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The Era of Digital Financial Innovation: Lessons from Economic History on Regulation

Economic history gives us many instances when financial innovations, rapid growth in credit supply and increased reliance on short-term financing have led to financial instability and crises. Therefore, at a time of rapid digital innovations in the financial sector, it is important that regulators pay close attention to what is happening and take appropriate action.

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The Study In Brief

While digital finance innovation has the potential to provide businesses and consumers with lower costs and a greater range of financial services, it has raised questions regarding the risks it poses to consumers, individual financial institutions, the financial system and the economy at large – and how Canadian financial regulators should respond to those risks.

This *Commentary* focuses on the major macro-level risks that might arise, and sets out to answer three questions. What do we know from economic history about financial innovation in general and banking crises? What are some key areas arising from current and future digital financial innovation that regulators need to examine? And what are the implications for actions by Canadian regulators?

Economic history gives us many examples of instances when financial innovations, rapid growth in credit supply and increased reliance on short-term financing have led to financial instability and crises. Therefore, at a time of rapid changes in the financial sector, it is important that regulators pay close attention to what is happening and take appropriate action.

After discussing key areas of concern for Canadian regulators, I recommend that they should:

(i) Require the explainability of machine-learning models used for lending decisions. As it is, artificial intelligence (AI) is being used in lending decisions at both regulated and largely unregulated institutions. If not properly examined by internal risk managers, it can lead to unsafe lending decisions.

(ii) Take care not to rush into open banking regulations, for example regarding money-moving apps, that could increase the likelihood of bank runs.

(iii) Collect better and more timely data by type of financial institution on types of credit and short-term financing.

(iv) Extend the coverage of stress tests to examine stresses related to rapid new borrowing from non-bank financial institutions, or shadow banks, that are not prudentially regulated.

At the micro level, regulators will have to weigh closely the costs of new regulations against the benefits of financial innovations. At the macro level, however, the steps suggested in this *Commentary* should have little or no effect on the vast majority of digital financial innovations that are underway or contemplated in the near future. Therefore, there would be no real trade-off between the increased stability coming from these actions and the increased competition, efficiency and range of financial services that should come from digital financial innovation.

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Digital financial innovation seems to be everywhere. Whether one focuses on artificial intelligence, including machine learning, or changes that could come about by the adoption of open banking, such innovation has been accelerating.

It has the potential to provide both businesses and consumers with lower costs and a greater range of financial services. Concurrently, digital financial innovation has raised the question of what risks these changes pose to consumers, individual financial institutions, the financial system and the economy at large, and how Canadian financial regulators should respond to those risks.[1]

Digital financial innovation can increase risks connected with privacy, cyber security, third-party technology providers and financial stability (Financial Stability Board 2017, 2019). This *Commentary* focuses only on the part of financial stability that concerns the major macro-level risks that might arise, and sets out to answer three questions. What do we know from economic history about financial innovation in general and banking crises? What are some key areas arising from current and future digital financial innovation that regulators need to examine? And what are the implications for actions by Canadian regulators?

In answering these questions, I look at the importance of credit booms historically, including those supported by various types of financial innovation both in credit granting and financial institution funding. I document the dominant influence of credit supply, examine changes in credit supply decisions stemming from machine-learning models and look at the introduction of particular open banking regulations that might increase the prevalence of bank runs. Recommended actions by regulators include requiring the "explainability" of machine-learning models used for credit decisions, taking care not to move too quickly away from the "stickiness" in retail bank deposits, requiring better data collection by type of non-deposit-taking financial institution on sorts of credit and short-term financing, and using stress tests for the overall financial sector.

Economic History, Financial Innovation and Banking Crises

Paraphrasing numerous authors, banking crises[2] can be summarized in the following way: "Every crisis is different. Every crisis is the same." Economic history focuses on what is the same across crises. In their writings, both Charles Kindleberger (1978) and Hyman Minsky (1982) put significant emphasis on financial innovations as a potential cause of subsequent banking crises. For Kindleberger, this conclusion remains as true in more recent times as it did 40 years ago (Kindleberger and Aliber 2011).

The author thanks Jeremy Kronick, Marie-Hélène Brière, Philip Howell, anonymous reviewers and members of the Financial Services Research Initiative of the C.D. Howe Institute for helpful comments on an earlier draft. He retains responsibility for any errors and the views expressed. An earlier version of some of the analysis in this *Commentary* was given as a slide presentation at the CDIC Conference "Deposit Insurance in the Digital Age" in Ottawa on May 9, 2019, under the title "History, Innovation and Regulation."

