Reports

Introduction

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

For the first time, the *Financial System Review* (FSR) includes the annual report on the Bank of Canada's oversight activities under the Payment Clearing and Settlement Act. This report covers the Bank's role with respect to the three designated systems (the Large Value Transfer System, CDSX, and CLS Bank) in 2005, as well as other Bank activities that support this role. This article by Clyde Goodlet is an elaboration of the discussion that appears in the *Bank of Canada Annual Report* and will be an annual feature of the FSR. For more information on the Bank's oversight role, see the article by Walter Engert and Dinah Maclean in the Policy and Infrastructure Developments section of this FSR.

In Canada, as in other G-10 countries, there is a growing need for investment capital to upgrade aging public infrastructure. At the same time, investment in infrastructure is gaining acceptance among institutional investors, particularly defined-benefit pension funds and life insurers. Globally, public-private partnerships (PPPs) are gaining more acceptance as a model for the alternative delivery of public infrastructure and services. Although there have been a number of PPPs in Canada, the market is still considered to be in its infancy. To take advantage of the availability of capital and to draw on the private sector's skills and expertise, some Canadian provinces now plan to increase the use of PPPs, suggesting that the market could grow significantly over the next decade or more. In the report, "The Market for Financing of Infrastructure Projects through Public-Private Partnerships: Canadian Developments," Elizabeth Woodman examines market developments in Canada, including a brief discussion of how the need for increased investment in infrastructure is prompting a greater role for PPPs. She also looks at the characteristics of a typical PPP; the international experience with PPPs; the structuring and financing of a PPP, using examples of projects recently launched in Canada; PPP as an investment; and what is required to support the development of a viable, efficient PPP financing market in Canada.

Monitoring risks to the stability of financial and non-financial public corporations is important for central banks, owing to the systemic importance of these sectors. Previous issues of the *Financial System Review* have explored the use of corporate financial information to monitor the health of public corporations in Canada. Information from financial markets can also be used in this analysis. Central banks use market-based indicators because they are forward looking and are available more frequently than accounting information. In "Using the Contingent Claims Approach to Assess Credit Risk in the Canadian Business Sector," Michal Kozak, Meyer Aaron, and Céline Gauthier explore one such method, the contingent claims approach (CCA), which uses Merton's extension of the option-pricing model to assess credit risk. The authors apply the CCA to non-financial public corporations and the six largest Canadian banks.

Bank of Canada Oversight Activities during 2005 under the Payment Clearing and Settlement Act

Clyde Goodlet

Since 1996, under the Payment Clearing and Settlement Act (PCSA), the Bank of Canada has had formal responsibility for the oversight of clearing and settlement systems that could be operated in a manner that would pose systemic risk. 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 in other systems. A clearing and settlement system is the set of instruments, procedures, and rules for the transfer of funds or other assets among system participants. Typically, there is agreement among the system participants on the technical infrastructure to be used.

This report summarizes the Bank of Canada's oversight activities under the PCSA during 2005. An article on the general oversight strategy and processes used by the Bank is presented on page 57 of this issue (Engert and Maclean 2006).

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 of Canada and must satisfy the Bank that they have appropriate risk controls in place to deal with concerns related to systemic risk. Three systems have been designated by the Bank: the Large Value Transfer System (LVTS), CDSX, and 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. During 2005, it processed about 18,000 transactions per day, worth approximately $145 billion. There have been few changes to the LVTS design or rules during its years of operation that could raise concerns about systemic risk, and 2005 was no exception. One important change was made to the system in 2005, however, to permit participants that might be experiencing problems with normal communication mechanisms to send each other payment messages using another route. This alternative mechanism, called the Direct Network, is normally used to send information about LVTS operations. After extensive discussion with the Bank, the CPA developed an arrangement that would permit participants to use the Direct Network to send a limited number of their most important payment messages to other participants should they have difficulties using their customary arrangements. Use of the Direct Network in these circumstances should significantly reduce the possibility of payments gridlock arising from a lack of liquidity in the system and would permit important time-sensitive payments to be made.

A rule change was made to the LVTS to permit the Direct Network to be part of the system. Payment messages sent using the Direct Network will be subject to LVTS risk controls and will benefit from the legal protection afforded such messages under the PCSA. The Bank was satisfied with this rule change, and the rule became operational in November 2005.

An important part of the Bank's oversight process is the use of Memoranda of Understanding (MOUs) with operators of designated systems. MOUs elaborate on the Bank's powers and its exercise of oversight responsibilities as laid out in the PCSA. They also address such questions as confidentiality of information, time frames for review of significant system changes, and the use of minimum standards. Having put such an arrangement in place with the operator of the CDSX, the Bank continued to work with the

CPA during 2005 to develop an MOU applicable to the oversight of the LVTS. The Bank expects that an MOU will be in place before the end of 2006.

CDSX

CDSX is a system for the clearing and settlement of securities transactions in Canada. The system is owned and operated by The Canadian Depository for Securities Limited (CDS) and processed about 300,000 trades daily, worth $200 billion, in 2005.

During 2005, the most important issue dealt with by the Bank and CDS involved potential systemic risk arising from the provision of cross-border services. Early in the year, CDS examined the possibility of consolidating three existing cross-border services into a single service. Under this arrangement, CDS would act on behalf of its participants in the clearing and settlement of equity trades in the U.S. market. Analysis by CDS and the Bank highlighted a number of areas in the structure of the proposed service where the potential to create financial losses for CDS could, in turn, impair its ability to operate CDSX. Of particular concern was the possibility that in the U.S. arrangement for clearing and settlement, transactions that had previously been accepted by the system could be unwound in the event of a participant failure. Further analysis by CDS indicated that it would be difficult to deal with these concerns in an acceptable manner. Consequently, CDS decided not to pursue this initiative and began to determine how they might address risks present in their current cross-border services.

The analysis and discussion regarding the risks posed by cross-border services are a prime example of the Bank's desire to foster effective and co-operative relations with the operators of designated systems. The timely and co-operative interaction between CDS and the Bank served to identify key issues early in the discussions, led to an examination of possible ways to address these concerns and, ultimately, resulted in a decision not to proceed with the original proposal before any significant development resources had been spent.

As part of the analysis of cross-border services, the Bank is also working with CDS to examine how U.S.-dollar liquidity could be accessed in the event of contingency situations to support continuing the operations of CDS and its participants.

Other issues examined by CDS and the Bank during 2005 included the reconstitution of collateral pools and participant funds following a participant's suspension (these pools and funds are an integral part of the arrangements to control systemic risk), methods used by CDS to calculate replacement-cost risk, and other arrangements used by CDS to protect itself as the central counterparty in its Continuous Net Settlement and DetNet services. A number of changes to the CDSX rules followed these examinations and were part of the fourteen rule changes approved by the Bank in 2005.

Bilateral meetings between the Bank and CDS that examine a range of topics related to the operation of CDSX are an extremely valuable part of the Bank's oversight of the system. These meetings provide the Bank and CDS with an opportunity to explore any concerns or questions related to proposed changes to the CDSX on a timely and efficient basis. The Bank can be alerted to possible changes very early in the process and can inform CDS of concerns that it may have, so that they can be dealt with efficiently by CDS as it develops changes to the system. During 2005, the Bank held three such meetings with CDS.

CLS Bank

Introduced in 2002, the CLS Bank now clears and settles foreign exchange transactions in fifteen currencies, including the Canadian dollar. 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 2005 involved its overall operations, and there were no specific changes to the arrangements used to settle the Canadian-dollar portion of foreign exchange transactions.

Four new currencies were smoothly incorporated into the system in December 2004. The U.S. Federal Reserve, which is the lead regulator of CLS Bank, reviewed CLS liquidity and capital policies relative to the standards set for CLS Bank. The results of this review, as well as additional information, were developed in consultation with other central banks that have their currencies settled 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, of course, to confidentiality requirements), the discussion of common oversight policies and approaches, and the coordination of oversight activities.

The G-10 central bank Committee on Payment and Settlement Systems announced that it will carry out a survey on the management of foreign exchange settlement risk at major banks. The survey will be conducted during the first part of 2006, and more than 100 institutions have been invited to participate.

The Bank of Canada continued to work with the Office of the Superintendent of Financial Institutions to encourage Canadian banks to make greater use of CLS Bank for the settlement of foreign exchange transactions. The CLS arrangement is now considered the most effective means through which to mitigate foreign exchange settlement risk. While some Canadian banks initially were very slow to settle their eligible foreign exchange transactions in CLS Bank, most are now doing so.

Other Oversight Activities

To date, most of the Bank of Canada's oversight activities have involved reviewing and analyzing new design proposals for systemically important systems or major innovations to these systems. With the establishment over the past seven years of a number of systemically important clearing and settlement systems that adequately and efficiently control systemic risk, the Bank conducted an extensive review in 2005 of its oversight strategy and processes. As a result, the Bank decided to implement 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, which resulted in a clearer mandate and oversight processes.

Over the past few years, the Bank has also enhanced its oversight resources to provide for greater analytical capability and better backup for important staff functions. These changes have enhanced the Bank's ability to carry out high-quality oversight of systemically important systems with a small number of staff focused on risk issues, while collaborating with the private sector to bring about safe and efficient clearing and settlement systems.

The Bank has also become more 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. The co-operative arrangement has been made more robust through a documented clarification of roles and responsibilities of the lead overseer (the National Bank of Belgium), other central banks, and the external auditors of SWIFT.

In line with international developments, changing perceptions of best practices, and domestic imperatives, the Bank of Canada continues to work with the operators and participants of systemically important Canadian clearing and settlement systems in their efforts 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 2005, the operators of these systems took steps to make their continuity of operations more robust by locating business staff at separate sites and by improving their ability to recover from severe operational disruptions in less than the current target of two hours.

The Bank has also been active in increasing its own ability to operate in a wide variety of circumstances. In 2005, it completed a three-year effort to improve the ability of its backup site to respond effectively to serious operational disruptions. It is examining other potential changes to its business-continuity plans, including the possibility of geographically splitting its banking-service operations to reduce the potential impact of so-called "wide-area disruptions." The Bank has also communicated its views on the crucial role of systemically important clearing and settlement systems to certain emergency-management organizations, with a view to having them give priority to supplying these systems with essential inputs, such as hydro, diesel fuel, or other municipal services.

Published Research Relevant to the Bank's Oversight Function

During 2005, the Bank published the following work carried out by its staff:

- McVanel, D. 2005. "The Impact of Unanticipated Defaults in Canada's Large Value Transfer System." Bank of Canada Working Paper No. 2005-25.
- Arjani, N. 2005. "Simulation Analysis: A Tool for Examining the Balance between Safety and Efficiency in Canada's Large Value Transfer System." Bank of Canada *Financial System Review* (December): 55–63.

Bank staff collaborated with others in the following areas:

- Tripartite Study Group (Bank of Canada, Department of Finance, Canadian Payments Association). 2005. "Conditions for Direct Participation in the ACSS." Consultation Report, Canadian Payments Association, June.
- With the Bank of England, the Bank of Finland, and the Federal Reserve Bank of New York, the Bank of Canada enhanced the functionality of a payment system simulator created by the Bank of Finland. The simulator is a useful tool for carrying out research on clearing and settlement systems.

Reference

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* (current issue).

The Market for Financing of Infrastructure Projects through Public-Private Partnerships: Canadian Developments

Elizabeth Woodman

This report examines developments in the market for private financing of public infrastructure projects through public-private partnerships (PPPs). In Canada, as in other G-10 countries, there is a growing need for governments to allocate capital to upgrade aging public infrastructure. At the same time, infrastructure investment is gaining increasing acceptance among institutional investors, particularly life insurers and pension funds; its long-term nature is well suited to their investment horizons. To take advantage of the availability of capital and to draw on the private sector's skills and expertise, some Canadian provinces plan to increase the use of PPPs, which suggests that the market could grow considerably over the next decade or more.

This report begins with a review of recent developments in the PPP market, including a brief discussion of how an increased focus on infrastructure investment is prompting a greater role for PPP. It then outlines the characteristics of a typical PPP; the international experience; the structuring and financing of a PPP, using examples of recently launched projects; PPPs as an investment; and requirements for the development of a viable, efficient PPP financing market in Canada.

Investment in Public Infrastructure Required

The need to address what is perceived to be a large and growing deficit in public infrastructure[1] has become a key public policy issue.[2] Much of Canada's existing stock of infrastructure requires repair or replacement, partly because of decisions to defer investment during the 1990s, when government spending at all levels was reduced in an effort to eliminate large fiscal deficits (Mirza and Haider 2003; Harchaoui, Tarkhani, and Warren 2004). Investment has also lagged in terms of new facilities to accommodate growth and the specific requirements of an aging population.

Addressing the infrastructure gap is likely to require increased spending over the medium term. To this end, some provincial governments have already increased the share of overall budget expenditures allocated to infrastructure investment. Several provinces are also looking at more efficient and innovative ways to deliver infrastructure and the associated services. One alternative, PPPs, has been shown to offer an efficient and cost-effective method of alternative delivery, provided that PPP contracts are well designed. Some provinces have recently created agencies dedicated to PPPs in order to build the public sector expertise required to develop a more effective, efficient, and transparent process for the implementation of PPPs.[3]

What Are PPPs?

There is no widely accepted definition of a PPP and, in practice, these arrangements are quite

1. The stock of infrastructure includes highways, public transit and transportation facilities, water supply, waste-water-treatment facilities, prisons, ports, schools and universities, hospitals, and utilities, some of which are owned by the private sector (e.g., railways).

2. See, for example, TD Bank Financial Group (2004). Estimates of the magnitude of the infrastructure "deficit" vary considerably, partly because of definitional differences and the high level of subjectivity involved in assessing "need" (Dodge 2005).

3. These are Partnerships B.C. (May 2002); Quebec's Agence des partenariats public-privé du Québec (Dec. 2005); and Ontario Infrastructure Projects Corporation (Nov. 2005), which replaces SuperBuild Ontario, created in 1999. Alberta has recently (2003) prepared a framework to evaluate infrastructure projects for PPP potential.

diverse. The Canadian Council for Public-Private Partnerships (CCPPP) defines a PPP as "a cooperative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards." PPPs permit private financing, design, construction, operation and, possibly, temporary ownership of an asset, while at the same time, the government remains involved as a partner. Such an arrangement offers an alternative to both traditional government delivery and privatization; projects can be structured according to the desired level of private sector involvement and the appropriate level of risk sharing.[4]

One benefit of PPP is that risks can be allocated to the partner best able to manage a particular risk, thus permitting a more efficient process. This requires the formal identification, quantification, and pricing of risk. In practice, the proper pricing of risk presents a considerable challenge, since there is no market for the provision of public goods and services. Ideally, efficient pricing mechanisms would develop over time as more PPP projects are undertaken. Risks that can be transferred to the private sector include those associated with design and construction, financing, operation, maintenance, and changes in technology.

For a PPP to be effective, it must demonstrate that it offers taxpayers value for money (VFM). VFM is complex to measure, since it goes beyond a comparison of the capital cost of a PPP relative to that of traditional procurement. Ideally, a PPP would be structured to put private capital at risk over the project's full life cycle, which might be from construction through to operation and maintenance. If risk is properly priced and incentives appropriately managed within well-developed contracts, PPP should contribute to greater efficiency and innovation, increasing the likelihood that more projects can be completed on time and within budget. The private sector can add VFM through a PPP in several ways, including exploiting economies of scale from multiple operations; facilitating the introduction of user charges, thereby achieving a better balance between supply and demand; integrating operational requirements in the basic design; and utilizing knowledge of and experience with new technologies (Allan 1999, 19).

Not all projects are well suited to PPP. Many projects (such as public transportation) that offer a public good requiring a high level of government subsidy are best handled using traditional government delivery. The international experience demonstrates that PPPs account for only a small fraction of overall capital spending on infrastructure.[5] Typically the projects felt to be best suited for PPP are large and capital intensive; have identifiable revenue streams; have some risks that can be transferred to the private sector; offer an opportunity for innovation in design, construction, or operation; have defined service specifications that are easily measured; and target areas where sufficient private sector expertise exists to permit a competitive process. From the perspective of the government and taxpayers, it is desirable that PPP projects are in the public interest, demonstrate VFM and, within the constraints of commercial confidentiality, are undertaken within a transparent process with full public accountability.

In Canada, PPPs have been used for a number of years. The best known are large transportation projects, such as Highway 407, an electronic toll highway in southern Ontario, and the Confederation Bridge that links New Brunswick and Prince Edward Island. There have also been numerous smaller projects in areas such as waste-water treatment, education, health care, and municipal facilities, such as courthouses and recreational centres. Although not all provinces have embraced PPPs, their use has recently gained momentum, particularly in British Columbia, where the assessment of projects for PPP potential is becoming a routine aspect of infrastructure development.[6]

4. In traditional government delivery, the private sector is typically engaged on a short-term basis to design and build a project. Its subsequent maintenance and operation are the responsibility of the public sector, although, over the past two decades, contracting out has become more common. See Levac and Wooldridge (1997).

5. Even in countries with established PPP markets, such as the United Kingdom, PPPs account for less than 15 per cent of total government capital spending. British Columbia and Ontario plan to use PPPs for about 10 per cent of planned investment.

6. A project tracker maintained by the CCPPP lists 54 PPPs that have been announced over the past few years, most of them in British Columbia and Ontario. Most of these projects are in health care and transportation. See <www.pppcouncil.ca/resources_project_tracker.asp>.

Table 1

Selected Recently Launched PPPs

Project	Province	Model	Value (Can$ millions)
Sea-to-Sky Highway	B.C.	DBFO 25 yr. (2/3 capital cost)	516.0
Canada Line (rapid transit)	B.C.	DBFO 35 yr.	1,900.0
Kicking Horse Canyon Highway upgrade (Phase 2)	B.C.	DBFO 25 yr.	n/a
William Bennett Bridge	B.C.	DBFOM 27 yr.	157.3
Abbottsford Hospital & Cancer Centre	B.C.	DBFOM	355.0
S.E. Edmonton Ring Road	Alberta	DBFOM 30 yr.	390.0
Bruce A Nuclear Restart Project	Ontario	n/a	4,250.0
Royal Ottawa Hospital	Ontario	DBFO 20+ yr.	148.0
William Osler Health Centre	Ontario	DBFO 25 yr.	550.0
Trans-Canada Highway (final)	N.B.	DBFOM 25 yr.	543.8

International Experience

PPP is gaining increasing acceptance internationally as a model for the alternative delivery of public infrastructure and services, and a growing number of countries have implemented PPP programs. The United Kingdom, which began using PPPs in the 1980s, has the longest track record. Under the Private Finance Initiative (PFI), launched in 1992, nearly 700 projects totalling about £43 billion, have been delivered to date. Australia also has extensive experience with PPPs; the capital value of Australian PPPs has exceeded AUD$20 billion (Malone 2005). Standard & Poor's (2005) notes that PPPs are on the rise globally, particularly in Europe, where Italy, Spain, Germany, and Portugal have worked to improve the requisite legal and institutional framework to facilitate their development. With more countries making use of PPPs, Canadian governments are likely to face greater competition in the future in their efforts to attract domestic and foreign capital and companies interested in bidding on projects.

Structuring and Financing of Recent Canadian PPPs

Many recently launched PPPs follow models that involve a high level of private sector involvement and risk sharing. Because of the complex, long-term risk-sharing arrangements involved, the terms of each PPP are unique. Nonetheless, most can be classified into various models according to the level of private sector involvement and the allocation of risks to each sector. As indicated in Table 1, many projects have been structured using a "design, build, finance, operate" (DBFO) model or a slight variation that includes maintenance (DBFOM). Under these types of arrangements, the private sector partner—usually a consortium—is responsible for engineering, design, and construction and typically assumes many of the associated risks (e.g., missed deadlines or cost overruns). The private sector usually provides the construction capital. But for many projects, particularly those that are large and capital intensive (e.g., Canada Line), the capital costs are often shared with the public sector. In the DBFO model, the private sector partner assumes operation of the asset upon its completion, under the terms of a long-term contract of,

generally 25 years or more.[7] The contract is typically structured so that investors receive "availability" payments that commence once construction is completed.[8] For example, in a number of hospital PPPs, the private sector receives payment for the facility and for the provision of non-clinical services. In all DBFOs, the asset is returned to the public sector at the end of the contract.

PPP financing is structured according to the unique features of each project, including the skills and resources brought together in the project team. Generally, equity represents a small share of the overall financing (between 10 and 15 per cent). It is provided by the project team, which, from a financing perspective, may include individual investors, infrastructure funds that pool the capital of several institutional investors, banks, and the financing arms of engineering/construction firms.

Three main types of debt financing have been used for the recent DBFO PPPs: bank loans, private placements, and broadly marketed bond placements (a type of private placement with a broader distribution). It is difficult to obtain detailed information because of commercial confidentiality, but it would appear that debt financing for most of the projects listed in Table 1 was provided through bank loans—typically from large European banks with broad experience in PPP—or through private placements. At least two projects were financed through broadly marketed bond placements.[9]

Given the long-term nature of PPPs, there has been a limited appetite among Canadian banks to lend to such projects. They have been involved in many aspects of the PPP market, however, including structuring deals and acting as lead underwriters in debt placements. The involvement of domestic banks may change in the future if a liquid, secondary market develops to provide debt and equity investors with an exit opportunity. In the United Kingdom, where there is a longer history of PPPs and the market has achieved "critical mass," investors have been able to reduce their PPP debt exposure through sales in the secondary market, most notably in the first-ever securitization of U.K. PPP loans. In November 2004, Depfa Bank Plc securitized 24 PFI loans with a capital value of £392 million.

PPP as an Investment

Over the past few years, there appears to have been a greater appetite among Canadian institutional investors for longer-term investments, such as infrastructure. Defined-benefit pension funds, in particular, are increasingly viewing infrastructure as a distinct asset class with unique properties relative to publicly traded equities and bonds. Infrastructure investment provides relatively stable long-term cash flows, as well as portfolio diversification, owing to its low correlation with publicly traded equities and, in some cases, a positive correlation with inflation (i.e., in regulated industries, where inflation is a key consideration in setting prices). Since the decline in global equity markets in 2000–03, defined-benefit pension funds have been investing more in assets with characteristics that better match their liabilities, which are long term and often indexed to inflation. Since infrastructure, including PPPs, is a long-term financial asset with cash flows that may be linked to inflation, it provides a good match to pension liabilities. Life insurers, whose liabilities are also long term have a much longer history of asset-liability matching. Recent industry consolidation has also given the larger remaining insurers a greater capacity to make the large minimum investment typically required.

Canadian pension funds began targeting infrastructure as a distinct asset class in about 2000. To date, investments have been made by only a handful of the largest public sector funds, partly because the investment required is large and because internal resources must often be developed to manage the asset class.[10] A number of these funds plan to invest as much as 10 to

7. Note that PPPs are often structured to include both construction of the asset (capital costs) and its maintenance and operation (operational costs, including service delivery).
8. Alternatively, some PPPs are structured so that the investors earn revenue from volume-based user charges (e.g., toll highways).
9. In the United Kingdom, 70 per cent of debt financing has been in the form of bank loans, and 30 per cent has been through the bond market. Market participants expect that an increasing share of financing will come from the bond market.
10. Infrastructure funds provide a means by which pension funds can invest without the responsibility of actively managing the investment. This is left to the fund manager.

15 per cent of their aggregate assets in infrastructure, although until recently, opportunities have been limited, particularly in Canada (Tuer and Woodman 2005). Most large investments have been made in foreign infrastructure projects, mainly in the United Kingdom, Australia, and the United States.

Typically, DBFO PPPs provide less potential for the large equity investment preferred by public sector pension funds than, for example, an investment in a privatized utility. Nonetheless, these types of PPPs have similar features, providing investors with stable, long-term cash flows that, ideally, offer returns somewhere between those typically earned on publicly traded equities and bonds. They are priced to take into account full life-cycle costs, including the cost of transferring certain functions and risks to the private sector. In other words, they are structured so that the private sector assumes responsibility and is accountable for delivering the project on schedule and within budget. The private sector will also assume operational and, often, maintenance risks. Investors, particularly equity investors, have a greater level of accountability and accept more risk than they would by simply purchasing a government bond. PPP investments must therefore offer returns commensurate with this risk.

Several of the projects listed in Table 1 were financed with capital from Canadian institutional investors. Public sector pension funds have participated both as equity partners and in debt offerings, although most prefer equity. The Ontario Municipal Employees' Retirement System (OMERS), one of the first pension funds to invest in infrastructure, has recently made its single largest infrastructure investment, as an equity partner, in the Bruce A Nuclear Restart project. Life insurers have typically participated only in debt offerings, both as individual investors and through infrastructure funds.

Developing a Viable PPP Market in Canada

Although a number of PPP projects have been developed in Canada, the market is still considered to be in its infancy relative to established markets. In contrast to the United Kingdom, for example, where there is an established PPP program that has tailored legislation and regulation, as well as ongoing, predictable long-term funding, Canadian PPPs have tended to be assessed on a case-by-case basis with no overall framework or strategy. As indicated earlier, a more coordinated, strategic approach to PPPs appears to be emerging in some Canadian jurisdictions, and PPPs are gaining wider use.

In practice, establishing a viable PPP market is quite challenging. Long-term political commitment to PPP is required, and the appropriate infrastructure and skills must be put in place to ensure an efficient, effective, and transparent process. Past experience with PPPs, both within Canada and in other jurisdictions, has demonstrated that, from a practical perspective, there is a long learning curve associated with the use of PPPs as a means of alternative asset procurement and service delivery.[11] Nonetheless, Canadian governments have the advantage of being able to learn from their own past experiences and from the experiences of other jurisdictions.

The United Kingdom, for example, created a centralized agency to coordinate PPP efforts (Partnerships U.K.) that has subsequently developed a set of best practices for successful PPPs. These include political commitment at a policy level to encourage the private sector to develop the resources needed to bid for contracts, enabling legislation, development of private and public sector PPP expertise, project prioritization, standardized contracts, and a regular and predictable flow of projects (deal flow) (International Finance Services 2003). Since 1997, deal flow in the United Kingdom has been about 70 projects per year, with an aggregate value between £2.5 billion and £5 billion, excluding the very large transportation PPPs, such as the London Underground.

The United Kingdom has identified two fundamental requirements for a PPP: first, the private sector must bear some of the risk of the project, and second, the PPP must demonstrate VFM from a taxpayer perspective.[12] In the United

11. PPPs are often quite controversial, partly because of fears that greater use of them will result in an erosion of service quality and a loss of public sector jobs. There is an extensive literature on the economics of PPPs and on the benefits to the public sector and taxpayers that have accrued, as well as some of the mistakes that have been made. For a discussion of some of the issues, see Allan (1999) and Poschmann (2003.)
12. See Allan (1999) for a good discussion of this.

Kingdom and increasingly in Canada, VFM is determined by developing a public sector comparator (PSC) for each project. A PSC is essentially a public sector alternative for delivering the service, and its development requires an explicit identification and quantification of project risks. The comparison of the PSC and PPP is undertaken from the perspective of cost over the full life cycle of the project, in net present-value terms, looking at the costs and benefits of the PPP relative to those of traditional procurement. Government delivery would remain the preferred option if the analysis fails to demonstrate that the PPP offers VFM relative to traditional procurement.

It has been suggested that among the obstacles to the development of the PPP market in Canada are a lack of public knowledge of and support for PPPs. At the forum, "Public-Private Partnerships: Dispelling the Myths," held in Toronto in October 2005, speakers highlighted the importance of a high level of political support and commitment to PPPs and to building an informed public debate to familiarize citizens with the issues. Other factors were identified as similar to the best practices recognized by Partnerships U.K.

One area where Canada differs from other countries is in the absence of active financial guaranty (monoline) insurers.[13] Monolines enhance the credit rating of lower-rated investment-grade PPPs through the provision of an unconditional and irrevocable guarantee to continue the payment of interest and principal in the event of a default. Historically, monolines have not been active in Canada,[14] but, to date, this has not been an impediment to financing projects. The large institutional investors that have been investing in PPPs have been able and willing to hold lower-rated, investment-grade debt.

13. These insurers, are referred to as "monolines" because they are restricted to only one business line—insuring the repayment of third-party debt.
14. Regulators have developed a tentative regime to regulate monolines, supporting their entry into the domestic market. But a regime that would meet both the business needs of monolines and the regulator's prudential mandate has not been finalized. These firms have yet to enter the Canadian insurance market.

In summary, many of the conditions required to support the development of a Canadian PPP market are in place. Governments appear to be committed to investing in infrastructure, including PPPs. Within the private market, there is an appetite for longer-term financial assets, and there is a pent-up demand for those investments in Canada. Adapting lessons learned from earlier experience with PPPs in Canada, and in other jurisdictions, should help to develop a viable, efficient PPP market.

References

Allan, J. 1999. "Public-Private Partnerships: A Review of Literature and Practice." Public Policy Paper No. 4. Regina: Saskatchewan Institute of Public Policy, University of Regina.

Dodge, D. 2005. "Investing in Productivity." Remarks by David Dodge, Governor of the Bank of Canada, to the Canadian Council for Public-Private Partnerships, Toronto, Ontario.

Harchaoui, T., F. Tarkhani, and P. Warren. 2004. "Public Infrastructure in Canada, 1961–2002." *Canadian Public Policy* 30 (3): 303–18.

International Finance Services. 2003. "Public Private Partnerships: UK Expertise for International Markets." London.

Levac, M. and P. Wooldridge. 1997. "The Fiscal Impact of Privatization in Canada." *Bank of Canada Review* (Summer): 25–40.

Malone, N. 2005. "The Evolution of Private Financing of Government Infrastructure in Australia—2005 and Beyond." *The Australian Economic Review* 38 (4): 420–30.

Mirza, S. and M. Haider. 2003. "The State of Infrastructure in Canada: Implications for Infrastructure Planning and Policy." Report prepared for Infrastructure Canada Research and Analysis, March.

Poschmann, F. 2003. "Private Means to Public Ends: The Future of Public-Private Partnerships." C.D. Howe Institute Commentary No. 183 (June).

Standard & Poor's. 2005. "Public Private Partnerships: Global Credit Survey." Infrastructure and Public Finance Ratings Group (May).

TD Bank Financial Group. 2004. "Mind the Gap, Finding the Money to Upgrade Canada's Aging Public Infrastructure." TD Economics Special Report (20 May). Available at <www.td.com/economics>.

Tuer, E. and E. Woodman. 2005. "Recent Trends in Canadian Defined-Benefit Pension Sector Investment and Risk Management." *Bank of Canada Review* (Summer): 21–35.

Using the Contingent Claims Approach to Assess Credit Risk in the Canadian Business Sector

Michal Kozak, Meyer Aaron, and Céline Gauthier

In analyzing the financial system, central banks are interested in systemic risk. This can generally be taken to include risks that may lead to substantial problems for the financial system and ultimately result in a significant decline in real GDP. Hence, monitoring the risks facing Canadian financial and non-financial corporate sectors is an important part of overall financial system surveillance.

Risk in the corporate sector can be assessed in different ways. A large body of literature links risk to balance sheet ratios of profitability, liquidity, and leverage (Aaron and Hogg 2005; Altman 1983; Vlieghe 2001). Other approaches use financial market information to assess risk.

This report explores one such method, the contingent claims approach (CCA), which relies on both market information (including a measure of risk stemming from the volatility of market prices) and balance sheet information to model corporate credit risk.

Although the CCA is an interesting modelling tool for analyzing credit risk, it is data and computationally intensive. It can also be difficult to implement, since it requires matching different types of data—usually obtained from different sources—for a large number of companies. Hence, judgment has to be exercised in balancing the surveillance requirements with the cost of data gathering and integration.

This report uses the Canadian non-financial corporate sector and the banking sector to explore the implementation of the CCA for macrofinancial surveillance. It begins with a brief overview of the methodology, together with the issues that arise in applying CCA at a sectoral level. Next, CCA-based risk indicators are presented for some industry sectors and for the entire non-financial corporate sector. This is followed by an application to the Canadian banking sector. The report concludes with an evaluation of the CCA for macrofinancial surveillance, and outlines further avenues of research.

The CCA: Merton-Type Models

Distance-to-default measure

The CCA is a method that uses Black-Scholes option-pricing techniques to calculate the likelihood of corporate default. It is an extension of the Merton (1974) model based on the insight that a shareholder has an implicit call option on the value of the assets of the firm. The CCA uses both historical balance sheet data (leverage ratio) and timely and forward-looking equity market information (volatility of returns) to calculate a measure called distance to default (DD).

Distance to default represents the number of standard deviations that the market value of a firm's assets is away from the level of its liabilities. A higher DD (which means that the level of a firm's assets is expected to be farther away from the level of its liabilities) is interpreted as a lower risk of default. This could be caused by an improving leverage ratio, better asset returns, lower asset volatility, or any combination of these.[1]

Market-based indicators derived from Merton models have several advantages over indicators that rely primarily on accounting data. Market indicators are forward looking, they are available at a higher frequency, and the methods for extracting risk measures are broadly accepted.[2] On the other hand, market prices may reflect changes in attributes that could be unrelated to

1. A brief overview of the Merton model is presented in the Appendix.
2. European Central Bank (2005); Sveriges Riksbank (2005); Danmarks Nationalbank (2005); Persson and Blåvarg (2003).

financial stability. For example, an increase in market prices would be reflected in a higher DD (lower default risk), even though the price increase was due to market overreaction to good news or herding behaviour, rather than being the result of improved fundamentals. Nevertheless, market-based indicators have been shown to have leading information on corporate distress (Chan-Lau and Gravelle 2005; Chan-Lau, Jobert, and Kong 2004; Dionne et al. 2006; Tudela and Young 2003; and Gropp, Vesala, and Vulpes 2002).

Assessing sector-level risk

The CCA can also be used for sector analysis. This can be done by applying the CCA to each firm in the sector and aggregating the results into a sector measure. This approach has the advantage of providing information on the distribution of individual DD measures, which allows the analysis to focus on the vulnerable tails of these distributions.[3] The disadvantage is in the cost of data integration, which can be substantial for frequent surveillance.

An alternative approach is to apply the CCA to sector-level data (Gapen et al. 2004). This approach treats each sector as a single firm by aggregating firm-level debt and equity information for all companies in a particular sector. Aggregating firm-level debt and equity information requires less computation and is easier to update regularly. Also, in aggregating the market values of equity and calculating its volatility, we implicitly take into account the individual volatilities and their correlations. This application of the CCA to sector-level data explicitly gives more weight to larger firms. Hence, these aggregate measures should be sensitive to systemic vulnerabilities arising from the deteriorating financial condition of a large firm or that of a critical mass of smaller firms.[4]

Regardless of the approach taken, it is important to recognize that extending Merton-type models to sector-wide analysis requires a different interpretation of the DD measure. It may not be appropriate to interpret a sector-level DD measure as a risk of "sector default." But since the sector-level DD will reflect the risks of the underlying firms, it should reflect the overall vulnerability of the sector.

This report uses both approaches. For the non-financial sector, where it is unlikely that any single non-financial corporation is systemically important, the CCA is applied to the sector-level aggregation.[5] For the major Canadian banks, which could be systemically important, the CCA is applied at both the individual and sector-level aggregation.

Methodology and data

All market data are from Thompson Financial Datastream. The balance-sheet data for the public non-financial companies are from the *Globe and Mail* database.[6] The balance sheet information for the Canadian banks was obtained from the monthly returns filed by the banks with the Office of the Superintendent of Financial Institutions. The distance-to-default measures were estimated using the method set out in Chan-Lau, Jobert, and Kong (2004).[7]

Corporate bond defaults are measured by the number of public companies that defaulted in a given year as a proportion of all companies in an industry rated by Standard & Poor's.[8] Because of

3. Aaron and Hogg (2005) follow this route, using different balance-sheet ratios to construct an indicator of vulnerability in the corporate sector.
4. Sector-level aggregation may mask the weak firms, since it implicitly assumes that the assets of one firm can be used to back up the liabilities of another firm, which is not strictly true. But a similar masking issue would arise if firm-level DD measures were averaged.
5. There are over 1,500 non-financial public companies in Canada.
6. The public companies in the *Globe and Mail* database represent 55 per cent of total assets of all companies (public and private) in the non-financial business sector in 2004, as reported by Statistics Canada, and the coverage varies by industry. For example, for the forestry industry, the share of assets of public companies in the *Globe and Mail* database represents 45 per cent of total assets (private and public companies) in the industry.
7. For non-financial companies, annual balance-sheet information was used to calculate the default barrier by adding current liabilities and half of long-term debt for all companies in an industry. Taking half of long-term debt is arbitrary and follows the practice presented in other studies. Total liabilities were used for the banks. Annualized equity volatilities were calculated at the beginning of every month, using a one-year rolling window of daily market values of equity. The monthly DD values were calculated following the procedure outlined in the Appendix.
8. Not all of the companies in the *Globe and Mail* database are rated, and, therefore, data on bond defaults might not include the defaults of all companies in the *Globe and Mail* database.

Table 1

Correlation Between Distance to Default and Bond Defaults

Distance to default	Bond defaults
Forestry (lagged)	-0.658
Forestry (contemporaneous)	-0.550
Manufacturing (lagged)	-0.146
Manufacturing (contemporaneous)	-0.524

Chart 1 Distance to Default and Bond Defaults

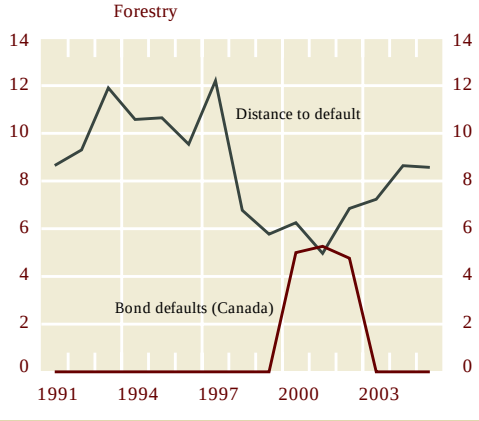
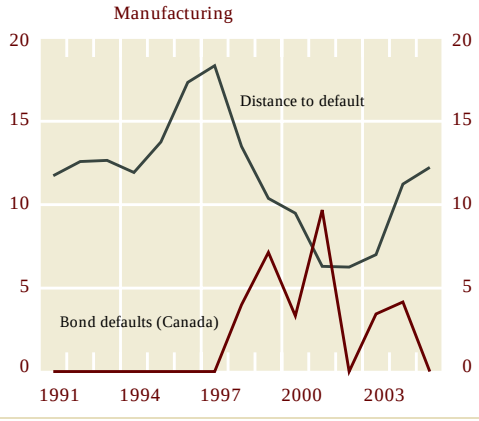


Chart 2 Distance to Default and Bond Defaults



data limitations, the sample period for the analysis of the non-financial sector is 1991–2005.

Assessing Risks in the Non-Financial Corporate Sector

To assess the usefulness of the CCA for macrofinancial surveillance, we applied the CCA to the major non-financial corporate sectors. Each sector underwent a preliminary examination of the leading-indicator properties of DD for corporate bond defaults.

Industry-level risk measure

Charts 1 and 2 show DD for the forestry and manufacturing sectors. In both sectors, DD began to decrease in 1997 and reached a trough in 2001. Since 2001, DD has shown an upward trend, suggesting that risk in these sectors has decreased.

The correlations between DD (and DD lagged one year) and bond defaults (Table 1) support the expected negative relationship.[9] The high correlation in the forestry sector suggests that DD has some leading-indicator properties for corporate bond defaults, which is desirable for financial-stability surveillance. For the manufacturing sector, contemporaneous correlation is also high, but one-year lagged correlation is rather low. Charts 1 and 2 suggest that DD may, indeed, have some leading-indicator properties for the sectors examined.

Risk measures for the overall corporate sector

Increased vulnerabilities in a small sector are likely to have a smaller risk of systemic impact than vulnerabilities in a larger sector. But a sector's size or its share of GDP or bank loans are not the only factors affecting its contribution to systemic risk. It is also important to take the correlation of risks among sectors into account. In this section, we propose two different ways to measure risk in the overall corporate sector.

The first approach is to aggregate the balance-sheet and equity information of all companies and then calculate DD for the aggregate corporate

9. Note that the correlations should be interpreted carefully, since the relationship between DD and bond defaults is not linear, and only 14 years of annual data were studied.

sector. An alternative approach uses the market value of assets, one of the main outputs from the CCA. Since the whole corporate sector can be viewed as a portfolio containing the assets (in market value) of all the companies in the corporate sector, we propose the variance of the return on this portfolio as a proxy for the risk in the overall corporate sector.

The resulting DD for the aggregate corporate sector seems to have some leading-indicator properties for bond defaults (Chart 3). The correlation between bond defaults and a DD lagged one year is high (-0.74) and is still significant using a two-year lagged variance (-0.56). Even though the analysis covers a short period, this suggests that the corporate sector DD has some leading-indicator properties for credit risk.

The variance of the corporate sector portfolio also seems to have some leading-indicator properties for bond defaults (Chart 4). The correlation between one-year lagged variance and bond defaults is very strong (0.84) and is still high using a two-year lagged variance (0.69), supporting the leading-indicator properties of the variance measure for bond defaults.[10]

Thus, both measures of aggregate credit risk seem to have some leading-indicator properties for bond defaults.[11] As expected, there is overlap in the information content of these two measures, which are highly correlated (-0.79).

Chart 3 Distance to Default and Bond Defaults for the Aggregate Corporate Sector

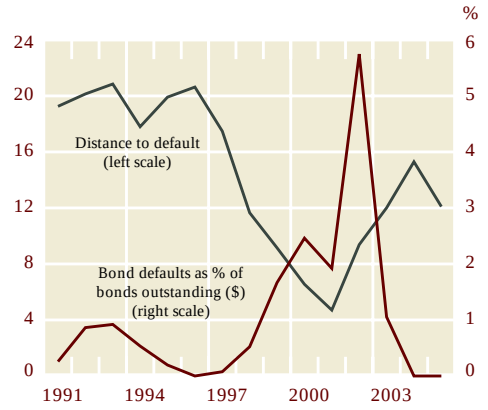
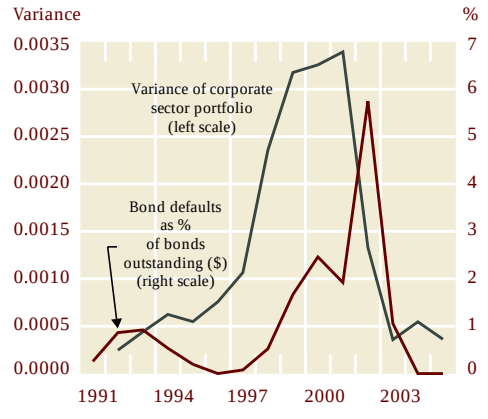


Chart 4 Variance of Corporate Sector Portfolio and Bond Defaults for the Corporate Sector

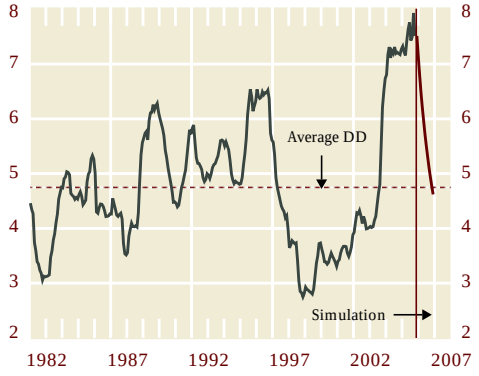


Assessing Risks in the Banking Sector

In this section, the DD measure is used to assess the overall financial health of Canadian banks. The Canadian banking sector is proxied here by the six largest Canadian Banks (major banks). This is justified by the high concentration of Canada's banking sector, where the major banks held approximately 91 per cent of the banking assets in Canada, as of January 2006.

10. In comparison, the microdata indicator developed in Aaron and Hogg (2005) had a one-year lagged correlation of 0.46. See also Box 2 on page 11 of this issue.
11. A similar correlation exercise with impaired business loans for banks gave much weaker results.

Chart 5 Average Distance to Default for Major Banks



Historical evolution of the risk measure

The average DD for the major banks during the period 1982–2005 is presented in Chart 5.[12] During this period, there have been important changes in the business practices of the major banks and in risk-management and risk-mitigation techniques.[13]

Movements in DD can be broadly related to major credit developments at the banks. For example, the measure fell sharply in the early 1980s, when many developing countries were encountering difficulties in servicing their debt, and was marginally below the mean in 1990 before the 1991 recession. Distance to default was also low following the crash in the technology sector in 2000–01 and the associated concerns about the exposure of some major banks to the telecom and cable sector. But there were also major declines around 1997–98, the period of extreme market volatility triggered by the 1997 Asian crisis and the 1998 Russian default/LTCM events, which are not thought to be particularly stressful for the major banks except, perhaps, for their market operations. Hence, these linkages must be interpreted cautiously, since changes in DD during the periods mentioned could be caused primarily by broader movements in the markets that might be only tangentially related to the risk exposure of Canadian banks.

The underlying drivers of DD (assets/liabilities and asset volatility) have subsequently improved, which has resulted in the observed decrease in risk (increase in DD) since that time. Of most interest is the strong increase in DD in 2003–04. Although all DD drivers improved during those years, the main driver was a strong decrease in asset volatility. This could emanate from a number of sources, such as a fundamental improvement in the riskiness of major

12. The average DD is the asset-weighted average of each individual bank's DD, computed using the procedure outlined in the Appendix. Although some information is lost in the aggregation process, it should provide a good indication of important changes in the risks of major banks.
13. For example, in the early 1990s, there was a major shift towards reliance on fee income at the expense of interest income, and the trading book expanded much more rapidly than the banking book. Moreover, since the mid-1980s, residential mortgage lending has risen at the expense of business lending.

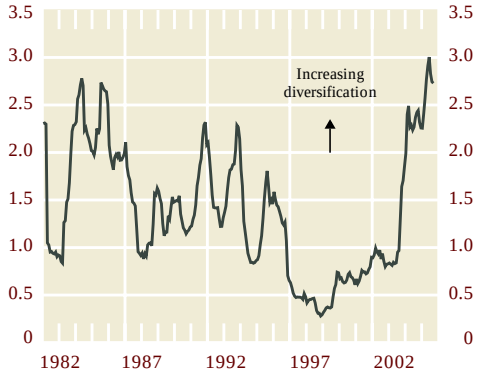
banks, or the banks may simply have benefitted from the low volatility of the stock market as a whole. To see if the latter is the case, a simulation was done using a scenario in which the volatility of the major banks' equity returns to its sample mean.[14] Chart 5 indicates that, should this occur, the recent improvement in the DD measure would be substantially reduced but DD would still be at the historical average.

Assessing risk diversification in the banking sector

The average DD measure analyzed above does not explicitly account for diversification of risk among the major banks, which requires the incorporation of correlations among these institutions. Calculating DD for a "representative bank" is one way to measure this benefit.[15]

As with the methodology used above for the non-financial corporations, DD for the representative bank is calculated by aggregating the major banks into a single entity. This procedure accounts for the correlation among the major banks and, hence, should include a measure of the diversification benefits.[16] Distance to default for the representative bank will be higher than the average DD because of diversification, and the difference between the two measures should reflect this benefit.[17] The lower the correlation among institutions, the more the system as a whole will benefit from "diversification" effects, and the larger the difference between the representative bank DD and average DD will be. The results are shown in Chart 6. This difference reached a peak recently, indicating good diversification across major

Chart 6 DD for Representative Bank Minus Average DD



14. This simulation assumes that all input parameters are fixed except for the volatility of major banks' equity, which returns to its sample average linearly over one year. The correlation between market value of equity and volatility is not significant, suggesting that this assumption is reasonable. A scenario where the volatility of the major banks' equity returns to its 10-year average gave similar results.
15. This approach has been used by the International Monetary Fund in its Article IV reports.
16. The aggregate market capitalization of the major banks and the volatility of their equity, which are used as inputs into the model calculations, will, by definition, include the correlations among the equity-price movements of the major banks.
17. In addition to the diversification effects, the difference may also reflect the effects of aggregation.

banks and that the "sector" is expected to be resilient to shocks. Note, however, that the profile for this measure follows the profile for the average DD (Chart 5). This implies that the diversification benefits seem to be reduced in times of greater stress (lower average DD).[18] Hence, this diversification benefit should not be overstated. In addition, although the DD for the sector incorporates the correlations, it does not account for second-round or network effects, which arise from the linkages between the constituent banks, except to the extent that movements in market prices incorporate such effects.

Conclusion

The CCA has advantages for macrofinancial surveillance over financial accounts measures, since it uses more timely and forward-looking information. These measures are gaining acceptance among many central banks and international institutions as tools for monitoring systemic risks.

The work summarized here shows that the CCA can be useful for analyzing systemic risks in the non-financial and financial corporate sector. Depending on the surveillance requirements, it can be applied at the firm level or at the aggregate sector level.

Additional research is being done to better understand the value of this tool. For example, Gropp, Vesala, and Vulpes (2002) suggest that DD leads downgrades of European banks by six to eighteen months. This result is being assessed for Canadian financial institutions. Research using simulations is also being conducted to quantify the impacts of aggregation in applying the CCA to sector-level analysis. Lastly, measures from the CCA are being incorporated into studies that are investigating the links between corporate vulnerabilities and macroeconomic variables.

18. It is well known that in bad times, not only does the likelihood of defaults increase, but also the correlation of defaults. The underlying causes of this behaviour and the methodologies to distinguish between them are still not well understood (Forbes and Rigobon 2002).

References

Aaron, M. and D. Hogg. 2005. "The Use of Microdata to Assess Risks in the Non-Financial Corporate Sector." Bank of Canada *Financial System Review* (December): 37–42.

Altman, E. 1983. *Corporate Financial Distress: A Complete Guide to Predicting, Avoiding, and Dealing with Bankruptcy.* New York, NY: John Wiley & Sons.

Chan-Lau, J.A. and T. Gravelle. 2005. "The END: A New Indicator of Financial and Nonfinancial Corporate Sector Vulnerability." IMF Working Paper No. WP/05/231.

Chan-Lau, J.A., A. Jobert, and J. Kong. 2004. "An Option-Based Approach to Bank Vulnerabilities in Emerging Markets." IMF Working Paper No. WP/04/33.

Danmarks Nationalbank. 2005. *Financial Stability Report* (May).

Dionne, G., S. Laajimi, S. Mejri, and M. Petrescu. 2006. "Estimation of the Default Risk of Publicly Traded Canadian Companies." Forthcoming Bank of Canada Working Paper.

European Central Bank. 2005. *EU Banking Sector Stability* (October).

Forbes, K.J. and R. Rigobon. 2002. "No Contagion, Only Interdependence: Measuring Stock Market Comovements." *Journal of Finance* 57: 2223–61.

Gapen, M.T., D.F. Gray, C.H. Lim, and Y. Xiao. 2004. "The Contingent Claims Approach to Corporate Vulnerability Analysis: Estimating Default Risk and Economy-Wide Risk Transfer." IMF Working Paper No. WP/04/121.

Gropp, R., J. Vesala, and G. Vulpes. 2002. "Equity and Bond Market Signals as Leading Indicators of Bank Fragility." European Central Bank Working Paper No. 150.

Merton, R. 1974. "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates." *Journal of Finance* 29: 449–70.

Persson, M. and M. Blåvarg. 2003. "The Use of Market Indicators in Financial Stability Analysis." *Economic Review* 2, Sveriges Riksbank (June).

Sveriges Riksbank. 2005. *Financial Stability Report* (November).

Tudela, M. and G. Young. 2003. "A Merton-Model Approach to Assessing the Default Risk of UK Public Companies." Bank of England Working Paper No. 194.

Vassalou, M. and Y. Xing. 2004. "Default Risk in Equity Returns." *Journal of Finance* 59: 831–68.

Vlieghe, G.W. 2001. "Indicators of Fragility in the UK Corporate Sector." Bank of England Working Paper No. 146.

Appendix

The Merton Model

The methodology followed here is Merton's option-based model of credit risk. The details of this methodology are explained in Chan-Lau, Jobert, and Kong (2004). The Merton model of credit risk treats the equity of a firm as a call option on the underlying assets of the firm. This formulation allows the calculation of an expected distance to default (DD), which can be taken as a measure of the probability that the market value of the assets will be equal to or less than the liabilities (also known as the default barrier) over the chosen time horizon, which is taken here to be one year.

More formally, the Merton equations for the pricing of a call option are:

$$E = AN(d_1) - Le^{-rT}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{A}{L}\right) + \left(r + \frac{1}{2}\sigma_A^2\right)T}{\sigma_A\sqrt{T}}, d_2 = d_1 - \sigma_A\sqrt{T}, \qquad (1)$$

where

- E = market value of equity
- A = market value of assets
- N = the cumulative density function of the standard normal distribution
- L = value of liabilities
- r = 1-year treasury bill rate
- T = the chosen time horizon
- σ_A = asset volatility
- σ_E = volatility of equity.

The Merton framework also links equity volatility and asset volatility through the following relationship:

$$\sigma_E E = N(d_1)\sigma_A A. \qquad (2)$$

Hence, given the book value of debt, the maturity, the firm's equity value, and its volatility, the implied market value of its assets, and the asset volatility can be calculated by solving equations (1) and (2) simultaneously. Now, using the known values of the liabilities and the calculated values of assets and asset volatility from above, the distance to default, which is a measure of the firm's credit risk, can be calculated as:

$$DD = \frac{\ln\left(\frac{A}{L}\right) + \left(r - \frac{1}{2}\sigma_A^2\right)T}{\sigma_A\sqrt{T}}. \qquad (3)$$

Note that a large DD is consistent with low risk, since the firm is a greater number of standard deviations away from the default threshold, and vice versa.

Given the assumptions of a standard normal distribution for DD, the probability of default is calculated as follows:

$$P_{def} = N(-DD). \qquad (4)$$

In practice, the probabilities of default calculated from Merton-type models do not map exactly into observed probabilities for firm default because they rely on risk-neutral pricing, which overstates the true probability of default. Hence, although this measure has been shown to be a complete and unbiased indicator of firm vulnerability, it is appropriate to think of it as a default-likelihood indicator (Gapen et al. 2004; Vassalou and Xing 2004). Commercial vendors such as Moody's KMV use historical data to map these calculated probabilities into estimated default frequencies.