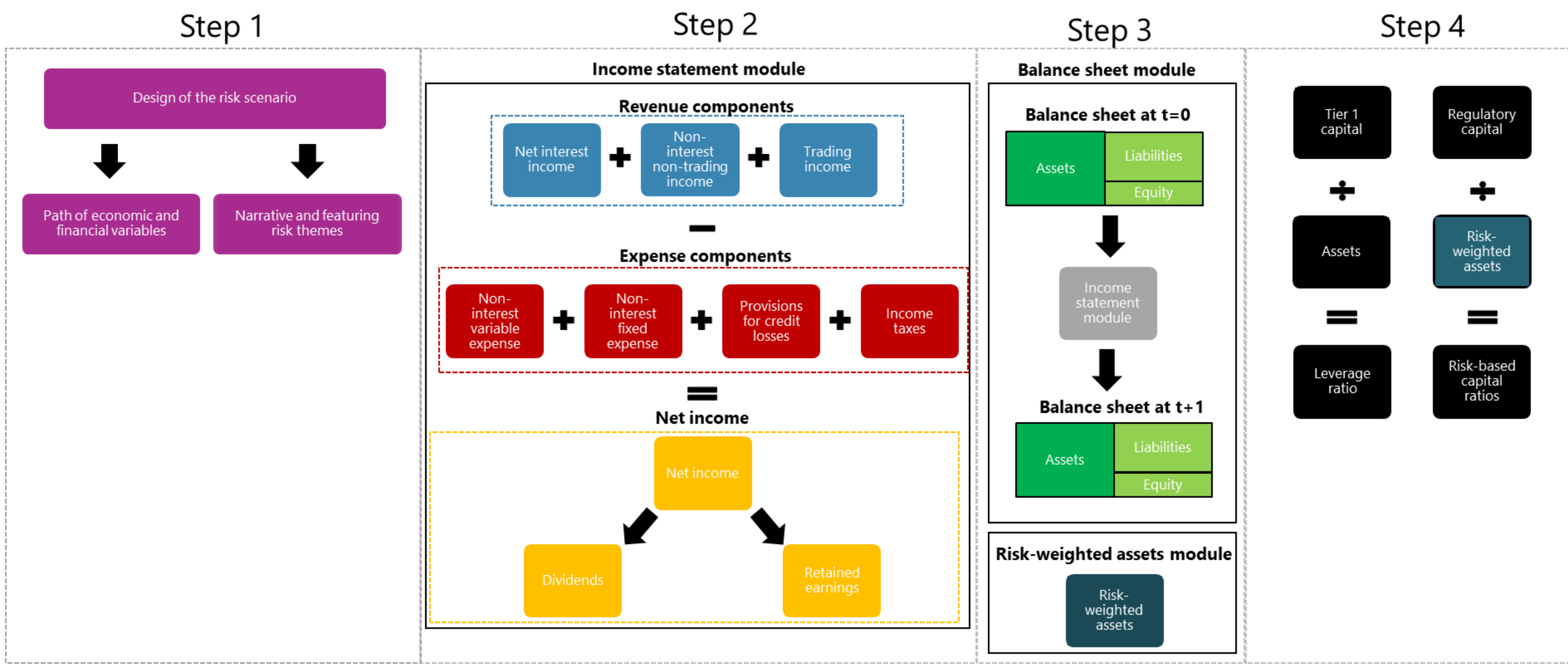
- provides a forward-looking assessment on the solvency of the banking sector using risk scenarios (**Figure 1**, dashed rectangle)
- identifies the underlying factors and channels that can affect the capital positions of the banking sector
- contributes to the monitoring outlook by projecting key financial indicators relevant to the banking system (e.g., provision for credit losses, net interest margin and deposit growth)
- is highly flexible and modular, so it can perform sensitivity analysis at a relatively low cost

This technical report is organized as follows. **Section 2** provides an overview of the tool's framework and describes the TDSA's various core modules. **Section 3** offers a technical description of TDSA's income statement module. **Section 4** reviews the balance sheet and risk-weighted asset (RWA) modules. **Section 5** covers the output of TDSA with particular emphasis on how it decomposes the impact of a given scenario on bank capital. **Section 6** highlights the main limitations and caveats of our model framework, while **Section 7** concludes.

2. Framework for the Top-Down Solvency Assessment

Figure 2 illustrates the key components of TDSA and how they are connected.

Figure 2: Framework for the Top-Down Solvency Assessment tool



The first step in TDSA is to design a scenario that is supported by a narrative (**Figure 2**, magenta rectangles). The risk scenario establishes the evolution of macroeconomic, credit and financial variables over a specified time horizon (*t*).[2] Risk scenarios can be created using a large range of in-house models:

- **Terms-of-Trade Economic Model** (**ToTEM**, Corrigan et al. 2021) is the Bank's main dynamic stochastic general equilibrium (DSGE) model that is used to conduct economic projections for the Canadian economy.
- **Large Empirical and Semi-structural model** (**LENS**, Gervais and Gosselin 2014) complements ToTEM because it empirically estimates a system of reduced-form equations that describe the interactions among key Canadian macroeconomic variables.
- **International Model for Projecting Activity** (**IMPACT**, Blagrave et al. 2020) determines the evolution of the global economy while accounting for cross-regional spillovers. IMPACT produces mutually consistent outlooks for different key regions around the world. It allows TDSA to account for the global exposures of the largest Canadian banks, making sure these exposures evolve in line with the regional macroeconomic conditions that are projected in the scenario.
- **Risk Amplification Macro Model** (**RAMM**, Tuzcuoglu 2024) is a nonlinear dynamic model that captures rare but severe adverse shocks and can assess the financial stability implications of both domestic- and foreign-originated risk scenarios. This model can generate different paths on a set of macroeconomic and financial variables depending on whether the state of financial stress is in a high or a low regime.
- **Multivariate Scenario Engine** (**MUSE**, Hipp mimeo) offers an integrated framework that directly accounts for the correlations between macroeconomic and financial variables to create multiple risk scenarios.
- **Household Risk Assessment Model** (**HRAM**, Peterson and Roberts 2016) analyzes the effects of shocks on household balance sheets, exploiting information from survey microdata on the distribution of debt, assets and income across Canadian households. The main HRAM output used by TDSA is the probability of households defaulting on their bank loans, such as residential mortgages, home equity lines of credit, credit cards and all other consumer loans.
- **Corporate Default model** (**CDM**, Bruneau, Duprey and Hipp 2022) employs statistical methods for modelling the link between macrofinancial conditions and the probability the corporate sector defaulting on bank loans.

The use of in-house models enables a more effective communication of the risk scenario narrative because it ensures consistency across various macroeconomic and financial variables. Moreover, models such as LENS, IMPACT and RAMM can account for the central bank's reaction function to the initial shock considered in the risk scenario.

[2] When TDSA is used for stress testing, the risk scenario is typically assumed to be severe but plausible. In other words, it is not a forecast but rather a hypothetical projection of events. Danaee et al. (2022) present a risk scenario that was previously used in TDSA.

The second step is to determine the impact of the risk scenario on banks' profits using the income statement. The income statement module provides estimates of the revenue and expense components and, ultimately, for the net income (or profit) that is generated between periods. The module is structured as follows:

- the revenue components (**Figure 2**, blue rectangles), which consist of:
    - net interest income (NII)
    - non-interest non-trading income (NINT)
    - trading income
- the expense components (**Figure 2**, red rectangles), which consist of:
    - non-interest expense (variable and fixed)
    - provisions for credit losses
    - taxes

Ultimately, the core function of the income statement module is to determine the amount of net income that is retained as capital and the amount that is paid out as dividends (**Figure 2**, yellow rectangles).

The third step (**Figure 2**, green rectangles) is to estimate the evolution of asset and liability categories over the scenario horizon (i.e., the balance sheet module), except for equity whose evolution has already been determined by the retained profits (or losses) calculated in the income statement module. TDSA also contains a module for projecting the evolution of risk-weighted assets (i.e., the risk-weighted assets module), the denominator of the common equity tier 1 (CET1) capital ratio. This module ensures that the evolution of assets on the balance sheet and the evolution of risk-weighted assets are broadly consistent. In the final step, TDSA calculates the capital ratio of the bank, which is the primary output of the framework (**Figure 2**, black rectangles) that aggregates the impact of all the different components on banks' solvency position.

Overall, TDSA offers a dynamic framework to project the evolution of the balance sheet and income statement variables over the time horizon of the risk scenario (i.e., $t = 1$, $t = 2$, …, $T = N$).

3. Technical description of the income statement components

We present the underlying methodology for projecting the income statement components (i.e., all rectangles illustrated in Step 2 of **Figure 2**) to calculate retained earnings. In TDSA, retained earnings and changes to RWAs are the two ways in which banks' capital position adjusts over the risk scenario horizon.

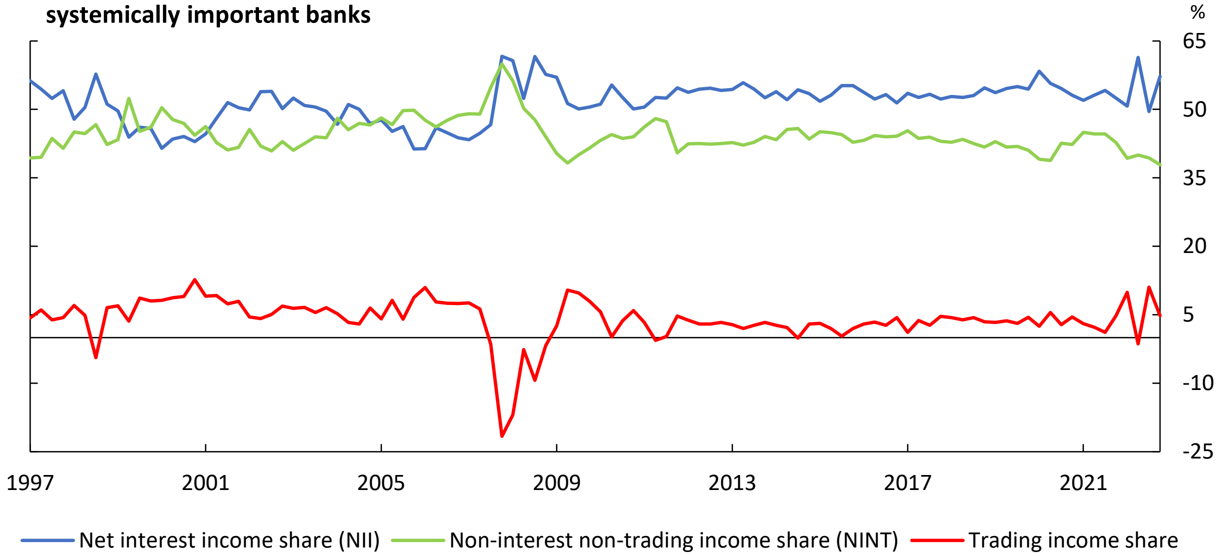
3.1 Revenues

One way that risk scenarios affect banks' financial position is through pressure exerted on their total revenues. TDSA breaks down the modelling of total revenues into three parts:

- NII
- NINT
- trading income

Historically, NII and NINT are the most important components of banks' revenues. Since 2009, NII and NINT have accounted for about 95% of the total revenues earned by the six domestic systemically important banks (D-SIBs) (**Chart 1**).[3] Trading income, which tends to be more sensitive to changes in financial markets conditions, has accounted for less than 5% of total revenues.

Chart 1: NII and NINT income represent the largest share of revenues for Canadian domestic systemically important banks



Sources: Regulatory filings of Canadian banks and Bank of Canada calculations

Last observation: 2022Q4

3.1.1 Net interest income

NII is the difference between the interest income earned on banks' assets and the interest expense paid on banks' liabilities. TDSA can project NII using two alternative approaches:

- the component-based approach
- the combined approach

Which approach to use depends on which one better suits the Bank's modelling needs for the risk scenario being considered. In addition, the two sets of results can be compared for sensitivity analysis; in other words, the baseline path of NII can be supplemented by an alternative NII path that relies on a different empirical approach. **Box 1** provides more details about the generic empirical framework that supports the estimation and specification of most of the core variables in TDSA.

[3] The six Canadian D-SIBs are the Bank of Montreal, the Bank of Nova Scotia, the Canadian Imperial Bank of Commerce, the National Bank of Canada, the Royal Bank of Canada and the Toronto-Dominion Bank.

Box 1: The main empirical framework in the Top-Down Solvency Assessment tool

This box describes the empirical approach that guides the specification of multiple core variables in the Top-Down Solvency Assessment (TDSA) tool.

Baseline equation

We first specify a baseline equation, given by:

$$y_t = \alpha + \sum_{i=1}^{p} \beta_i \, y_{t-i} + \sum_{i=0}^{q} \gamma_i \, macro_{t-i} + \delta_t X_t + \varepsilon_t,$$

where y_t is the variable of interest (either in level, first differenced or as a ratio), y_{t-i} is the lagged autoregressive term, and $macro_{t-i}$ is the contemporaneous and lagged set of relevant macroeconomic and financial variables identified by the literature. Depending on the specification, this time series model also includes a set of additional variables (*X*), such as balance sheet composition or a time trend, to control for long-term secular changes in the variable of interest. We use the baseline equation to estimate the evolution of the main revenue and expense items in TDSA.

Data

We collect data from the following sources:

- banks' regulatory filings, including their balance sheets and income statements
- the history of macroeconomic and financial market variables captured in our risk scenario

The data are aggregated across Canada's six domestic systemically important banks (D-SIBs). The sample period starts in the first quarter of 1997, which is the first quarter with full macroeconomic, financial and banking data, and ends in the fourth quarter of 2022. **Appendix A** (**Table A-1**) provides the summary statistics and the details of the variables used.

Model assessment

We assess model fit based on the methodology suggested by Bruneau, Duprey and Hipp (2022). We:

- estimate a wide range of specifications over the entire sample (from 1997Q1 to 2022Q4) based on the set of available variables
- use the LASSO model-selection criteria (Tibshirani 1996) to choose the initial set of controls that produce the best out-of-sample fit[4]
- apply expert judgment to determine the final model specification for each variable of interest

[4] We use LASSO to select the optimal set of controls when the projected dependent variable is a ratio. When we project growth rates of asset categories, we use an autoregressive distributed lag (ARDL) model and select the optimal number of autoregressive and distributed lags based on the Akaike information criterion or the Schwarz criterion.

NII projection—the component-based approach

This approach consists of two stages. First, we project the outstanding balances of six asset categories ($A_{i,t}$) and six liability categories ($L_{i,t}$) over the time horizon *(t)* of the risk scenario. **Table 1** lists these; **Appendix A** provides further details on their definitions.

Table 1: Categories of interest-earning assets and interest-bearing liabilities

Interest-earning assets (A_i)	*Interest-bearing liabilities (L_j)*
Loans	**Deposits**
Mortgages	Personal demand deposits
Consumer loans	Personal term deposits
Business loans	Non-personal demand deposits
	Non-personal term deposits
Other interest-earning assets	**Other liabilities**
Securities	Subordinated debt
Reverse repurchase agreements	Other interest-bearing liabilities
Interbank deposits	

The evolution of the asset categories is based on the empirical approach presented in **Box 1**, where we estimate the relationship between the growth rate of a given asset category and its own lagged value, including a set of macrofinancial control variables. For instance, we use the equation below to estimate the historical evolution of mortgages:

$$\Delta y_t = \alpha + \beta_1 \Delta y_{t-1} + \beta_2 Termsprd_t + \beta_3 \Delta TSX_t + \beta_4 \Delta GDP_t + \beta_5 \Delta UR_t + \beta_6 \Delta HPI_t + \beta_7 \Delta HPI_{t-1} + DUM + \varepsilon_t, \quad (1)$$

where:

- Δy_t is the quarterly growth rate in outstanding mortgages
- Δy_{t-1} is the lagged value of the dependent variable
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and the 3-month Government of Canada treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian gross domestic product (GDP)
- ΔUR_t is the quarterly change in the Canadian unemployment rate
- ΔHPI_t the year-over-year growth in the Canadian house price index
- *DUM* is a dummy variable set to 1 for the period of 2011Q4 to control for accounting rule changes that moved mortgages that were off the bank's balance sheet back onto it

We follow an approach similar to the one we use for interest-earning assets to estimate the path of interest-bearing liabilities. For instance, the empirical specification to project the path of personal demand deposits takes the following form:

$$\Delta y_t = \alpha + \beta_1 \Delta y_{t-1} + \beta_2 Termsprd_t + \beta_3 \Delta TSX_t + \beta_4 \Delta GDP_t + \beta_5 \Delta UR_t + \beta_6 \Delta Credit_t + \beta_7 ST_t + \beta_8 ST_{t-1} + \varepsilon_t, \quad (2)$$

where:

- Δy_t is the quarterly growth rate in outstanding personal demand deposits
- Δy_{t-1} is the lagged value of the dependent variable
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and the 3-month Government of Canada treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ΔUR_t is the quarterly change in the Canadian unemployment rate
- $\Delta Credit_t$ growth rate of total credit
- ST_t is the short-term yield on 3-month treasury bills

Results for the estimations of the six asset categories and three of the liability categories at the industry level are available in **Appendix B** (**Table B-1,** and **Charts B-1** to **B-9**).

In the second stage of the component-based approach, we model the effective interest rates that relate to each respective category of interest-earning asset ($A_{i,t}$) and interest-bearing liability ($L_{j,t}$) by estimating a set of error correction models (ECMs) of the following form:

$$\Delta r_{i,t} = \alpha_0 + \alpha_1 \left(r_{i,t-1} - \left(\hat{\beta}_1 ST_{t-1}^{CA} + \hat{\beta}_2 LT_{t-1}^{CA} + \hat{\beta}_3 ST_{t-1}^{US} + \hat{\beta}_4 LT_{t-1}^{US} \right) \right) + \varepsilon_{i,t}, \tag{3}$$

where:

- $\Delta r_{i,t}$ is the change in effective rates earned or paid on asset category (*i*) or liability category (*j*) over period (*t*)
- α_1 is the long-term adjustment in the respective rate category
- $r_{i,t-1}$ is its own lagged value
- ST_{t-1}^{CA} is the lagged short-term yield on three-month treasury bills for Canada
- ST_{t-1}^{US} is the lagged short-term yield on three-month Treasury bills for the United States,
- LT_{t-1}^{CA} is the lagged long-term yield on five-year government bonds for Canada
- LT_{t-1}^{US} is the lagged long-term yield on 5-year government bonds for the United States
- $\hat{\beta}s$ are the estimated coefficients capturing the long-term relationship between the rates and our set of covariates

We follow a two-step procedure for this ECM specification. First, we estimate the long-run relationship between each rate and its respective covariates to obtain the $\hat{\beta}$coefficients. We then use those $\hat{\beta}$s in the ECM specification presented above. Note that for this parsimonious model we assume short- and long-term rates are the main drivers of interest income and interest expense. **Appendix B** (**Table B-2** and **Chart B-10**) shows the results for all categories of interest-earning assets and interest-bearing liabilities.

We then calculate the NII as follows:

$$NII_t = r_{i,t}^A * \sum_{i=1}^{6} A_{i,t-1} - r_{j,t}^L * \sum_{j=1}^{6} L_{j,t-1}, \tag{4}$$

where, for time (*t*), we multiply the effective rate earned on a given asset category over that period ($r_{i,t}^A$) by its respective amount as of the previous period ($A_{i,t-1}$) and sum across the six categories to come up with the dollar value of earned interest. We repeat the procedure on the liability side (multiplying $r_{j,t}^L$ by its respective category $L_{j,t-1}$) and obtain the amount of interest expense over the period. The NII is the difference between the two quantities (interest earned minus interest expense).

NII projection—the combined approach

As a complement to the component-based approach, the combined approach calculates banks' NII as follows:

$$NII_t = IEA_{t-1} * NIM_t, \tag{5}$$

where:

- NII_t is the total net interest income at time (*t*)
- $IEA_{t-1}$is the interest-earning assets as at the previous period
- NIM_t is the net interest margin at (*t*), defined as NII divided by the average amount of interest-earning assets over the period

For this approach, we first obtain a projection of the dollar value of (*IEA*) over the horizon (*t*) of the risk scenario. We use the equation below to estimate the historical evolution of the growth rate of (*IEA*) as a function of the following explanatory variables:

$$\Delta IEA_t = \alpha + \sum_{i=1}^{4} \beta_i \, \Delta IEA_{t-i} + \gamma_1 Termsprd_t + \gamma_2 \Delta TSX_t + \gamma_3 \Delta GDP_t$$

$$+ \gamma_4 \Delta UR_t + \gamma_5 Crsprd_t + \gamma_6 Crsprd_{t-1} + \gamma_7 Crsprd_{t-2} + DUM + \varepsilon_t, \tag{6}$$

where:

- ΔIEA_t is the quarterly growth rate in outstanding interest-earning assets, defined as the sum of total loans and securities
- ΔIEA_{t-i} is the lagged value of the dependent variable
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and the 3-month Canadian treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ΔUR_t is the quarterly change in the Canadian unemployment rate
- $Crsprd_t$ is the corporate non-financial spread (yield of BBB-rated bonds – yield of 10-year Government of Canada bonds),
- DUM is a dummy variable set to 1 for the period starting in 2011Q4 to control for accounting rule changes that moved mortgages that were off the bank's balance sheet back onto it

Appendix B (**Table B-3** and **Chart B-11**) shows the results of this estimation. We then obtain the projected path by multiplying the previous period's amount of interest-earning assets by the projected growth rate over the quarter.

Next, we project the aggregate (NIM_t) ratio using the empirical methodology described in **Box 1**. The empirical specification takes the following form:

$$NIM_t = \alpha + \beta_1 NIM_{t-1} + \beta_2 \Delta NIM_{t-1} + \beta_3 Termsprd_t + \beta_4 \Delta TSX_t + \beta_5 \Delta HPI_t$$

$$+ \beta_6 \Delta Credit_t + \beta_7 FX_t + \beta_8 Crsprd_t + \beta_9 Mtg_t + \beta_{10} Bus_t + \beta_{11} Sec_t + u_t + \varepsilon_t, \tag{7}$$

where:

- NIM_{t-1} its own lagged value

- ΔNIM_{t-1} is the lagged first difference in the ratio
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and the 3-month Canadian treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔHPI_t is the year-over-year growth in the Canadian house price index
- $\Delta Credit_t$ is the growth rate of total credit
- FX_t is the USD/CAD exchange rate
- $Crsprd_t$ is the corporate non-financial spread (yield of BBB-rated bonds– yield of 10-year Government of Canada bonds)
- Mtg_t is the ratio of residential mortgages to assets
- Bus_t is the ratio of (business + non-residential mortgage loans) to assets
- Sec_t is the share of securities to assets
- u_t is a time trend

Appendix B (**Table B-4** and **Chart B-12**) presents the detailed results from the NIM regressions.

As a robustness check, we also run a variant of the NIM model based on the following error correction model specification:

$$\Delta NIM_t = \alpha_0 + \alpha_1 \left(NIM_{t-1} - \left(\hat{\beta}_0 + \hat{\beta}_1 Termsprd_{t-1} \right) \right) + \varepsilon_t, \quad (8)$$

where:

- ΔNIM_t is the first difference in the quarterly change of the NIM ratio
- α_1 is the long-term adjustment in the NIM ratio
- NIM_{t-1} is its own lagged value
- $Termsprd_{t-1}$ is the lagged difference in the yield between the 10-year Government of Canada bond and the 3-month Canadian treasury bill
- $\hat{\beta}$s are the estimated coefficients capturing the long-term relationship between the NIM and our set of covariates

We follow a two-step procedure for this specification. First, we estimate the long-run relationship between the NIM and the respective covariates to obtain the $\hat{\beta}$s coefficients. We then use those $\hat{\beta}$s in the NIM specification presented above. Note that we only include the term spread for this parsimonious model because of its significant effect on banks NIMs. **Appendix B** (**Table B-5** and **Chart B-13**) shows results from the ECM estimation.

We obtain the dollar value of NII from **Equation (5)** by multiplying the projected aggregate NIM (from **Equation 7**) by the projected amount of interest-earning assets (IEA_{t-1}).

3.1.2 Non-interest non-trading income

Non-interest non-trading income (NINT) consists of a diverse set of revenue streams, including:

- **banking fees**, such as service charges on deposit accounts, credit and debit card fees, loan or acceptance fees and income from securitization
- **investment management fees**, such as those generated from mutual funds
- **capital market revenues**, such as those generated from underwriting fees and securities commissions

- **net insurance revenue**, which is the difference between the premiums that banks generate and any expense related to their insurance operations

With NINT income accounting for roughly 45% of the revenue of Canadian D-SIBs (**Chart 1**), it is important to have empirical specifications that perform well to complement our NII modelling framework. The literature documents that the set of macrofinancial controls that we use in the aggregate approach is a good determinant of the evolution of NINT income (see Hirtle et al. 2016). In TDSA, the NINT specification is given by two different approaches.

NINT empirical specification—the disaggregated approach

The first NINT income specification is given by:

$$NINT_t = (1 + r_t) * MS\_NINT_{t-1} + \rho * \sum_{p=1}^{3} Drawn_{p,t}, \quad (9)$$

where:

- $NINT_t$ is the non-interest non-trading income at period (t)
- r_t represents the growth on the price index of a hypothetical portfolio of investment assets
- MS_NINT_{t-1} represents market-sensitive non-interest non-trading income
- ρ is a fixed ratio of non-market-sensitive income to drawn loan balances, calibrated based on its historical average
- $\sum Drawn_{p,t}$ is the sum of drawn loan balances over three types of portfolios (business, mortgage and consumer loans)

Table 2 breaks down the NINT revenue streams into market-sensitive and non-market-sensitive components based on how these categories behave under stress. In line with MacDonald and Traclet (2018), market-sensitive income moves with the price index on a hypothetical investment portfolio of equities and bonds. We calculate the change in the price index of that portfolio, (r_t), to be consistent with the risk scenario. We assume non-market-sensitive income is more stable, and it therefore grows in fixed proportion (ρ) with the overall loan book.