1 The Competition Bureau (Canada 2017) has recommended how regulators might foster innovation through competition.

2 "Banking crisis" is used in this *Commentary* as short-hand for a financial sector crisis that includes major difficulties in some part of the banking sector. For greater clarification, it excludes sovereign-debt and foreign-exchange crises.

Financial Innovations Historically

Historically, the range of financial innovations leading to credit expansion and potential banking crises has been extremely varied. In some cases, these innovations have been linked to the development of assets that are substitutes for traditional types of money. Examples include bills of exchange and eurocurrency deposits. In other cases, the innovations have occurred through the introduction of poorer-quality credit, including junk bonds and some types of securitized products (Kindleberger and Aliber 2011, chap. 4).

For a more recent example, one can consider the role of financial innovations in causing the global financial crisis of 2008–09, which has come under much scrutiny. In particular, there has been significant emphasis on innovations creating new types of loans or securities, such as:

- securitization and tranching (slicing and dicing) of prime, alt-A and subprime mortgages;
- collateralized mortgage obligations;
- asset-backed commercial paper (Kacperczyk and Schnabl 2010);
- repurchase agreements (repos) collateralized by the above (Gorton and Metrick 2012); and
- money market mutual funds.

The first four of these techniques, together with overcollateralization and equity and lower-quality tranches held by loan originators and others, created long-term and short-term AAA assets. These assets, desired by both the financial sector and the non-financial sector, enabled an increase in the supply of both US subprime mortgages (themselves an innovation) and other mortgages.

Concurrently, there were innovations in the techniques financial institutions used to look at risk. First, value-at-risk calculations, which quantitatively measured the amount of risk in a portfolio of securities and loans, were rising in importance and were often based on very short samples and statistical distributions that did not allow for fat tails.[3] Second, the increase in financial institutions' use of experts in quantitative analysis, who developed and used value-at-risk calculations. These experts differed from many traditional fundamental risk managers, who historically have been able to step back from all the math and statistics and ask whether everything about a particular loan, investment or way of funding makes enough sense to proceed with it. As a result of overreliance on both of these innovations, the risks taken on by some financial institutions, particularly investment banks and other banks, were greater than they appreciated at the time. Thus, they were willing to expand their balance sheets significantly and create more credit.

The Roles of Credit Growth, New Borrowing and Debt Service

Since the global financial crisis, research drawing on insights from Kindleberger and Minsky has provided stronger empirical evidence that excessive credit growth could lead to crises. This research has been part of a larger research agenda using financial variables that can be taken to describe a financial cycle to predict financial crises, growth of gross domestic product (GDP) and recessions. The private-sector credit variables studied include the growth of credit, the growth of the ratio of credit to nominal GDP, the detrended ratio of credit to nominal GDP, new borrowing relative to nominal GDP and debt service (interest payments and repayments of principal) relative to nominal GDP.[4]

3 Fat-tailed distributions, as opposed to normal distributions, incur outlier events with higher probability.

4 At times, total private-sector credit is disaggregated into household and business credit, or mortgage credit and other credit. When household credit is used, it is often as a ratio to personal disposable income.

Other financial variables include the growth of real asset prices – especially house prices and stock prices.

Because countries have few banking crises – by one often-used measure, Canada has not had one in the past 50 years (Laeven and Valencia 2018) – and a limited number of financial cycles, it is important to look at cross-country studies to predict and understand the causes of crises and economic downturns linked to the financial sector.[5] Fortunately, because Canada is one of a small number of countries with relevant annual and quarterly data over long historical periods, it is included in all of the studies discussed below.

Cross-country research on the prediction of banking crises that focuses on credit (and real asset prices) developed in an important way at the Bank for International Settlements (BIS), both prior to the global financial crisis (for example, Borio and Lowe 2002) and since (Borio and Drehmann 2009; Drehmann, Borio, and Tsatsaronis 2012). More recent BIS research notes that credit booms were useful in predicting crises as long as five years ahead while not always leading to a crisis. In contrast, debt-service payments (interest payments plus repayment of principal) were better short-term predictors of crises as long as two years ahead (Drehmann and Juselius 2013). More recently, Drehmann and colleagues show that flows of new borrowing have had some persistence. These flows, as expected, lead debt service, which builds up over time as the stock of credit continues to increase (Drehmann, Juselius, and Korinek 2018). The net flow of borrowing – the flow of new borrowing less the flow of debt service – tends to remain positive for some time, but to decline as debt service rises, eventually becoming negative. This pattern of net flows was first associated with an increase in the growth of real consumption and output, and then by a decrease, likely because many borrowers are constrained by their disposable incomes plus their net flows of borrowing.[6] Consistent with the story, the authors find that new borrowing and debt servicing are more important predictors of output growth and financial crises than are traditional measures such as the ratio of credit to GDP. Ambler and Kronick (2020), in a paper focusing on Canada, similarly conclude that these two key variables are good predictors of Canadian output growth and financial stress.

