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Bank of Canada's participation in the 2007 FSAP macro stress-testing exercise

by

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October 31, 2007

Abstract

In this paper, the authors discuss the Bank of Canada (Bank) participation in Canada's 2007 Financial Sector Assessment Program (FSAP) stress-testing exercise. They describe general features of the macroeconomic scenario that was selected and explain how this scenario was translated into sectoral default rates. They also describe the top-down exercise that was conducted at the Bank as a consistency check of the main bottom-up exercise. Costs and benefits of the stress-testing exercise, as well as lessons learned, are also discussed by the authors. Their general conclusion is that, on balance, participation in this FSAP stress-testing was a positive experience that helped identify challenges for future research.

* The authors would like to thank Allan Crawford, Toni Gravelle, Rhys Mendes, and Mark Zelmer for useful comments and discussions. The views expressed in this paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada.

1. Introduction

In 2007, Canada's financial system was the subject of an FSAP (Financial Sector Assessment Program) update. FSAPs are an International Monetary Fund and World Bank program aimed at helping countries identify vulnerabilities in their financial system and determine needed reforms. The 2007 exercise was an update for Canada in that a first Canadian FSAP had already taken place in 1999. The main difference between a full FSAP and an FSAP update is that the latter focuses on aspects of the financial system that were not covered in the full FSAP or that are in need to be updated. Canada was the first G7 country to participate in an FSAP update.

Canada's 2007 FSAP update had two main components. The first one was a review of standards and codes (ROSCs), and the objective was to assess these against internationally recognized best practices (the Bank of Canada was mostly involved in an assessment of Canada's security settlement system). The second component was macro stress-testing (the 1999 FSAP did not include a stress-testing component). The present document focuses on this second component.

The purpose of stress testing is to identify potential vulnerabilities in a segment of the financial system under various stress-testing events. In the context of the FSAP exercise, two types of events were considered: single factor shocks and a macroeconomic scenario. Single-factor shocks were used to assess market risks, whereas the macroeconomic scenario was designed to assess credit risks in the loans portfolio of Canadian banks. The former were designed by the Office of the Superintendent of Financial Institutions, whereas the latter were done by the Bank of Canada (Bank). The Bank's contribution to the scenario analysis was three-fold:

- designing the macroeconomic scenario using an in-house model;
- tracing the impact of the scenario on default rates in the business and household sectors;
- conducting an independent assessment of losses under the scenario (consistency check).

The general framework underlying the exercise is summarized in Figure 1. The presentation here follows that general framework. More specifically, in Section 2 we describe the general features of the macroeconomic scenario (Block 1). In Section 3, we explain how we translated the macroeconomic scenario into sectoral default rates (Block 2), and some data issues that had to be dealt with in that context. Section 4 contains a summary of the results of the Bank's top-down (consistency check) exercise (Block 3). Finally, in the last section we offer some thoughts on the costs and benefits of Canada's participation in this FSAP, on lessons learned through this participation, and on implications for future macro stress-testing research.

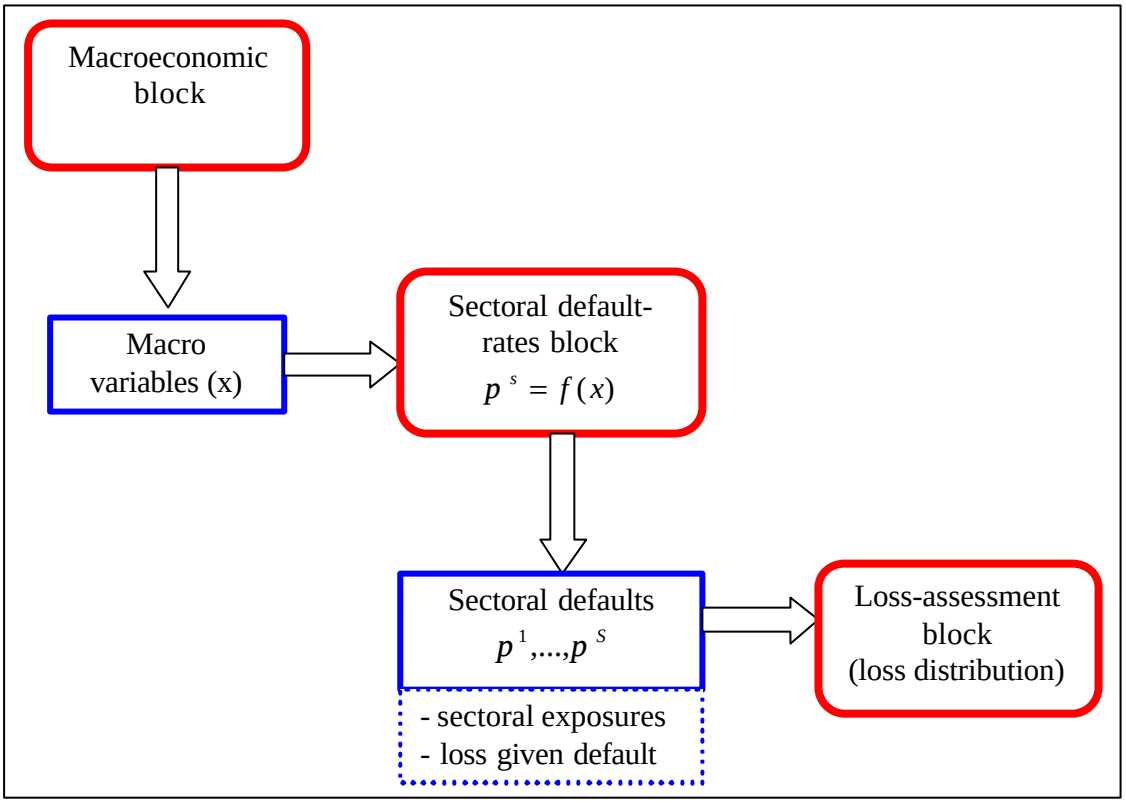

Figure 1: Components of the stress testing approach

2. Macroeconomic scenario design (Block 1)

In the approach that we follow the shocks that hit the economy are linked through a consistent economic story and then analyzed within a global general equilibrium model. The macroeconomic scenario is developed using the Bank of Canada's version of the Global Economy Model (BoC-GEM) (Lalonde and Muir 2007) which is a variant of the GEM developed at the IMF (Faruqee et. al 2007).

The BoC-GEM is a representative-agent model with a fully optimizing framework based on microfoundations. It is a multi-region model encompassing the entire world economy, and includes bilateral trade flows and their relative prices for each region, including exchange rates. The model includes five regional blocs- the United States, emerging Asia, commodity exporters, Canada and the remaining countries (includes Japan and the

European Union). Each regional economy has five sectors of production – tradables, non-tradables, gasoline, energy, and non-energy commodities.

2.1 Policy Assumptions

Monetary policy plays an important role in the scenario. Canada's monetary policy is based on two key elements: a flexible exchange rate and inflation-control targets. As we will see, monetary policy plays a key role in our model in helping the Canadian economy adjust to shocks. In particular, our scenario assumes that central banks play an active role in stabilizing the economy by trying to keep inflation near the levels seen in recent history.[1] Also, with the exception of Emerging Asia that is fixed to the U.S. dollar, exchange rates in the scenario are flexible, as they are determined endogenously and move to help facilitate the macroeconomic adjustment required. Fiscal policy in the scenario is geared to maintaining a stable government debt to GDP ratio.

2.2 Productivity Meltdown: A Reversal of Fortunes

Our scenario has its origins in the historically high level of trend labour productivity growth experienced in the latter half of the 1990s and the early 2000s in the United States and to a lesser extent in Canada. As expectations of higher long-term labour productivity growth in the U.S. were gradually revised upward to two percent and higher, perceived rates of return on U.S. investments were boosted leading to increased investment demand as well as increased capital inflows and a stronger U.S. dollar. In addition, expectations of higher permanent income also led to an increase in consumption and a drop in the savings rate. In turn, all of these factors led to a rise in imports and an expansion of the U.S. current account deficit.[2]

In our scenario, we assume that expectations of a permanent rise in labour productivity growth in the United States prove to be overly optimistic. In fact, we assume that trend labour productivity growth takes a very sharp turn for the worse falling from about two percent over the 1996 to 2004 period to about 1.1 percent per year for the next ten years (see Appendix 1).[3]

In addition to the endogenous response of the economy to the downward revision of productivity, we assume that consumers and firms in the United States suffer temporary losses in confidence and react by increasing their savings rates for precautionary motives. We also assume that the fall in productivity leads to significant losses in U.S. equity

[1] For example, we assume that monetary policy in Canada continues to target two percent inflation. The model is solved under commitment thus implying that both monetary and fiscal policies are fully credible.
[2] Our analysis is predicated on the assumption that the acceleration in U.S. trend labour productivity growth played an important role in the emergence of the U.S. current account deficit (see Ferguson 2005).
[3] We estimate over the 1969 to 2006 period that U.S. trend labour productivity growth has been between 0 and 1.1 percent about 15 percent of the time.

markets and that workers attempt to resist the resulting downward pressure on real wages over the short term. [4]

The downward revision to expectations of U.S. growth leads foreigners to revise down their risk-adjusted expectations of the return on holding U.S. assets. In addition, heightened uncertainty about future economic prospects in the United States results in a sudden sell-off of U.S. dollar assets, a rapid depreciation in the U.S. dollar and a very quick reversal of the current account deficit.[5]

The weakness in the U.S. economy and the resulting increase in the loan default probabilities of consumers and firms are assumed to lead to a rise in financial risk premiums further magnifying the economic slowdown. We assume that the risky spread (the difference between the medium-term business loan rates and the 5-year U.S. government bond rate) widens to reach historical highs in early 2007 (the starting point of the shock scenario).[6] Our analysis assumes similar increases in spreads on consumer interest rates.

Canada experienced a comparable rise in labour productivity growth in 1998 two years after the United States which has since proven to be considerably less robust. In our scenario, we assume that Canadian trend labour productivity growth falls from an estimated one percent in recent history to average about 0.8 percent over the next ten years.[7] As in the United States, we assume that consumers and firms suffer losses in confidence and increase their savings rates for precautionary motives.[8] As a result of the domestic and U.S. shocks, including the appreciation of the Canada-U.S. exchange rate, the Canadian economy contracts, leading to a rise in the loan default probabilities of domestic consumers and firms. In turn, there is a rise in commercial interest rate premia, further exacerbating the weakness in Canadian GDP growth. We assume that the risky spread between the medium-term business loan rate and the 5-year Canada government bond rate widens to historically high levels.[9] We assume similar increases in risky spreads on consumer interest rates.

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[4] Although, the equity channel is already accounted for in BoC-GEM, the model likely significantly understates the extent of the reaction of equity prices to the shock. Accordingly, we add judgment to magnify these effects to make them more in line with estimates from MUSE – the Bank's model of the United States economy (Gosselin and Lalonde 2005).

[5] The impact of heightened uncertainty on the value of the U.S. dollar is introduced through an exogenous shock to the country risk premium.

[6] The shock to the risky spread is exogenous to BoC-GEM. Risky spreads of this magnitude have occurred only about 3 percent of the time in the United States over the 1976 to 2006 period. The average U.S. corporate rate is based on the yield of BBB rated firms which represents the median rating of U.S. Corporate borrowers.

[7] We estimate over the 1972 to 2006 period that Canadian trend labour productivity growth has been between 0 and 1 percent about 10 percent of the time.

[8] As in the U.S., we also assume that workers attempt to resist the required fall in real wages. A shock to account for a larger effect from equity markets is also included.

[9] Risky spreads of this magnitude have occurred only about two percent of the time in Canada over the 1980 to 2006 period. The medium-term Canadian business loan rate is based on the yield of A-rated firms which represents the median rating of Canadian corporate bond borrowers.

Taken as a package, the shocks considered in our scenario are extremely large by historical standards. As a result, our scenario results in high real interest rates for consumer and business loans and an extremely severe economic contraction in the United States.

The recession in the United States combined with the higher Canada-U.S. real exchange rate, falling world commodity prices, the downward revision to expectations of domestic trend labour productivity growth, the temporary loss in consumer and firm confidence, and the rise in domestic financial risk premiums lead to a significant recession in 2007 in Canada (see Appendix 1). In terms of cumulative output loss, the domestic recession embodied in our scenario is about one-third larger than the 1990-1991 experience.

The core consumer price index falls throughout 2008 before returning to the two percent inflation target by the end of 2010. Canadian policy interest rates fall quickly to 0.25 percent in early 2008 and remain very low for several years. The aggressive decline in policy rates plays a very important role in mitigating the impact of the adverse shocks on the Canadian economy. As a result, the 5-year Canadian medium-term business loan rate actually declines in early 2007 despite the large rise in the financial risk premium.

2.3. Advantages and Limitations of our Macro Scenario

One of the advantages of using the BoC-GEM for the macroeconomic scenario is that the model is both consistent with modern macroeconomic theory and also capable of tracking the data reasonably well. This is no small feat. Coletti, Lalonde and Muir (forthcoming) provide a fairly detailed analysis of the ability of a Canada-U.S. version of the GEM to replicate some key unconditional univariate and bivariate moments in the Canadian and U.S. data. The models' responses to various domestic shocks are consistent with those of ToTEM –the Bank of Canada's principal model of the Canadian economy (Murchison and Rennison 2006) and MUSE – the Bank's model of the United States economy (Gosselin and Lalonde 2005).

In addition, given the important international dimension in the scenario, the BoC-GEM's global general equilibrium nature is particularly well suited for the analysis. The integration of supply, demand, trade and international asset markets in a single theoretical structure allows transmission mechanisms to be fully articulated.

Another key advantage of using the BoC-GEM is that policy and the real economy are solved for simultaneously. Our results do not rely on the unrealistic assumption that policy would somehow sit idly by allowing economic conditions to deteriorate. In turn, economic agents are assumed to understand that policy will be proactive and this would in turn mitigate the extent of the policy response required.

Our approach does however have some important limitations. In particular, the model is designed primarily to replicate the behaviour of the economy in normal circumstances. This means we assume that monetary policy is both well understood and fully credible. As a result, future actions of the central bank are fully anticipated and policy exhibits

substantial control over the economy. In normal circumstances, this assumption is likely appropriate. In fact, several studies have suggested that better monetary policy has in fact played a key role in reducing the variability of the macro economy.[10]

Our interest in generating an economic scenario which is unusually severe by historical standards is in direct conflict with this feature of the model (and with the properties of most policy models). It would be easy to imagine how the realization of unusually large (or even unprecedented) shocks to the economy would lead to a rise in uncertainty about future economic conditions including future policy actions. Monetary policy could become less effective and as a result economic outcomes would be worse.[11]

A second shortcoming of the analysis involves the behaviour of financial markets.[12] The widening of risky spreads is an important feature of the scenario yet the process of financial intermediation plays no role in the model itself. In our scenario we simply assume the widening of spreads to historical highs and add an exogenous shock to the risk premium, which is largely arbitrary.

One way of addressing this issue is to introduce a financial accelerator into the model.[13] Adding a financial accelerator can give the balance sheets of borrowers (firms or consumers) a role to play in the business cycle. The procyclical behaviour of net worth leads the cost of borrowing to rise in downturns and to fall in booms. The model can be set-up so that the risk premium is convex – it rises more rapidly as a firm borrows more. As a result, a shock that reduces asset prices would shift the cost of funds curve, making firms operate on the steeper part of the curve. Thus, negative shocks to asset prices will raise the premium faster than positive shocks will reduce the premium. Although introducing this feature into the model would certainly impart some interesting dynamics, it is unlikely that a model which is calibrated to replicate actual movements in observed risk premiums would introduce a sufficiently large disruption to the economy. Consequently, it is likely that some degree of credit rationing will need to be introduced into the model. This would allow us to consider the implications of a large increase in perceived idiosyncratic and systemic risk which would in turn allow us to more closely replicate sharp disruptions in financial markets.

A final important limitation of our work is that we were not able to formally assess the likelihood of the scenario materializing. In order to be able to do this we would need to be able to assess the uncertainty around our model's parameters as well as the shocks

[10] For an example with U.S. data see Boivin and Giannoni (2006).

[11] Alternatively, we would not have had to rely on such an extreme set of shocks to generate the economic outcomes realized in our scenario.

[12] We thank Rhys Mendes for very useful discussion on the subject of modeling the financial sector.

[13] The canonical paper that introduces a financial accelerator for firms is Bernanke, Gertler and Gilchrest (1999). For an application in a Canadian setting see Christensen and Dibb (2006). Aoki, Proudman and Vlieghe (2004), Iacoviello (2005) and Basant Roi and Mendes (2007) provide three alternative approaches to modeling the financial accelerator for consumer borrowing. Christensen, Corrigan, Mendicino, and Nishiyama (forthcoming) propose a model, estimated with Canadian data, with financial accelerator mechanisms in both the household and business sectors.

themselves.[14] Our inability to assess parameter uncertainty arises because the model's parameters are calibrated rather than estimated. The sheer size of the BoC-GEM means that estimation is not likely to be a viable option anytime in the near future. We were also not able to quantify the extent of uncertainty emanating from economic shocks. Important progress has been made on this front since the completion of this work. Coletti, Lalonde and Muir (forthcoming) calculate shock uncertainty for a simplified two-country (Canada-U.S.) version of the GEM.

3. Default rates under stress (Block 2)

To assess the impact of the scenario on banks' portfolios, one has to map the macro variables into defaults. In the context of the FSAP exercise, it was agreed that the mapping would be done by the Bank of Canada. Here we briefly describe the key features of that work.

In modeling sectoral default rates, our interest is in identifying systemic factors that affect default rates in all sectors. We assume that these factors are related to the overall performance of the economy. The approach taken is to start from a set of macroeconomic variables that are part of the macroeconomic scenario, and arrive at a final specification of sectoral default rate regressions using a model selection criterion based on maximizing the predictive power of the final specification.

The initial set of variables (X) is the following:

- GDP growth rate
- Unemployment rate
- Interest rate (medium-term business loan rate)
- Credit/GDP ratio

The dependent variable is sectoral default rates. Unfortunately, a long series of historical sectoral default rates with broad coverage is not available for Canada. We have dealt with this problem by constructing proxies based on sectoral bankruptcy rates, and some additional information. The adjusted data spans the period from 1988:1 to 2005:4, at quarterly frequency. The adjustment procedure is described in detail in Misina and Tessier (2007 a,b).

The specification of the sectoral regressions relating defaults probabilities to macroeconomic variables takes the following form:

$$\ln\left(\frac{p_t^s}{1-p_t^s}\right) = m + \sum_{l=1}^{L} b_l^{(1)} X_{t-l} + \sum_{l=1}^{L} b_l^{(2)} X_{t-l}^2 + e_t$$

where X is a vector of explanatory variables.

[14] Misina and Tessier (2007b) discuss the impact of macroeconomic uncertainty on stress-testing results coming out of Block 3.

This specification includes non-linear terms (i.e., squared values of explanatory variables).[15] We have investigated the impact of non-linearities in different explanatory variables, and in the end opted for non-linearities in the GDP growth rate, and the unemployment rate.

Starting from this set of variables, the final specification is determined based on the maximization of the adjusted R-squared of each regression. This criterion is consistent with our objective of maximizing the predictive power of each regression. The implementation of this criterion involves recursive elimination of the variables with the lowest t-statistic until the adjusted R-squared is maximized.

Explanatory power of these regressions is good with the R^2 between 0.78 and 0.82. in all sectors except for agriculture, where the explanatory power is lower (0.58).

Table 1 summarizes the information on historical peaks and the forecasted values under the specifications obtained as described above.[16]

	ACC	AGR	CON	MAN	RET	WHO	MOR
Scenario	13.75	1.61	6.38	12.22	4.31	7.42	0.57
History	7.58	0.83	3.27	8.28	5.31	4.63	0.63

Table 1: Peaks of default rates (scenario and historical)

Note that the scenario presented in Table 1 includes and upward ad hoc adjustment (equivalent to 0.25 percent standard deviation) reflecting a compromise with the IMF mission. The objective was to obtain a more severe scenario than implied by Bank of Canada estimates excluding such an adjustment.

To compute losses under the scenario we need, in addition to default rates, the information on exposures, and losses given default. The loan exposures data are taken at 2006Q4, the last available point. There is very little information on losses given default in Canada. A very rough proxy can be obtained by looking at the ratio of estimated assets to liabilities at the time of bankruptcy. This information is available from the Office of the Superintendent of Bankruptcy. For the corporate sector, the average for the 1988 – 2006 period is 0.35, which would suggest an expected recovery rate of 35%, or losses given bankruptcy of 65%. Since bankruptcy is the last stage of distress, and most losses occur due to missed interest payments, we believe that this recovery rate might be somewhat low, and for the purpose of the FSAP exercise have agreed with the IMF to set the recovery rate at 50%.

[15] Misina and Tessier (2007a, b) explain in detail the reasons for this specification.

[16] The sectors included were accommodation (ACC), agriculture (AGR), construction (CON), manufacturing (MAN), retail (RET), wholesale (WHO), and default rates on mortgages (MOR) in the household sectors. For the sectors for which default rates were not provided, they could be either merged with the above, or classified into a separate category ('OTHER'), and an average of default in the above sector used. Both approaches were used by individual banks in implementing the scenario.

4. Loss assessment (Block 3)

In this section we describe two sets of results which quantify the effect of the macroeconomic scenario on the banks. First we discuss the results on expected and unexpected (99.9 per cent value-at-risk estimates) losses arising under this scenario, which is followed by a discussion of the impact of these losses on the capital-adequacy ratio (CAR). Each set contains the aggregate average of the results provided by individual banks, as well as the comparable result obtained using our own internal model. We also discuss some adjustment that had to be made in using our internal model to take into account banks' practices in stress-testing their credit portfolios.

a. Expected and unexpected losses

Each bank was asked to provide an estimate of expected and unexpected losses arising from the macroeconomic scenario, for each quarter over a two-year horizon. Individual results depend on how the banks used the inputs provided to them. The approaches taken vary across banks, but there are, nonetheless some key commonalities which had to be taken into account in arriving at the estimates of losses using our internal model. In particular,

1. the exposures used by individual banks are not based on the publicly available balance sheet data:[17]
    - in assessing the risks in their portfolios the banks rely on their internal estimates of the exposures at default. These estimates are based on the authorized amounts, whereas the balance sheet exposures are based on the drawn amounts. Since the authorized amounts are always greater than the drawn amounts, use of the balance sheet exposures would result in systematically lower estimates of losses.
    - in addition to the above, some banks have, for the purpose of stress testing, brought some of their securitized loans back into their loan book.

2. The banks' results indicate that the loss distribution is a heavy-tailed one. In the meetings, the banks confirmed that their loss distributions were indeed fat-tailed.

To deal with the first set of issues, we have asked the banks to provide us the values of exposures they used in their stress tests, and adjusted our result upwards by the difference

[17] It may, nonetheless, be possible to approximate their exposures by combining their on- and off-balance sheet information.

between the exposures they used and the ones in their balance sheets. The difference between the two varied from bank to bank, with the lowest being 4 percent, and the largest being 45 percent.[18] To deal with the second set of issues, in our simulations we have used a t-distribution, rather than the normal.[19]

Figure 1 contains a summary of the impact of the scenario on the participating banks.

Note banks results presented in this section are preliminary and subject to be revised.

There are two sets of results shown in the figure:

1. average losses based on the stress-testing results provided by banks,
2. average losses computed using our internal stress testing model (labeled MT)

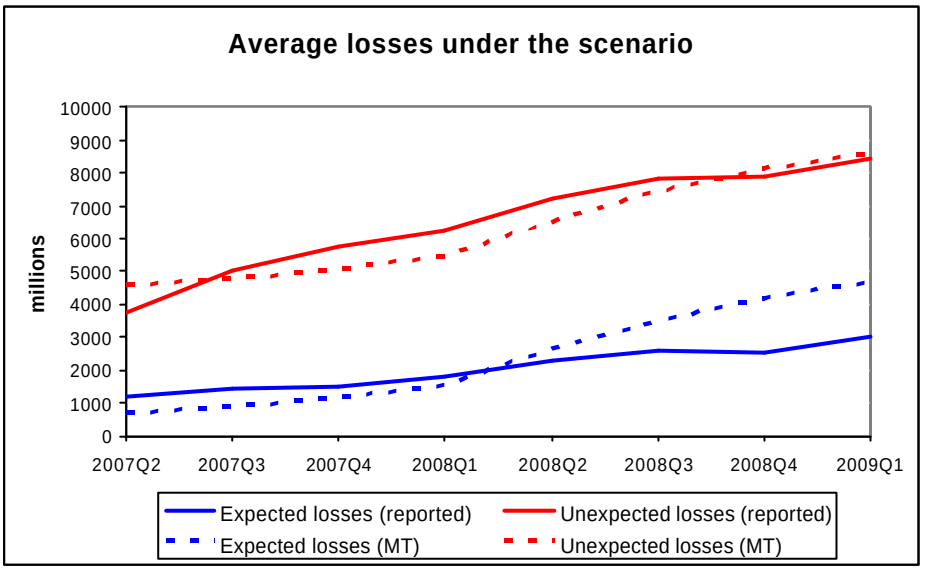

Figure 1: Stress-testing results (averages)

[18] Scaling up of the results by the difference between exposures is implicitly based on the assumption that the sectoral distribution of exposures used by banks, in relative terms, corresponds to their balance sheet exposures. This assumption is difficult to verify since the exposures provided to us by banks were totals only.

[19] The use of t distribution is non-controversial, but in choosing it one has to deal with the problem of estimation of the scale parameter of that distribution (degrees of freedom). There are established procedures for accomplishing this task, but their performance in small samples is highly unreliable. Statistical literature suggests that in small samples in which the use of t distribution is deemed appropriate, reasonable values of the scale parameter are between 4 and 5. We have opted for the former, and used the same value for all banks, since there is no a priori reason to believe that the values should be different.

The two sets of results are quite similar in terms of the overall magnitudes, although the banks estimate smaller expected losses in the second year.[20]

b. Impact of the scenario on the capital adequacy ratio

To assess the ability of the banks to absorb the losses that arise under the scenario, we translate them into the impact on their capital adequacy ratio. The assessment is based on the following considerations:

- expected losses should be covered out of the available loss allowances. We assume that shortfalls, if any, will be deducted from capital;
- capital (Tier 1 + Tier 2) should be sufficient to cover the losses at the 99.9 percent value-at-risk, while staying within the regulatory requirements.

Current regulatory requirements set the legal minimum at 8 percent; OSFI sets the threshold at 10 percent.

The results are presented in Figure 2. Again, we present the results based on losses reported by banks, as well as our estimates.

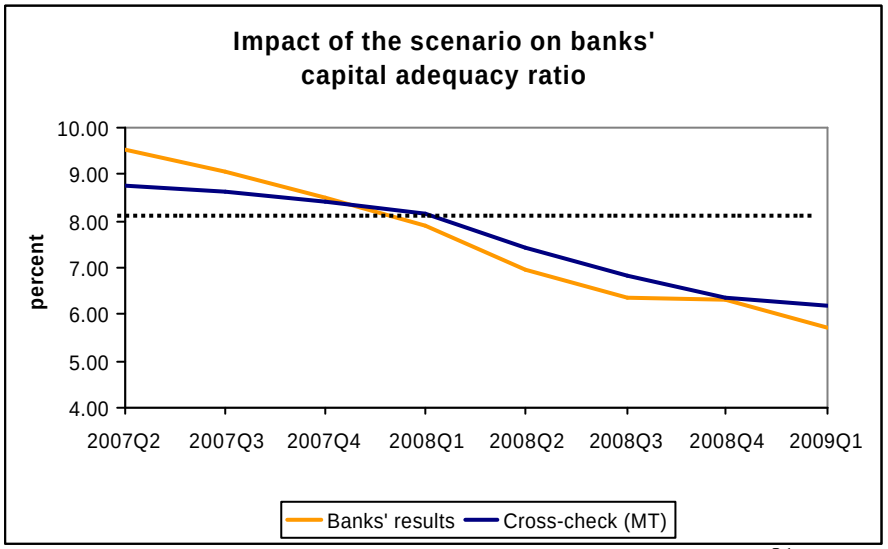

Figure 2: Impact of the scenario on the CAR (average)[21]

The two sets of results are similar, and both suggest that the CAR would fall below the legal minimum about 1 year after the initial shock, and that it would fall below the OSFI

[20] Inspection of individual results reveals that some banks have dealt with the problem of translating the provided default rates into changes in quality of their lending portfolio ('portfolio migration') in ways that have led to a significant dampening of the impact of the scenario on their portfolio.

[21] For both sets of results, the impact is determined using our internal method.

threshold almost immediately. The results do vary across banks: the earliest breach occurs in 2007Q4, and in the best case there is no breach even after two years.[22]

The above results are based on the assumption that no mitigating action by bank management takes place. This assumption results in very conservative (worst-case) estimates. As part of the exercise, the banks were asked to assess the impact of the shock on the CAR allowing for the management action. The assessments were based on a variety of assumptions, and some banks did not provide the required information. In cases where the information was provided, the estimated CAR under stress was above the OSFI thresholds.

There is no doubt that the banks would use a variety of measures to maintain their CAR above the stipulated threshold. Nonetheless, a big discrepancy between our estimates and the banks' assessments which allow for management actions may be indicative of the banks' determination to take actions to manage their CAR (reduction/halt in dividend payments, change in lending practices towards less risky borrowers etc.), with potentially negative impact on the real economy. Banks' estimates may be overly optimistic as well, as simultaneous actions by all banks to manage their capital (by, for example, tightening credit) may exacerbate the problem.

5. Conclusions

The Bank's participation in this FSAP stress-testing exercise was not without cost. Indeed our rough estimate is that the equivalent of between one and two employees' efforts were invested in this exercise in 2007. This is based on an estimate of the work that was done and that would not have been done in 2007 otherwise (a caveat is that some of that work may have been done in 2008 or later).[23]

However, the Bank drew significant benefits from its participation in the FSAP stress-testing exercise.

(1) *It stimulated cooperation between Bank of Canada departments*. Various Bank of Canada departments were involved in designing the macroeconomic scenario. Such inter-departmental cooperation could serve as a model for future financial stability work.

(2) *It contributed to improving information sharing with Bank of Canada partners*. Various working relationships were developed with Canadian government agencies, IMF staff and Canadian banks. These will certainly prove useful in future financial stability work.

[22] Since the default rates reach their peaks around 2009Q1, we expect the biggest impact on banks' CAR to occur around that time, with a possible improvement later on.
[23] Developing tools to analyze financial stability risk is a research objective at the Bank.

(3) *It contributed to improving our stress-testing data and models*. We learned a lot through discussions with external partners and Bank colleagues about data sources (for instance data about default rates, corporate bond spreads and banks' exposures), stress-testing modeling techniques (including approaches to modeling loss-distributions) and Canadian banks' internal stress-testing approaches. Our participation in the bottom-up exercise was particularly helpful in these areas.

We also learned about (or were reminded of) limitations in our set of stress-testing tools that we would like to address in future work:

(1) As was discussed in Section 2, the fact that GEM is a global model with good micro-foundations was useful in simulating and interpreting the macroeconomic scenario. However, judgment had to be used to determine the path of some financial variables (e.g. risk premiums) and we could not produce paths for others (e.g. house prices). Also, the current version of GEM could not be used to provide an estimate of macroeconomic uncertainty. Ongoing work on GEM and on other Bank of Canada models that could be used to produce macroeconomic scenarios is addressing these limitations.

(2) Our default probability equations have interesting characteristics, including the fact that they allow for non-linear effects. However, they are reduced form equations, which makes economic interpretation difficult. Work on more structural equations is needed.[24]

(3) To fully specify loss distributions, some judgment was needed in setting the values of key parameters. More work is needed on determining the appropriate approach for estimating loss distributions in small samples of data.

(4) The information we gathered helped us greatly improve our top-down approach. The tools we developed enabled us to arrive at an independent view of the banks' results. With these tools we could, in the future, perform our own stress-testing exercises, without imposing the burden on individual banks, based on scenarios we think are interesting and relevant at a point in time. However, it would be desirable to perform other bottom-up exercises as a check on the appropriateness of our top-down tools. Also research is needed to improve these tools. In particular, they cannot really take into account contagion, common exposure and feed-back effects that individual banks stress-testing exercise can't factor in. The Bank would contribute very useful information if it were able to estimate these effects.

[24] We had long discussions with the IMF Staff concerning characteristics of our macro-model and of our default equations. They thought our macro model implied an adjustment to the shocks that was too efficient and criticized our approach to modeling default probabilities. Given the state of the literature on these topics, it was not clear to us what the alternative to our tools could be. In the end, we agreed to an ad hoc upward adjustment to our default probabilities as compromise solution.

(5) This FSAP stress-testing exercise focused on banks' credit risk. It will also be important to try to include market risk and other financial institutions in future stress-testing work.

Overall, we feel that the learning that took place and the contacts we developed through our participation in this FSAP exercise mean that, from the Bank's point of view, the benefits outweighed the cost of this participation.

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Appendix 1

Key Macro Variables