Table 2: Breakdown of non-interest non-trading income

Market-sensitive	Non-market-sensitive
Investment management and custodial fees	Deposit and other payment service fees
Mutual fund fees	Debit and credit card fees
Underwriting and advisory fees	Loan and acceptance fees
Securities commissions and fees	Net insurance revenues
	Other non-interest income

NINT empirical specification—The aggregated approach

To complement the disaggregated approach, the aggregated approach calculates the dollar value of banks' NINT as follows:

$$NINT_t = TA_{t-1} * NINT\_ratio_t, \quad (10)$$

where:

- $NINT_t$ is the total non-interest non-trading income at time (t)
- TA_{t-1} are total assets as at the previous period
- $NINT\_ratio_t$ is the NINT income divided by the average amount of total assets over the period (t)

We first obtain a projection of the dollar value of (*TA*) over the risk horizon. We use the equation below to estimate the historical evolution of the (*TA*) growth rate as a function of the following controls:

$$\Delta y_t = \alpha + \beta_1 \Delta y_{t-1} + \gamma_1 Termsprd_t + \gamma_2 \Delta TSX_t + \gamma_3 \Delta GDP_t + \gamma_4 \Delta UR_t + \gamma_5 Crsprd_t + \gamma_6 Crsprd_{t-1} + DUM + \varepsilon_t, \quad (11)$$

where:

- Δy_t is the quarterly growth rate in total assets
- Δy_{t-1} is the lagged value of the dependent variable
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and the 3-month Canadian treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ΔUR_t is the change in the Canadian unemployment rate over the quarter
- $Crsprd_t$ is the corporate non-financial bond spread (yield of BBB-rated bonds – yield of 10-year Government of Canada bonds),
- DUM is a dummy variable set to 1 for the period starting in 2011Q4 to control for accounting rule changes that moved mortgages that were off the bank's balance sheet back onto it

Appendix C (**Table C-1** and **Chart C-1**) shows the results of this estimation. The projected path is then obtained by multiplying the previous period's amount of total assets by the projected growth rate over the quarter.

In the next step, we project the aggregate ($NINT\_ratio_t$) using the approach described in **Box 1**. The empirical specification takes the following form:

$$NINT\_ratio_t = \alpha + \beta_1 NINT\_ratio_{t-1} + \beta_2 \Delta NINT\_ratio_{t-1} + \beta_3 \Delta TSX_t + \beta_4 \Delta GDP_t + \beta_5 ST_t + \beta_6 \Delta HPI_t + \beta_7 FX_t + \beta_8 Crsprd_t + \beta_9 Mtg_t + \beta_{10} Cons_t + \beta_{11} Sec_t + u_t + \varepsilon_t, \quad (12)$$

where:

- $NINT\_ratio_t$ is the NINT ratio as defined above
- $\Delta NINT\_ratio_{t-1}$ is the lagged first difference of the NINT ratio
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ST_t is the short-term rate proxied by the yield on the three-month Canadian treasury bill
- ΔHPI_t is the year-over-year growth in the Canadian house price index
- FX_t is the USD/CAD exchange rate
- $Crsprd_t$ is the corporate non-financial bond spread (yield of BBB-rated bonds – yield of 10-year Government of Canada bonds)
- Mtg_t is the ratio of residential mortgages to assets
- $Cons_t$ is the ratio of consumer loans to assets
- Sec_t is the ratio of securities to assets
- u_t is a time trend

Appendix C (**Table C-2** and **Chart C-2**) presents the detailed results from the aggregate NINT regressions.

As an alternative, we also run a variant of the aggregate NINT ratio model using an error correction model based on the following specification:

$$\Delta NINT\_ratio_t = \alpha_0 + \alpha_1 \left(NINT\_ratio_{t-1} - \left(\hat{\beta}_0 + \hat{\beta}_1 TSX_{t-1} + \hat{\beta}_2 FX_{t-1} + \hat{\beta}_3 Crsprd_{t-1} \right) \right) + \varepsilon_t, \quad (13)$$

where:

- $\Delta NINT\_ratio_t$ is the first difference in the quarterly change of the NINT ratio
- α_1 is the long-term adjustment in the ratio
- $NINT_{t-1}$ is its own lagged value
- TSX_{t-1} is the lagged quarterly growth in the S&P/TSX index
- FX_{t-1} is the lagged USD/CAD exchange rate
- $Crsprd_{t-1}$ is the lagged corporate non-financial bond spread (yield of BBB-rated bonds – yield of 10-year Government of Canada bonds)
- $\hat{\beta}s$ are the estimated coefficients capturing the long-term relationship between the NINT ratio and our set of covariates

We follow a two-step procedure for this specification. First, we estimate the long-run relationship between the NINT and the respective covariates to obtain the $\hat{\beta}$ coefficients. We then use those $\hat{\beta}s$ in the NINT specification presented above. Note that we only include the main macrofinancial covariates identified from the aggregate NINT specification in **Equation (12)** for this parsimonious model. **Appendix C** (**Table C-3** and **Chart C-3**) shows the results of the ECM estimation.

In the final step, we obtain the dollar value of NINT from **Equation (10)** by multiplying the projected aggregate NINT ratio (from either the generic approach in **Box 1** or the ECM model) by the projected amount of total assets (TA_{t-1}).

3.1.3 Trading income

Trading income is generated from realized gains and losses on valuation changes. Trading income is relatively small, representing on average only about 5% of banks' revenues between the first quarter of 1997 and the fourth quarter of 2022 (**Chart 1**). However, trading income is a volatile component that is sensitive to changes in financial market conditions. Our methodology calculates the dollar value of banks' trading income as follows:

$$TradIncome_t = Sec_{t-1} * TradInc\_ratio_t, \quad (14)$$

where:

- $TradIncome_t$ is the income from trading at time (*t*)
- Sec_{t-1} is the total value of outstanding securities as at the previous period
- $TradInc\_ratio_t$ is the income from trading divided by the average amount of securities over the period

We first estimate the dollar value of *Sec* over the risk horizon. We then use the equation below to project the historical evolution of the *Sec* growth rate as a function of the following controls:

$$\Delta y_t = \alpha + \beta_1 \Delta y_{t-1} + \gamma_1 Termsprd_t + \gamma_2 \Delta TSX_t + \gamma_3 \Delta GDP_t + \gamma_4 \Delta UR_t + \gamma_5 ST_t + \gamma_6 Crsprd_t + \gamma_7 Crsprd_{t-1} + DUM + \varepsilon_t, \quad (15)$$

where:

- Δy_t is the quarterly growth rate in outstanding securities
- Δy_{t-1} is the lagged value of the dependent variable
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and the yield of the 3-month Canadian treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ΔUR_t is the change in the Canadian unemployment rate over the quarter
- ST_t is the short-term rate proxied by the yield on the 3-month Canadian treasury bill
- $Crsprd_t$ is the corporate non-financial bond spread (yield of BBB-rated bonds – yield of 10-year Government of Canada bonds)
- DUM is a dummy variable set to 1 for the period around the global financial crisis between 2009Q1 and 2011Q3, during which banks increased their holdings of securities

Appendix B (**Table B-2** "Securities" column and **Chart B-4**) shows the results of this estimation. The projected path is then obtained by multiplying the previous period's amount of total assets by the projected growth rate over the quarter.

In the next step, we project the aggregate ($TradInc\_ratio_t$) using the generic approach that is described in **Box 1**. The preferred empirical specification takes the following form:

$$TradInc\_ratio_t = \alpha + \beta_1 TradInc\_ratio_{t-1} + \beta_2 \Delta TSX_t + \beta_3 ST_t + \beta_4 FX_t + \varepsilon_t, \quad (16)$$

where:

- $TradInc\_ratio_t$ is the ratio as defined above
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ST_t is the short-term rate proxied by the yield on the 3-month Canadian treasury bill
- FX_t is the USD/CAD exchange rate

Appendix D (**Table D-1** and **Chart D-1**) presents the detailed results from the aggregate NINT regressions. In the final step, we obtain the dollar value of *TradingIncome* from **Equation (14)** by multiplying the projected aggregate *TradInc_ratio* (derived from the generic approach in **Box 1**) by the projected value of securities (Sec_{t-1}).

3.2 Non-interest expenses

Non-interest expenses (NIE) consist of variable items, such as employee compensation, and fixed items, such as expenses related to premises and fixed assets. Because these are quite diverse, we expect them to evolve differently depending on the risk scenario. For example, banks are more likely to adjust employee compensation by cutting back on bonuses when they face revenue pressures than they are to breach long-term real estate lease agreements. **Table 3** breaks down the items that compose variable NIE and fixed NIE. For the purpose of TDSA, we estimate the evolution of variable and fixed NIE separately using the same approach as presented in **Box 1** because empirical evidence in the literature on the determinants of non-interest expenses is limited.

Table 3: Breakdown of non-interest expenses	
Variable non-interest expenses	**Fixed non-interest expenses**
Employee compensations	Premises and equipment
Advertising and public relations expenses	Office and general expenses
Donations	Deposit insurance premiums
Employee training and development	Audit and legal fees
Consulting fees	All other expenses

Our methodology calculates the dollar value of banks' variable NIE income as follows:

$$NIE\_var_t = TA_{t-1} * NIE\_var\_ratio_t, \tag{17}$$

where:

- NIE_var_t are the variable non-interest expenses as at time (*t*)
- TA_{t-1} are the total assets as at the previous period
- $NIE\_var\_ratio_t$ is NIE_var divided by the average amount of total assets over the sample period

Similarly, we calculate the dollar value of banks' fixed NIE income as follows:

$$NIE\_fix_t = TA_{t-1} * NIE\_fix\_ratio_t, \tag{18}$$

where:

- NIE_fix_t is the fixed non-interest expense at time (*t*)
- TA_{t-1} are total assets as at the previous period
- NIE_fix_ratio is NIE_fix divided by the average amount of total assets over the period

Section **3.1.2** describes the methodology to estimate *TA,* and **Appendix C** presents the results of our analysis (**Table C-1** and **Chart C-1**).

We use the generic approach described in **Box 1** to project the variable component of the NIE, the (NIE_var_t) ratio. The empirical specification takes the following form:

$$NIE\_var_t = \alpha + \beta_1 NIE\_var_{t-1} + \beta_2 \Delta NIE\_var_{t-1} + \beta_3 Termsprd_t + \beta_4 \Delta TSX_t + \beta_5 \Delta GDP_t + \beta_6 ST_t$$
$$+ \beta_7 \Delta HPI_t + \beta_8 \Delta Credit_t + \beta_9 FX_t + \beta_{10} Crsprd_t + \beta_{11} Mtg_t + \beta_{12} Sec_t + u_t + \varepsilon_t, \tag{19}$$

where:

- NIE_var_t is the variable component of the NIE ratio as defined above
- ΔNIE_var_{t-1} is the lagged first difference of the ratio
- $Termsprd_t$ is the difference in the yield of the 10-year government of Canada bond and yield of the 3-month Canadian treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ST_t is the short-term rate proxied by the yield on the 3-month Canadian treasury bill
- ΔHPI_t is the year-over-year growth in the Canadian house price index
- $\Delta Credit_t$ is the growth rate of total credit
- FX_t is the USD/CAD exchange rate

- $Crsprd_t$ is the corporate non-financial bond spread (yield of BBB-rated bonds – yield of 10-year Government of Canada bonds)
- Mtg_t is the ratio of residential mortgages to assets
- Sec_t is the ratio of securities to assets
- u_t is a time trend

Similarly, we project the fixed component the NIE, the (NIE_fix_t) ratio. This empirical specification takes the following form:

$$NIE\_fix_t = \alpha + \beta_1 NIE\_fix_{t-1} + \beta_2 \Delta NIE\_fix_{t-1} + \beta_3 Termsprd_t + \beta_4 \Delta GDP_t + \beta_5 \Delta UR_t + \beta_6 ST_t + \beta_7 \Delta HPI_t + \beta_8 \Delta Credit_t + \beta_9 FX_t + \beta_{10} Crsprd_t + \beta_{11} Mtg_t + \beta_{12} Cons_t + \beta_{13} Sec_t + u_t + \varepsilon_t, \quad (20)$$

where:

- NIE_fix_t is the fixed component of the NIE ratio as defined above
- ΔNIE_fix_{t-1} is the lagged first difference of the ratio
- $Termsprd_t$ is the difference in the between the yield of the 10-year Government of Canada bond and the yield of the 3-month Canadian treasury bill
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ΔUR_t is the change in the Canadian unemployment rate over the quarter
- ST_t is the short-term rate proxied by the yield on the 3-month Canadian treasury bill
- ΔHPI_t is the year-over-year growth in the Canadian house price index
- $\Delta Credit_t$ is the growth rate of total credit
- FX_t is the USD/CAD exchange rate
- $Crsprd_t$ is the corporate non-financial bond spread (yield of BBB-rated bonds – yield of 10-year Government of Canada bonds)
- Mtg_t is the ratio of residential mortgages to assets
- $Cons_t$ is the ratio of consumer loans to assets
- Sec_t is the ratio of securities to assets
- u_t is a time trend

Appendix E (**Table E-1** and **Table E-2; Chart E-1** and **Chart E-2**) present the detailed results of the variable and fixed NIE regressions. In the final step, we obtain the dollar value of variable NIE from **Equation (17)** by multiplying the projected variable NIE ratio (from the generic model) by the projected amount of total assets (TA_{t-1}). Similarly, we obtain the dollar value of fixed NIE from **Equation (18)** by multiplying the projected fixed NIE ratio (from the generic model) by the projected amount of total assets (TA_{t-1}). The total dollar value of NIE is then the sum of the variable and the fixed components.

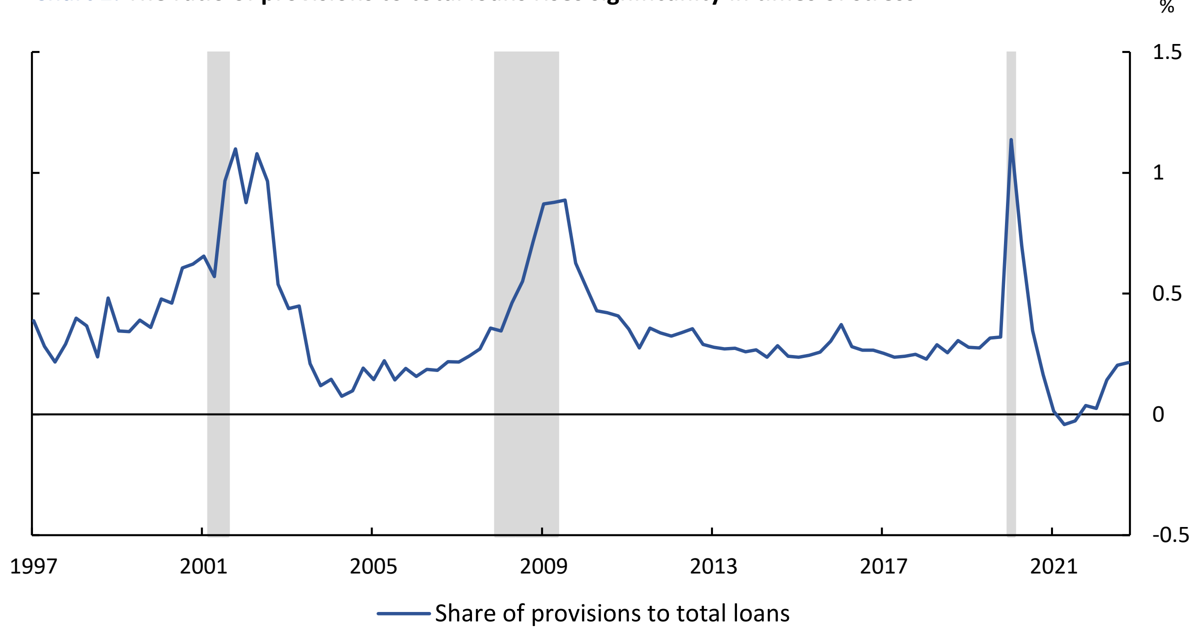
3.3 Provision for credit losses

For most banks, credit losses arising from borrowers' failure to meet contractual loan obligations represents the single largest source of risk for the bank. This could impair their assets and ultimately their capital positions. For this reason, the projection of credit losses is a key element of TDSA.

The accounting framework for credit loss provisioning requires banks to take a forward-looking approach that results in the timely recognition of credit losses. Not only do banks have to set aside funds when there is evidence that a loss is apparent (i.e., for impaired assets), but they are also expected to recognize expected future losses on performing assets based on current conditions and forecast information.[5] Collectively, these funds are called provisions for credit losses (PCLs), which tend to rise as banks' assets face increased credit risks.

Chart 2 plots the share of annual PCLs as a percentage of total loans outstanding across the Canadian D-SIBs. It shows that the PCL ratio had increased significantly in past periods of stress, such as the case in the early 2000s, during the global financial crisis and at the onset of the COVID-19 crisis.[6]

Chart 2: The ratio of provisions to total loans rises significanlty in times of stress



Sources: Regulatory filings of Canadian banks, Statistics Canada, Haver, Intercontinental Exchange and Bank of Canada calculations

Last observation: 2022Q4

Ultimately, PCLs represent an expense booked on the bank's income statement to cover realized or potential loan losses. TDSA offers two different modelling approaches to estimate PCLs, which are presented below:

- the sectoral PCL approach
- the aggregated PCL approach

[5] International Financial Reporting Standard 9—Financial Instruments (IFRS 9), issued in 2014 and effective in 2018, made significant changes to how banks recognize and provide for credit losses for financial statement reporting purposes. Under the previous standard, the incurred loss framework required banks to recognize credit losses only when evidence of a loss was apparent. Under IFRS 9's expected credit loss (ECL) impairment framework, however, banks are supposed to recognize expected credit losses even on performing assets and to update these expectations at each reporting date to reflect changes in an asset's credit risk.

[6] The peak in provisions in the early 2000s was driven by a few factors: deterioration in the telecommunication and utilities sectors, exposure to companies impacted by accounting malfeasance and exposure of some banks to economic and political instability in Argentina.

3.3.1 Approach 1: Sectoral provisions for credit losses

For this approach, we differentiate between credit loss provisions for impaired loans (Stage 3 under International Financial Reporting Standard [IFRS] 9) and performing loans (Stages 1 and 2 under IFRS 9). In TDSA, provisions for impaired loans are incurred in the period in which the default occurs. For simplicity, we assume that defaulted loans are written off in the period of default and that there are no further losses or recoveries after the initial provision is taken.

We calculate impaired provisions for loan category (*i)* at period (*t)* as follows:

$$PCL\_impaired_{i,t} = DR_{i,t} * LRDE_{i,t} * EAD_{i,t-1}, \tag{21}$$

where:

- $DR_{i,t}$ is the projected default rate for loan category (*i*) at period (*t*), generated from auxiliary models (CDM/HRAM)
- $LRDE_{i,t}$ is the loss rate on defaulted exposures for the given loan type; it is derived from banks' estimates of downturn loss given default used in the regulatory capital framework and is adjusted using expert judgment[7]

The last term on the right-hand side of **Equation (21)** is the exposure at default ($EAD_{i,t-1}$). It is defined as:

$$EAD_{i,t-1} = Drawn_{i,t-1} + DDR_i * Undrawn_{i,t-1}, \tag{22}$$

where:

- $Drawn_i$ is the outstanding loan balance of loan category (*i*)
- $Undrawn_i$ is the amount of authorized but unused space on existing loan facilities for category *(i)*
- DDR_i (drawdown rate) is the expected rate at which undrawn amounts of loan category (*i*) are drawn down before a borrower enters default

In **Equation (22)**, the exposure at default equals outstanding drawn balances plus the undrawn amount multiplied by the drawdown rate. The formula implies that, just before default, a borrower draws down on existing credit facilities, increasing banks' exposure to losses. The drawdown rate is calibrated for each loan category using the credit conversion factors (CCFs) estimated by banks in the regulatory capital framework. The CCF is the expected share of an off-balance-sheet position (such as undrawn amounts) that becomes on balance sheet at the time a counterparty defaults, taking into account whether the undrawn amounts are unconditionally cancellable or contractually committed. The drawdown rate used in TDSA makes a downward adjustment to the bank-estimated CCF to account for the fact that undrawn amounts are typically larger for lower-risk loan facilities.

Loan categories (*i*) captured in TDSA are presented in **Table 4**, which also provides the mapping rule with our models used to generate portfolio-level default rates, e.g., CDM and HRAM. The sectoral approach is also flexible to allow variation according to the banks' geographical exposures. For instance, the paths of

[7] Expert judgment is warranted in some circumstances. For example, banks' estimates of losses given default related to mortgages may be adjusted upward in a risk scenario that is characterized with a severe decline in house prices. Recall that $LGD = \frac{foreclosure\ costs}{mortgage\ value} + \max(1 - \frac{1}{LTV} * (1+g), 0)$, which means that it rises when the growth rate in house prices (*g*) is negative.

default rates and loss rates on defaulted exposures can be tied to the evolution of economic activity in each geographical region. This offers the opportunity to account for the differential performance of foreign bank loan exposures and allow them to vary across Canada, the United States and the rest of the world. **Appendix F** (**Table F-1**) provides the default rates and loss rates on defaulted exposures used in past stress-testing exercises to calculate **Equation (21)**.

Table 4: List of loan categories (*i*) in the sectoral PCL approach*

Business sector loan book

- Natural resources, sum of:
  - Agriculture
  - Fishing and trapping
  - Logging and forestry
- Mining, quarrying and oil wells
- Manufacturing
- Construction and real estate
- Non-residential mortgages
- Transportation, communications, other utilities
- Wholesale trade
- Retail Trade
- Service
- Other corporate, sum of:
  - Multi-conglomerates
  - Others
  - Lease receivables
- Financials
- Governments

Retail sector loan book

- Insured residential mortgages
- Uninsured residential mortgages
- Home equity lines of credit
- Credit cards
- Other consumer loans, sum of:
  - Personal loans
  - Other personal credit

*Note: Corporate Sector's Industries are classified under Standard Industrial Classification (SIC), with balance sheet data coming from OSFI's A2 Return (all domestic systemically important banks and across all currencies); retail sector data source comes from OSFI's N3 Return. OSFI is the Office of the Superintendent of Financial Institutions.

In a deteriorating macrofinancial environment, banks may also recognize additional provisions for credit losses on performing exposures in anticipation of higher future losses. To simulate this forward-looking provisioning behaviour, TDSA calculates PCLs for performing loans using a formula that reallocates incurred credit losses from the later periods of the scenario to the early periods. This formula incorporates an assumption on the degree of foresight that banks have into their future credit losses, which affects the degree to which provisions are pulled forward. Under a perfect foresight assumption, all credit provisions would be recognized in the first quarter of the scenario.

3.3.2 Approach 2: Aggregate provisions for credit losses

To complement the sectoral approach, the aggregated methodology calculates the dollar value of banks' provision for credit losses across all loan types as follows:

$$PCL\_impaired_t = Drawn_{t-1} * PCLratio_t, \tag{23}$$

where:

- $PCL\_impaired_t$ is the amount of provisions for credit losses for impaired loans at (*t*) (i.e., Stage 3 under IFRS 9)
- $Drawn_{t-1}$ is the total amount of loans outstanding (both retail and business) as at the previous period
- $PCLratio_t$ is provisions for impaired loans divided by the average amount of loans at (*t*)

We first obtain a projection of the dollar value of *Drawn* (i.e., loans outstanding) over the risk horizon. We use the equation below to estimate the historical evolution of this category's growth rate as a function of the following controls:

$$\Delta y_t = \alpha + \beta_1 \Delta y_{t-1} + \gamma_1 Termsprd_t + \gamma_2 \Delta TSX_t + \gamma_3 \Delta GDP_t$$
$$+ \gamma_4 \Delta UR_t + \gamma_5 Crsprd_t + \gamma_6 Crsprd_{t-1} + DUM + \varepsilon_t, \tag{24}$$

where:

- Δy_t is the quarterly growth rate in total loans
- Δy_{t-1} is the lagged value of the dependent variable
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and the yield of the 3-month Canadian treasury bill
- ΔTSX_t is the quarterly growth in the S&P/TSX index
- ΔGDP_t is the annualized growth rate in Canadian GDP
- ΔUR_t is the change in the Canadian unemployment rate over the quarter
- $Crsprd_t$ is the corporate non-financial bond spread (yield of BBB-rated bonds – yield 10-year Government of Canada bonds)
- DUM is a dummy variable set to 1 for the period starting in 2011Q4 to control for accounting rule changes that moved mortgages that were off the bank's balance sheet back onto it

Appendix F (**Table F-2** and **Chart F-1**) shows the results of this estimation. We then obtain the projected path by multiplying the previous period's amount of outstanding loans by the projected growth rate over the quarter.

Next, we project the impaired ($PCLratio_t$). We use data from the first quarter of 2018 to the fourth quarter of 2022 to capture how banks set provisions on a forward-looking basis under IFRS 9. We adjust the generic approach from **Box 1** and relate the evolution of the PCL ratio with the change in the one-period ahead values of key macrofinancial variables based on the following specification:[8]

[8] Note that these variables are typically provided as part of the scenario, so their future paths over the projection horizon are known. We test for different lead values of these variables and choose the one-period ahead scenario because they generate a better fit.

$$PCLratio_t = \alpha + \beta_1 PCLratio_{t-1} + \beta_2 \Delta TSX_{t+1} + \beta_3 \Delta GDP_{t+1} + \beta_4 \Delta UR_{t+1} + \beta_5 \Delta HPI_{t+1} + \varepsilon_t, \quad (25)$$

where:

- $PCLratio_t$ is the ratio as defined above
- ΔTSX_{t+1} is the quarterly growth in the S&P/TSX index over the next period
- ΔGDP_{t+1} is the annualized growth rate in Canadian GDP over the next period
- ΔUR_{t+1} is the change in the Canadian unemployment rate over the next period
- ΔHPI_{t+1} is the year-over-year growth in the Canadian house price index over the next period

Appendix F (**Table F-3** and **Chart F-2**) presents the detailed results of the PCL regressions for impaired loans. Note that we also provide the results from estimating the total PCL ratio, which includes provisions from stages 1, 2 and 3 of IFRS 9.

In the final step, we obtain the dollar value of provisions for impaired loans during the current period from **Equation (23)** by multiplying the projected PCL ratio for impaired loans by the projected amount of total loans ($Drawn_{t-1}$).

3.4 Taxes

Canadian D-SIBs operate in multiple tax jurisdictions and therefore face multiple tax rates. For simplicity, TDSA calculates an average tax rate based on the total taxes paid at the consolidated entity level over the two years before the start of the risk scenario. We then apply this tax rate to banks' pre-tax net income in each period. When pre-tax net income is negative, a deferred tax asset that reduces the size of the net loss in that period is generated. If the bank has positive net income in subsequent quarters, taxable income is reduced by the amount of accumulated deferred tax assets.

3.5 Net income and split between retained earnings and dividends

For a given risk scenario, we determine how the estimated net income flows into retained earnings and dividends. This split is important in TDSA because the estimated amount of retained earnings (positive or negative) is the primary driver of capital accumulation or capital depletion between period *t* and period *t+1*. We combine the revenues, expenses, provisions and tax projections to compute projected after-tax net income, which we then split between retained earnings and dividends.

3.5.1 Common shareholders' dividends

In TDSA, banks that generate positive net income determine their profit distribution, i.e., how they allocate retained earnings that allow them to accumulate capital and pay dividends. Historically, Canadian D-SIBs have distributed between 40% and 50% of their after-tax net income to shareholders in the form of dividends.[9]

We assume that publicly traded banks would prefer to avoid the negative market signalling that results from cutting a dividend and instead maintain a fixed payout ratio (the ratio of dividends to after-tax net income) until their net income starts to decline. At that point, banks continue to pay their most recent dividend until the distribution of earnings is restricted due to a breach of the capital conservation buffer (CCB). Upon breaching the CCB, banks pay the lower of their pre-stress dividend and the maximum

[9] Banks can also deploy excess capital into acquisitions of other financial institutions or into share repurchase programs, which return additional capital to shareholders.

dividend permitted by the CCB framework.[10] The reduction in dividends that results from a breach of the CCB typically leads to an improvement in banks' internal capital generation. Finally, TDSA does not provide means for banks to deploy excess capital other than dividends (i.e., acquisitions or share repurchases). As a result, scenarios that are severe enough to reduce banks' capital could lead to increases in regulatory capital ratios beyond banks' internal targets.

3.5.2 Other comprehensive income

Other comprehensive income (OCI) includes revenues, expenses, gains and losses that have yet to be realized and are excluded from the net income calculation on the income statement. For instance, OCI captures interim adjustments to the value of securities that are categorized as available for sale. Under Basel III rules, changes in accumulated OCI, such as those arising from securities available for sale, become part of the calculation of regulatory capital. Other major items that OCI captures include gains and losses from the currency translation of foreign operations and changes to the value of the banks' pension plans.

Our methodology calculates the dollar value of banks' OCI as follows:

$$OCI_t = TA_{t-1} * OCI\_ratio_t, \tag{26}$$

where:

- OCI_t is other comprehensive income at time (t)
- TA_t are total assets as at the previous period
- OCI_ratio_t is the OCI divided by total assets over the period

Section **3.1.2** describes the methodology used to estimate *TA,* and **Appendix C** reviews the results of our analysis (**Table C-1** and **Chart C-1**).

We use the generic approach described in **Box 1** to project the OCI ratio. It is in line with Correia at al. (2020), who propose a similar econometric approach for projecting OCI as part of the Federal Reserve Board's top-down assessment model. The empirical specification takes the following form:[11]

$$OCI\_ratio_t = \alpha + \beta_1 OCI_{ratio_{t-1}} + \beta_2 \Delta OCI\_ratio_{t-1} + \beta_3 Termsprd_t$$
$$+\beta_4 \Delta TSX_t + \beta_5 FX_t + \beta_6 Sec_t + \varepsilon_t, \tag{27}$$

where:

- OCI_ratio_t is the variable component of the NIE ratio as defined above
- ΔOCI_ratio_{t-1} is the first difference in the quarterly change of the ratio
- $Termsprd_t$ is the difference in the yield between the 10-year Government of Canada bond and yield of the 3-month treasury bill
- ΔTSX_t is quarterly growth in the S&P/TSX index
- FX_t is the USD/CAD exchange rate
- Sec_t is the ratio of securities to assets

[10] The capital conservation buffer can also be breached if other measures of capital (tier and total capital) breach their respective ratios. However, because we assume balances of additional tier 1 and tier 2 capital remain unchanged, these thresholds will not be breached before the Common Equity Tier 1 threshold.

[11] Note that the sample period is between the first quarter of 2007 and the fourth quarter of 2022 due to data availability and that the empirical specification includes a set of quarterly dummy variables to control for extreme values of the OCI ratio.

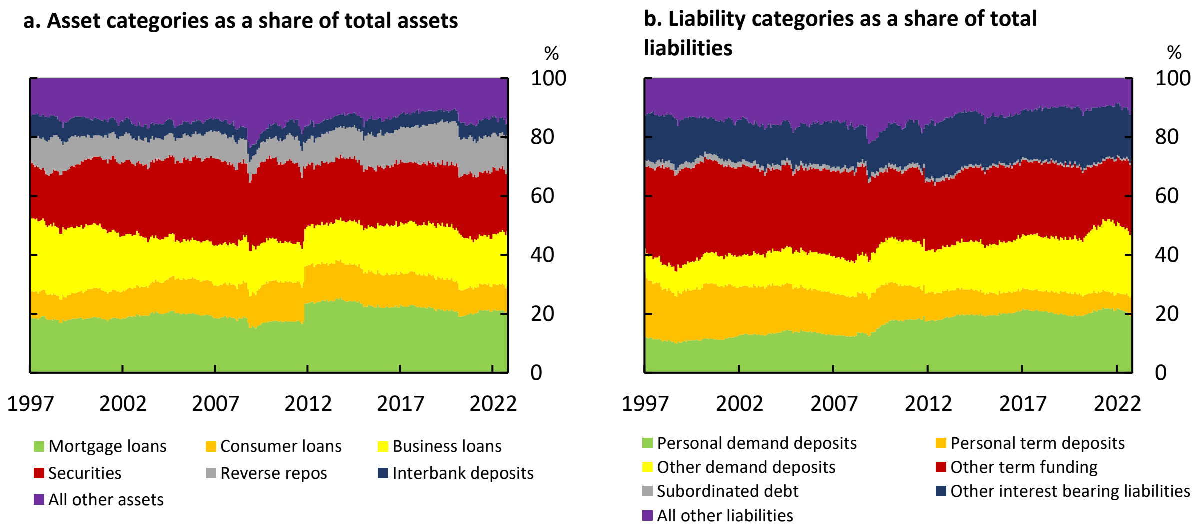
[**Appendix G**] ([**Table G-1**] and [**Chart G-1**]) presents the detailed results of the OCI ratio regressions.

In the final step, we obtain the dollar value of OCI from **Equation (26)** by multiplying the projected aggregate *OCI ratio* by the projected amount of total outstanding assets (TA_t).

4. Technical description of the balance sheet items

With the estimation of retained earnings at *t+1*, we can use TDSA to calculate the effect on the banks' balance sheet positions. **Chart 3** presents the historical evolution of the main asset and liability categories. We describe their projection in this subsection.

Chart 3: Composition of assets and liabilities in the Top-Down Solvency Assessment tool



Sources: Regulatory filings of Canadian Banks

Last observation: 2022Q4

4.1 Evolution of assets

Table 5 summarizes the two complementary approaches we use for the growth rate rules and assumptions that determine the evolution of the different asset categories in TDSA. Because Approach 1 is discussed in **Section 3.1**, we focus on Approach 2 in this section.

TDSA uses a stylized loan book segmented into a retail loan portfolio (i.e., loans to households) and a business loan portfolio, with further segmentation in line with the sectors modelled in HRAM and CDM. Each sub-portfolio is divided geographically into Canadian, US and the rest-of-the-world (RoW) exposures.

<table>
<tr><th colspan="5">Table 5: Asset categories growth rate rules
and underlying assumptions</th></tr>
<tr><th rowspan="2"></th><th rowspan="2">Approach 1</th><th colspan="3">Approach 2</th></tr>
<tr><th>Canada</th><th>United States</th><th>Rest of the World</th></tr>
<tr><td>Mortgage loans</td><td rowspan="6">Evolution path determined based on the regression specification described in Box 1. Projected results for each asset category are presented in Appendix B (Table B-1 and Charts B1-B6).</td><td rowspan="2">Generated by RAMM for the Canadian household sector</td><td rowspan="3">Generated by RAMM for total US credit</td><td rowspan="3">Calibrated based on the scenario and expert judgment</td></tr>
<tr><td>Consumer loans</td></tr>
<tr><td>Business loans</td><td>Generated by RAMM for the Canadian business sector</td></tr>
<tr><td>Securities</td><td colspan="3" rowspan="2">Remain static</td></tr>
<tr><td>Reverse repos</td></tr>
<tr><td>Interbank deposits</td><td colspan="2">Generated by RAMM, based on aggregate credit growth</td><td>Calibrated based on the scenario and expert judgment</td></tr>
<tr><td>All other assets</td><td>Remain static</td><td colspan="3">Remain static</td></tr>
</table>

The evolution of loan balances for a given sub-portfolio p at time t is described by the following formula:

$$Drawn_{p,t} = (1 + g_{p,t} - DR_{p,t})\ x\ Drawn_{p,t-1}, \tag{28}$$

where:

- $Drawn_{p,t}$ is the drawn loan balance at time *t* of portfolio type *p*
- $g_{p,t}$ is the rate of loan growth of that respective portfolio
- $DR_{p,t}$ is the default rate

We assume loan portfolios grow or decline at rate *g*, which equals the rate of credit growth over the risk scenario for the corresponding sector and geography (e.g., Canadian household credit, Canadian business credit or US business credit). As mentioned previously, we make a simplifying assumption that defaulted exposures are written off in the period of default and are deducted from loan balances.

The evolution of interbank deposits follows the aggregate credit growth rate based on the jurisdiction where they are sourced (i.e., Canada, the United States or RoW). Under the second approach, we use simplifying assumptions that all other assets, including cash, securities and reverse repos, remain static throughout the projection horizon.

4.2 Evolution of liabilities and equity

Table 6 summarizes the two complementary approaches for the growth rate rules and assumptions that determine the evolution of the different liability categories and shareholder equity in TSDA.

Table 6: Liability categories and equity growth rate rules and underlying assumptions

	Approach 1	Approach 2
Personal demand deposits	Evolution path of core deposits determined based on the regression specification described in **Box 1**; Projected results for each category presented in **Appendix B** (**Table B1** and **Charts B7** to **B9**).	Core deposits evolve based on historical growth rates.[12]
Personal term deposits		
Non-personal demand deposits		
Other term funding	Adjust up or down to ensure balance sheet identity holds	
Subordinated debt	Remain static	Remain static
All other liabilities		
Equity	Evolves based on the change in retained earnings from the income statement	

Under Approach 1, we model the evolution of core deposits (e.g., personal demand, non-personal demand and personal term deposits) because those historically account for a large share of the banking sector's liabilities (**Chart 3**). **Section 3.1** discusses the details of the empirical approach, and **Appendix B** (**Table B2** and **Charts B7 to B9**) shows the corresponding results. As an alternative, Approach 2 assumes these deposit types simply evolve based on their historical growth rate.

The remaining liability categories are treated similarly under both approaches. In TDSA we implement a rule to ensure that the balance sheet identity holds (i.e., total assets equal total liabilities and equity) at every period of the scenario. We achieve this by adjusting the level of other term funding iteratively to balance the assets with liabilities and equity. Other term funding is a diverse category that includes most of banks' wholesale funding (i.e., the marginal funding source) and is typically more expensive than core deposits.[13] The category is adjusted upward to meet incremental funding needs that are not met by other liabilities or core deposits. It is adjusted downward if assets decline faster than core deposits or other liabilities. Subordinated debt and all other liabilities remain static because it is difficult to model their evolution in relation to macrofinancial variables.

Finally, although banks can raise equity by issuing new shares in capital markets in the normal course of business, we assume that this option is not available to banks in TSDA because we expect the cost of new equity to be prohibitively high given the stressed macrofinancial environment. Hence, changes in common equity are driven by changes in retained earnings only.

[12] Alternatively, these deposits may contract over a few periods if in the risk scenario banks face depositor runs.

[13] Other term funding is a diverse category that includes fixed term deposits held by governments, other financial institutions and non-financial corporations. The category also includes bank wholesale funding debt (for instance deposit notes).

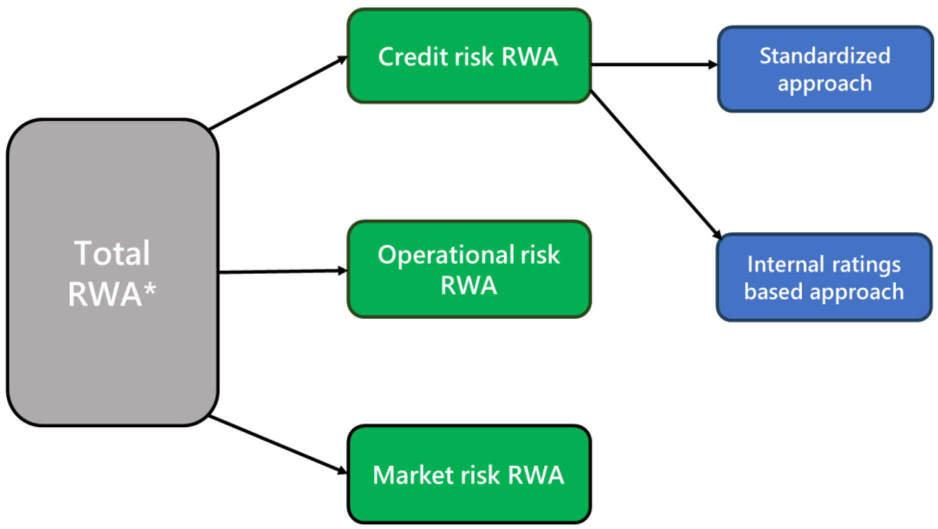
4.3 The risk-weighted assets module

This section describes how TDSA projects the evolution of RWAs over the course of the risk scenario. RWAs are the denominator in key capital adequacy ratios (e.g., CET1) and are calculated by weighting banks' on- and off-balance sheet exposures according to their risks. The evolution of RWAs is important in solvency stress testing because they tend to have a procyclical (i.e., amplifying) impact on capital ratios during economic downturns as asset risks increase.

To comply with regulatory capital requirements, banks must hold a minimum amount of capital in relation to their risk exposures. These risk exposures are split into three categories (**Figure 3**):

- **Credit risk:** Unexpected losses on credit exposures due to debtor, counterparty or issuer default
- **Market risk:** Risk of losses due to adverse changes in market conditions
- **Operational risk**: Risk of loss resulting from inadequate or failed processes or systems or due to external events that are neither market- nor credit-related

Figure 3: The components of risk-weighted assets

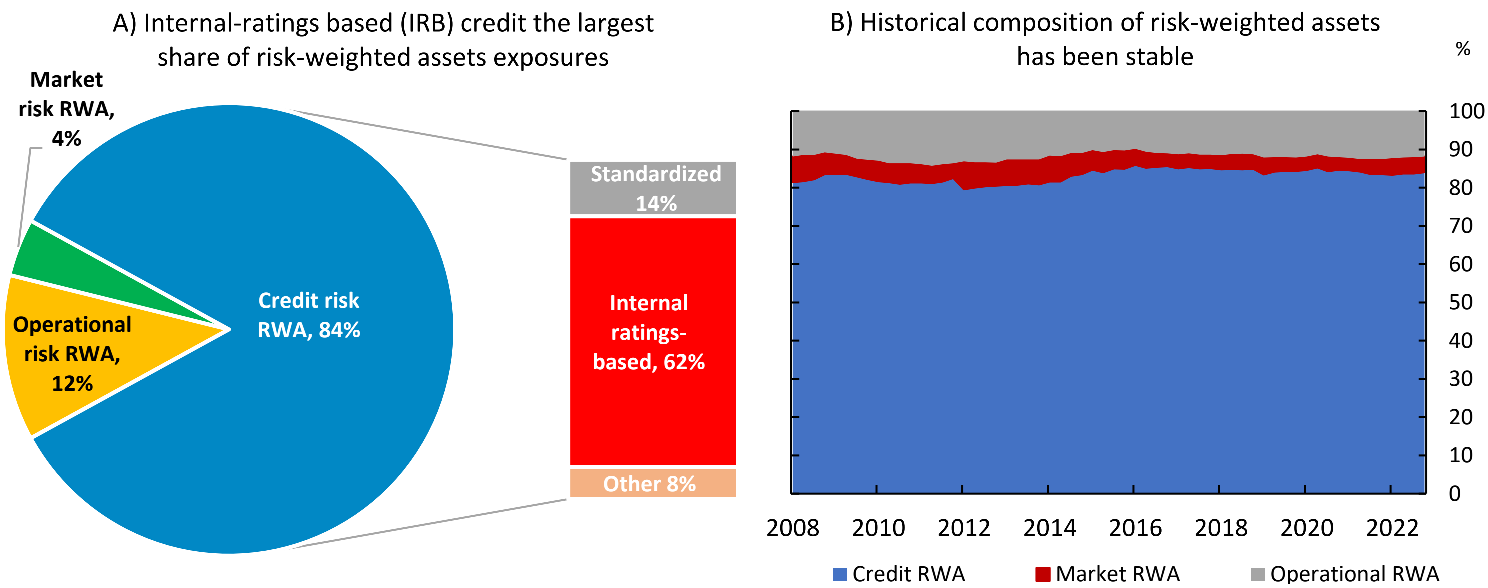


*RWA: risk-weighted assets

The RWA module in TDSA provides projections for all sources of RWAs but is focused primarily on credit RWAs, which account for the bulk of banks' required capital (**Chart 4**).[14]

[14] In TDSA, market RWAs are held constant throughout the risk scenario. Operational RWAs are calculated throughout the risk scenarios based on revenues, consistent with the standardized approach to operational risk used by banks. Note that the RWA module does not model some components of credit risk RWAs subject to special treatment in the BCAR. These include equities, securitization, trading and credit valuation adjustments.

Chart 4: Composition of risk-weighted assets (RWA) by type of risk



Sources: Regulatory filings of Canadian banks

Last observation: 2022Q4

Under Basel III, banks can use two methodologies to calculate credit RWAs:

- **The standardized approach (SA):** Banks apply fixed risk weights set by regulators based on ratings from external credit-rating agencies.
- **The internal ratings-based (IRB) approach:**[15] Banks calculate capital requirements for credit risk based on their own estimates of risk parameters (e.g., probability of default, loss given default and exposure at default). Risk weights are generally more sensitive to changes in macrofinancial conditions under this approach than under the standardized approach.

Section 4.3.1 presents how TDSA models credit RWAs for the SA and IRB approaches.

4.3.1 Projection of credit risk-weighted assets

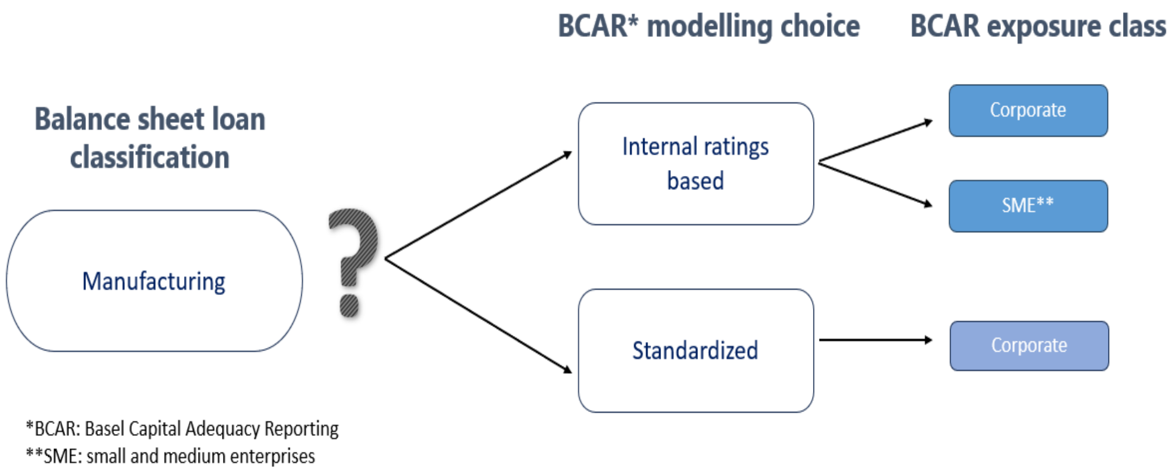
Sector mapping

First, a mapping function is required to link the sectors used in the balance sheet module with the sectors used in the RWA module. Our methodology for the RWA module relies on granular data submitted by banks using the Basel Capital Adequacy Reporting (BCAR) regulatory return. The BCAR and the data used for the balance sheet module have different sectoral classifications that need to be reconciled.

[15] There are two modelling approaches within IRB: the advanced internal ratings-based (A-IRB) approach and the foundation internal ratings-based (F-IRB) approach. The key difference between the two is the number of parameters that banks estimate. Under the F-IRB approach, banks only estimate the probability of default, while the regulator provides exogenous estimates of loss given default and exposure at default. In contrast, A-IRB requires banks to estimate all parameters. In this report, we focus on the A-IRB approach.

Figure 4 illustrates the issue posed by differences in sectoral classifications. A loan exposure classified to the manufacturing sector on the balance sheet could plausibly be allocated to more than one exposure class (i.e., sector) in the BCAR. To overcome this issue, the RWA module defines seven portfolios that have mappings to both the balance sheet data and the BCAR (see **Appendix H**).

Figure 4: Example of differences in sectoral classifications across data sources



Projecting credit risk-weighted assets using the internal ratings-based approach

In TDSA, we calculate IRB credit RWAs using the formulas set out for each exposure class in the BCAR (**Appendix I** discusses the prescribed formulas by exposure class).[16] RWAs are calculated for each exposure class (*s*), exposure type (*i*) and risk bucket (*b*), at each period (*t*) as a function of the following parameters:

$$RWA_{s,i,b,t} = f\left(PD_{s,i,b,t},\ EAD_{s,i,b,t},\ LGD_{s,i,b,t}, M_{s,i,b,t}\right), \quad (29)$$

where:

- $PD_{s,i,b,t}$ is the probability of default
- $EAD_{s,i,b,t}$ is the exposure at default
- $LGD_{s,i,b,t}$ is the downturn loss given default
- $M_{s,i,b,t}$ is the weighted average maturity

Much of the granular data required for these calculations is obtained from banks' BCAR submissions (**Box 2** provides more details about the data structure of the BCAR). The projections of IRB credit RWAs in TDSA requires projections of the probability of default and exposure-at-default parameters consistent with the risk scenario, which is discussed in detail below. The losses given default are typically based on the parameters modelled by banks in their BCAR submission and remain constant throughout the scenario.[17] These downturn losses given default are estimated by banks using post-default loss and

[16] The formulas used to calculate credit RWA are based on Merton's model application of Vasicek (2002), commonly known as the asymptotic single risk factor (ASFR) model. The ASFR model has been central to the IRB approach to credit risk in the Basel framework since its introduction within Basel II (BCBS 2005).

[17] In some cases, expert judgment can be applied to losses given default (e.g., in the case of residential lending portfolios) based on loan-to-value ratio data and house price profiles.

recovery information over a historical observation period. Finally, the weighted average maturity (*M*), which is used only for certain exposure classes, is also based on values reported in banks' BCAR submissions and remains constant throughout the scenario.

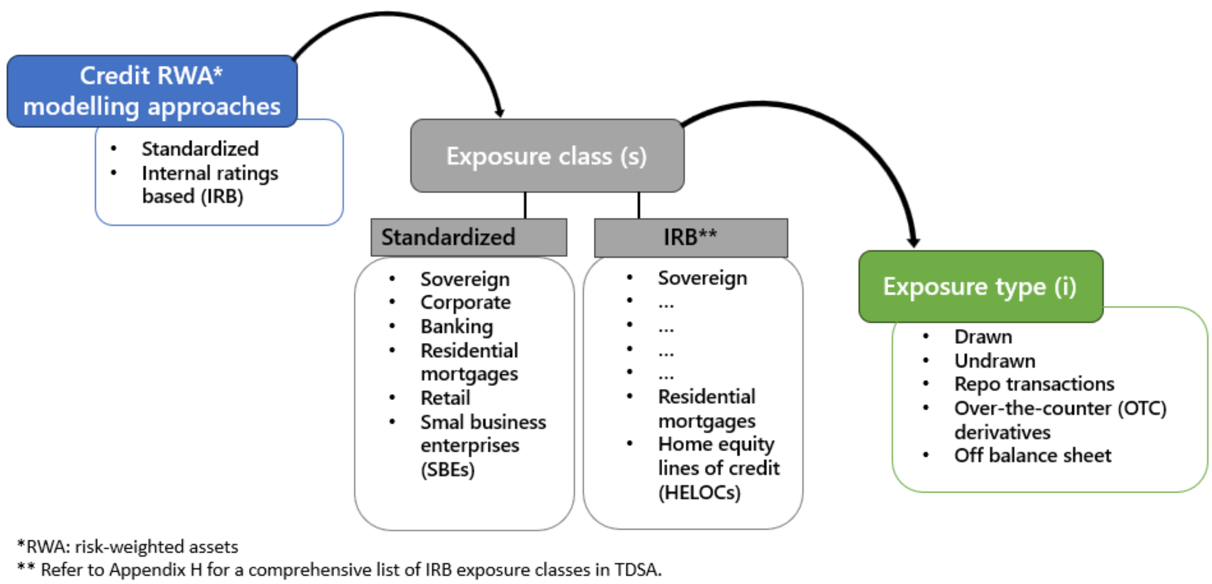
After we calculate RWAs for each exposure class, exposure type and risk bucket, we aggregate them to obtain total IRB credit risk RWAs for each period in the scenario:

$$Total\ IRB\_Credit\_RWA_t = \sum_{s=1}^{S}\sum_{i=1}^{I}\sum_{b=1}^{B} \mathrm{f}\,(PD_{s,i,b,t}, EAD_{s,i,b,t}, LGD_{s,i,b,t}, M_{s,i,b,t})\ , \qquad (30)$$

Box 2: Data structure of the Basel Capital Adequacy Reporting regulatory return

We first divide credit exposures into the two possible modelling approaches (i.e., standardized and internal ratings-based), as shown in **Figure 5**. We then segment exposures by exposure class (i.e., sector). **Appendix H** lists the complete set of exposure classes contained in the BCAR for both the standardized and internal ratings-based approaches.[18] Next, for each exposure class, exposures are further segmented into five exposure types (*i*): drawn, undrawn, repurchase transactions, over-the-counter derivatives and other off-balance sheet exposures. Finally, each exposure type (*i*) is further divided into risk buckets with a corresponding probability of default.

Figure 5: Overview of credit risk-weighted asset (RWA) exposure classification in the Basel Capital Adequacy Reporting (BCAR)

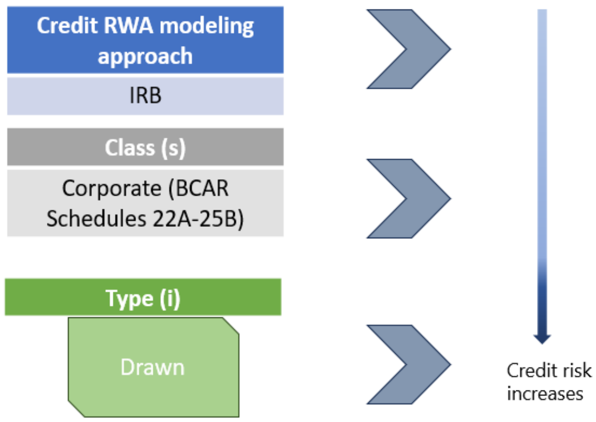


Banks report a set of estimated risk parameters for each risk bucket. Risk buckets include probability of default, loss given default, exposure at default effective maturity.[19] For illustrative purposes, **Figure 6** shows a simplified data structure for a given exposure class (*s*) and exposure type (*i*).

[18] This technical report uses the BCAR regulatory data structure as of the first quarter of 2023. Note that exposure class classifications in the BCAR regulatory return changed in the second quarter of 2023.The mapping assumption has been updated accordingly and is available upon request.

[19] The BCAR return is more granular than the high-level presentation in Figure 5. For some BCAR classes, additional variables are required for the final RWA calculation. For instance, weighted average firm size is included for exposures classified under the SME sector.

Figure 6: High-level example of the Basel Capital Adequacy Reporting (BCAR) structure for internal ratings-based (IRB) exposures



Risk bucket	Probability of Default (PD, %)	Exposure at Default (EAD) (C$, x1000)	Loss Given Default (LGD) (%)	Maturity (M) (Years)	RWA (C$, x1000)
1	0.2	1579265	4.1	2.12	25122
2	0.3	1112800	40.06	3.69	310845
3	0.4	4436950	39.21	2.87	195362
4	0.5	220369	49.20	1.08	55298
..	...	...	...	...	...
..	...	...	...	...	...
..	...	...	...	...	...
..	...	...	...	...	...
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..	...	...	...	...	...
..	...	...	...	...	...
24	40	15469	43.74	1.42	148232
Default	100	361544	59.8	N/A	2147823

Projection of probability of default for internal ratings-based exposures

The probability of default used in the regulatory capital framework is the bank's best estimate of the long-run average one-year default rate for borrowers in each risk bucket. These estimates must use at least five years of underlying data, and at least 10% of the data should come from downturn periods (OSFI 2023). While using long-run probabilities of default reduces procyclicality of capital requirements, these probabilities of default could still be sensitive to an economic downturn—particularly if default rates increase significantly compared with recent historical experience. Another source of procyclicality is the migration of exposures from lower to higher risk buckets (with higher corresponding probabilities of default) as the economic environment deteriorates and banks adjust borrowers' internal risk ratings.

While TDSA does not model the migration of exposures between risk buckets, the long-run probabilities of default for each risk bucket are adjusted for the projection period based on projected default rates in the risk scenario (typically from internal CDM and HRAM models for corporate and household default rates, respectively). This has the effect of increasing the average risk weight across portfolios.

Specifically, we project the probability of default using an exponentially weighted moving average of scenario default rates. The procedure works in three steps. First, we calculate an exponentially weighted moving average for the default rate of each sector in the balance sheet module.

We then generate a sector-weighted default rate for each of the seven portfolios used in the RWA module, defined in **Appendix H** (**Table H-1 to Table H-7**), with each balance sheet sector-weighted based on its share of total loans

Finally, we generate a growth rate for the weighted default rate of each of the seven portfolios. We then apply this growth rate to the starting point probability of default for each portfolio's respective BCAR exposure classes, at the exposure type and risk bucket level. This procedure generates a path for the probability of default for the calculation of risk-weighted assets that is consistent with the default rates in the scenario, as shown in **Equation 31** below.

$$PD_{s,i,b,t} = \frac{WMADR_{p,t}}{WMADR_{p,t-1}} * PD_{s,i,b,t-1}, \quad (31)$$

where:

- $\frac{WMADR_{p,t}}{WMADR_{p,t-1}}$ is the growth rate of transformed (exponentially weighted moving average) scenario default rates for portfolio (*p*)
- $PD_{s,i,b,t-1}$ is the probability of default in the previous period for risk bucket (*b*) in exposure type (*i*) in exposure class (*s*) in portfolio (*p*)

Projection of exposure at default for internal ratings-based exposures

The procedure for projecting the path of exposure at default for each risk bucket is intended to ensure consistency with the projection of credit losses (see **Section 3.3.1, Equation 21**) and balance sheet growth (see **Section 4.1, Equation 28**). Specifically, the procedure first allocates and removes defaults from BCAR exposure classes and risk buckets in proportion to their risk (i.e., defaults are assumed to occur in the risk buckets with the highest probabilities of default). This reduces the average risk weight of each exposure class. The procedure then allocates the remaining change in loan balances (i.e., due to credit growth or contraction) to exposure classes and risk buckets in proportion to their exposure at default. This has no effect on average risk weight of each exposure class. The three steps in this procedure are as follows.

Step 1

We first calculate defaulted exposures for each of the seven portfolios (*p*) using the equation below. Since defaulted exposures are assumed to be written off in the period of default (see **Section 3.3.1)**, we must also deduct these balances from the drawn exposure at default.

$$Defaulted\ Exposures_{p,t} = Drawn\ \ \text{exposures}_{p,t-1} \times DR_{p,t}\,, \quad (32)$$

where:

- $Defaulted\ exposures_{p,t}$ are the credit loss amounts for portfolio (*p*)
- $Drawn_{p,t-1}$ are the drawn loan balances in the previous period (see **Section 4.1, Equation 28**)
- $DR_{p,t}$ is the default rate for portfolio (*p*)

We then allocate defaulted exposures for each portfolio (*p*) into a vector of exposures moving to default (EMD). This vector performs the mapping of credit losses across BCAR exposure classes and risk buckets. The allocation of defaulted exposures to each risk bucket involves scaling them using the three terms in **Equation (33)** below.

$$IRB\ EMD_{s,b,t} = [Defaulted\ exposures_{p,t}] \times \underbrace{\frac{IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}}{\sum_{b=1}^{B} IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}}}_{\#1} \times$$

$$\underbrace{\frac{\sum_{b=1}^{B} IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}}{\sum_{s=1}^{S}\sum_{b=1}^{B} IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}}}_{\#2} \times \underbrace{\frac{\sum_{s=1}^{S} IRB\ Drawn\ EAD_{s,t-1}}{\sum_{s=1}^{S} IRB\ Drawn\ EAD_{s,t-1} + \sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}}}_{\#3}\,, \quad (33)$$

where:

- $Defaulted\ exposures_{p,t}$ are the credit loss amounts for portfolio (*p*)

- $Term$ #1 is the probability of default-weighted share of risk bucket (*b*) in BCAR class (*s*)
- $Term$ #2 is the probability of default-weighted share of BCAR exposure class (*s*) in all the BCAR exposure classes that make up portfolio (*p*)
- $Term$ #3 is the share of IRB exposures across the BCAR exposure classes in portfolio (*p*) relative to total BCAR exposures for those classes (i.e., total exposures classified under both IRB and standardized approaches)

Step 2

Next, we calculate the change in loan exposures between periods that is unrelated to defaults (i.e., due to credit growth or contraction). The first term of **Equation (34)** below represents the change in drawn loan exposures relative to the prior period (*t*). Recall that **Equation (28)** (**Section 4.1**) already accounts for the write-off of defaulted exposures, which we later remove in Step 3 of the exposure-at-default process (see **Equation 35**). In turn, we add back these defaults in Term #2 of **Equation (34)** to avoid double-subtraction.

$$\Delta Drawn\ BSE_{p,t} = \underbrace{\left(Drawn\ \ exposures_{p,t}\ -\ Drawn\ \ exposures_{p,t-1}\right)}_{\#1} + \underbrace{Defaulted\ \ exposures_{p,t}}_{\#2}\ , \tag{34}$$

where:

- $\Delta Drawn\ BSE_{p,t}$ is the change in the drawn balances unrelated to defaults to be reflected in the EAD projection
- $Drawn\ \ exposures_{p,t}$ are drawn exposures (from **Equation 28**)
- Term #1 incorporates the changes in drawn loan exposures, consistent with the balance sheet growth projections in **Section 4.1** for each portfolio
- Term #2 ($Defaulted\ exposures_{p,t}$) is the expected loss amounts for each of the seven portfolios (**Equation 32**)

Step 3

In the final step, outputs from Step 1 and Step 2 are combined to calculate the path for exposure at default at the risk bucket level:

$$IRB\ Drawn\ EAD_{s,b,t} = \underbrace{IRB\ Drawn\ EAD_{s,b,t-1} - IRB\ EMD_{s,b,t}}_{\#1}$$

$$+ \underbrace{\Delta Drawn\ BSE_{p,t} \times \frac{IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}}{\sum_{b=1}^{B} IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}} \times \frac{\sum_{b=1}^{B} IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}}{\sum_{s=1}^{S}\sum_{b=1}^{B} IRB\ Drawn\ EAD_{s,b,t-1} \times PD_{s,b,t-1}} \times \frac{\sum_{s=1}^{S} IRB\ Drawn\ EAD_{s,t-1}}{\sum_{s=1}^{S} IRB\ Drawn\ EAD_{s,t-1} + \sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}}}_{\#2}\ , \tag{35}$$

In component #1 of **Equation (35)**, the vector for exposures moving to default (calculated in **Equation 33**) is subtracted from the exposure at default in the previous period, reflecting the write-off of defaulted loans. Component #2 of the equation accounts for additional changes in loan balances due to credit growth or contraction (calculated in **Equation 34**). These changes are allocated using the same scaling process followed in **Equation 33.**

The path of exposure at default for other exposure types are calculated using a simplified approach. Undrawn exposure at default is assumed to evolve in proportion with drawn exposure at default such that the usage rate at the portfolio level remains constant. The exposure at default for over-the-counter derivatives, repo-style transactions and other off-balance sheet exposures are assumed to remain constant over the risk scenario.

Standardized approach for credit risk risk-weighted assets

For exposures using the standardized approach, RWAs are calculated as the product of the standardized risk weight and the exposure at default for each risk bucket. These risk weights are based on the borrower's external credit ratings and vary across exposure classes (see **Table 7)**.[20] For instance, exposures to corporates carry the following risk weights:

Table 7: Risk weights on corporate exposures under the standardized approach

External rating	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to B-	Below B-
Risk weight	20%	50%	75%	100%	150%

In TDSA, the approach to credit RWA for standardized exposures is simplified compared with IRB exposures. RWAs are calculated for each BCAR risk bucket, exposure class and exposure type and then aggregated using the formula below:

$$Total\ SA\_Credit\_RWA_t = \sum_{s=1}^{S} \sum_{i=1}^{I} EAD_{s,i,t} \times Risk\ weight_{s,i,t}, \quad (36)$$

Since risk weights are fixed, the change in standardized RWA throughout the risk scenario is driven only by the change in exposure at default. As with IRB exposures, the projection of exposure at default for standardized exposures ensures consistency with the projections for credit losses (see **Section 3.3.1, Equation 21**) and balance sheet growth (see **Section 4.1**).

First, we allocate defaulted exposures to each exposure class proportionally based on exposure at default in the previous period and the share of standardized approach relative to IRB exposures.

The following is an example for drawn exposures:[21]

[20] See CRE20 - Standardised approach: individual exposures for details on all other exposures and their corresponding risk weights.

[21] Undrawn exposures follow the same approach as drawn exposures. Exposures at default for repo-style transactions, OTC derivatives and other off-balance sheet exposures are assumed to remain constant.

$$SA\ EMD_{s,t} = \underbrace{[Defaulted\ exposures_{p,t}]}_{\#1} \times \underbrace{\frac{SA\ Drawn\ EAD_{s,t-1}}{\sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}} \times \frac{\sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}}{\sum_{s=1}^{S} IRB\ Drawn\ EAD_{s,t-1} + \sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}},}_{\#2} \quad (37)$$

where:

- $Defaulted\ exposures_{p,t}$, are the credit loss amounts for portfolio (*p*)
- Term #2 allocates $Defaulted\ exposures_{p,t}$, using the same scaling process followed in **Equation 33**

Next we calculate $\Delta Drawn\ BSE_{p,t}$, the change in loan exposures between periods that is unrelated to defaults (i.e., due to credit growth or contraction) and allocate them to each exposure class (term #2 of **Equation 38**). We then calculate exposure at default as follows:

$$\text{SA}\ Drawn\ EAD_{s,t} = \underbrace{SA\ Drawn\ EAD_{s,t-1} - SA\ EMD_{s,t}}_{\#1} + \underbrace{\{\Delta Drawn\ BSE_{p,t}\} \times \frac{SA\ Drawn\ EAD_{s,t-1}}{\sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}} \times \frac{\sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}}{\sum_{s=1}^{S} IRB\ Drawn\ EAD_{s,t-1} + \sum_{s=1}^{S} SA\ Drawn\ EAD_{s,t-1}},}_{\#2} \quad (38)$$

5. Calculating the regulatory capital ratios

The primary output of TDSA is the CET1 capital ratio, which is the amount of CET1 capital divided by the amount of risk-weighted assets. This metric can be aggregated across banks to represent the overall solvency of the banking sector.

CET1 capital at period *t* is given by:

$$CET1_t = CET1_{t-1} + RE_t + OCI_t, \quad (39)$$

where:

- *RE* is retained earnings calculated in the income module, i.e., after-tax net income minus dividend distributions
- *OCI* is the amount of other comprehensive income calculated in the income module

RWAs are calculated in the RWA module.

The regulatory leverage ratio is calculated as the amount of Tier 1 capital divided by the leverage ratio exposure measure. Tier 1 capital is given by:

$$Tier1_t = CET1_t + Additional\_Tier1_t, \quad (40)$$

where:

- *CET1* is defined in **Equation (39)**
- $Additional\_Tier1$ is the amount of additional tier 1 capital, which is held constant throughout the risk scenario [22]

Leverage exposure is given by:

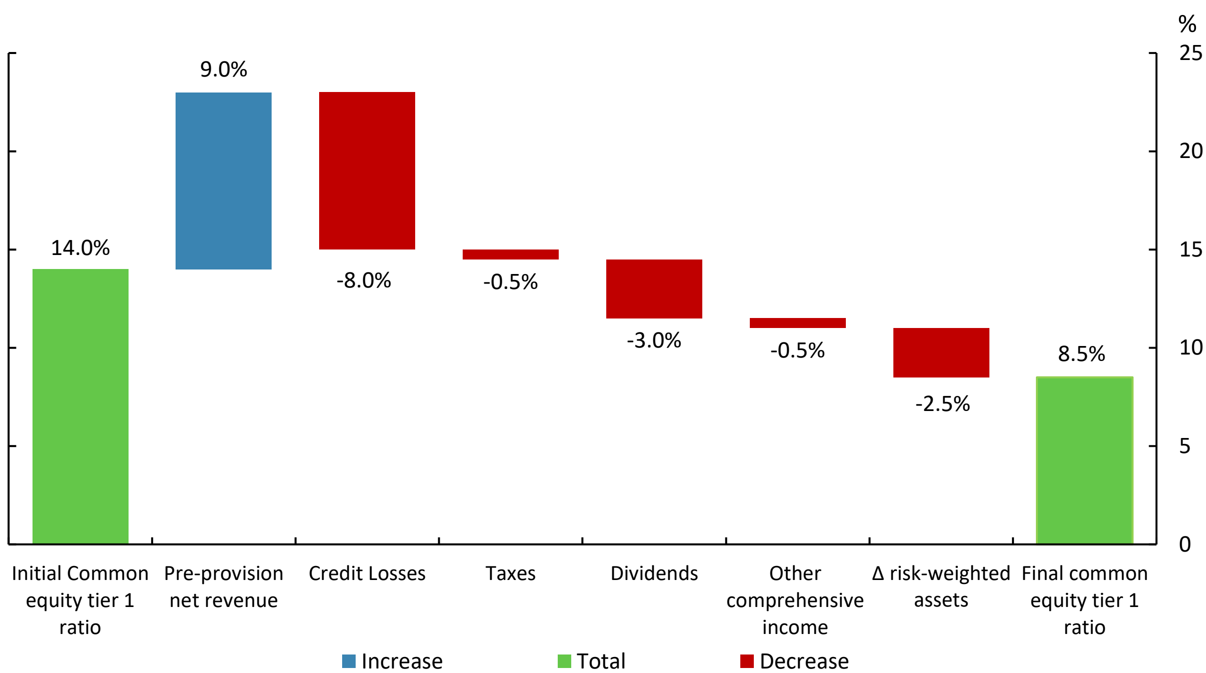
$$Leverage\_Exposure_t = Total\_assets_t + OBS\_exposure_t, \quad (41)$$

where:

- $Total\_assets_t$ is total assets calculated in the balance sheet module
- $OBS\_exposure_t$ is the additional leverage exposure in excess of total balance sheet assets, which is held constant throughout the risk scenario

We can leverage the flexibility of TDSA to decompose the impact of the different components on the CET1 ratio, as in Danaee et al. (2022). **Chart 5** provides an illustration, based on artificial data, of how TDSA can decompose the impact of a risk scenario on the CET1 ratio over the projection horizon.

Chart 5: An example of how TDSA decomposes the impact on the common equity tier 1 ratio for a given risk scenario



For ease of interpretation, we divide all components by the initial period's value of RWAs and include the following factors:

[22] For details see the Capital Adequacy Requirements guidelines (2024).

- Pre-provision net revenues (PPNR), defined as (NII + NINT income + trading income – non-interest expense). These components are covered in **Section 3.1** (the income items) and in **Section 3.2** (the variable and fixed expenses).
- Credit losses (e.g., provisions) and taxes, which are described in **Section 3.3 and Section 3.4**.
- Dividend payouts and OCI, which are presented in **Section 3.5**.
- The change in RWAs, for which the modelling methodology is explained in **Section 4.3**.

An important feature of TSDA is its ability to compare each factor's impact on the banks' solvency ratio. This allows policy-makers to identify areas for increased regulatory and supervisory focus.

Finally, we summarize the main outputs that TDSA generates in **Table 9**. Note that each output is calculated at the aggregated industry level and for each bank separately.

Table 9: Main output of the Top-Down Solvency Assessment tool

Components	Item	Output description
		Income statement module
Revenues	NII NIM NINT Income Trading income	Cumulative share of each item relative to RWA Cumulative PPNR as a share of RWA Path of each metric over the risk horizon
Expenses	NIE Ratio of provisions to loans (i.e., credit loss rate)	Path of NIE (relative to RWA) over the risk horizon Cumulative losses rate over the risk horizon Credit loss rates, by asset category Credit loss rates, by bank
		Balance sheet module
Assets and liabilities	Assets RWA Liabilities	Growth rate of each item over the risk horizon RWA density (ratio of RWA to assets)
Regulatory ratios	CET1 ratio Leverage ratio	Cumulative impact on the CET1 ratio by drivers (see **Figure 3**) Path of the ratios over the risk scenario Peak-to-trough change in the ratio

Note: NII is net interest income, NIM is net interest margin, NINT is non-interest non-trading (income), RWA is risk-weighted assets, PPNR is pre-provisioning net revenue, NIE is non-interest expense, and CET1 is common equity tier one (ratio).

6. Model limitations

Like any other model, TDSA has some limitations that should be acknowledged and understood. This section documents these limitations and outlines complementary tools at the Bank of Canada that can help address these gaps.

Contagion and macro-feedback loop

TDSA measures the first-round impact of risk scenarios on bank solvency through credit losses and income by projecting banks' balance sheets, income statements and regulatory capital ratios. TDSA does not model the potential second-round effects of the risk scenario on the economy and financial system. For example, a significant deterioration in the solvency of a D-SIB could have negative spillover effects on other entities, either through direct or indirect interconnections. This could trigger a second-round impact through funding liquidity risk, fire sales of securities, or interbank exposures.

Another channel for second-round effects is if banks reduce credit to the real economy because their capital is severely impaired by the initial shock (i.e., a credit crunch). This reaction could exacerbate the slowdown in economic activity and exert further pressures on banks. To capture contagion and the macro-feedback loop, the Bank is developing a more holistic system-wide stress-testing framework that allows banks to interact with the real economy through households and businesses.

Dynamic balance sheet

While TDSA allows some flexibility to model the evolution of banks' balance sheets over the risk scenario (See **Section 4**), it does not account for extraordinary actions that bank management could take to preserve capital. For example, bank management could proactively reduce limits on existing credit facilities when they are not bound by contractual commitments or they could eliminate dividend payments to shareholders before it would be required by regulation.

The Bank is developing some alternative stress-testing models, such as the Banks' Strategy Module (Hipp 2025), which feature dynamic balance sheet mechanisms that allow for banks to take more proactive actions as the risk scenario unfolds.[23]

Scope of risk factors

TDSA does not account for certain risk factors or accounts for them in only a simplistic way—including market risk, funding or liquidity risk, operational risk and credit risk arising from exposures to assets other than loans. These gaps exist when the risk factor accounts for only a small share of banks' total risks or when adequate data for modelling is lacking.

Solvency-liquidity nexus

TDSA can be viewed as stand-alone solvency stress-testing tool. However, in practice, bank solvency and liquidity risk are linked, and this relationship can materialize through several channels (e.g., margin calls, credit downgrades, funding costs and fire sales). In the event of a severe shock, a problem that initially appears to affect only the liquidity of a bank can quickly turn into serious solvency problem. Similarly, a problem that initially affects the solvency of a bank can transmit to funding liquidity issues. The Bank recognizes the value in jointly modelling these risks on banks, especially under highly adverse risk scenarios. Recent modelling efforts include Hipp (2024); for more discussion, see Bruneau et al. (forthcoming).

7. Conclusion

In this report, we describe how the TDSA model provides insights about the resilience of the Canadian banking system. In particular, it allows Bank of Canada staff to:

- quantify the loss-absorbing capacity of Canadian banks under stress using a set of empirical relationships, decision rules, accounting identities and assumptions
- identify the underlying factors that affect banks' solvency risk in a given risk scenario

[23] See also Hałaj and Priazhkina (2021), who model strategic bank behaviour under adverse market conditions.

- generate projections of banks’ balance sheets, income statements and regulatory capital ratios for monitoring purposes

TDSA has many advantages. It is flexible, does not require a heavy calibration and generates insights that can be communicated to a diverse audience (e.g., practitioners, regulators and academic researchers). However, like any model, TDSA has limitations. Therefore, TDSA can be viewed as one important component of the Bank’s analytical tool kit that, when used alongside other models, can help form an overall assessment of financial stability risks in Canada.

Bank staff will continue to maintain and enhance TDSA in the coming years. More specifically, future work will focus on improving the modelling of market and funding and liquidity risks. Potential extensions could also explicitly introduce an endogenously determined credit growth that is tied to the severity of the risk scenario. These are all promising avenues for model development that will make sure TDSA remains fit for purpose.

8. References

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Appendix A: Macrofinancial variables—Summary statistics and glossary

Table A-1: Summary statistics

Sample includes quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. Income statement ratios are adjusted by the average amount of their relevant denominator asset balance over the quarter. Interest-earning assets is the sum of outstanding loans and securities. Residential mortgages include on-balance sheet mortgages and off-balance mortgages. Business loans include interbank and government loans. Consumer loans include all non-mortgage loans to individuals for non-business purposes.

	Transformation/definition	Avg.	Std. dev	Min	Max
Selected assets and liabilities (quarterly growth rates, %)					
Mortgages	$[\ln(\text{asset type})_t - \ln(\text{asset type})_{t-1}] \times 100$	2.08	3.79	-4.92	37.70
Consumer loans	$[\ln(\text{asset type})_t - \ln(\text{asset type})_{t-1}] \times 100$	1.99	2.08	-2.52	15.26
Business loans	$[\ln(\text{asset type})_t - \ln(\text{asset type})_{t-1}] \times 100$	1.71	3.66	-11.18	12.01
Securities	$[\ln(\text{asset type})_t - \ln(\text{asset type})_{t-1}] \times 100$	2.08	3.37	-7.94	11.23
Reverse repos	$[\ln(\text{asset type})_t - \ln(\text{asset type})_{t-1}] \times 100$	2.38	6.24	-13.23	23.24
Interbank deposits	$[\ln(\text{asset type})_t - \ln(\text{asset type})_{t-1}] \times 100$	1.42	8.32	-28.41	29.72
Interest-earning assets (=loans + securities)	$[\ln(\text{asset type})_t - \ln(\text{asset type})_{t-1}] \times 100$	1.91	2.43	-4.42	11.92
Total assets	$[\ln(\text{asset})_t - \ln(\text{asset})_{t-1}] \times 100$	1.92	2.93	-4.18	11.62
Personal demand deposits	$[\ln(\text{deposit type})_t - \ln(\text{deposit type})_{t-1}] \times 100$	2.32	3.03	-4.74	12.71
Personal term deposits	$[\ln(\text{deposit type})_t - \ln(\text{deposit type})_{t-1}] \times 100$	1.05	3.41	-4.50	16.28
Non-personal demand deposits	$[\ln(\text{deposit type})_t - \ln(\text{deposit type})_{t-1}] \times 100$	2.74	2.98	-5.29	16.46
Effective rates (error correction model, annualized %)					
Interbank deposits	Interest earned over respective asset	2.21	1.83	0.19	5.91
Securities	Interest earned over respective asset	2.94	1.10	1.34	5.18
Mortgage loans	Interest earned over respective asset	4.43	1.49	2.42	7.50
Consumer loans	Interest earned over respective asset	6.81	1.02	5.22	9.48
Business loans	Interest earned over respective asset	4.93	1.63	2.95	8.49
Reverse repos	Interest earned over respective asset	2.61	2.11	0.30	8.51
Personal demand deposits	Interest expense over respective liability	0.76	0.48	0.12	1.97
Personal term deposits	Interest expense over respective liability	2.96	1.30	1.04	5.46
Non-personal demand deposits	Interest expense over respective liability	1.23	0.87	0.20	3.41
Non-personal term deposits	Interest expense over respective liability	2.79	1.61	0.88	6.41
Subordinated debt	Interest expense over respective liability	4.86	1.58	2.02	8.10
Other liabilities	Interest expense over respective liability	2.98	1.70	0.55	6.59

Core variables (generic approach model, annualized %)					
Net interest margin	(NII/ interest-earning assets) x 400	1.94	0.21	1.59	2.40
Non-interest non-trading ratio	(NINT income / assets) x 400	1.45	0.25	0.92	2.19
Trading income ratio	(Trading income / securities) x 400	0.16	0.16	-0.1	0.59
Non-interest variable-expense ratio	(Variable expense / assets) x 400	1.30	0.25	0.87	1.80
Non-interest fixed-expense ratio	(Fixed expense / assets) x 400	0.73	0.16	0.48	1.19
Provision for loan losses for impaired loans	(Stage 3 impairments / loans) x 400	0.28	0.09	0.14	0.45
Provision for loan losses	(Total impairments / loans) x 400	0.36	0.24	-0.04	1.14
Other comprehensive income ratio	(OCI / assets) x 400	0.16	0.41	-1.26	1.02
Control variables					
3-month Treasury bill yield (in %)		2.10	1.62	0.08	5.61
5-year GoC yield		2.94	1.67	0.36	6.03
3-month Treasury (US)		1.94	2.00	0.01	6.19
5-year GoC yield (US)		2.95	1.72	0.27	6.57
Term spread (in %)	10-year government bond yield – 3-month government bond yield	1.29	0.96	-0.80	3.58
Quarterly growth stock market return (in %)	$[\ln(TSX)_t - \ln(TSX)_{t-1}] \times 100$	1.14	8.65	-27.17	19.00
Annualized real GDP growth (in %)	$[\ln(GDP)_t - \ln(GDP)_{t-1}] \times 400$	2.24	6.37	-46.29	34.54
Annualized Δ unemployment rate	$[\%UR_t - \%UR_{t-1}] \times 4$	-0.18	3.23	-12.93	27.33
Year-over-year ΔHPI (in %)	$[\ln(HPI)_t - \ln(HPI)_{t-4}] \times 100$	5.26	6.61	-11.4	28.5
Growth rate total credit (in %)	$[\ln(ratio)_t - \ln(ratio)_{t-1}] \times 100$	-0.05	0.06	-0.25	0.14
USD/CAD rate		0.80	0.11	0.62	1.04
Corporate non-financial spread (in %)	(BBB-rated bonds yields – 10-year gov yield)	1.26	0.53	0.34	3.60
Share of residential mortgages (in %)	[(on-balance-sheet + off-balance-sheet mortgages)/assets] x 100	22.16	1.78	17.86	25.53
Share of business loans (in %)	[(business loans + non-residential mortgages)/assets]x 100	14.64	3.05	10.94	22.61
Share of consumer loans (in %)	[Non-mortgage consumer loans / assets] x 100	10.91	1.58	8.29	13.85
Share of securities (in %)	(securities / assets) x 100	27.85	2.82	24.35	33.62

Table A-2: Glossary of key macrofinancial variables

Variable	Description	Source	Series	Frequency
Real GDP	Gross domestic product at market prices (seasonally adjusted annual rate, chained 2012 Can$)	Statistics Canada	V62305752	Quarterly
Unemployment rate (level)	Unemployment rate: both sexes, 15 years and over (seasonally adjusted, %)	Haver	S156ELUR@G10	Monthly (average)
Consumer credit	Total credit liabilities of households (seasonally adjusted, Can$)	Statistics Canada	V1231415625	Monthly (end of period)
Business credit	Total credit liabilities of private non-financial corporations (seasonally adjusted, Can$)	Statistics Canada	V1231415669	Monthly (end of period)
Residential mortgage credit	Residential mortgage credit (seasonally adjusted, Can$)	Statistics Canada	V1231415621	Monthly (end of period)
CAD/USD	Foreign exchange rate: Canada (EOP, CAD/USD)	Haver	E156@FXRATES	Monthly (end of period)
Non-financial corp. spread	FONF BAML Canada Non-financial Corporate Index	Int'l Exchange (ICE)	F0NF_OAS	Daily (end of period)
S&P TSX	S&P/TSX: Composite, Close	Bloomberg finance l.p.	SPTSX_INDEX	Business daily (end of period)
National house price	Average sale price: residential: Canada (seasonally adjusted, Can$)	Haver	CACERPSQ@CREA	Quarterly
3-month treasury bill	Treasury Bills, 3-month	Bank of Canada	V39065	Business daily (end of period)
5-year gov't bond yield	GoC benchmark bond yield, 5-year	Bank of Canada	V39053	Business daily (end of period)
10-year gov't bond yield	GoC benchmark bond yield, 10-year	Bank of Canada	V39055	Business daily (end of period)
3-month treasury bill	US; treasury bills, 3-month	Bloomberg finance l.p.	USGG3M_INDEX	Business daily (end of period)
5-year government bond yield	US; US Government benchmark bond yield, 5-year	Bloomberg finance l.p.	USGG5YR_INDEX	Business daily (end of period)

Appendix B: Net interest income (NII)

- **Table B-1** presents the growth rate estimations of the six asset categories and the three main liability categories (personal demand deposits, non-personal demand deposits, and personal term deposits). Estimates are based on an autoregressive distributed lag model, with the optimal number of lags selected based on the Akaike or Bayesian (also known as Schwarz) information criterion.

- **Charts B-1** to **B-6** illustrate the model fit from the asset growth regressions. The projected path is obtained by multiplying the previous period's asset amount by the projected growth rate over the quarter. Overall, the model fits the data well, especially in the earlier years of the analysis.

- **Charts B-7** to **B-9** illustrate the model fit from the liability growth regressions. The projected path is obtained by multiplying the previous period's outstanding deposit amount by the projected growth rate over the quarter. Note that all three deposit types strongly relate to their lagged value given the significant coefficient on the autoregressive term. Overall, the models fit the data well.

- **Table B-2** presents the preferred error correction model (ECM) specification for each effective rate estimation (both on the asset and the liability side). The coefficient on the error correction term should be interpreted as follows: for instance, when mortgage rates diverge from their long-term equilibrium, about 20% of the disequilibrium is corrected each period (α_1 = 0.21). Note that the speed of adjustment is higher for the rates on consumer loans (α_1 = 0.57).

- **Chart B-10** plots the fitted and projected paths of each effective rate generated by the ECM. Overall, the ECM produces paths that fit the data well, given that for most variables the level and the evolution of the rates follows their observed paths.

- **Table B-3** provides the estimated coefficients from the regression specification of the growth rate in interest-earning assets (IEA), which are the sum of total loans plus securities. It indicates that the growth rate of IEA is persistent given the significance of the lagged autoregressive terms. The table also shows that the growth rate of IEA slows down as the economy grows, but also as the unemployment rate rises.

- **Chart B-11** provides the projected path of IEA. The path is obtained by multiplying the previous period's amount by the projected growth rate over the quarter. Overall, the model fits the data well throughout the sample period.

- **Table B-5** presents the estimated coefficients from the generic net interest margin (NIM) model specification (i.e., the combined approach) with additional details provided in **Box 1**. The results suggests that the lagged autoregressive term is large and persistent, indicating that the projected NIM ratio will converge toward its long-run steady-state level. In the preferred specification, the

NIM ratio rises with the term spread.[24] The interpretation of the estimate is as follows: if the term spread over one quarter increases by 100 basis points, which equals a one standard deviation change in that variable (see **Table A-1**), the expected NIM ratio will increase by about 3 basis points. We also note that the NIM moves both with corporate spreads and with the share of residential mortgages.[25]

- **Chart B-12** provides a visualization of the performance of the model. It plots the observed NIM, its fitted values and the NIM projections conditional only on the observed macrofinancial predictors.[26] The figure shows that the generic model fits the data well because it tracks the level and the timing of the NIM swings.

- **Table B-6** provides the estimated coefficients from the ECM NIM specification. We obtain these coefficients based on the following procedure. First, we estimate the long-term relationship between the NIM and the selected covariates and obtain the residuals for each period (i.e., the error correction terms). Next, we estimate the relationship between the change in the NIM and the change in the selected covariates, while including the lagged error correction term from the first step. The coefficient on the error correction term should be interpreted as follows: when the NIM diverges from its long-term equilibrium, about 9% of the divergence is corrected over the next period (α_1 = 0.086).

- **Chart B-13** illustrates that the ECM NIM specification does not match the evolution of the NIM ratio as well and tends to overestimate its level in the latter period of our sample.

[24] This is consistent with evidence from Hirtle et al. 2016, Claessens et al. (2016), Kohlscheen et al. (2018) and the Ong and Jobst (2020).

[25] This may seem counterintuitive because residential mortgage lending typically generates lower margins (for instance, compared with business lending). However, we note that this positive relationship is driven by the earlier years of the sample, when Canadian banks business models were still evolving as they shifted exposures away from the business sector and into the more profitable household sector; Repeating the exercise for the period from 2012Q1 to 2022Q4 generates a negative (but insignificant) coefficient on the residential mortgage share.

[26] In other words, we only use the first period's observable NIM value to seed the model, and from that period onward, we use the lagged projected NIM (not the observed ones). This means that as we roll the projection forward, the projection errors are accumulated overtime.

Table B-1: Asset and liability growth-rate regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 2022Q4. The dependent variable is the quarterly growth rate in the outstanding amount of each respective category. AR is the autoregressive component with up to three lags. HPI is the house price index. Box 1 describes the methodology, the regression specification and the model assessment procedure, while Table A-1 provides the definition and summary statistics of the main variables. Standard errors in parentheses. Significance levels at 1%, 5% and 10% are represented by ***, ** and *, respectively.

Panel A: Asset categories

	Mortgage loans	Consumer loans	Business loans	Securities	Reverse Repos	Interbank deposits
AR(L1)	0.002	-0.011	0.560***	-0.082	0.222**	-0.009
	(0.034)	(0.099)	(0.091)	(0.095)	(0.092)	(0.088)
AR(L2)			-0.448***			-0.286***
			(0.082)			(0.086)
AR(L3)			0.262***			
			(0.081)			
Term spread (10 years to 3 months)	-0.002	-0.007	-0.009**	-0.009**	-0.001	0.002
	(0.001)	(0.005)	(0.004)	(0.004)	(0.007)	(0.008)
Term spread (10 years to 3 months) (L1)		0.015***				
		(0.005)				
Stock market quarterly log change	-0.000	0.000	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
Stock market quarterly log change (L1)		0.001*				-0.002*
		(0.000)				(0.001)
Stock market quarterly log change (L2)		0.001***				0.000
		(0.000)				(0.001)
Stock market quarterly log change (L3)						0.003***
						(0.001)
Real GDP annual log change	0.002***	-0.000	0.001	0.004**	-0.002	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)
Change in unemployment	0.003**	-0.000	0.004*	0.006**	-0.004	0.004
	(0.001)	(0.002)	(0.002)	(0.003)	(0.005)	(0.006)
Change in unemployment (L1)			-0.002**			
			(0.001)			
3-month treasury bill yield		0.007***	-0.003*	0.002		
		(0.002)	(0.002)	(0.002)		
Year-over-year change in HPI	-0.001*				-0.000	-0.000
	(0.000)				(0.001)	(0.002)
Year-over-year change in HPI (L1)	0.001***					0.004**
	(0.000)					(0.002)
Corporate non-financial bond spread		0.022***	0.082***			
		(0.006)	(0.012)			
Corporate non-financial bond spread (L1)			-0.077***			
			(0.013)			
Constant	0.012***	-0.035***	0.019	0.022***	0.018	-0.022
	(0.003)	(0.012)	(0.012)	(0.008)	(0.014)	(0.017)
Observations	102	102	100	102	102	101
Time dummies (Y/N)	Yes	No	No	Yes	Yes	Yes
Adj R-sq	0.885	0.215	0.677	0.170	0.080	0.365

Panel B: Liability categories

	Personal demand deposits	Personal term deposits	Non-personal demand deposits
AR (L1)	-0.248**	0.672***	-0.233**
	(0.102)	(0.089)	(0.115)
Term spread (10 years to 3 months)	0.004	0.026***	-0.004
	(0.003)	(0.009)	(0.003)
Term spread (10 years to 3 months) (L1)		-0.025***	
		(0.009)	
Stock market quarterly log change	-0.000	-0.001**	-0.000
	(0.000)	(0.000)	(0.000)
Stock market quarterly log change (L1)			0.001***
			(0.000)
Real GDP annual log change	-0.000	-0.001	-0.000
	(0.001)	(0.001)	(0.001)
Change in unemployment	-0.001	0.000	0.000
	(0.002)	(0.002)	(0.003)
Total real credit growth rate	0.075*	-0.048	0.053
	(0.045)	(0.040)	(0.052)
3-month treasury yield	-0.045***	0.046***	-0.027***
	(0.008)	(0.010)	(0.009)
3-month treasury yield (L1)	0.044***	-0.045***	0.026***
	(0.008)	(0.010)	(0.009)
Constant	0.031***	0.001	0.043***
	(0.007)	(0.006)	(0.009)
Observations	102	102	102
Time dummies (Y/N)	No	No	No
Adj R-sq	0.327	0.602	0.082

Table B-2: Effective interest rates—Error correction model regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. See section 3.1.1 on net interest income (NII) for a description of the interest-earning assets and interest-bearing liabilities categories and Table A-1 for all other variable definitions. Regression results are based on Equation (3) specification. p-values in parentheses. Significance levels at 1%, 5% and 10% are represented by ***, ** and *, respectively.

Panel A: Effective rates on six asset categories

	Mortgage loans	Consumer loans	Business loans	Securities	Reverse repos	Interbank deposits
	Estimated long-term relationship (in levels)					
Canada 3-month treasury yield	-0.001	-0.000	-0.000	-0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Canada 5-year bond yield	0.010***	0.005***	0.008***	0.005***	0.007***	0.005***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
US 3-month Treasury yield	0.001	0.004***	0.006***	0.003***	0.009***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
US 5-year bond yield	-0.002	-0.004**	-0.005***	-0.001	-0.006**	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Constant	0.021***	0.058***	0.030***	0.015***	0.004**	0.001
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Observations	104	104	104	104	104	104
Adj R-sq	0.848	0.697	0.874	0.819	0.864	0.888
	Estimated short-term relationship (in first differences)					
Δ Canada 3-month treasury yield	-0.001**	-0.002*	-0.001	-0.000	-0.002*	-0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Δ Canada 5-year bond yield	0.001***	0.002*	0.001	-0.000	0.004***	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Δ US 3-month Treasury yield	0.001**	0.002	0.004***	0.001	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Δ US 5-year bond yield	-0.002***	-0.005***	-0.004***	-0.001	-0.006***	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Lagged error correction term	-0.210***	-0.576***	-0.373***	-0.312***	-0.500***	-0.384***
	(0.030)	(0.078)	(0.066)	(0.053)	(0.066)	(0.051)
Constant	-0.000***	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	103	103	103	103	103	103
Adj R-sq	0.425	0.422	0.449	0.326	0.496	0.625

Panel B: Effective rates on six liability categories	Personal demand deposits	Personal term deposits	Non-personal demand deposits	Non-personal term deposits	Sub-ordinated debt	Other liabilities
	Estimated long-term relationship (in levels)					
Canada 3-month treasury yield	0.001*	-0.002	0.002***	-0.000	0.001	0.002*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Canada 5-year bond yield	0.001**	0.009***	0.001	0.006***	0.006***	0.005***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
US 3-month Treasury yield	0.001***	0.003**	0.003***	0.008***	-0.000	0.005***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
US 5-year bond yield	-0.001	-0.003	-0.002*	-0.005**	0.001	-0.003
	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
Constant	0.002***	0.011***	0.004***	0.012***	0.024***	0.010***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Observations	104	104	104	104	104	104
Adj R-sq	0.792	0.822	0.827	0.869	0.787	0.874
	Estimated short-term relationship (in first differences)					
Δ Canada 3-month treasury yield	-0.000	-0.001	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
Δ Canada 5-year bond yield	0.000	0.002**	-0.001	0.001	-0.001	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Δ US 3-month Treasury yield	0.001*	0.002***	0.001**	0.004***	0.002	0.004***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Δ US 5-year bond yield	-0.001***	-0.002***	-0.001	-0.004***	-0.000	-0.002*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lagged error correction term	-0.344***	-0.127***	-0.503***	-0.333***	-0.220***	-0.361***
	(0.046)	(0.039)	(0.052)	(0.047)	(0.042)	(0.057)
Constant	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	103	103	103	103	103	103
Adj R-sq	0.515	0.282	0.661	0.606	0.297	0.477

Table B-3: Interest-earning assets (IEA) growth-rate regression specification

The model uses quarterly data aggregated across Canadian domestic systemically important banks between 1997Q1 and 2022Q4. The dependent variable is the quarter-over-quarter growth rate of the outstanding amount of interest-earning assets (i.e., loans + securities). AR is the autoregressive component with up to four lags. Box 1 describes the methodology, the regression specification and the model assessment procedure, while Table A-1 provides the definition and summary statistics of the main variables. Standard errors in parentheses. Significance levels at 1%, 5% and 10% are represented by ***, ** and *, respectively.

	Dependent variable: growth rate in IEA
AR (L1)	-0.217**
	(0.100)
AR (L2)	-0.066
	(0.092)
AR (L3)	-0.183*
	(0.096)
AR (L4)	0.194**
	(0.092)
Term spread (10 years to 3 months)	-0.002
	(0.003)
Stock market quarterly log change	-0.000
	(0.000)
Real GDP annual log change	-0.002*
	(0.001)
Change in unemployment	-0.003*
	(0.002)
Corporate non-financial bond spread	-0.008
	(0.005)
Constant	0.036***
	(0.009)
Observations	99
Time dummy (Y/N)	Yes
Adj R-sq	0.336

Table B-4: Net interest margin (NIM) regression specifications (the combined approach)

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. Net interest margin is the ratio of net interest income divided by the average interest-bearing assets (i.e., loans + securities) over the quarter. HPI is the house price index. Box 1 describes the methodology, the regression specification and the model assessment procedure, while Table A-1 provides the definition and summary statistics of the main variables. Standard errors reported in parentheses. Significance levels at the 1%, 5% and 10% are represented by ***, ** and *, respectively.

	AR-1 only	With macro financials	With ratios	Preferred specification
Lagged NIM	0.855***	0.681***	0.643***	0.630***
	(0.057)	(0.086)	(0.093)	(0.090)
Lagged delta NIM	-0.090	-0.121	-0.133	-0.127
	(0.100)	(0.100)	(0.100)	(0.096)
Term spread (10 years to 3 months)		0.023	0.032	0.032**
		(0.015)	(0.021)	(0.012)
Stock market qtr. log change		-0.001	-0.001	-0.002*
		(0.001)	(0.001)	(0.001)
Real GDP annual log change		-0.001	-0.001	
		(0.003)	(0.003)	
Change in unemployment		-0.004	-0.004	
		(0.006)	(0.006)	
3-month treasury yield		-0.007	0.001	
		(0.014)	(0.020)	
Year-over-year change in HPI		-0.002	-0.001	-0.001
		(0.001)	(0.002)	(0.001)
Total real credit growth rate		-0.140	-0.102	-0.136
		(0.123)	(0.124)	(0.110)
USD/CAD exchange rate		-0.101	-0.110	-0.138
		(0.066)	(0.133)	(0.102)
Corporate non-financial bond spread		0.043**	0.055***	0.051***
		(0.020)	(0.020)	(0.018)
Residential real estate loan ratio			0.019	0.017*
			(0.013)	(0.009)
Business loan ratio			0.006	0.005
			(0.011)	(0.009)
Consumer loan ratio			-0.005	
			(0.013)	
Securities ratio			-0.003	-0.003
			(0.006)	(0.004)
Time trend	-0.003**	-0.008**	-0.009**	-0.009***
	(0.002)	(0.003)	(0.004)	(0.003)
Constant	0.316**	0.741***	0.414	0.481
	(0.127)	(0.252)	(0.633)	(0.571)
Observations	102	102	102	102
Adj R-sq	0.884	0.903	0.906	0.910

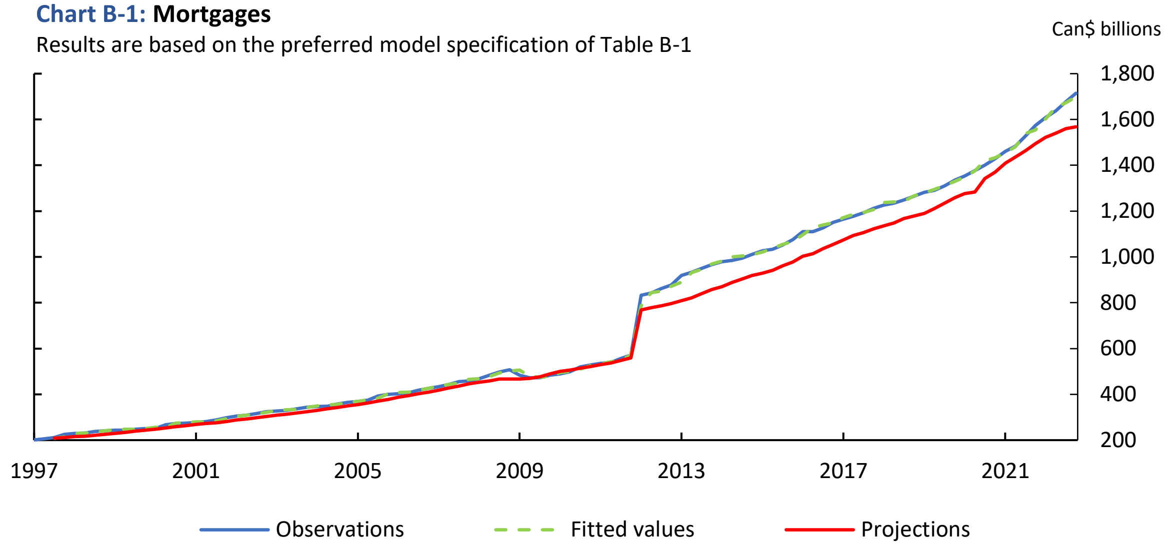
Table B-5: Error correction model specification for the NIM ratio

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. NIM is the ratio of net interest income divided by average interest-earning assets over the quarter. See Table A-1 and Box 1 for all other variable definitions and regression specifications. Standard errors reported in parentheses. Significance levels at the 1%, 5% and 10% are represented by ***, ** and *, respectively.

	Dependent variable	
	NIM	Δ NIM
Term spread (10 years to 3 months)	0.135***	
	(0.016)	
Δ term spread (10 years to 3 months)		0.038**
		(0.017)
Lagged error correction term		-0.086*
		(0.043)
Constant	1.772***	-0.004
	(0.026)	(0.007)
Observations	104	103
Adj R-sq	0.391	0.052

Chart B-1: Mortgages

Results are based on the preferred model specification of Table B-1

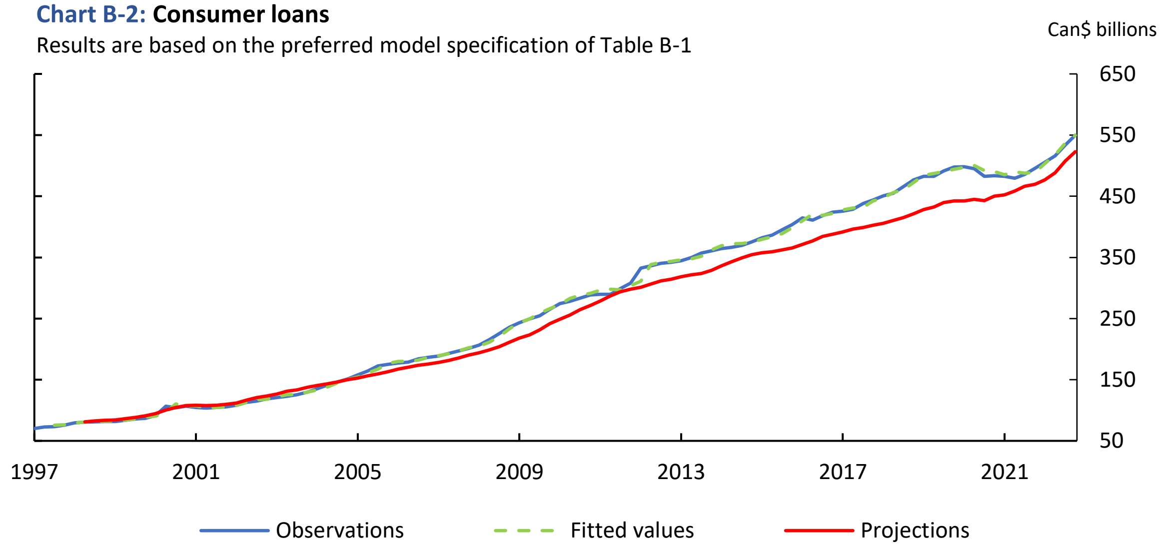


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-2: Consumer loans

Results are based on the preferred model specification of Table B-1

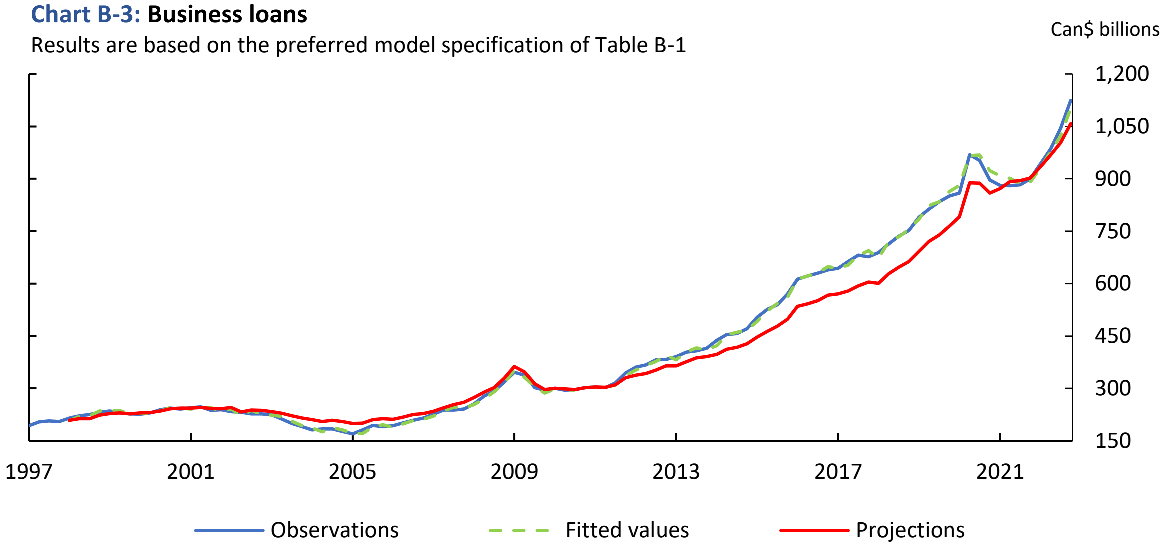


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-3: Business loans

Results are based on the preferred model specification of Table B-1

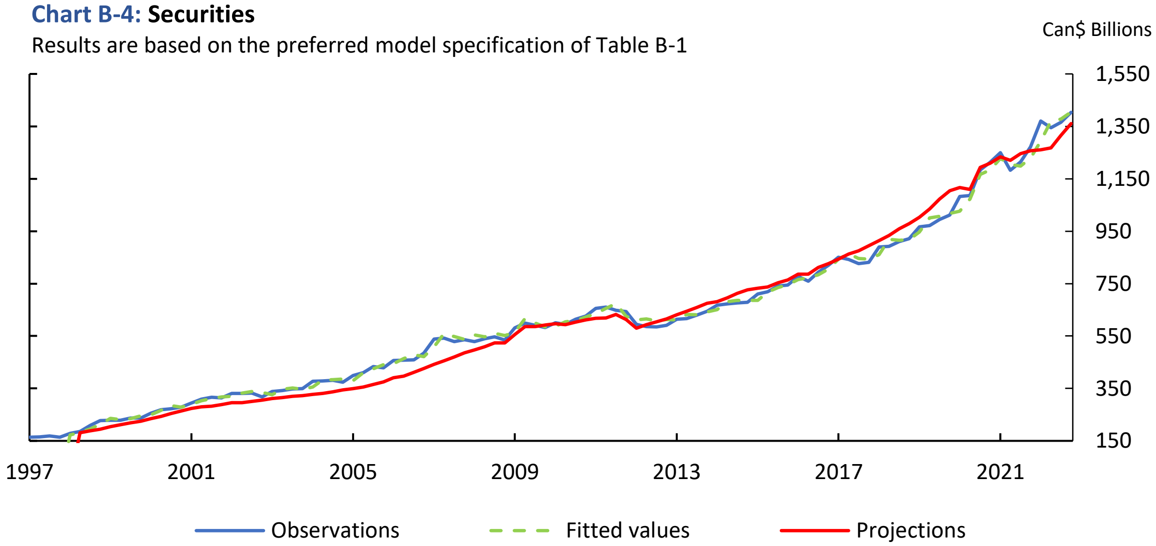


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-4: Securities

Results are based on the preferred model specification of Table B-1

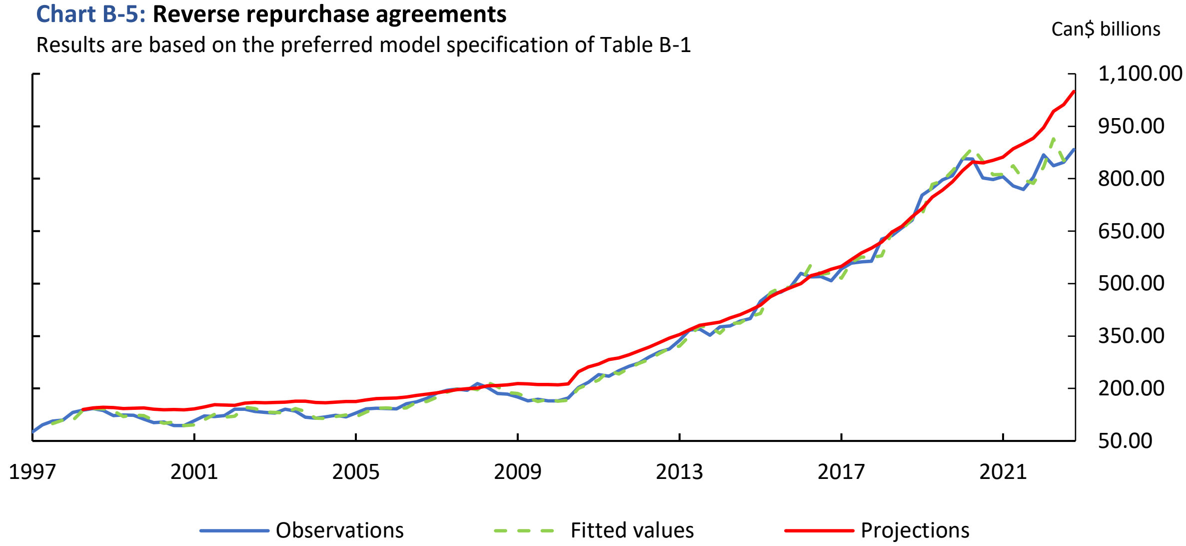


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-5: Reverse repurchase agreements

Results are based on the preferred model specification of Table B-1

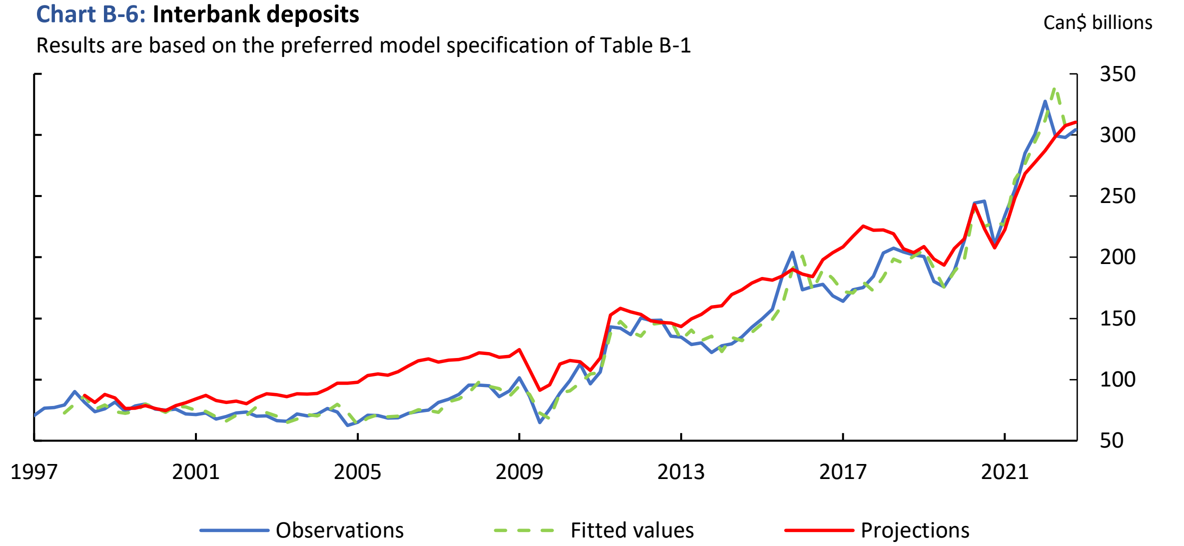


Sources: Regulatory filings of Canadian banks,
Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-6: Interbank deposits

Results are based on the preferred model specification of Table B-1

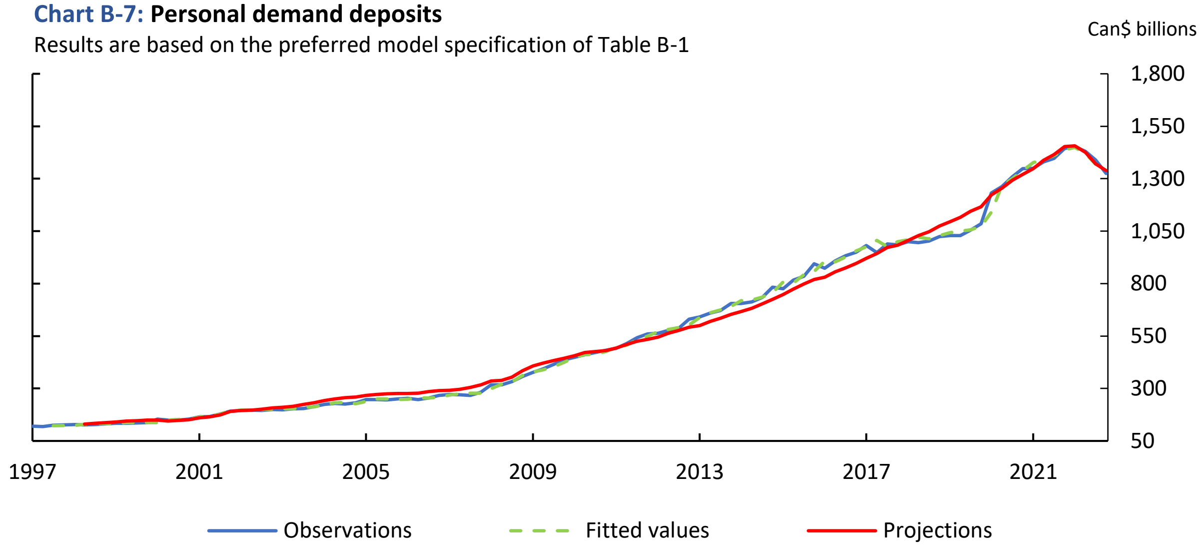


Sources: Regulatory filings of Canadian banks,
Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-7: Personal demand deposits

Results are based on the preferred model specification of Table B-1

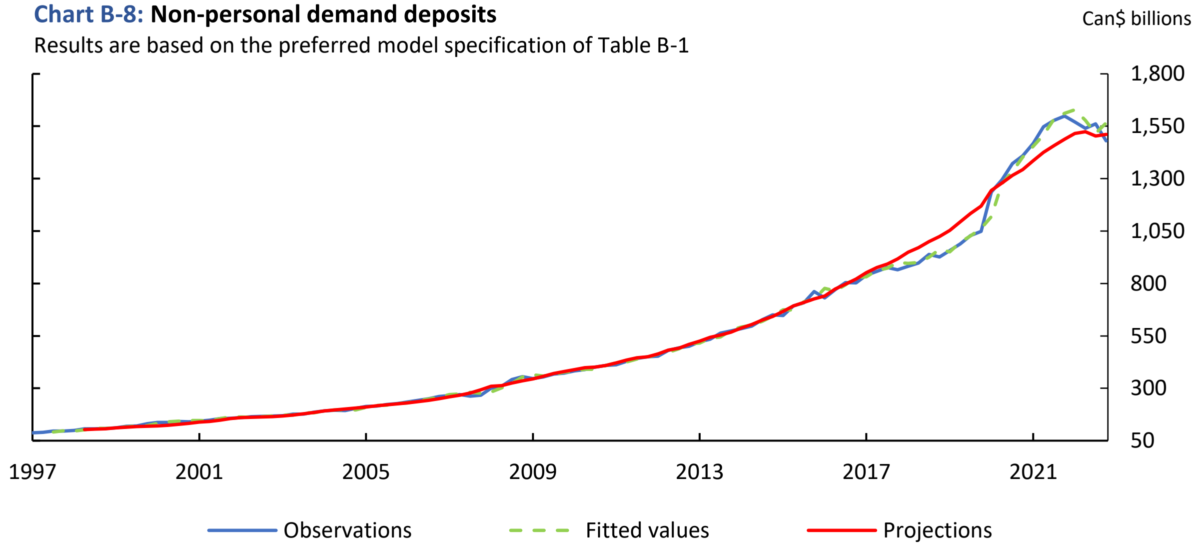


Sources: Regulatory filings of Canadian banks,
Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-8: Non-personal demand deposits

Results are based on the preferred model specification of Table B-1

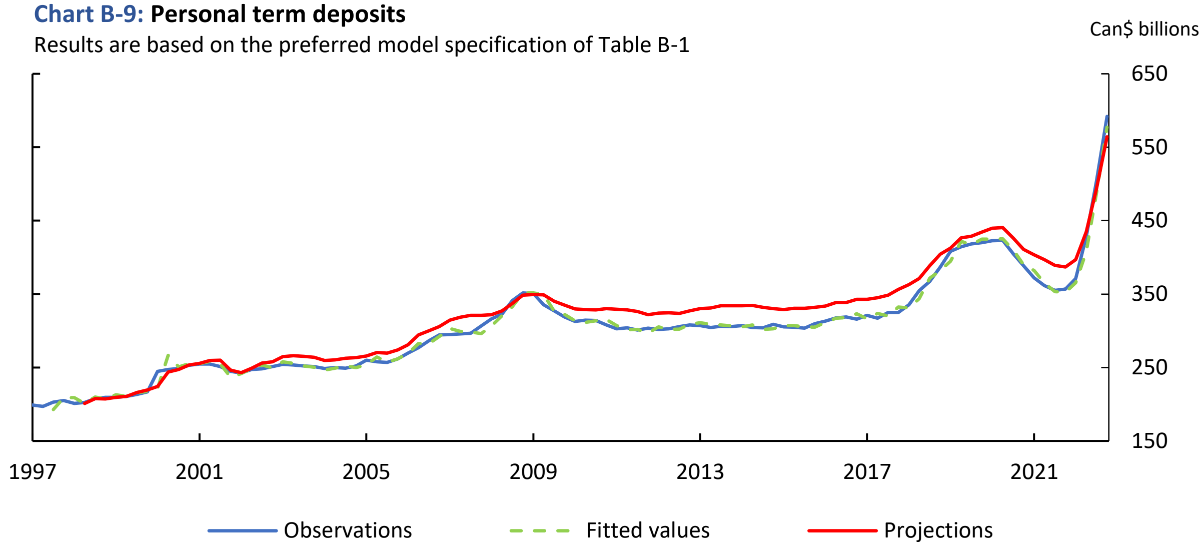


Sources: Regulatory filings of Canadian banks,
Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-9: Personal term deposits

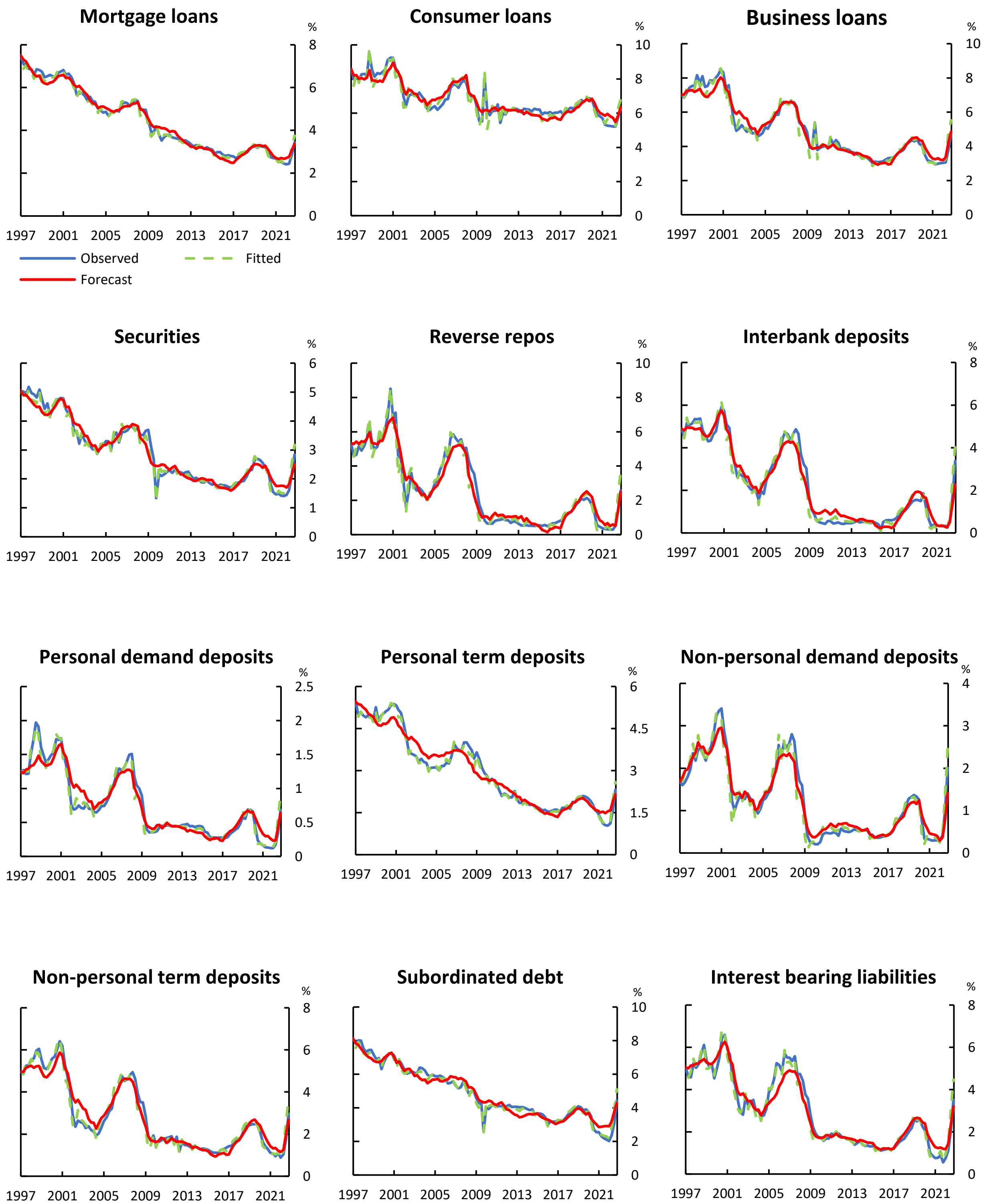
Results are based on the preferred model specification of Table B-1



Sources: Regulatory filings of Canadian banks,
Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-10: The error correction model fits well with the levels and evolution of the effective rates earned or paid

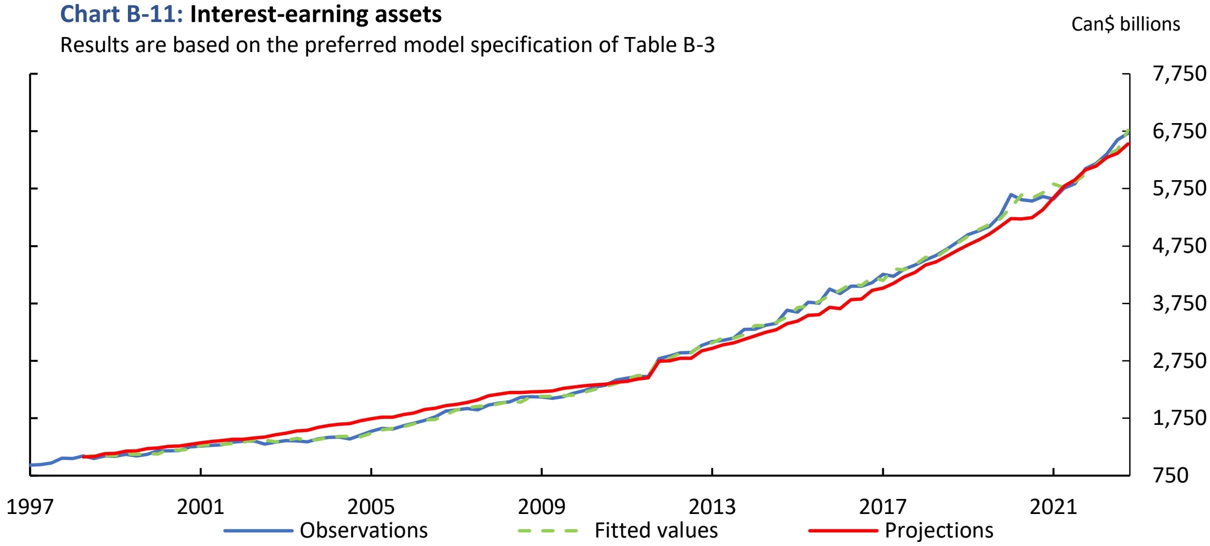


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver, Intercontinental Exchange, and Bank of Canada calculations

Last observation: 2022Q4

Chart B-11: Interest-earning assets

Results are based on the preferred model specification of Table B-3

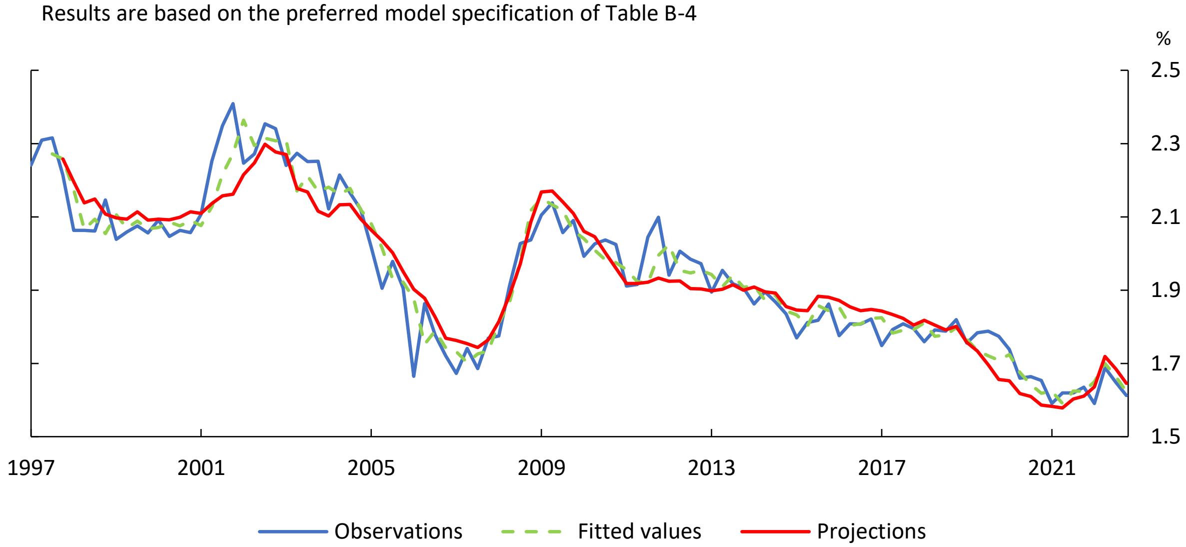


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart B-12: The combined approach model fits well with the level and evolution of the NIM ratio

Results are based on the preferred model specification of Table B-4

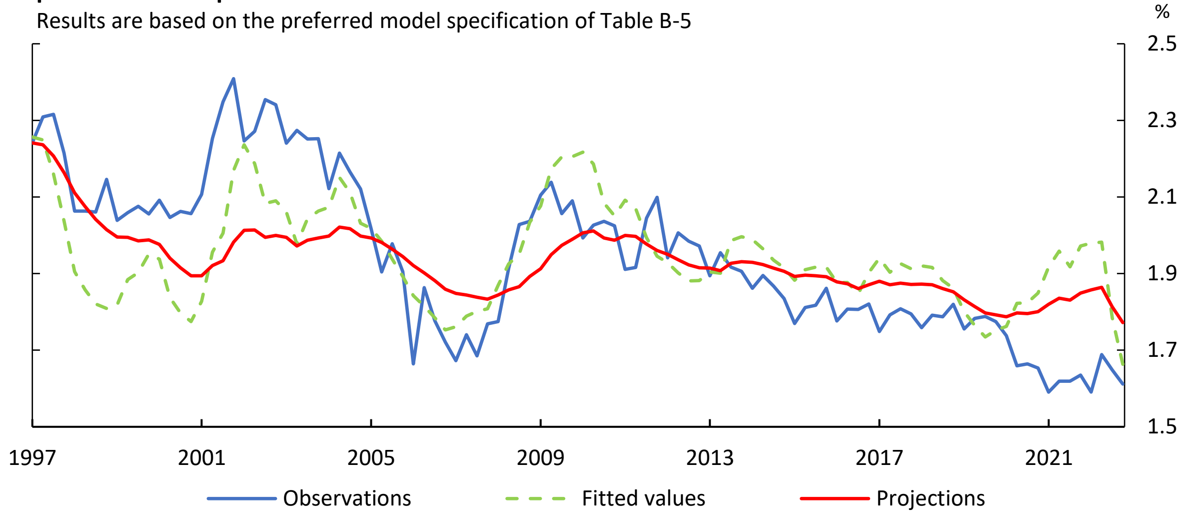


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver, Intercontinental Exchange and Bank of Canada calculations

Last observation: 2022Q4

Chart B-13: The error correction model tends to overestimate the level of the NIM ratio in the latter parts of the sample

Results are based on the preferred model specification of Table B-5



Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver, Intercontinental Exchange and Bank of Canada calculations

Last observation: 2022Q4

Appendix C: Non-intertest non-trading income (NINT)

- **Table C-1** presents the growth rate estimations of total assets. Estimates are based on an autoregressive distributed lag (ARDL) model, with the optimal number of lags selected based on the Akaike or Bayesian (also known as Schwarz) information criterion. Note that the growth rate in total assets slows when the stock market appreciates and when corporate bond spreads widen.

- **Chart C-1** illustrates the model fit from the asset growth regression. The projected path is obtained by multiplying the previous period's asset amount by the projected growth rate over the quarter. The model tends to overestimate the level of assets in earlier years of our sample but generates a closer fit in the era that follows the global financial crisis.

- **Table C-2** presents the coefficients from the multiple specifications. The results from the preferred NINT-ratio specification indicate that NINT income offers diversification benefits to banks because under certain market conditions it rises when NII falls.[27] For example, the NINT grows with the stock market and contracts with corporate credit spreads, but the NIM's relationship with these two controls is inverse (it contracts with the stock market but rises with corporate spreads [see **Table B-5**]).[28] The estimates can be interpreted as follows: if the stock market grows by a rate of 8% over the period, which equals a one standard deviation change in that variable (see **Table A-1**), the expected NINT ratio will increase by about 4 basis points (or 0.005*8.0).

- **Chart C-2** assesses the model's performance. Overall, the model fits the level and evolution of the NINT ratio inline with its historical path, especially from the onset of the global financial crisis in 2008.

- **Table C-3** provides the estimated coefficients from the error correction model (ECM) NINT specification. These coefficients are obtained based on the following procedure. First, we estimate the long-term relationship between the NINT and the selected covariates and obtain the residuals for each period (i.e., the error correction terms). Next, we estimate the relationship between the change in the NINT and the change in the selected covariates, while including the lagged error correction term from the first step. The coefficient on the error correction term should be interpreted as follows: when the NINT diverges from its long-term equilibrium, about 20% of the divergence is corrected over the next period (α_1 = 0.21).

- **Chart C-3** plots the ECM fit. Compared with the generic approach specification, the ECM model generates a less accurate projection of the NINT ratio because it tends to overestimate the ratio's level, especially in the latter years of our sample.

[27] See, for instance, Smith et al. (2003), Stiroh (2004) and Stiroh and Rumble (2006). Evidence by Kok et al. (2019) on banks in the euro area also confirms the strong autoregressive nature of non-interest income and that it relates to stock market returns.

[28] Note also that the in the preferred specification (**Table C-2**) the NINT ratio does not respond to the term spread, but the NIM strongly relates to it (**Table B-5**).

Table C-1: Total assets growth-rate regression specification

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. The dependent variable is the quarter-over-quarter growth rate of the outstanding amount of total assets. AR is the autoregressive component. Box 1 describes the methodology, the regression specification and the model assessment procedure, while Table A-1 provides the definition and summary statistics of the main variables. Standard errors in parentheses. Significance levels at 1%, 5% and 10% are represented by ***, ** and *, respectively

	Growth rate in total assets
AR (L1)	-0.440***
	(0.099)
Term spread (10 years to 3 months)	-0.002
	(0.003)
Stock market quarterly log change	-0.001**
	(0.000)
Real GDP annual log change	-0.002
	(0.001)
Change in unemployment	-0.002
	(0.002)
Corporate non-financial bond spread	0.017
	(0.014)
Corporate non-financial bond spread (L1)	-0.033**
	(0.014)
Constant	0.051***
	(0.008)
Observations	102
Time dummies (Y/N)	Yes
Adj R-sq	0.295

Table C-2: Non-interest non-trading income ratio (NINT ratio) regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. NINT is the ratio of non-interest non-trading income divided by average assets over the quarter. Table 5 shows the components that make up NINT. HPI is the house price index. See Table A-1 and Box 1 for all other variable definitions and regression specifications. Standard errors reported in parentheses. Significance levels at 1%, 5% and 10% are represented by ***, ** and *, respectively.

	AR-1 only	With macro financials	With ratios	Preferred specification
Lagged NINT ratio	0.602***	0.564***	0.356***	0.337***
	(0.089)	(0.095)	(0.115)	(0.112)
Lagged delta NINT ratio	-0.160*	-0.219**	-0.133	-0.121
	(0.096)	(0.088)	(0.090)	(0.089)
Term spread (10 years to 3 months)		0.014	-0.022	
		(0.023)	(0.029)	
Stock market quarterly log change		0.005***	0.004***	0.005***
		(0.001)	(0.001)	(0.001)
Real GDP annual log change		0.008	0.005	0.002
		(0.005)	(0.005)	(0.002)
Change in unemployment		0.010	0.006	
		(0.010)	(0.010)	
3-month treasury yield		0.011	-0.003	0.026
		(0.021)	(0.033)	(0.016)
Year-over-year change in HPI		0.001	0.002	0.002
		(0.002)	(0.002)	(0.002)
Total real credit growth rate		0.103	0.043	
		(0.202)	(0.198)	
USD/CAD exchange rate		0.026	-0.321	-0.476***
		(0.101)	(0.204)	(0.170)
Corporate non-financial bond spread		-0.049	-0.074**	-0.072**
		(0.032)	(0.032)	(0.031)
Residential real estate loan ratio			0.026	0.003
			(0.020)	(0.012)
Business loan ratio			0.022	
			(0.016)	
Consumer loan ratio			0.033	0.044**
			(0.021)	(0.019)
Securities ratio			0.018*	0.008
			(0.010)	(0.005)
Time trend	-0.012***	-0.009*	-0.012**	-0.011***
	(0.003)	(0.004)	(0.005)	(0.003)
Constant	0.735***	0.720***	-0.302	0.733***
	(0.164)	(0.213)	(0.800)	(0.208)
Observations	102	102	102	102
Adj R-sq	0.790	0.837	0.852	0.855

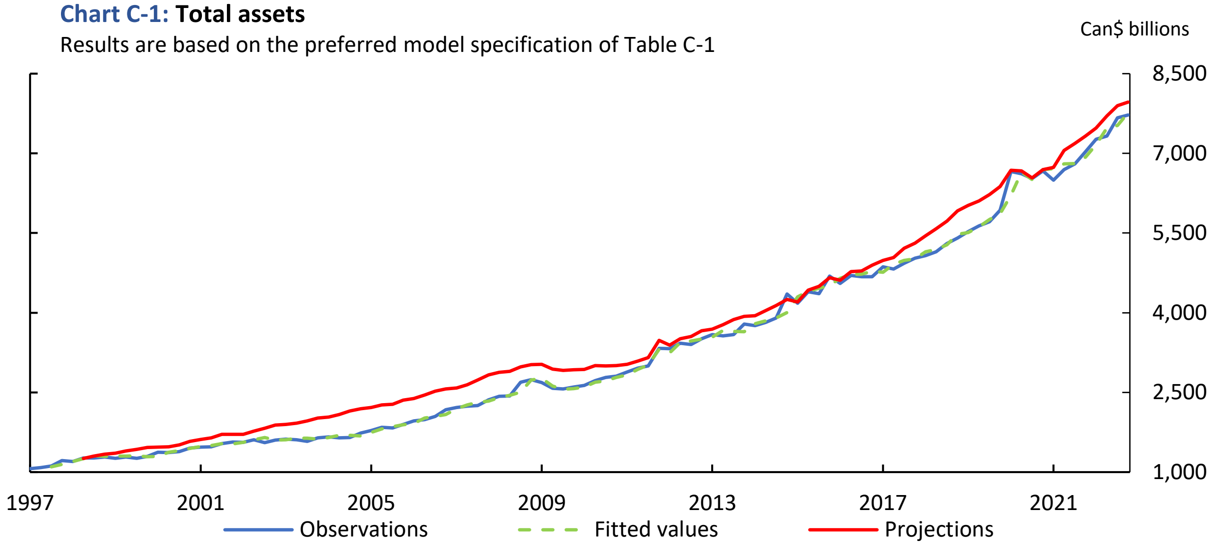
Table C-3: Error correction model specification for the NINT ratio

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. NINT is the ratio of non-interest non-trading income divided by average assets over the quarter. Components that make up NINT are provided in Table 5. See Table A-1 and Box 1 for all other variable definitions and regression specifications. Standard errors reported in parentheses. Significance levels at the 1%, 5% and 10% are represented by ***, ** and *, respectively.

	Dependent variable	
	NINT	Δ NINT
Term spread (10 years to 3 months)	0.003	
	(0.002)	
USD/CAD exchange rate	-0.099	
	(0.172)	
Corporate non-financial bond spread	-0.298***	
	(0.038)	
Δ Term spread (10 years to 3 months)		0.004***
		(0.001)
Δ USD/CAD exchange rate		-0.211
		(0.450)
Δ Corporate non-financial bond spread		-0.176***
		(0.061)
Lagged error correction term		-0.213***
		(0.063)
Constant	1.900***	-0.001
	(0.135)	(0.012)
Observations	104	103
Adj R-sq	0.413	0.211

Chart C-1: Total assets

Results are based on the preferred model specification of Table C-1

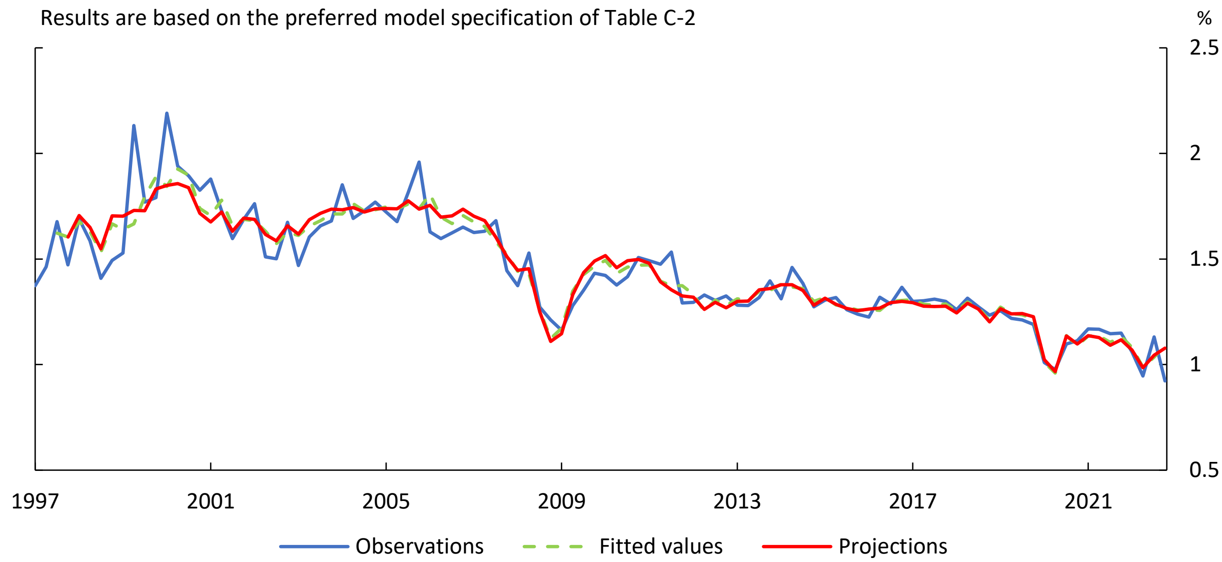


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart C-2: The model generates a close fit of the NINT income ratio, especially since 2005

Results are based on the preferred model specification of Table C-2

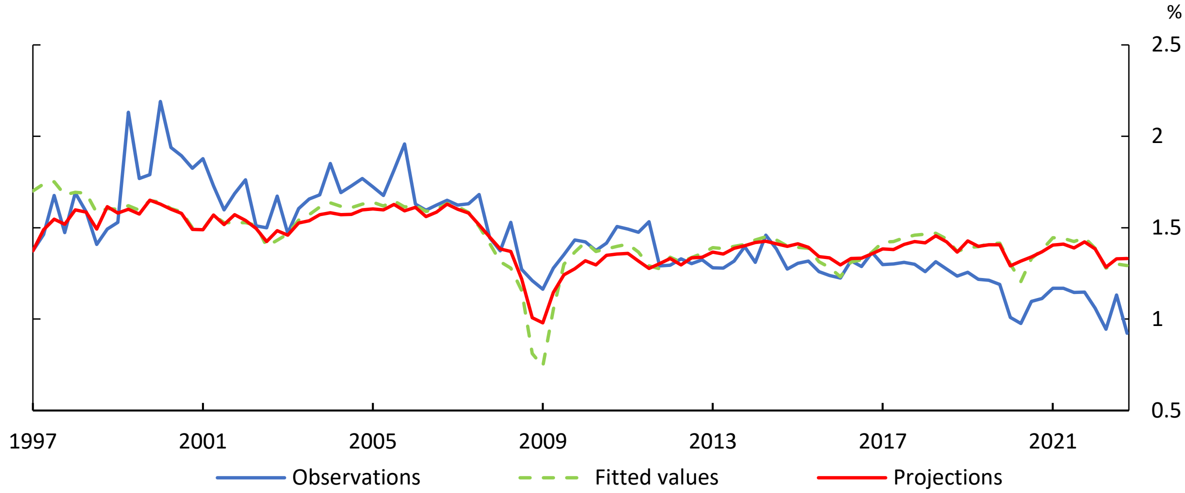


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver, Intercontinental Exchange and Bank of Canada calculations

Last observation: 2022Q4

Chart C-3: The error correction model tends to overestimate the NINT income ratio starting in 2012

Results are based on the preferred model specification of Table C-3



Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver, Intercontinental Exchange and Bank of Canada calculations

Last observation: 2022Q4

Appendix D: Trading income

- **Table D-1** presents the growth rate estimations of securities. Estimates are based on an autoregressive distributed lag (ARDL) model, with the optimal number of lags selected based on the Akaike or Bayesian (also known as Schwarz) information criterion. Note that the growth rate in securities slows when the term spread widens but rises with GDP and the unemployment rate.

- **Chart B-4** illustrates the model fit from the securities growth regression. The projected path is obtained by multiplying the previous period's outstanding amount by the projected growth rate over the quarter. The model slightly overestimates the level of securities in the era following the global financial crisis, but the fit becomes closer in more recent years.

- **Table D-1** presents our trading income ratio estimations. The ratio is responsive to financial conditions, such as the return on the stock market index or the USD/CAD exchange rate. The interpretation of the estimate is as follows: if the stock market grows by a rate of 8% over the period, which equals a one standard deviation change in that variable (see **Table A-1**), the expected trading income ratio will increase by about 6 basis points (or 0.007*8.0). Note that in the preferred specification, none of the macroeconomic variables is selected by LASSO. This is consistent with Giglio et. al (2021), who find that trading income is non-responsive to slow-moving macroeconomic factors.

- **Chart D-1** suggests that the model generates a path that follows the evolution of the trading income ratio, but it does not match as well the peaks and troughs in the data.

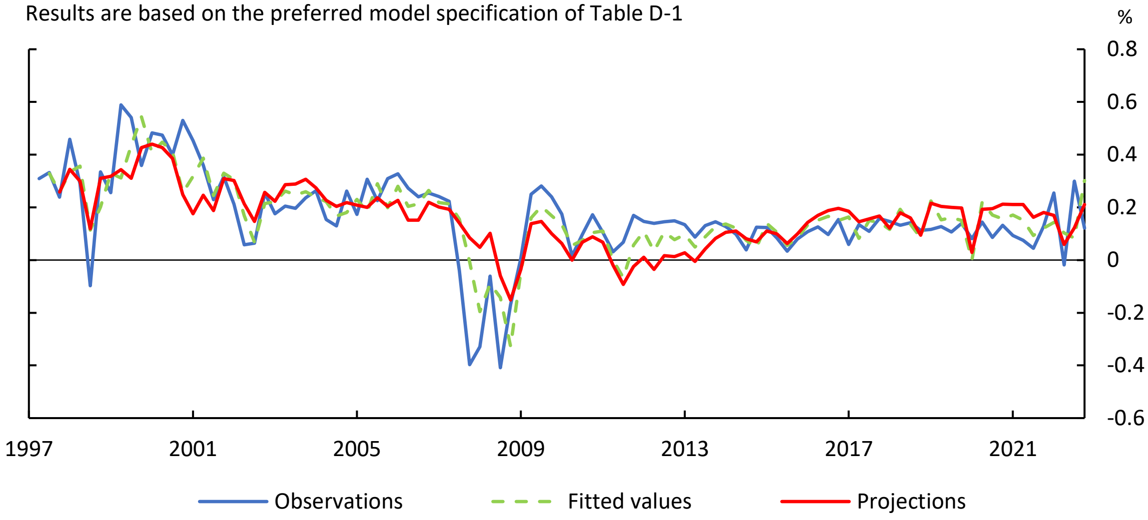
Table D-1: Trading income ratio regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. The trading ratio equals trading income divided by average outstanding securities over the quarter. HPI is the house price index. See Table A-1 and Box 1 for all other variable definitions and regression specifications. Standard errors reported in parentheses. Significance at the 1%, 5% and 10% levels are represented by ***, ** and *, respectively.

	AR-1 only	With macro financials	With ratios	Preferred specification
Lagged trading ratio	0.732***	0.652***	0.660***	0.507***
	(0.079)	(0.111)	(0.111)	(0.074)
Lagged delta trading ratio	-0.169*	-0.185*	-0.194*	
	(0.100)	(0.102)	(0.103)	
Term spread (10 years to 3 months)		0.008	0.000	
		(0.012)	(0.016)	
Stock market quarterly log change		0.007***	0.007***	0.007***
		(0.001)	(0.001)	(0.001)
Real GDP annual log change		-0.000	0.000	
		(0.005)	(0.005)	
Change in unemployment		-0.001	-0.001	
		(0.010)	(0.010)	
3-month treasury yield		0.008	0.001	0.011
		(0.010)	(0.014)	(0.007)
Year-over-year change in HPI		-0.002	-0.003	
		(0.002)	(0.002)	
Total real credit growth rate		-0.030	-0.030	
		(0.181)	(0.181)	
USD/CAD exchange rate		-0.291***	-0.339***	-0.322***
		(0.100)	(0.116)	(0.096)
Corporate non-financial bond spread		0.030	0.026	
		(0.036)	(0.037)	
Securities ratio			0.005	
			(0.006)	
Constant	0.042**	0.207*	0.144	0.310***
	(0.018)	(0.124)	(0.147)	(0.086)
Observations	101	101	101	102
Adj R-sq	0.471	0.610	0.609	0.622

Chart D-1: Trading income ratio model fit

Results are based on the preferred model specification of Table D-1



Sources: Regulatory filings of Canadian banks,Bloomberg, Haver and Bank of Canada calculations

Last observation: 2022Q4

Appendix E: Non-interest expense

- **Tables E-1** and **E-2** present the estimated coefficients for the variable and fixed non-interest expense (NIE) components, respectively. We find that, under the preferred specification, the variable-expense ratio moves with the return on the stock market and grows with overall economic conditions (positive coefficient on the GDP growth rate). In contrast, the fixed NIE ratio does not respond to broad economic and credit growth indicators: it moves with short-term rates and the term spread. This indicates that some fixed components are repriced as rates in the economy change. Finally, both the variable and the fixed NIE ratios contract as the Canadian dollar appreciates.

- **Charts E-1** and **E-2** present the model fit for the two components. For both components the models fit the data well, especially from the middle part of the sample period (around 2005) onward.

Table E-1: Non-interest variable-expense ratio regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. Non-interest variable expense (VarExp) is defined in Section 3.2, and the ratio is divided by average assets over the quarter. HPI is the house price index. See Table A-1 and Box 1 for all other variable definitions and regression specifications. Standard errors reported in parentheses. Significance levels at the 1%, 5% and 10% are represented by ***, ** and *, respectively.

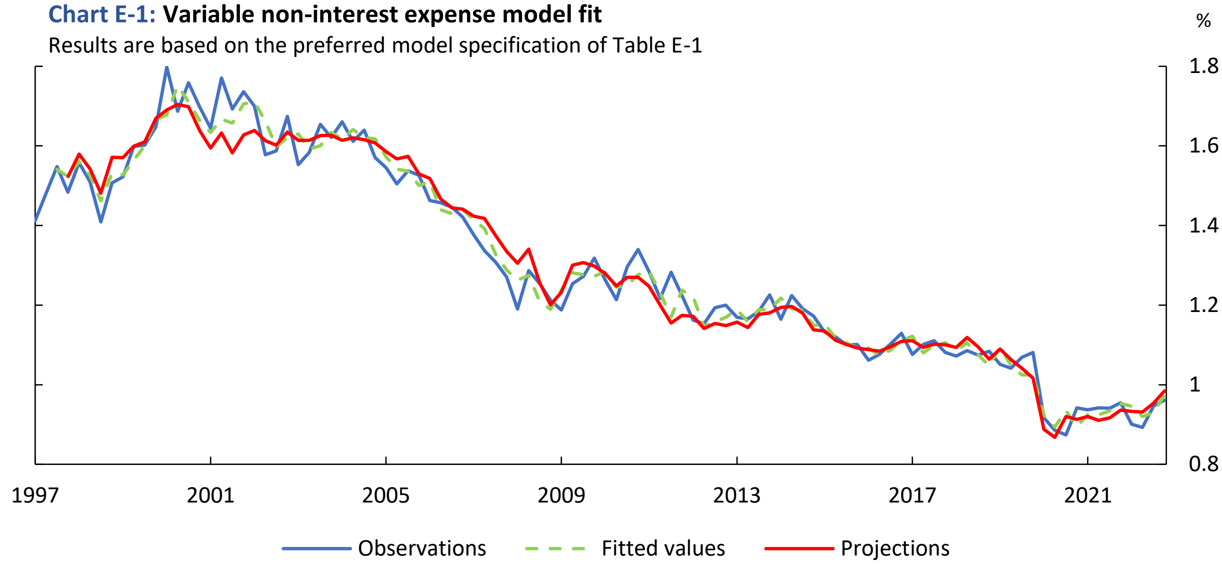
	AR-1 only	With macro financials	With ratios	Preferred specification
Lagged VarExp ratio	0.810***	0.818***	0.663***	0.662***
	(0.058)	(0.056)	(0.093)	(0.082)
Lagged delta VarExp ratio	-0.181*	-0.266***	-0.196**	-0.187**
	(0.094)	(0.082)	(0.089)	(0.086)
Term spread (10 years to 3 moths)		0.014	0.015	0.017
		(0.010)	(0.013)	(0.011)
Stock market quarterly log change		0.003***	0.003***	0.003***
		(0.001)	(0.001)	(0.001)
Real GDP annual log change		0.003	0.002	0.001*
		(0.002)	(0.002)	(0.001)
Change in unemployment		0.002	0.002	
		(0.004)	(0.004)	
3-month treasury yield		0.009	0.015	0.015
		(0.009)	(0.014)	(0.010)
Year-over-year change in HPI		-0.001	-0.001	-0.001
		(0.001)	(0.001)	(0.001)
Total real credit growth rate		-0.095	-0.092	-0.088
		(0.082)	(0.081)	(0.079)
USD/CAD exchange rate		-0.065	-0.230**	-0.213***
		(0.041)	(0.112)	(0.072)
Corporate non-financial bond spread		0.006	0.001	0.002
		(0.013)	(0.014)	(0.013)
Residential real estate loan ratio			0.014*	0.014***
			(0.008)	(0.005)
Business loan ratio			0.005	
			(0.007)	
Consumer loan ratio			0.008	
			(0.009)	
Securities ratio			0.002	0.001
			(0.004)	(0.003)
Time trend	-0.007***	-0.004*	-0.007**	-0.008***
	(0.002)	(0.002)	(0.003)	(0.003)
Constant	0.328***	0.288**	0.107	0.320***
	(0.100)	(0.112)	(0.396)	(0.111)
Observations	102	102	102	102
Adj R-sq	0.959	0.972	0.974	0.974

Table E-2: Non-interest fixed-expense ratio regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. Non-interest fixed expense (FixExp) is defined in Section 3.2, and the ratio is divided by average assets over the quarter. HPI is the house price index. See Table A-1 and Box 1 for all other variable definitions and regression specifications. Standard errors reported in parentheses. Significance levels at 1%, 5% and 10% are represented by ***, ** and *, respectively.

	AR-1 only	With macro financials	With ratios	Preferred specification
Lagged FixExp ratio	0.663***	0.468***	0.137	0.119
	(0.096)	(0.119)	(0.141)	(0.134)
Lagged delta FixExp ratio	-0.446***	-0.384***	-0.201**	-0.188*
	(0.089)	(0.096)	(0.100)	(0.097)
Term spread (10 years to 3 months)		0.025*	0.029	0.034**
		(0.015)	(0.019)	(0.016)
Stock market quarterly log change		0.000	0.000	
		(0.001)	(0.001)	
Real GDP annual log change		-0.000	-0.000	0.000
		(0.003)	(0.003)	(0.003)
Change in unemployment		-0.003	-0.002	-0.001
		(0.007)	(0.006)	(0.006)
3-month treasury yield		0.016	0.027	0.033**
		(0.013)	(0.021)	(0.016)
Year-over-year change in HPI		-0.001	0.000	0.000
		(0.001)	(0.001)	(0.001)
Total real credit growth rate		-0.027	-0.043	-0.056
		(0.130)	(0.122)	(0.119)
USD/CAD exchange rate		-0.243***	-0.610***	-0.651***
		(0.074)	(0.162)	(0.135)
Corporate non-financial bond spread		0.021	0.026	0.025
		(0.020)	(0.019)	(0.018)
Residential real estate loan ratio			0.029**	0.024***
			(0.013)	(0.007)
Business loan ratio			0.006	
			(0.010)	
Consumer loan ratio			0.008	0.010
			(0.013)	(0.012)
Securities ratio			0.002	-0.000
			(0.006)	(0.004)
Time trend	-0.007***	-0.007**	-0.010***	-0.010***
	(0.002)	(0.003)	(0.003)	(0.003)
Constant	0.332***	0.583***	0.256	0.530***
	(0.096)	(0.167)	(0.535)	(0.159)
Observations	102	102	102	102
Adj R-sq	0.822	0.839	0.866	0.868

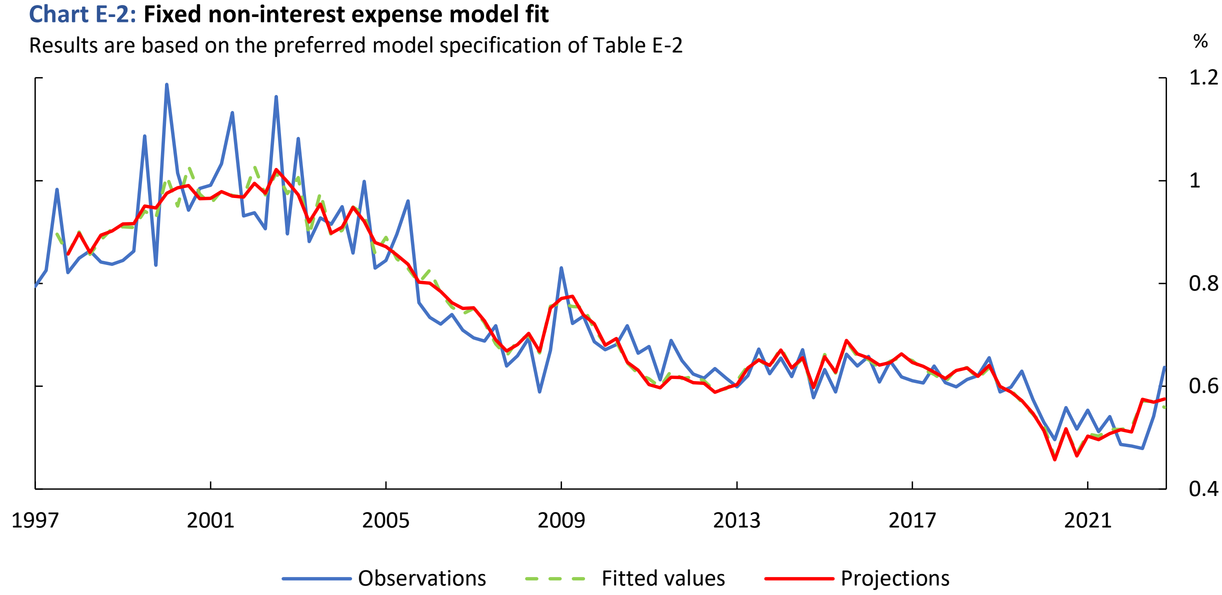
Chart E-1: Variable non-interest expense model fit
Results are based on the preferred model specification of Table E-1



Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver, Intercontinental Exchange and Bank of Canada calculations

Last observation: 2022Q4

Chart E-2: Fixed non-interest expense model fit
Results are based on the preferred model specification of Table E-2



Sources: Regulatory filings of Canadian banks, Statistics Canada, Haver, Intercontinental Exchange and Bank of Canada calculations

Last observation: 2022Q4

Appendix F: Provisions for credit losses

- **Tables F-1** presents the default rates and loss rates on defaulted exposures used in the sectoral provisions for credit losses approach.

- **Tables F-2** presents the coefficients from the growth rate estimations of total loans. Estimations are based on an autoregressive distributed lag (ARDL) model, with the optimal number of lags selected based on the Akaike or Bayesian (also known as Schwarz) information criterion. Note that the growth rate of total loans slows when the unemployment rate rises or when corporate spreads widen.

- **Charts F-1** illustrates the model fit from the loan growth regression. The projected path is obtained by multiplying the previous period's outstanding amount by the projected growth rate over the quarter. The model slightly overestimates the level of loans in the era preceding the global financial crisis, but the fit becomes closer from 2011 onward.

- **Table F-3** presents our PCL ratio estimations. The PCL ratio for impaired loans (i.e., based only on stage 3 provisions) is highly autoregressive but also moves with the one-period ahead growth rate in GDP. The total PCL ratio is most responsive to the one-period-ahead change in the unemployment rate. The interpretation of the estimate is as follows: if the unemployment rate increases by one standard deviation, which is about 3% on an annualized basis (see **Table A-1**), the expected total PCL ratio will increase by about 19 basis points (or 0.063*3.0).

- **Charts F-2** and **F-3** suggest that for the IFRS period between 2018 and 2022, our PCL models fit the data well.

Table F-1: DRs and LRDEs used in the sectoral provisions for credit loss approach

The table reports the average default rates (DRs) and the loss rate on defaulted exposures (LRDEs) used in stress testing exercises between 2019 and 2023. Statistics are calculated over the corresponding stress horizon of each exercise (between 12 and 20 quarters). Annualized DRs come from model-generated estimations (Corporate Default model and Household Risk Assessment Model). LRDEs are derived from banks' estimates of downturn loss given default used in the regulatory capital framework and is adjusted using expert judgment.

	DR %	LRDE %
Corporate sectors		
Natural resources	7.1	38.3
Mining	9.1	38.3
Manufacturing	5.6	38.3
Construction	9.2	38.3
Non-residential mortgages	9.2	31.3
Transportation	4.4	38.3
Wholesale	4.7	38.3
Retail	5.9	38.3
Services	5.9	38.3
Corporate	6.6	38.3
Financials	0.8	30.7
Government	0.0	13.6
Consumer loans		
Insured mortgages	1.8	4.6
Uninsured mortgages	1.0	26.0
Home equity lines of credit	1.1	26.3
Credit cards	8.7	86.7
Other consumer loans	4.3	51.7

Table F-2: Total loans growth-rate regression specification

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 1997Q1 and 2022Q4. The dependent variable is the quarter-over-quarter growth rate of the outstanding amount of total loans. AR is the autoregressive component. Box 1 describes the methodology, the regression specification and the model assessment procedure, while Table A-1 provides the definition and summary statistics of the main variables. Standard errors in parentheses. Significance levels at 1%, 5% and 10% are represented by ***, ** and *, respectively.

	Growth rate total loans
AR (L1)	-0.053
	(0.077)
Term spread (10 years to 3 months)	0.001
	(0.003)
Stock market qtr. log change	-0.000
	(0.000)
Real GDP annual log change	-0.002**
	(0.001)
Change in unemployment	-0.004**
	(0.002)
Corporate non-financial bond spread	-0.011**
	(0.005)
Constant	0.031***
	(0.007)
Observations	102
Time dummies (Y/N)	Yes
Adj R-sq	0.459

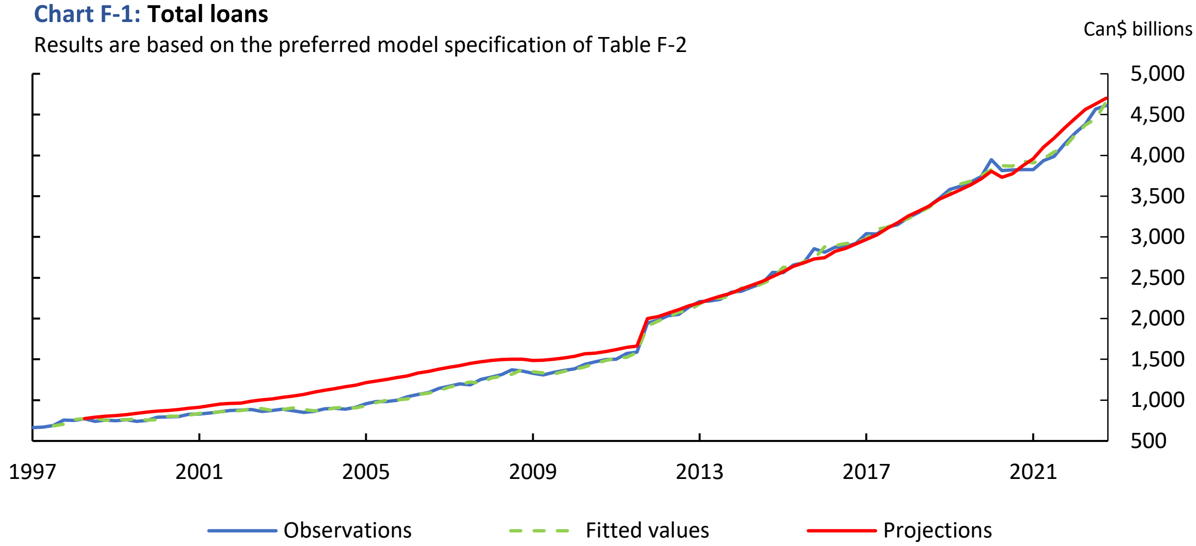
Table F-3: Provision for loan losses regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 2018Q1 and 2022Q4. The provisions ratio for impaired loans is the charge for stage 3 impairments divided by average outstanding loans over the quarter. The total ratio is the charge for total provisions (stages 1, 2 and 3) divided by average outstanding loans over the quarter. HPI is the house price index. See Table A-1 and Box 1 for all other variable definitions and regression specifications. Standard errors reported in parentheses. Significance levels at the 1%, 5% and 10% levels are reported as ***, ** and *, respectively.

	Impaired provisions ratio		Total provisions ratio	
	AR-1 only	Preferred specification	AR-1 only	Preferred specification
Lagged provisions	0.843***	0.931***	0.550**	0.635***
	(0.145)	(0.163)	(0.229)	(0.062)
Lagged delta provisions	0.188		0.130	
	(0.282)		(0.256)	
Stock market quarterly log change$_{t+1}$		-0.002		0.000
		(0.001)		(0.001)
Real GDP annual log change$_{t+1}$		0.008*		0.020***
		(0.004)		(0.005)
Change in unemployment$_{t+1}$		0.014		0.063***
		(0.008)		(0.010)
Year-over-year change in HPI$_{t+1}$		-0.001		-0.002
		(0.001)		(0.001)
Constant	0.041	0.010	0.114	0.098***
	(0.045)	(0.044)	(0.082)	(0.018)
Observations	18	18	18	18
Adj R-sq	0.713	0.757	0.289	0.970

Chart F-1: Total loans

Results are based on the preferred model specification of Table F-2

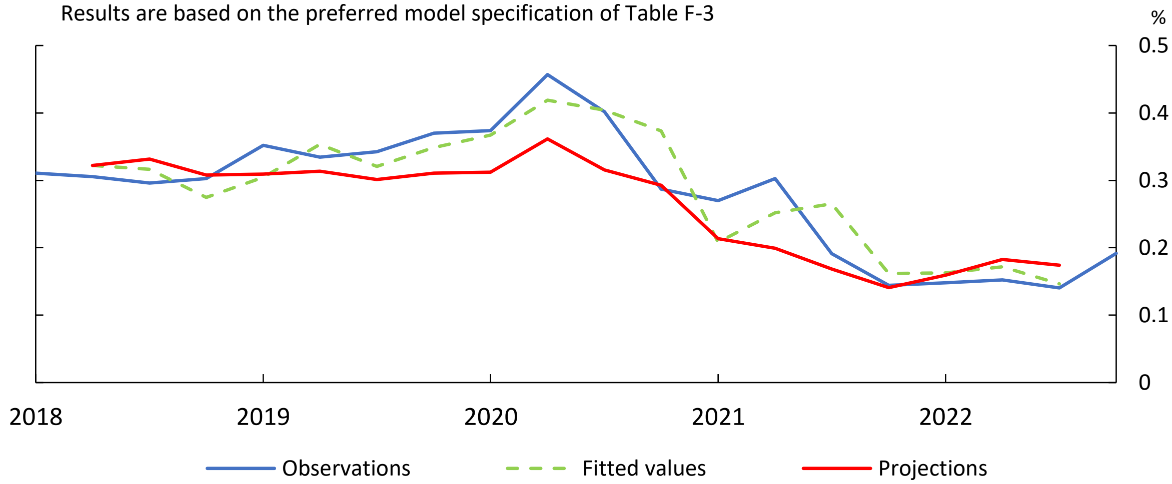


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart F-2: The projection of the impaired provisions for credit loss ratio generally matches the data since 2018

Results are based on the preferred model specification of Table F-3

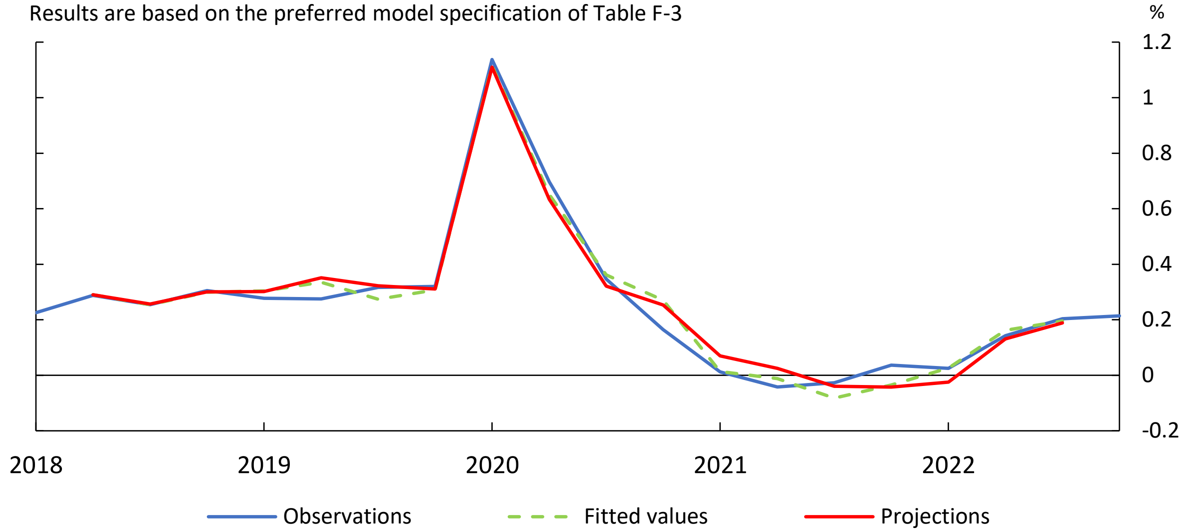


Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Chart F-3: The projection of the total provision for credit loss ratio matches the data since 2018

Results are based on the preferred model specification of Table F-3



Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Appendix G: Other comprehensive income

- **Table G-1** presents the coefficients for the other comprehensive income (OCI) ratio estimation. We find that the ratio is strongly related to its own lagged value and to the previous period's growth rate. Under the preferred specification, we also show that the ratio is sensitive to the level of the term spread and to the return on the stock market. Note that in the preferred specification, we also include the USD/CAD exchange rate as a factor, even though our variable selection criteria do not include it. We choose to do so because *ex ante* we expect the OCI to be sensitive to swings in the exchange rate. Finally, we also find that the OCI ratio relates to the banking sectors' balance sheet composition, given the negative and significant coefficient on the share of securities.

- **Chart G-1** presents the model fit for the above specification. Note that the large fluctuations in the ratio are driven by foreign currency movements, changes in the fair value of securities, and by net actuarial gains or losses related to pension plans. Overall, the chart shows that the model generally fits the swings in the data, especially from 2015 onward.

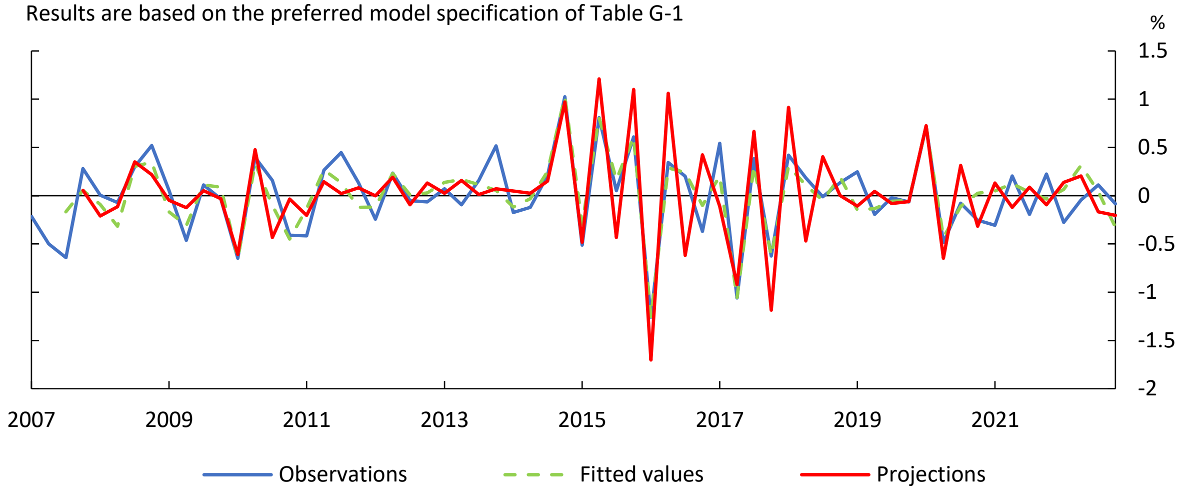
Table G-1: Other comprehensive income ratio regression specifications

The model uses quarterly data aggregated across the Canadian domestic systemically important banks between 2007Q1 and 2022Q4. The ratio is the amount of other comprehensive income (OCI) divided by average assets over the quarter. HPI is the house price index. See Table A-1 and Box 1 for all other variable definitions and regression specifications. The preferred specification includes a set of quarterly dummies that captures extreme values of the ratio. Standard errors reported in parentheses. Significance levels at 1%, 5% and 10% levels are represented by ***, ** and *, respectively.

	AR-1 only	With macro financials	With ratios	Preferred specification
Lagged OCI ratio	-0.373*	-0.554**	-0.670***	-0.593***
	(0.211)	(0.245)	(0.248)	(0.134)
Lagged delta OCI ratio	0.010	0.091	0.163	0.272***
	(0.129)	(0.137)	(0.137)	(0.086)
Term spread (10 years to 3 months)		-0.074	0.285*	0.137***
		(0.109)	(0.166)	(0.044)
Stock market quarterly log change		-0.017**	-0.005	-0.013***
		(0.007)	(0.008)	(0.004)
Real GDP annual log change		-0.013	-0.009	
		(0.023)	(0.022)	
Change in unemployment		-0.019	-0.014	
		(0.045)	(0.046)	
3-month treasury yield		-0.138	0.173	
		(0.095)	(0.151)	
Year-over-year change in HPI		-0.015*	-0.007	
		(0.008)	(0.011)	
Total real credit growth rate		-0.258	-0.557	
		(1.132)	(1.170)	
USD/CAD exchange rate		-0.478	-1.053	-0.091
		(0.987)	(1.550)	(0.328)
Corporate non-financial bond spread		-0.073	-0.019	
		(0.162)	(0.206)	
Residential real estate loan ratio			-0.237**	
			(0.104)	
Business loan ratio			-0.159	
			(0.095)	
Consumer loan ratio			0.055	
			(0.112)	
Securities ratio			-0.156***	-0.057***
			(0.057)	(0.016)
Time trend	-0.002	-0.020	-0.015	
	(0.011)	(0.029)	(0.038)	
Constant	0.035	1.034	11.646***	1.494***
	(0.104)	(1.213)	(4.189)	(0.412)
Observations	62	62	62	62
Adj R-sq	0.088	0.173	0.246	0.728

Chart G-1: The projection of the ratio of other comprehensive income generally matches the evolution of the data since 2015

Results are based on the preferred model specification of Table G-1



Sources: Regulatory filings of Canadian banks, Bloomberg, Statistics Canada, Haver and Bank of Canada calculations

Last observation: 2022Q4

Appendix H: Risk-weighted assets sector mapping and statistics[29]

Table H-1: Sector mapping from the balance sheet returns to the Basel Capital Adequacy Reporting (BCAR) regulatory returns (Portfolio 1)

Balance sheet			BCAR			TDSA Portfolio
Sectors	**Return**	**Return section**	**Sectors**	**Modelling approach**	**BCAR schedule**	**#**
Natural resources, sum of agriculture, fishing and trapping, and logging and forestry	A2	6b(i)-6b(iii)	Corporates excluding SMEs and specialized lending	IRB	22A, 22B	Portfolio 1
Mining, quarrying, and oil wells	A2	6b(iv)				
Manufacturing	A2	6b(v)	Specialized lending—high volatility commercial real estate (HVCRE)	IRB	23A, 23B	
Construction and real estate	A2	6b(vi)				
Transportation, communications and other utilities	A2	6b(vii)	Specialized lending—non-HVCRE	IRB	24A, 24B	
Wholesale trade	A2	6b(viii)				
Retail trade	A2	6b(ix)	SMEs treated as corporates	IRB	25A, 25B	
Services	A2	6b(x)				
Other corporate, sum of multi-conglomerates and other business loans, and own acceptances, lease receivables, and loans made by securities subsidiaries	A2	4, 6b(xi-xii), 7, 9b	Corporates	Standardized	5	
Insured and uninsured non-residential mortgages	E2	Part III, section 1c, 2b				

[29] This technical report uses the BCAR regulatory data structure up to and including 2022Q4 observations. Note that sectoral classifications in the BCAR regulatory return have changed since 2023Q2. The mapping assumption has been updated accordingly and is available upon request.

Table H-2: Sector mapping from the balance sheet returns to the Basel Capital Adequacy Reporting (BCAR) regulatory returns (Portfolio 2)

Balance sheet			BCAR			TDSA Portfolio
Sectors	**Return**	**Return section**	**Sectors**	**Modelling approach**	**BCAR schedule**	**#**
Financials	A2	1a-1g	Banks	IRB	27	**Portfolio 2**
			Banks	Standardized	8	

Table H-3: Sector mapping from the balance sheet returns to the Basel Capital Adequacy Reporting (BCAR) regulatory returns (Portfolio 3)

Balance sheet			BCAR			TDSA Portfolio
Sectors	**Return**	**Return section**	**Sectors**	**Modelling approach**	**BCAR schedule**	**#**
Canadian and foreign governments, public sector	A2	2a-2c, 3, 6	Sovereign	IRB	26	**Portfolio 3**
			Sovereign	Standardized	7	

Table H-4: Sector mapping from the balance sheet returns to the Basel Capital Adequacy Reporting (BCAR) regulatory returns (Portfolio 4)

Balance sheet			BCAR			TDSA Portfolio
Sectors	**Return**	**Return section**	**Sectors**	**Modelling approach**	**BCAR schedule**	**#**
Insured and uninsured residential mortgages	E2	Part III, section 1a-b, 2a	Residential mortgages	IRB	30	**Portfolio 4**
			Residential mortgages	Standardized	9	

Table H-5: Sector mapping from the balance sheet returns to the Basel Capital Adequacy Reporting (BCAR) regulatory returns (Portfolio 5)

Balance sheet			BCAR			TDSA Portfolio
Sectors	Return	Return section	Sectors	Modelling approach	BCAR schedule	#
Home equity lines of credit (HELOCs)	R2	Part I, section5 d(iii-a)	HELOCs	IRB	31	Portfolio 5

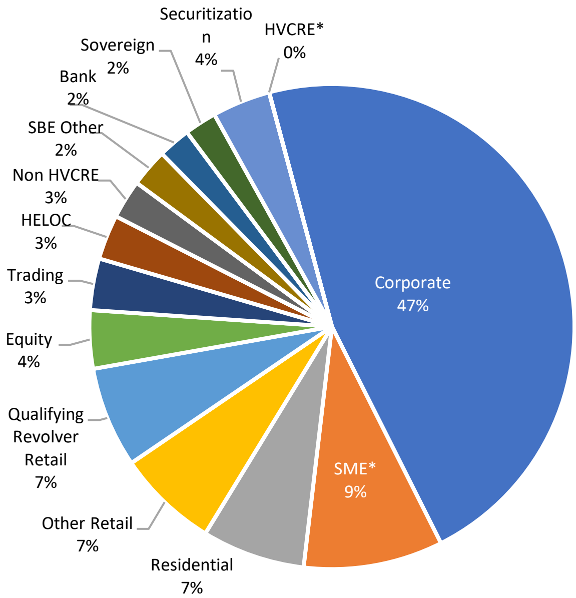
Table H-6: Sector mapping from the balance sheet returns to the Basel Capital Adequacy Reporting (BCAR) regulatory returns (Portfolio 6)

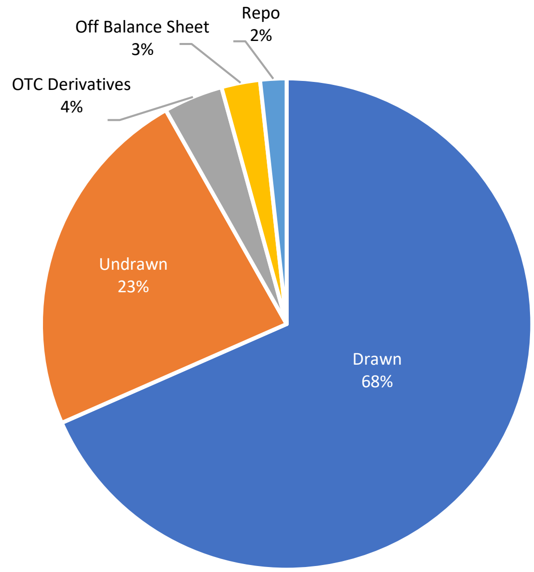
Balance sheet			BCAR			TDSA Portfolio
Sectors	Return	Return section	Sectors	Modelling approach	BCAR schedule	#
Credit cards	R2	Part I, section 5d(ii)	Qualifying revolver credit (QRR)	IRB	33	Portfolio 6

Table H-7: Sector mapping from the balance sheet returns to the Basel Capital Adequacy Reporting (BCAR) regulatory returns (Portfolio 7)

Balance sheet			BCAR			TDSA Portfolio
Sectors	Return	Return section	Sectors	Modelling approach	BCAR schedule	#
Other consumer loans, sum of personal loans and other personal credit	R2	Part I, section 5d(i), 5d(iii), 5d(iv)	Other retail	IRB	32	Portfolio 7
			Small business enterprises (SBE) other retail	IRB	34	
			Other retail	Standardized	10	
			SBE other retail	Standardized	11	

Chart H-1: statistics on internal ratings-based risk-weighted asset exposures for domestic systemically important banks

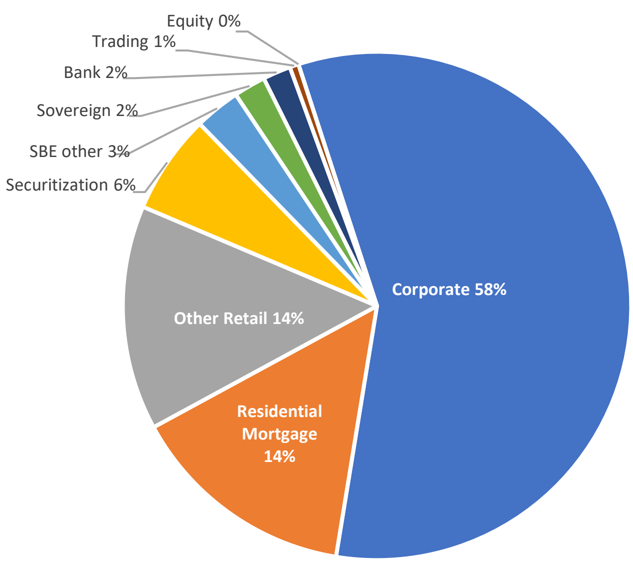


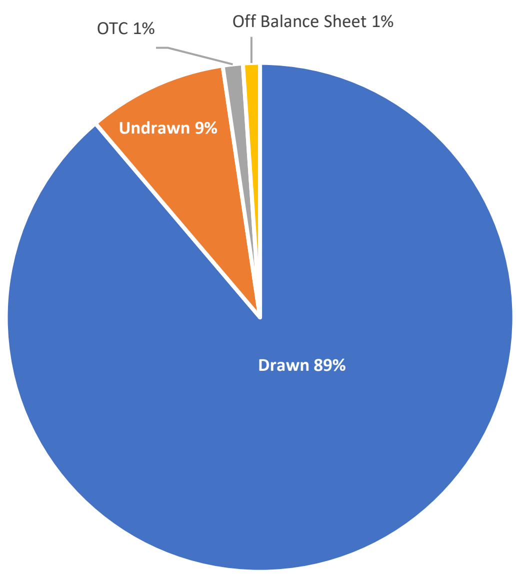


Source: Regulatory filings of Canadian Banks

Last observation: 2022Q4

Chart H-2: statistics on standardized risk-weighted asset exposures for domestic systemically important banks





Source: Regulatory filings of Canadian banks

Last observation: 2022Q4

Appendix I: Internal ratings-based risk-weighted asset formulas

Table I-1: Internal-ratings-based risk-weighted assets formulas

Corporates
Specialized lending—High volatility commercial real estate (HVCRE)
Specialized lending—Non-HVCRE
Small and medium enterprises (SMEs) treated as corporates
Sovereigns
Banks

$$Correlation\ (R) = 0.12 \times \frac{1-e^{(-50\times PD)}}{1-e^{(-50)}} + 0.24 \times \left[1 - \frac{1-e^{(-50\times PD)}}{1-e^{(-50)}}\right]$$

$$Maturity\ adjustment\ (b) = [0.11852 - 0.05478 \times ln(PD)]^2$$

$$Capital\ requirement = \left[LGD \times N\left[\frac{G(PD)}{\sqrt{(1-R)}} + \sqrt{\frac{R}{1-R}} \times G(0.999)\right] - PD \times LGD\right] \times (1 - 1.5 \times b)^{-1} \times [1 + (M - 2.5) \times b]$$

$$RWA = K \times 12.5 \times EAD$$

Retail residential mortgage exposures
Home equity lines of credit (HELOCs)

$$Correlation\ (R) = 0.15$$

$$Capital\ requirement\ (K) = \left[LGD \times N\left[\frac{G(PD)}{\sqrt{(1-R)}} + \sqrt{\frac{R}{1-R}} \times G(0.999)\right] - PD \times LGD\right]$$

$$RWA = K \times 12.5 \times EAD$$

Qualifying revolving retail exposures

$$Correlation\ (R) = 0.04$$

$$Capital\ requirement\ (K) = \left[LGD \times N\left[\frac{G(PD)}{\sqrt{(1-R)}} + \sqrt{\frac{R}{1-R}} \times G(0.999)\right] - PD \times LGD\right]$$

$$RWA = K \times 12.5 \times EAD$$

Other retail exposures
Small business enterprises

$$Correlation\ (R) = 0.03 \times \frac{1 - e^{(-35\times PD)}}{1 - e^{(-35)}} + 0.16 \times \left(1 - \frac{1 - e^{(-35\times PD)}}{1 - e^{(-35)}}\right)$$

$$Capital\ requirement\ (K) = \left[LGD \times N\left[\frac{G(PD)}{\sqrt{(1-R)}} + \sqrt{\frac{R}{1-R}} \times G(0.999)\right] - PD \times LGD\right]$$

$$RWA = K \times 12.5 \times EAD$$