The persistence of the effects of shocks to new borrowing on output likely is less in countries, like Canada, with a higher prevalence of floating or short- to medium-term interest rates on debt (particularly mortgages), than in countries with long-term fixed interest rates. This is because the average interest rate on outstanding debt is more responsive to changes in the monetary policy interest rate, which itself, all else being equal, responds to the output effects of the net flow of borrowing.[7]

The BIS research focused on quarterly data for advanced and some emerging market countries since the 1970s. At the same time, another group of researchers were putting together an annual database since 1870 for 14 to 17 industrial countries, depending on the study (see, for example, Jordà, Schularick, and Taylor 2013; Schularick and Taylor 2012). They too found that, even over this longer period, credit flows were extremely important in predicting banking crises. As well,

5 Calomiris and Haber (2014) claim that Canada is one of only six countries (of the more than 100 surveyed) that have had a crisis-free, stable banking system, as well as abundant credit.

6 More generally, borrowers typically have higher marginal propensities to consume out of income and wealth than have lenders, which is consistent with the relationship found between the new flow of borrowing and consumption growth.

7 In the data, debt servicing peaks more rapidly when mortgage rates are flexible rather than fixed (Drehmann, Juselius, and Korinek 2018).

the researchers found that recessions associated with financial crises were more serious than other recessions. Moreover, even if credit booms did not lead to banking crises, they were typically associated with economic slowdowns, a finding that has been used to show that financial booms have leading information on recessions (Borio, Drehmann, and Xia 2019).

An important commonality in findings from the two databases is that both total household credit and household mortgage credit tend to be much more important than business credit or overall total credit in predicting crises and GDP booms and busts (Drehmann, Juselius, and Korinek 2018; International Monetary Fund 2017; Mian and Sufi 2018; Mian, Sufi, and Verner 2016; Jordà, Schularick, and Taylor 2015, 2016). The GDP booms associated with household credit are, however, lower in countries with: stricter financial supervision and regulation, greater capital account openness and flexible exchange rates (International Monetary Fund 2017). These factors, of course, are all present in Canada. Moreover, the tighter regulation of risk-weighted capital, leverage ratios and liquidity (through the liquidity-coverage ratio and net stable funding ratio) under the Basel III global regulatory framework is likely to reduce the possibility of credit booms leading to banking crises.

Part of the explanation for the link between credit booms and subsequent recessions is the importance of shocks to credit supply, as opposed to credit demand (Mian and Sufi 2018; Mian, Sufi, and Verner 2016). Thus, one observes that credit conditions – as measured by interest rate spreads between, say, mortgage rates and comparable sovereign yields, and non-price indications of credit availability[8] – typically ease, not tighten, when credit booms take place.[9] Increases in supply can, of course, be underpinned by financial innovations, as was the case to at least some degree during the global financial crisis.[10] Future credit-supply-induced booms (and crises) perhaps could be mitigated by a more anticipatory regulatory culture, empowered by legislation and by the advocation by leaders of financial institutions of more cooperative relations with regulators.[11]

The Role of Runnable Short-term Funding

Bank runs at individual institutions or panics across institutions or markets have often occurred just before bank failures and full-fledged banking crises. Historically, the emphasis was on runs on core short-term bank deposits, but as deposit insurance was instituted, that became less likely. The global financial crisis showed that significant runs could occur not only from short-term wholesale deposits at banks, but also from short-term financing of non-bank financial intermediaries (NBFIs) – more popularly known as shadow banks. Two examples are financial commercial paper (Kacperczyk and Schnabl 2010) and repo transactions supported by dodgy collateral (Gorton and Metrick 2012).[12] As well, in the case of the United Kingdom, there was

8 The Bank of Canada's Senior Loan Officers Survey measures both price and non-price elements of credit conditions, but focuses on business lending. The price and non-price elements tend to move in the same direction.

9 When the increase in the quantity of anything (here, credit) is associated with a decline in its price (here, credit conditions), it must be because positive supply shifts have been larger than any demand shifts.

10 Mis-selling, as was the case with some US subprime mortgages that had extremely low interest payments in the first few years, might (in some cases) be the source of increases in credit supply.

11 Thanks to an anonymous referee for suggesting this point.

12 Researchers have shown that the pricing of money market debt is fundamentally different from the pricing of stocks, and that such debt goes from a situation where its price is not sensitive to new information to one where it is very sensitive (see, for example, Holmstrom 2015).

a run on core deposits at Northern Rock against a background of the absence of 100 percent deposit insurance up to a significant level (Shin 2009). Over a long period, when increases in the ratio of bank loans to deposits – likely indicating an increase in other types of short-term financing – accompany credit booms and real house price booms, a banking crisis is more likely (Richter, Schularick, and Wachtel 2017).[13]

The experience of the global financial crisis was consistent with the association of runs with concerns about the credit quality of a financial institution's asset portfolio – especially its mortgage portfolio – and its ability to continue to attract funds. In some cases, these concerns were well founded; in others, such as that of Canadian banks, runs in interbank funding seemed to reflect unfounded contagion.

The Role of Capital and Earnings Cushions

The global financial crisis also reinforced the idea that capital and annual earnings can cushion the effects of provisions taken on non-performing loans. Indeed, the simple leverage ratio – the ratio of a bank's equity capital to its total assets – tended to be a good predictor of which banks would get into trouble during the crisis (Haldane and Madouros 2012). To the extent that financial innovations reduce bank charter values and the annual earnings of banks in cases where business moves from the banking sector to NBFIs, banks will have fewer buffers against unexpected shocks.[14]

Lessons for Today

The lessons I draw from the historical experience for the likelihood that today's digital financial innovation will cause financial instability are threefold. First, this risk will be higher if it leads to an easing of credit conditions overall that, in turn, leads to a credit supply boom. Based on previous experience, this is likely to be more problematic if the boom is in household mortgage credit. Moreover, it likely will be no less a problem for the overall economy if it occurs in the NBFI sector. Second, the risk will be higher if it leads to increased probability of runs on short-term funding from financial institutions. Third, it will be higher if digital financial innovations cause business to move away from banks to NBFIs, thus reducing bank charter value and earnings cushions. In all three cases, however, regulators need to examine the full context of what is happening.

Some Key Areas Regulators Should Examine

Because past financial innovations have often been associated with either the easing of credit conditions and credit booms or the creation of new runnable deposits, it is important to look carefully at current and contemplated innovations that will affect these two areas. To that end, I look at the potential effects of the use of machine learning on credit decisions and the potential effects of one possible open banking initiative on bank runs.

Machine Learning and Credit Decisions

Artificial intelligence (AI) has many useful contributions to make in increasing the safety and efficiency of financial institutions. One branch of AI, machine learning, is being used in lending decisions at both regulated and largely unregulated institutions. It typically uses data on many

13 As well, an increase in the share of funding that does not come from deposits indicates increased financial instability (Jordà et al. 2017).

14 A bank's charter value is the value (part of its share price) of its ability to carry on its banking business in the future.

borrowers and potential borrowers and a multitude of their characteristics (Bank of England and Financial Conduct Authority 2019).

The use of machine learning in lending decisions, if not properly examined by internal risk managers, auditors and regulators, can lead to unsafe lending decisions.[15] Consider, for example, the hype about "big data" in recent years. Big data has allowed machine learning to increase the efficiency of verification and other decisions. But big data for lending decisions can pose big problems if it is analyzed with a "black box" – in which all the interest is on the inputs and outputs without concern for the logic of the internal workings – comes from a short period of time (a short sample) or is not big or broad in all relevant dimensions.

Consider the nature – the length and breadth of credit scores of past borrowers – of various data samples that might be available to actual and potential lenders, as shown in Figure 1. Traditional lenders have long samples (the blue horizontal rectangle in the figure), but the range of their measure of the credit quality of borrowers might not be as wide as that of newer lenders, and the range of characteristics of borrowers available for their long sample also might not be as wide. Some traditional lenders at some point might have broadened both the range of credit quality at which they have been willing to lend and the range of borrowers' characteristics they have gathered (the gold square in the figure), although at the expense of shorter sample periods. Even more recently, some new lenders using AI techniques might have further broadened the range of borrowers' characteristics they have gathered and the range of credit quality at which they are willing to lend (the gray rectangle in the figure). Yet again, however, the sample period shortens.

Models estimated over short samples are problematic because they are likely to be very unstable over both business and financial cycles. This is somewhat similar to the short samples in value-at-risk models and other models that experts in quantitative analysis used prior to and during the global financial crisis. If a sample does not contain significant economic and financial downturns, it is unlikely that the model estimated over that sample would perform well during a future downturn.

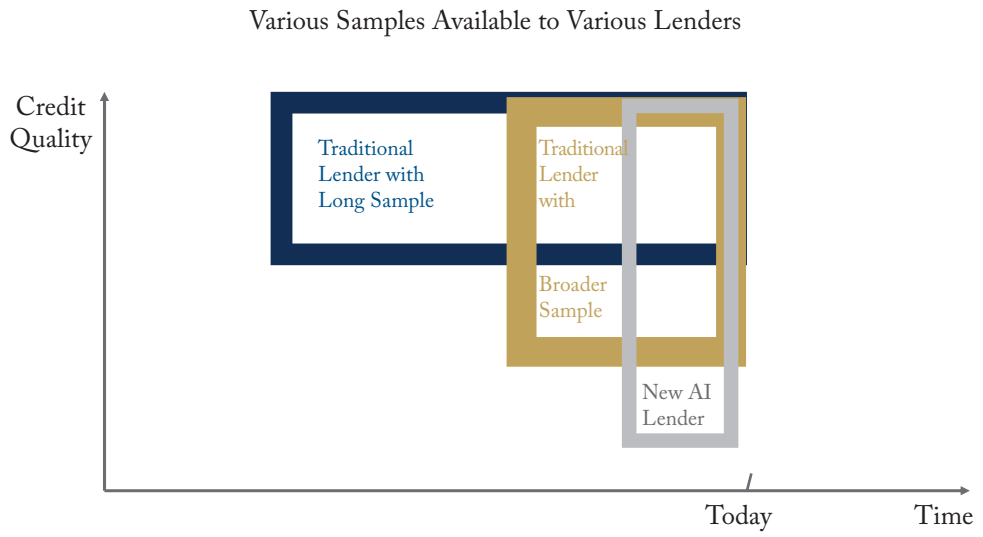
Large data samples are not necessarily better if they are not sufficiently big and broad in all dimensions. For example, data samples might have too few loans to those on the current lending/no-lending boundary. In that case, it might be difficult to know whether credit conditions can be eased for a new class or type of borrower.

For all these reasons, Explainable AI (XAI) has increased in popularity. XAI does not accept decisions made by a black box that is not understood. Rather, it employs techniques such as examining the effects of variables in the lending model one at a time to see if the effects are of the right sign (and of a believable size) or if there is a plausible explanation. XAI is needed most if final loan decisions are totally computerized, without any human input. Prudential regulators should require the use of XAI or similar approaches in computerized models on which loan approvals are based. They should also require more risk-weighted capital at an institution if they are unsatisfied with the approaches taken and if loan growth at that institution is accelerating. Macroprudential regulators should focus on whether the increased use of AI lending is leading to an acceleration of overall credit.

The above discussion raises the question of model risk when big data might not be as

15 The internal logic of previous credit adjudication technologies typically was very clear, but this might not always be the case for machine learning, as described later in the text.

Figure 1: Samples Available to Various Lenders



Source: Author's compilation.

big and broad as it seems at first glance. Bank regulators, who consider model risk as a key non-financial risk, do indeed spend time looking at this (Gully 2019). Some lenders, however, are not regulated for prudential purposes. Model risk, especially unappreciated model risk, can lead to the crystallizing of credit risk. But before the risk crystallizes, one might see credit accelerating at an individual financial institution in the regulated sector, in the non-regulated sector or in the overall financial sector. This would tend to raise the risk of a subsequent economic downturn, especially when the risk crystallizes. Macroprudential authorities need to keep their eye on financial innovations that are causing large changes in the non-regulated sector, especially when overall credit begins to accelerate.

Open Banking, Money-Moving Apps and Runs

Open banking typically is defined as a system that gives users data from financial institutions through the use of computer applications (apps). In particular, read/write open banking allows funds to move from one account to another (Open Banking Limited 2018). Read open banking, for example, allows an app that receives a customer's financial data to perform such activities as data aggregation. