Reports

Introduction

Reports address specific issues of relevance to the financial system (whether institutions, markets, or clearing and settlement systems) in greater depth.

The report on **Bank of Canada Oversight Activities during 2006 under the Payment Clearing and Settlement Act** covers the Bank's role in 2006 with respect to the three systems designated in accordance with that act (the Large Value Transfer System, CDSX, and the CLS Bank). This annual report by Clyde Goodlet also reviews other Bank activities that support this role. The report is an elaboration of the discussion that appears in the Bank's *Annual Report*.

In the report **An Overview of Risk Management at Canadian Banks**, Meyer Aaron, Jim Armstrong, and Mark Zelmer review current and evolving risk-management practices at Canadian banks and highlight some related issues and concerns. This report is partly based on interviews with major Canadian banks conducted by Bank of Canada officials in early 2007. The Bank of Canada is interested in developments in risk management at Canadian banks because of the critical role that banks play in the Canadian financial system. The report highlights how the changing business of banks—particularly their growing exposures to markets and complex instruments—has created new challenges for risk management. The report contains a review of the major categories of risk and how banks are dealing with them. Some important techniques, such as VaR and stress testing, are discussed. The report concludes with a discussion of some of the major challenges ahead, including model risk and the integration of risk management across the institution.

In the report **Sectoral Default Rates under Stress: The Importance of Non-Linearities**, authors Miroslav Misina and David Tessier examine the impact of the introduction of non-linearities on predicted default rates and illustrate their arguments with a series of experiments that focus on the recession in Canada in the early 1990s. The report also provides a detailed description of the proxies for sectoral default rates for the 1988–2005 period constructed by the authors.

Bank of Canada Oversight Activities during 2006 under the Payment Clearing and Settlement Act

Clyde Goodlet

The Payment Clearing and Settlement Act (PCSA) formally requires the Bank of Canada (the Bank) to exercise oversight of clearing and settlement systems that could be operated in a manner that could pose systemic risk.[1] Systemic risk is defined in the PCSA as the risk that the default of one participant in a clearing and settlement system could, through the operation of the system, lead to the default of other participants in the system or other systems. A clearing and settlement system is the set of instruments, procedures, and rules governing the transfer of funds or other assets among system participants. Typically, there is agreement among the participants on the technical infrastructure to be used by the system.

The purpose of this report (the second in an annual series) is to review the Bank of Canada's oversight activities under the PCSA during 2006, as part of its efforts to be transparent and accountable for its activities in this area.[2]

Under the PCSA, the Bank identifies clearing and settlement systems in Canada that could be operated in a manner that could pose systemic risk. Once identified, and provided the Minister of Finance agrees that it is in the public interest to do so, these systems are designated for oversight by the Bank and must satisfy the Bank that they have appropriate risk controls in place to deal with any concerns related to systemic risk. Three such systems have been designated by the Bank: the Large Value Transfer System (LVTS), the CDSX, and the CLS Bank.

The Large Value Transfer System

The LVTS is owned and operated by the Canadian Payments Association (CPA). It began operations in February 1999. It currently processes about 19,000 transactions per day, worth approximately $166 billion. Since its inception, there have been very few changes to the design or rules of the LVTS that could raise concerns about systemic risk, and this pattern continued in 2006. However, some important changes were made to the system's rules last year to reduce certain potential sources of operational risk. These changes addressed the responsibilities of participants in the testing of changes to the LVTS, the adequacy of contact information, and the procedures to follow should the LVTS Direct Network be used to initiate a payment.[3]

Integral to the Bank's oversight process is the use of Memoranda of Understanding (MOUs) with operators of designated systems. MOUs describe the roles and responsibilities of both parties under the PSCA and set out how they intend to work together to meet those responsibilities. They address such topics as the Bank's exercise of its oversight responsibilities and powers, as laid out in the PCSA, confidentiality of information, time frames for review of significant system changes, and the use of minimum standards. A major accomplishment in this regard was the conclusion of intensive discussions with the CPA and the signing of an MOU covering the oversight of the LVTS in November 2006. The MOU reflects the collaborative and co-operative nature of the oversight process that the Bank prefers to follow. It has added clarity to the relationship between the Bank and the CPA and has enhanced the oversight process.

1. The PCSA came into force in 1996. Prior to that time, the Bank carried out this responsibility on an informal basis.
2. See Engert and Maclean (2006) for a discussion of the general oversight strategy and processes used by the Bank.
3. See Goodlet (2006) for a description of the use of the Direct Network to address certain types of operational risk.

For example, the CPA will now provide advance written notice of any significant change to the LVTS bylaws or rules, so that the Bank can determine if the proposed changes raise any concerns about systemic risk.

CDSX

CDSX is a system for the clearing and settlement of securities transactions in Canada. The system, which is owned and operated by CDS Clearing and Depository Services Inc., processes, on average, about 390,000 trades daily, worth $230 billion.

During 2006, the most important issue dealt with by the Bank and The Canadian Depository for Securities Ltd. (CDS) involved the corporate restructuring of CDS. The purpose of the restructuring is to gain operational efficiencies by aligning various functions with corporate subsidiaries of CDS. This includes the separation of the clearing and settlement activities of CDS from its other activities.

From the perspective of systemic risk, one benefit of this separation is that it largely addresses the Bank's concern that, in very unlikely circumstances, the non-regulated activities of CDS could result in CDS being unable to make and receive payments in CDSX, thus compromising the ability of CDSX to settle payment obligations in a timely fashion. This situation could arise if, for example, the non-regulated activities of CDS were to cause its insolvency or result in legal actions that would prevent CDS from performing its role as central counterparty.

A new legal entity, called CDS Clearing and Depository Services Inc. (created on 1 November 2006), now acts as system operator and central counterparty in CDSX, and its ability to act will not be compromised, directly or indirectly, by the design and operation of services other than the clearing and settlement of securities transactions and associated activities. The Bank considers this step to be an enhancement of the risk proofing of the CDSX system.[4] The restructuring involved much work by many parties (CDS staff, CDSX participants, and its regulators), and the smooth transition to the new corporate structure is a testament to their collaborative and co-operative approach.

An important aspect of the new structure is that the entity operating and serving as the central counterparty in CDSX also operates its cross-border services, which link CDSX or CDSX participants to foreign securities settlement systems. To deal with the potential systemic risk impact on CDSX, the Bank has clearly specified its information needs and the areas to be examined for possible risks when considering any future cross-border linkages involving the new operating entity. This specification is based on extensive discussions with CDS.

Another important development during 2006 was the self-assessment carried out by CDS concerning its compliance with international standards in its role as a central counterparty. CDS and the Bank have been strong supporters of the work in this area. Consequently, CDS made a presentation to the Bank for International Settlements Committee on Payment and Settlement Systems (which developed the standards) on the process and the results of the self-assessment. The Bank has also encouraged CDS to keep its financial-risk model current. CDS has now put in place processes to do this, which will facilitate the ability of the Bank and other parties to systematically examine potential risks arising from proposals for new clearing and settlement services.

A valuable component of the Bank's oversight process with regard to CDSX is the bilateral meetings between the Bank and CDS that examine a range of topics related to the operation of CDSX. These meetings provide the Bank and CDS with an opportunity to explore any concerns or questions related to proposed changes to CDSX on a timely and efficient basis. The Bank is thus alerted to possible changes very early in the process and can raise any concerns that it may have so they can be dealt with efficiently by CDS in the process of developing system changes. During 2006, the Bank held two such meetings with CDS.

The Bank approved 35 changes to CDSX rules and procedures during the year.

4. The Bank also arranged with the Department of Finance for an Order-in-Council to designate the new entity as a securities and derivatives clearing house under Section 13.1 of the PCSA, which provides the continuation of important legal protections in the event of the failure of a CDSX participant. An Amendment to the PCSA to include the name of the new operating entity came into effect in April 2007.

The CLS Bank

CLS Bank, which began operations in 2002, now clears and settles foreign exchange transactions in 15 currencies, including the Canadian dollar, with an average daily value of US$2.7 trillion. The average daily value of Canadian-dollar transactions in 2006 was US$60 billion. Since CLS Bank operates transnationally, the Bank of Canada, as well as a number of other central banks, has oversight responsibilities or interests in the operation of the system. Most of the developments with regard to CLS Bank in 2006 involved its overall operations, since there were no specific changes to the arrangements used to settle the Canadian-dollar portion of foreign exchange transactions.

The Federal Reserve, which is the lead supervisor of CLS Bank, reviews the liquidity and capital policies of the CLS as they relate to the supervisory standards set for CLS Bank. The results of this review, as well as other supervisory information, are shared with the central banks whose currencies settle in CLS Bank. This is part of the co-operative oversight arrangement for CLS Bank that facilitates the sharing of information among central banks (subject to confidentiality requirements), the discussion of common oversight policies and approaches, and the coordination of oversight activities.

As CLS Bank has evolved, the addition of new currencies and the expansion of the types of settlement services it offers have been a major focus of the analytical work of the co-operative oversight group. Since CLS Bank has a very robust process for settling transactions across borders, it continues to search for opportunities to spread the significant fixed costs associated with this process across a greater volume of transactions in existing or new types of business. With regard to the settlement of foreign exchange transactions, CLS Bank modified the prices for its services during 2006 to help increase the volume of transactions that it processes. In addition, CLS Bank is exploring the processing of new types of transactions on its existing platform by offering the financial sector a means of reducing risks or costs associated with current practices. The Bank of Canada believes that the fundamental principle guiding the oversight group in considering these issues should be that the addition of new currencies or new business should comply with the core principles for systemically important payments systems and, in particular, should not impair the risk-mitigation arrangements employed by CLS Bank to deal with foreign exchange settlement risk.

During 2006, the central banks with CLS-eligible currencies carried out a survey of the management of foreign exchange settlement risk at major banks in their countries. The survey results and an analysis of the data are expected to be published by the Bank for International Settlements. With the decision of a fourth large Canadian bank to use CLS Bank for its eligible transactions, Canadian banks are recognizing that the CLS arrangement is increasingly being considered best practice for mitigating foreign exchange settlement risk.

Other Oversight Activities

Following an extensive review of its oversight processes conducted in 2005, the Bank made a number of changes in 2006 to better align these processes with the ongoing operations of designated clearing and settlement systems. These included the implementation of more formalized internal processes, including those for handling system changes and conducting annual audits. The Bank and the Department of Finance reviewed the operation of the Payment Advisory Committee, resulting in a clearer mandate and oversight processes. In addition, the Bank continued to enhance its oversight resources to provide for greater analytical capability and better backup for important staff functions.

Internationally, during 2006, the Bank became a member of a BIS working group examining the cross-border interdependencies among clearing and settlement systems and their participants. In particular, the group is interested in the potential for systemic disruptions and contagion across borders should a major clearing and settlement system experience a serious disruption.

The Bank is also increasingly involved in the co-operative oversight arrangement for the Society for Worldwide Interbank Financial Telecommunication (SWIFT). SWIFT is the principal payment messaging service provider for financial institutions around the world and for critical systems, such as the LVTS and CLS Bank. In 2004, the G-10 central banks established a joint Oversight Group for SWIFT under the leadership of the National Bank of Belgium. This

Group monitors and assesses the extent to which SWIFT maintains appropriate governance arrangements, structures, processes, risk-management procedures, and controls to effectively address any potential concerns it may pose to financial stability.

Since 2002, SWIFT has been the subject of subpoenas issued by the U.S. Treasury Department for access to information on global payments using SWIFT messaging services. These subpoenas were imposed on SWIFT as part of a global scrutiny of terrorism financing. Knowledge of these subpoenas became public in 2006 and raised privacy concerns in several countries, including Canada, about the nature of the payments information being requested. The National Bank of Belgium issued a press release on behalf of the SWIFT Oversight Group and the G-10 Governors indicating that such issues were beyond the Oversight Group's mandate, which covers the financial stability implications of SWIFT services to systemically important systems. Moreover, the Oversight Group does not have the authority either to approve or prohibit SWIFT's compliance with such subpoenas. Privacy commissions in a number of countries conducted investigations into the actions of SWIFT. The Office of the Privacy Commissioner in Canada recently completed its investigation and concluded that SWIFT did not contravene Canada's Personal Information Protection and Electronic Documents Act when it complied with lawful subpoenas served outside of Canada.

During 2006, the Bank continued to work with the operators and participants of systemically important Canadian clearing and settlement systems to enhance arrangements for continuity of operations. These systems are at the centre of Canada's financial system, and serious economy-wide repercussions could arise if their operations were not extremely reliable. In 2006, the working group that was created to address systemic issues related to business-continuity planning (BCP), and to examine the coordination of BCP among system operators and participants and the Bank of Canada, completed the second phase of its work. The major findings of the phase II report of the Joint Working Group were: (i) the CPA and CDS had reduced their operational risk, with split operations initiatives accounting for much of the improvement; (ii) their BCP practices compared favourably with those of similar organizations in other countries, although it was recognized that benchmark practices continue to evolve rapidly; and (iii) efforts to achieve a priority-recognition status with federal and provincial organizations with responsibilities for emergency management have yet to yield positive results. Recognition of the priority to access the supply of essential inputs such as hydro, diesel fuel, or municipal services during a seriously disruptive event is an important component of these systems and of the Bank's BCP work. The next phase of the group's work will be to involve the participants in the LVTS and CDSX to examine their roles in dealing with potential systemic BCP risks and the coordination of BCP efforts. The Bank is working actively with the CPA and CDS to facilitate this process.

The Bank has also been involved in groups addressing preparations for a possible flu pandemic. It has worked with the federal Department of Finance to review the BCP arrangements of federal agencies with responsibilities for the financial sector with a particular emphasis on a flu pandemic scenario. Similarly, the Joint BCP Working Group also gave special emphasis to this scenario. Internally, the Bank is re-examining its program for business-continuity planning with regard to any particular changes that might be necessary should a flu pandemic materialize.

During 2005, the Bank completed its three-year program to improve the ability of its backup site to respond effectively to serious operational disruptions. IT and business-recovery testing during 2006 revealed some shortcomings in meeting the Bank's objectives for internal recovery time. Most of these gaps have now been addressed and tested. Testing of further refinements is planned for 2007. The multi-year redevelopment of a high-availability system for providing banking services to financial institutions and critical clearing and settlement systems was expected to be completed in 2006. However, extended testing has resulted in a significant delay in the implementation of the system. The Bank of Canada remains committed to improving its ability to deliver its unique services to major clearing and settlement systems on a high-availability basis.

Published Research Relevant to the Bank's Oversight Function

During 2006, the Bank published the following staff work related to clearing and settlement systems:

- Arjani, J.N. 2006. "Examining the Trade-Off between Settlement Delay and Intraday Liquidity in Canada's LVTS: A Simulation Approach." Bank of Canada Working Paper No. 2006-20.
- García, A. and R. Gençay. 2006. "Risk-Cost Frontier and Collateral Valuation in Securities Settlement Systems for Extreme Market Events." Bank of Canada Working Paper No. 2006-17.
- Kamhi, N. 2006. "LVTS, the Overnight Market, and Monetary Policy." Bank of Canada Working Paper No. 2006-15.
- Lai, A., N. Chande, and S. O'Connor. 2006. "Credit in a Tiered Payments System." Bank of Canada Working Paper No. 2006-36.
- McVanel, D. 2006. "The Impact of Unanticipated Defaults in Canada's Large Value Transfer System." Bank of Canada *Financial System Review* (June): 69–72.

Research summaries of the papers by Lai, Chande, and O'Connor, and García and Gençay were also published in the December 2006 issue of the Bank's *Financial System Review*.

References

Engert, W. and D. Maclean. 2006. "The Bank of Canada's Role in the Oversight of Clearing and Settlement Systems." Bank of Canada *Financial System Review* (June): 57–64.

Goodlet, C. 2006. "Bank of Canada Oversight Activities during 2005 under the Payment Clearing and Settlement Act." Bank of Canada *Financial System Review* (June): 31–34.

An Overview of Risk Management at Canadian Banks

Meyer Aaron, Jim Armstrong, and Mark Zelmer

The Bank of Canada is interested in developments in risk management at Canadian banks because of the critical role that banks play in the Canadian financial system.

This report provides a brief overview of risk-management practices at Canadian banks. It is based, in part, on recent interviews conducted with some Canadian and foreign banks.

The business of banks has changed noticeably over the last 15 or 20 years (Calmès 2004). Although deposit taking and lending continue to be key business lines, banks have expanded into other areas, including investment banking and trading, insurance, trusts, brokerage, and mutual funds. An important consequence of this shift has been an increase in the exposure of banks to financial markets.

In light of this exposure, banks have adopted sophisticated risk-management practices. Boards of directors now play a more active role in ensuring that risks are well understood and in overseeing risk exposure. They also ensure that management has appropriate strategies, systems, and controls in place to manage risk. Indeed, banks have adopted sophisticated risk management as a core function, and risk-management principles are now used across banking organizations to allocate capital, price products, and invest in new markets.

Managing the Major Risks

General trends

Like any other business, banking involves taking calculated risks to generate profits. Today, Canadian banks face a diverse range of risks. In this report, we focus on credit risk, market risk, liquidity risk, and operational risk.

Canadian banks have always faced these categories of risk. But the underlying complexity and importance of certain risks has increased as a result of market pressures and the business strategies adopted by the banks. For example, market risk has grown in importance and has become more complicated to manage. Back offices and other parts of banks are facing challenges in keeping up with the pace of innovation in front offices.[1]

This trend towards increasing complexity, coupled with advances in information technology, is driving the rapid adoption of quantitative models, where appropriate, and a move towards a more integrated approach to risk management within banks.[2] But the day-to-day choices in risk management essentially depend on the type of risk, the availability of instruments to transfer or mitigate the risk, and where the risk resides on the balance sheet.

A bank's balance sheet—together with off-balance-sheet arrangements—can be divided into financial instruments that make up its trading book and those that make up its banking book. The trading book includes instruments held for shorter-term trading and other financial market activities. The banking book includes most loans and securities held for longer investment horizons. Both "books" normally contain similar types of financial instruments and risks. They tend to be managed differently, however, because of their differing time horizons.

1. Part of this complexity arises from the growing importance of very complex legal documentation governing transactions, as well as from issues of whether the trade on the books matches the trade outlined in the confirmation.
2. Sometimes referred to as enterprise-wide risk management or ERM (Standard & Poor's 2006).

Credit risk

Credit risk refers to the potential for loss if a borrower or a counterparty to a transaction fails to meet its obligations as they fall due. Credit risk remains the most important risk that banks have to manage. Large banks tend to allocate roughly half of their economic capital to this risk.

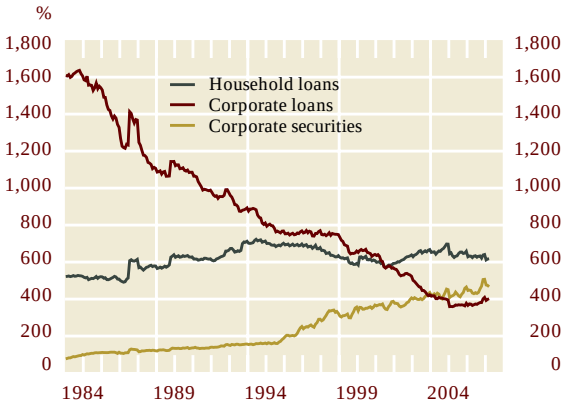
Historically, credit risk was lodged mainly in the banking book. However, with the growth in holdings of corporate securities and derivatives, credit risk in the trading book has increased.

Diversification is a first line of defence against major credit losses. In the banking book, diversification is used to avoid concentration of credit risk with a particular borrower, or group of borrowers, or with a particular industry or region.

The trading book houses both credit risk related to the issuers of securities and counterparty risk incurred from derivatives contracts. The former is mitigated through single-name and sector limits, as well as, more recently, credit derivatives. The latter is mitigated through various arrangements, such as netting agreements and collateral. Similarly, diversification across counterparties and products avoids the concentration of credit risk in the trading book.

Banks have systems in place to monitor their exposure to any one group or related set of counterparties/borrowers to ensure that this exposure does not exceed chosen limits relative to their capital base. Exposures to single names and sectors are managed largely on a consolidated basis, regardless of whether the risk arises from different instruments or from different books (banking or trading). Chart 1 presents the trend in major categories of bank credit exposure relative to capital. In recent years, bank lending to the household sector has risen relative to corporate lending.[3] However, holdings of corporate securities have also risen; these are held mainly in the trading book.

Chart 1 Trend in Bank Major Asset Categories Relative to Tier 1 Capital



Source: Balance sheet information from OSFI returns

Exposure to households and small business enterprises (SMEs)

Management of exposure to households and SMEs involves numerous borrowers that, taken

3. The risk involved in some of this lending to households is mitigated through mortgage insurance.

as a portfolio, have fairly uniform credit-risk properties. This permits banks, because of "the law of large numbers," to rely on statistical models that incorporate certain key risk variables to assess borrower creditworthiness.[4] This helps to streamline the process for credit approval and enforce uniform standards across the many lending offices of large institutions.[5]

Banks also securitize some of their household assets, such as residential mortgages, consumer loans, and credit card loans, to shed balance sheet assets and reduce exposure to these sectors, while retaining a relationship with household or small business clients.

Exposure to large corporations and institutions

Large exposures to corporate credit and to other institutions are more "lumpy" and, thus, less amenable to assessment through basic statistical models. Consequently, banks continue to rely on in-depth credit analysis of individual borrowers to assess their creditworthiness, with results graded by probability of default and loss-given-default. This is similar to the approach of the credit-rating agencies.

The larger the exposure, the more scrutiny it attracts within the bank, with the largest exposures reviewed and approved by the board of directors. Part of credit-risk management has traditionally been through the terms and conditions associated with individual loans. These may include pledging of securities for collateral. There may also be various performance covenants that help banks monitor the creditworthiness of borrowers over time and that trigger renegotiations if credit quality deteriorates.

Recent developments in markets for credit-risk transfer (CRT) have enhanced the ability of banks to better manage large corporate exposures through financial instruments, while allowing them to maintain client relationships. CRT techniques include securitizations, loan syndications, secondary loan sales and, more recently, credit derivatives (Reid 2005). Canadian banks have expertise in these techniques, although banks tend to be more active in using them in offshore markets—notably those in the United States—given the relatively small size of these markets in Canada.[6]

There have been important developments in modelling the credit risk of large corporate exposures. The emergence of Credit VaR (Value at Risk) models and other techniques, such as the Moody's KMV approach (based on the Merton model), provide banks with a quantitative framework for calculating the economic capital required to backstop their exposure to credit risk.[7] Banks have invested considerable time and effort in ensuring that their internal ratings process is more formalized and documented so that they can easily defend how they arrived at an internal rating decision. This has been reinforced by Basel II with its emphasis on risk-based capital (Box 1).

Growth in market-based activities has increased large credit exposures in the trading book, arising from holdings of credit instruments and from counterparty exposures.[8] Chart 2 shows the trend in trading book assets and liabilities. Banks employ both derivatives and offsetting transactions in cash markets (such as short selling of similar securities) to manage credit risk in the trading book.

This has resulted in a growing reliance on collateral to mitigate the counterparty risk involved in derivatives contracts and other financial transactions. Collateral takes the form of cash or high-grade securities, like government debt, that have low credit risk and are very liquid. This has led to increased demand for high-grade securities, which has occasionally affected the liquidity of underlying markets. This has likely contributed to a broadening out in the range of eligible collateral beyond government securities, particularly the use of cash collateral (very short-term instruments), which is now the

4. The subprime segment of the mortgage market has proven to be less amenable to the same modelling techniques. But this market is small in Canada. See Highlighted Issue on page 6.
5. The use of credit-scoring models is a fairly recent development in Canada.
6. The securitization technique is relatively well developed in Canada.
7. Credit VaR is typically defined as an estimate of the loss related to credit-rating transitions, over a given horizon (usually one year), that is statistically unlikely to be exceeded at a given probability level.
8. OSFI recently conducted a review of bank exposures to hedge funds and concluded that banks' exposures are relatively small and that risk-management practices are adequate (OSFI 2007).

Box 1

Basel II and Bank Risk Management

In June 2004, the Basel Committee on Banking Supervision released its report titled "International Convergence of Capital Measurement and Capital Standards: A Revised Framework" (Basel II). The revised Basel II framework will be implemented for Canadian banks effective 1 November 2007, following a one-year parallel run with the existing capital-adequacy regime. Basel II is designed to achieve a closer alignment of regulatory capital requirements with underlying risks by introducing significant changes to the treatment of credit risk, as well as by introducing a new capital charge for operational risk. The underlying principles of the new framework are intended to be suitable for application to banks of varying levels of complexity and sophistication. The framework will allow qualifying banks to determine capital levels consistent with the manner in which they measure, manage, and mitigate risk.

Basel II rests on three pillars: minimum capital requirements, supervisory review, and market discipline. Risk management is given a key role in the first pillar of the new framework—minimum capital requirements—in terms of emphasizing the measurement and management of risks, and providing banks with incentives to adopt more advanced risk-management techniques. The new framework provides a spectrum of methodologies, from simple to advanced, for the measurement of both credit and operational risk. (Those applied to market risk are largely unchanged from the 1996 market-risk amendment to the original Basel Capital Accord.)

For credit risk, banks may choose between the standardized approach, the foundation IRB (internal-ratings-based) approach, and the advanced IRB approach. Under the standardized approach, banks use risk weights based on ratings assigned by a recognized external credit-assessment institution, such as a rating agency, to calculate required regulatory capital.

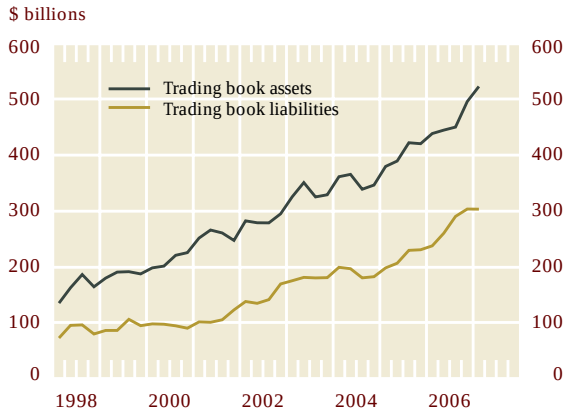
Under the two IRB approaches, banks use their own internal assessments and risk models to arrive at the key risk drivers needed to calculate capital risk weights, to varying degrees. For banks using the foundation IRB approach, probability of default (PD) must be internally generated with other risk factors provided by supervisors. By contrast, banks using the advanced IRB approach are required to estimate probability of default, loss-given-default (LGD), exposure at default (EAD), and maturity (M) for each exposure.

Similarly, for operational risk, Basel II offers three progressively more complex methods: the basic indicator approach, the standardized approach, and the advanced measurement approach (AMA). Most major Canadian banks are planning to adopt the advanced IRB approach for credit risk and the standardized approach for operational risk.

The second pillar of Basel II focuses on the supervisory review process. It allows banking supervisors (Office of the Superintendent of Financial Institutions in Canada) to set minimum capital requirements that exceed those outlined in Pillar 1, depending on the risk profile of the bank. This assessment process may involve reviews of bank risk-management processes and stress tests. Meanwhile, the third pillar is aimed at strengthening market discipline by requiring enhanced disclosure of risk information by banks in Canada and abroad.[1]

1. In Canada, advanced IRB and AMA banks will be required to meet advanced disclosure requirements in 2008.

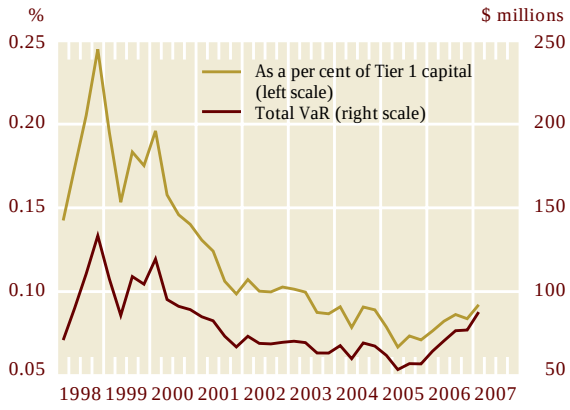
Chart 2 Trend in Bank Trading Book



Source: OSFI

Chart 3 Trend in Bank VaRs

Quarterly average*



* 99 per cent VaR probability threshold for all institutions, for trading portfolios only

primary collateral instrument in over-the-counter derivatives markets (BIS 2007).

Market risk

Market risk represents the potential for adverse changes in the prices or volatility of financial assets and liabilities.[9] While market risk is typically not the largest risk that Canadian banks face, it has risen in importance over the past two decades and poses unique challenges, given the complexity of the financial instruments from which it is derived and the markets where they trade. The complexity of new products and strategies derived from market activities has increased the banks' reliance on quantitative methods that employ a number of assumptions and sophisticated statistical theory to price products and manage their exposures.

Most banks continue to use the toolkit of model technology generically referred to as value at risk (VaR) for measuring and managing their exposure to market risk at the portfolio level. Technically, VaR represents the maximum expected dollar loss that could be experienced, given a specified confidence level, over a specified time horizon.[10] While originally developed to measure market risk in the trading book, this approach has, to some extent, been extended to other areas, such as market risk in the banking book and even credit risk.

Chart 3 shows the recent trend in bank VaRs, calculated as an aggregate of the major Canadian banks. Note that reported VaRs tend to be small compared with the gross value of trading book assets reported in Chart 2. This is because the VaR reflects the netting of various offsetting balance sheet and off-balance-sheet items and can be reduced by diversification.

The reported VaR numbers have recently started to rise, reversing the declining trend that had been in place since the start of the decade. Given the declining trend in volatility, the rising VaRs are likely driven by larger exposures. However, the chart shows that VaRs remain at a low

9. Market risk is normally considered to include foreign exchange risk, interest rate risk, equity risk, and commodity risk.
10. For example, suppose a bank reported 1-day VaR of $10 million at 99 per cent. This means that, 99 days out of 100, the trading portfolio should not lose more than $10 million.

proportion of Tier 1 capital. Reported VaRs of major Canadian banks tend to be smaller than those of many of their global peers.

A review of bank annual reports suggests that the majority of their trading book assets and liabilities (excluding derivatives) are valued based on observable prices. For the most part, however, over-the-counter derivatives are valued based on modelled prices; exchange-traded derivatives normally have quoted prices. According to the banks, the majority of these modelled values are based on observable parameters (e.g., yield curves or implied volatility on a stock index), with the remainder having significant unobserved parameters (e.g., default correlation). For more on this issue, see CSFI (2006).

Liquidity risk

Liquidity risk is the risk that a bank cannot meet a demand for cash or fund its obligations because of its inability to liquidate assets or raise funds in a timely manner at a reasonable price. While banks may have access to central bank lender-of-last-resort facilities in extremis, they are expected to make arrangements to meet their liquidity needs in all currencies relevant to their business (Bank of Canada 2004).

Effective management of liquidity risk at banks is essential to ensuring that core businesses continue to function under adverse circumstances. In today's interconnected markets, liquidity risk presents certain challenges from a conceptual and measurement point of view. Indeed, the management of liquidity risk takes on an even greater significance when its interaction with, and potential amplification of, market and credit risk during periods of market stress is considered.[11]

Banks typically manage liquidity on a global consolidated basis. As with other types of risk, diversification of funding sources is one element of managing liquidity risk. Banks diversify these sources across maturities, customer types, markets, currency, and regions. They monitor the balance between their core deposits (comprising customer accounts and term deposits), which are more stable, and wholesale deposits, which are usually more volatile and for shorter terms.[12] Relatively new techniques, such as securitization, have helped to diversify funding sources.

Banks also set and adhere to limits with respect to the key elements of liquidity risk, such as minimum thresholds for very liquid assets. They maintain contingency plans for liquidity and conduct regular stress testing to gain confidence in their ability to operate under a liquidity crisis.

Operational risk

Operational risk can be defined as the risk of loss resulting from inadequate or failed internal processes, people, and systems or from external events. It is important to note that these risks have been around for a very long time and are inherent in the way a bank runs its business. However, practices for managing operational risk have assumed a greater profile because of new requirements under Basel II, which inject more formality into the measurement of operational risk, and in the wake of foreign bank failures that occurred as a result of breakdowns in operational controls.

Operational risk can take various forms. It can involve people (incompetence or fraud), system failures (breakdowns in systems or technology), and process failures (i.e., back-office problems).

By its nature, operational risk, which is present in all activities, is difficult to avoid. In contrast to financial risks, such as credit risk and market risk, there are few traded instruments to help mitigate this risk, although in some cases it can be managed through insurance contracts. Operational risk is typically managed through rigorous internal processes and controls. Banks have a long history of extensive and well-documented formal procedures. Moreover, internal audit groups play an active role in testing internal controls, with support from external auditors.

In the course of our interviews, banks indicated that their expansion into various financial markets is demanding more power and

11. It is worth noting some commentary in a recent Bank of England *Financial Stability Report* in the context of the U.K. banking system. "The severe crystallization of credit, market and liquidity risk in combination could lead to a material erosion of UK banks' capital, with potential knock-on effects to supporting markets, institutions and infrastructures" (Bank of England 2006).

12. Wholesale funding entails issuing relatively large deposits to institutional and corporate depositors.

sophistication from IT systems. This, in turn, poses challenges for gathering information from disparate sources and legacy systems that are expensive to replace. Some banks are shying away from some of the most complex financial products, apparently because of the challenges in understanding the associated risks. Instead, they are spending time and resources looking for ways to streamline their supporting infrastructure, including IT.

The recent trend towards strengthening corporate governance, noted earlier, has been very helpful in dealing with operational risk. Examples include the greater involvement of boards of directors and the growing role of independent directors in risk governance. There has also been a growing focus on business contingency planning (BCP) to cope with potential external shocks to business, such as terrorism and pandemics.

Several banks are building databases on various types of operational risk incidents to allow them to better understand and measure this type of risk. Some Canadian banks are actively involved in a banking industry initiative to develop industry-wide databases on operational risk events that can be used to develop more sophisticated measures of operational risk.

Issues and Challenges

We will now briefly address some important issues and challenges related to bank risk-management practices going forward.

Limitations of risk models

Quantitative models have limitations that can restrict their scope. They require a large amount of high-frequency data to estimate distributions. Hence, they tend to excel in the management of market risk, given the large amount of data available on financial asset prices. They are more difficult to implement for credit, liquidity, and operational risk.

These models, such as VaR, tend to be very sensitive to model parameters, such as market volatility and correlations between risks (which are difficult to estimate). Certain types of risk, such as liquidity risk, currently can be incorporated in only a rudimentary manner, while other risk factors (such as competitive responses and feedback effects) are difficult to model.

Lastly, most risk models assume that future distributions will be the same as the distributions estimated from historical data. These limitations may make it difficult to apply these models in crisis events that have systemic impacts (Bouchaud and Potters 2003; Daníelsson 2002). For example, VaR is "backward looking," being based on historical experience, and may not accurately capture risk if volatilities and corre-lations suddenly change in a crisis event.

Banks are well aware of the shortcomings associated with quantitative models. Judgment is always involved to a greater or lesser extent, so that the process never becomes purely mechanical. Given the growing importance of models, banks have well-developed processes in place for managing model risk.[13] These include strict procedures for model development, independent validation (including backtesting and stress testing), and implementation.[14] Banks also have procedures in place to prescribe reserves against model risk.[15]

The growing importance of stress tests

Banks are also addressing the problems and limitations of quantitative models through a wide variety of stress tests.

Stress testing is used to assess the impact of uncertainties arising from model limitations or data availability. It involves using the models to evaluate the impact on the chosen risk measure of "what if" scenarios involving extreme events.[16] For example, for market risk, it can help to gauge the impact of sudden changes

13. Model risk can be broadly defined as the risk of error in estimates caused by inadequacies in the model or its implementation (Dowd 2005).
14. Backtesting and stress testing are obligatory under Basel I and II. They are among many procedures used by supervisors to evaluate the reliability of bank risk models.
15. With regard to mitigating model risk, it is interesting to note that some banks suggest that a constructive consequence of the growing reliance on collateral to manage counterparty risk is the need for counterparties to mutually agree on collateral valuation, providing an independent form of model validation.
16. The Basel Accord and Basel II require banks to have a program for rigorous stress testing, including significant past events. A summary of the BIS stress-testing survey was included in the June 2005 issue of the *Financial System Review* (p. 21).

from current norms in volatility or correlations. Thus, stress tests frequently contribute to the setting of risk limits.

Stress tests at large Canadian banks tend to vary in terms of degree of development by type of risk. They appear to be most developed with respect to market risk and structural interest rate risk (interest rate risk residing in the banking book) and perhaps less developed for liquidity risk and credit risk. However, stress testing for credit risk is rapidly evolving, propelled by changing international standards, largely related to Basel II, which comes into effect in Canada in late 2007 (Box 1).

Banks run stress tests based on both hypothetical and historical scenarios. Under a hypothetical scenario, one or more risk factors are shocked to simulate extreme events. In a historical scenario, movements in risk factors are based on observations of actual prior periods of financial stress.[17] Banks are not quite at the point where they can reliably take into account correlation effects across the major categories of risk. However, the field continues to evolve.

Banks state that they view the results from these stress tests as valuable for better understanding the risk profile of an institution, for setting risk limits, and as a communication tool to assist management in linking strategic planning with risk management. They are also used in the supervisory process to evaluate the reliability of bank models.

Integrated risk management

Important challenges remain for Canadian and foreign banks in areas such as moving towards a full-enterprise, risk-management system that links information on different risk types and across the banking and trading books, so that banks can have a holistic perspective on their risk exposures. Like their foreign counterparts, Canadian banks have been working towards—but have not yet achieved—the integration of measures for market risk, credit risk, and liquidity risk through stress tests to obtain a more complete view of total exposure to financial risk. At this stage, formal macroeconomic models are not widely used.[18]

Clearly, the greater integration of risk management is an important challenge for large and complex Canadian and other global banks going forward, and they continue to devote significant resources to achieving it.

While endeavouring to address the problem of integration, risk models will continue to grow in complexity as banks develop and utilize sophisticated financial products to meet the needs of their clients. The challenge is for risk practices to keep up with rapid changes in products and strategies.

Conclusion

The competitive pressures in banking are increasing the pace of innovation and the complexity of the business. Like their foreign counterparts, Canadian banks are coping with these pressures in diverse ways and have developed improved governance practices and risk-management infrastructures that meet their differing business strategies.

Interviews with foreign banks suggest that the practices of Canadian banks are broadly in line with those of their global peers. Furthermore, the banks—like their global counterparts—have made significant progress in improving risk-management practices. This has been motivated largely by business needs, but Basel II has also played a role in building momentum for change within the industry. Past experience points to the need for continuous vigilance in internal controls and risk management by the banks.

Risk-management practices are also affecting the global financial system. Over the past decade, the financial system has shown considerable resilience during a number of market and credit episodes, adding credence to the view that risk management has made the financial system more robust (Kohn 2005). This view should, however, be tempered by the reality that these events occurred during a period of largely favourable macroeconomic conditions.

17. Commonly used historical scenarios include the 1987 stock market crash, the 1994 bond-market decline, and the 1998 Russian default/LTCM crisis.

18. However, Canadian banks are participating in a macro stress-test exercise this year as part of an update of the IMF's assessment of the stability of the financial system through the FSAP program.

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Sectoral Default Rates under Stress: The Importance of Non-Linearities

Miroslav Misina and David Tessier

The purpose of aggregate-level stress testing is to identify the circumstances that could impair the functioning of the financial system and have economy-wide (systemic) implications. In models typically used for stress tests of aggregate credit risk, macroeconomic shocks are assumed to affect financial institutions via their impact on either individual or industry-level default probabilities.[1] Therefore, sound modelling of the relationship between macroeconomic variables and defaults is of considerable importance.

In this report, we examine how the functional form used in the specification of default regressions affects the nature of the responses of default probabilities under stress. In particular, we argue that the assumption of a linear relationship imposes severe restrictions on the responses of default probabilities to macroeconomic shocks. These restrictions are particularly undesirable in stress-testing exercises. To remedy this problem, we introduce non-linearities in a simple, but effective, way and illustrate their impact on responses with a series of examples.

We begin with a general discussion of the nature of the restrictions that linearity implies and their undesirability in the context of stress testing. This is followed by an empirical exercise in which we compare the performance of linear and non-linear models by varying the severity of a recession and the initial state of the economy. In the concluding section, we draw broader implications of our results for stress testing.

1. See, for example, Jiménez and Mencía (2007), Virolainen (2004), or Wilson (1997). Misina, Tessier, and Dey (2006), summarized in this *Review*, provides a general description of the structure of these models.

The Importance of Taking Non-Linearities into Account

Let π denote the default probability and x a set of explanatory variables. The relationship between π and x can be expressed as

$$\pi = f(x).$$

Specifying f as a linear function is a simple solution but has a number of undesirable consequences. To see this, consider the following example in which $\pi = ax$. The impact of changes in x is given by

$$\frac{d\pi}{dx} = a.$$

This simple expression makes it clear that the restrictions that linear models impose on responses are rather severe and have the following properties.

- *Symmetry:* the magnitude of the response is the same, regardless of whether the shock is positive or negative.
- *Proportionality:* the response is proportional to the change in the exogenous variable.
- *History independence:* the response is independent of initial conditions (x).

None of these restrictions is appealing in the context of stress-testing exercises, where asymmetry, non-proportionality, and history dependence would seem to be desirable properties. For example, one would expect a negative shock to have a different impact on companies, depending on whether the economy was in recession or in an expansionary phase.

Stress tests generally select scenarios that are severe but plausible, with the result that experimental shocks are usually quite large. With shocks of such magnitude, linear approximations to a possibly non-linear process might prove to be particularly poor.

To develop response profiles with features more suitable for stress testing, the assumption of linearity has to be relaxed. This can be done by introducing higher-order terms, while preserving additivity. The following non-linear specification,

$$\pi = ax + bx^2 + cx^3,$$

delivers the response function

$$\frac{d\pi}{dx} = a + 2bx + 3cx^2,$$

which generates asymmetric, non-proportional, and history-dependent responses. This type of response function implies that the impact of shocks would differ in good and bad economic states, both qualitatively and quantitatively.

Examples

The examples in this section build on the linear specification of default-probability regressions in Misina, Tessier, and Dey (2006). In that paper, regressions on sectoral default probability take the form

$$\ln\left(\frac{\pi_t}{1-\pi_t}\right) = \mu + \sum_{l=1}^{L} \beta_l X_{t-l} + e_t.$$

The explanatory variables are Canadian macroeconomic variables (real GDP and real interest rates) and their lags. One way to introduce non-linearities is to retain additivity but include higher-order terms:

$$\ln\left(\frac{\pi_t}{1-\pi_t}\right) = \mu + \sum_{l=1}^{L} \beta_l^{(1)} X_{t-l} + \sum_{l=1}^{L} \beta_l^{(2)} X^2_{t-l} + \sum_{l=1}^{L} \beta_l^{(3)} X^3_{t-l} + e_t$$

The key advantages of introducing non-linearities in this manner are simplicity and flexibility. The addition of other variables and higher-order terms does not present difficulties, since the relationship of the parameters remains linear.

The data used to estimate these regressions are the growth rate of real Canadian GDP, the real interest rate on medium-term business loans,[2] and sectoral default rates as proxies for sectoral default probabilities. The data cover the period 1987Q1 to 2005Q4. Details on constructing sectoral default rates are given in Box 1.

To examine the impact of introducing non-linearities, we focus on the behaviour of predicted sectoral default rates following the Canadian recession of the early 1990s, which peaked between 1990Q4 and 1991Q3. The forecasts are given for the period starting in 1991Q4.[3] Chart 1 contains the paths of historical and predicted default rates, where the latter are estimated using linear and non-linear models.[4] The benefit of non-linearities is particularly evident in this stressful period, when the default rate reached its historical peak. As is clear from the chart, the non-linear model captures the actual default rate over this period much better than the linear model. As the impact of the recession diminishes, the paths developed under these two specifications tend to converge.

To get a better sense of the limitations of the linear model, we perform two sets of experiments: (i) a change in the severity of the recession; and (ii) a change in the initial conditions. The experiments are performed by exogenously changing Canadian GDP over the period 1990Q4 to 1991Q3, and deriving the implications for the GDP and interest rate in the subsequent period using a two-variable vector-autoregression model.[5]

2. The real medium-term rate is equal to the nominal rate minus inflation expectations, where the latter was calculated as a geometric mean of the five-years-ahead realized inflation rate.
3. Our specification includes four lags, which fully take into account the period 1990Q4 to 1991Q3.
4. In this report, we show the results for the manufacturing sector only. The results for other sectors (accommodation, construction, retail) are qualitatively similar.
5. We applied the method proposed in Jordà (2005), which uses a set of sequential regressions of the endogenous variable shifted several periods ahead.

Box 1

Constructing a Proxy for Sectoral Default Rates

Default probabilities are a key input in any model of credit risk. To arrive at reliable estimates of the relationship between the macroeconomic variables and defaults, a long series of data on historical defaults is required. Although some data are available for large publicly traded companies, a long series with broad coverage is not available for Canada. This box describes the construction of such a data set and the issues involved in this process.

Misina, Tessier, and Dey (2006) used bankruptcy rates (the ratio of bankruptcies in a sector to the total number of establishments in that sector) as a proxy for sectoral default probabilities. Data were obtained from the Office of the Superintendent of Bankruptcy (numerator) and Statistics Canada (denominator).

There are two issues with this choice. First, bankruptcy is not a good proxy for the events that affect banks and their economic capital. Bankruptcy is the last stage of a company's distress. Prior to that, a company would typically go through two stages (missed interest payments, distressed exchange),[1] both of which result in losses to the lender. To capture all these credit events, rating agencies use a broad category of default that includes anything from missed payments to bankruptcy. Use of the number of bankruptcies will lead to an underestimation of the number of credit events that affect the credit risk of banks.

Second, the total number of establishments in a sector does not accurately reflect banks' lending practices. Only the establishments that borrow from the banks are relevant. Use of the total number of establishments will, again, underestimate the number of credit events that have an impact on the credit risk of banks.[2]

To deal with these issues, we start with the data on bankruptcy rates and construct proxies that better reflect credit events that affect banks.

The adjustment was based on the following considerations:

- Reported data on default events from Moody's for the period 1989 to 2005 indicate that bankruptcies account for roughly one-third of default events.[3]
- Statistics Canada's (2004) "Survey of Financing of Small and Medium Enterprises" (SMEs) indicates that small and medium-sized enterprises account for 99.7 per cent of business establishments in Canada.[4]
- Statistics Canada's (2005) "Survey of Suppliers of Business Financing" offers an exceptionally detailed picture of banks' lending activities to small and medium-sized enterprises in Canada, which includes information on debt financing by authorization size of client businesses (Section B2), as well as debt losses by authorization size of client businesses (Section B6), for the years 2000–05. This information can be used to construct historical default rates for that period.[5]

1. This refers to a situation in which the issuer offers bondholders a new security or a package of securities that amount to a diminished financial obligation, with the purpose of helping the borrower avoid default.
2. In addition, the number of establishments overestimates the number of companies in a sector. Given that bankruptcies are reported at a company level, use of the number of establishments in the denominator will lead to a further underestimation of the bankruptcy rate.
3. "Default and recovery rates of Canadian corporate bond issuers, 1989–2005" (April 2006). Moody's provides the data on default rates as well, but the rates are computed relative to the number of companies they cover. That number is quite small, especially for the period prior to the mid-1990s, resulting in large fluctuations in default rates driven by a very small number of default events.
4. http://strategis.ic.gc.ca/epic/site/sbrp-rppe.nsf/en/rd00999e.html, Table 2.
5. Data prior to 2000 do not exist, since the first survey was conducted in that year. (http://sme-fdi.ic.gc.ca/epic/site/sme_fdi-prf_pme.nsf/vwapj/SurveyofSuppliersTables_Eng.pdf/$FILE/SurveyofSuppliersTables_Eng.pdf)

Box 1

Constructing a Proxy for Sectoral Default Rates (cont'd)

The adjustment process, then, consists of two steps:

- First, we use the information from Moody's to convert bankruptcies into defaults.[6] The adjustment for each year is done separately by scaling up the bankruptcy rate for that year by the ratio of defaults to bankruptcies for that year, to take into account the difference in dynamics between bankruptcies and defaults.[7]
- We then compare the adjusted series with the observed default rates in 2000–05, and make additional adjustments, as necessary. These adjustments involve scaling the whole series up or down to match the survey data as closely as possible.

Charts A and B contain the adjusted series, and Chart C compares the adjusted rates with the historical default rates for 2000–05. The match over the past five years is quite close, both in year-to-year and average comparisons. Nonetheless, it should be kept in mind that the variable adjustment is based on a small sample of bankruptcies and defaults documented by Moody's.

Chart A Constructed Proxies for Sectoral Default Rates

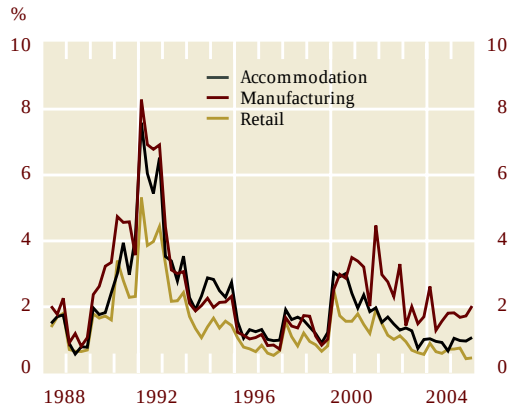


Chart B Constructed Proxies for Sectoral Default Rates

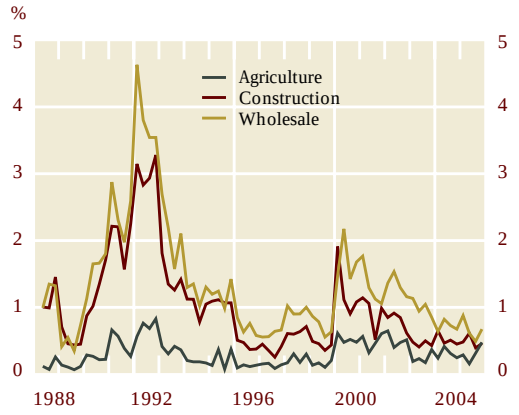
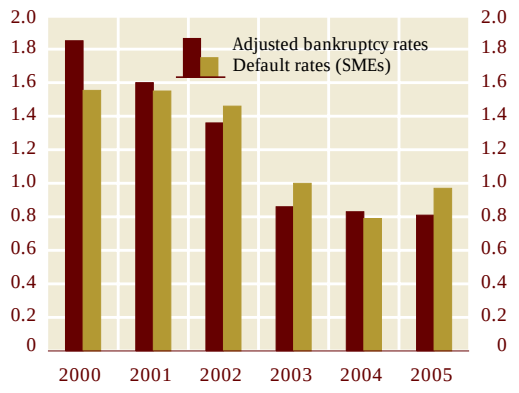


Chart C Comparison of Average Default Rates



6. Given that the Moody's data cover mostly large publicly traded companies, the relationship between bankruptcies and defaults in Moody's data set may not be representative of that relationship more generally. One can argue, however, that the second step of the adjustment process corrects for any biases that might be present here.
7. The difference in dynamics is due to the fact that credit events, such as missed interest payments, are much more sensitive to changes in business conditions than bankruptcies, which represent the last stage of distress and typically occur with a lag.

Chart 1 Historical and Predicted Default Rates: Manufacturing Sector

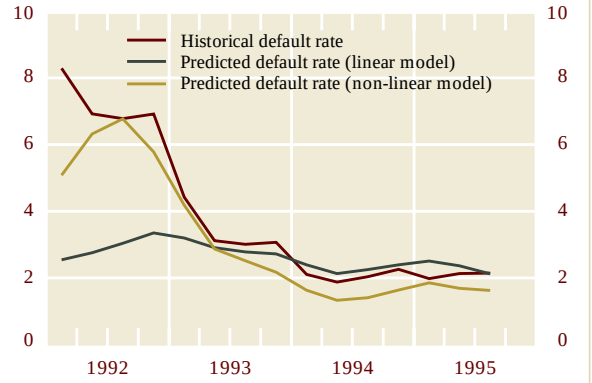


Chart 2 Impact of a Change in the Severity of Recession on Default Rate: Linear Model

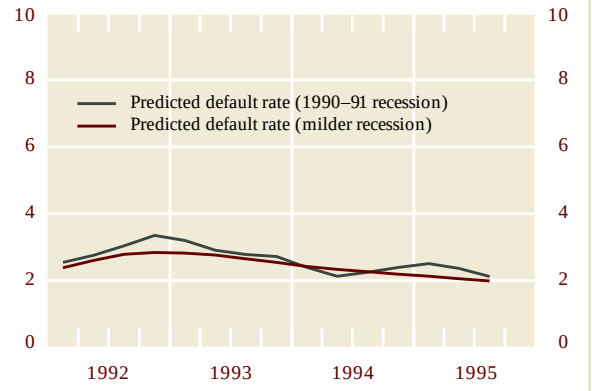
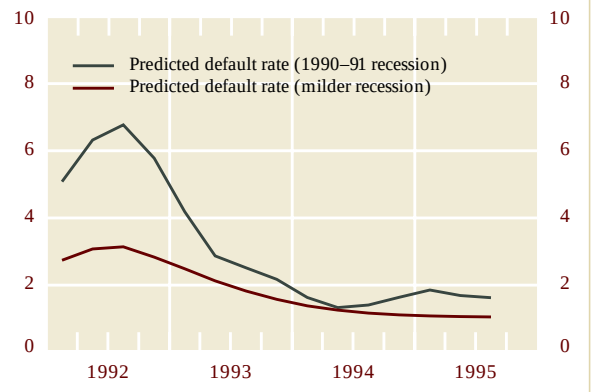


Chart 3 Impact of a Change in the Severity of Recession on Default Rate: Non-Linear Model



Change in the severity of recession

In this experiment, we assume that the recession is very mild (10 per cent of the 1990–91 recession). This is done by multiplying the observations of GDP in the 1990Q4–1991Q3 period by 0.1. All else being the same, this should result in a significant decrease in default rates predicted by the model.

Charts 2 and 3 contain the results for linear and non-linear models, respectively. In both charts, we compare the default rate paths predicted under the 1990–91 recession to the paths predicted under our much milder hypothetical recession. The non-linear model is clearly more responsive than the linear one, and the difference is more significant the larger the shock. The key reason is that the non-linear model is not bound by the assumption of proportionality, and therefore the shocks are magnified. This is not the case with the linear model.

Change in the initial conditions

In this experiment, we change the conditions prior to the recession by converting them from unfavourable (approximately zero per cent GDP growth) to favourable (3 per cent GDP growth). The latter is similar to the conditions in Canada over the past few years. One would expect that, starting from these more favourable conditions, a decline in GDP of the magnitude observed in 1991 would have a much smaller impact than was the case at that time, since favourable economic conditions put companies in a better position to absorb shocks.

Charts 4 and 5 contain the results for linear and non-linear models. In both cases, there is a decline in default rates relative to the original setting, but it is much more significant in the case of the non-linear model. Indeed, this model now predicts only a slight change in default rates, while the responses in the linear model are limited to an approximately parallel shift down.[6] This example highlights the invariance of the shape of the response in the linear specification to changes in initial conditions.

6. The shift would be exactly parallel if the changes in both explanatory variables were fixed exogenously. In our model, the interest rate is determined endogenously.

One implication of this result is that if the initial conditions are favourable, a much larger decline in GDP would be needed to induce a response in the default rates comparable to that observed in the 1991 recession.

Conclusions

The findings described here raise questions about the suitability of linear models for stress testing. The net result of the limited ability to generate plausible behaviour around extreme events, together with a limited responsiveness to initial conditions, is that these models tend to underestimate the impact of shocks during bad times, and fail to take into account the fact that favourable initial conditions put the economy in a relatively better position to withstand shocks of a given magnitude. Our solution to this problem is to relax the assumption of linearity and replace it with a more plausible alternative.

Of course, the importance of non-linearities will depend on the nature of the sample and the incidence of stressful episodes. Even when there is only one stressful episode in the sample, the non-linear terms may capture it well, but the robustness of the specification might be an issue. To fully assess the extent of the problem, if any, a sample with more than one stressful episode is needed.

Chart 4 Impact of a Change in Initial Conditions on Default Rate: Linear Model

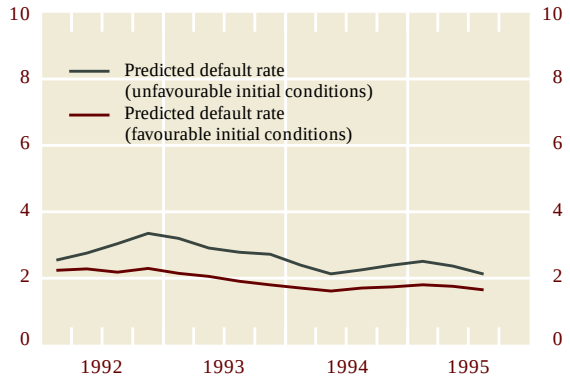
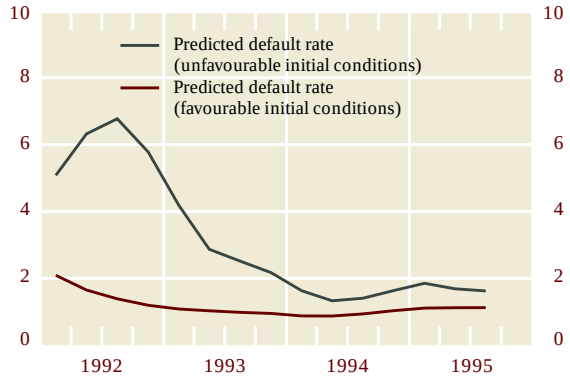


Chart 5 Impact of a Change in Initial Conditions on Default Rate: Non-Linear Model



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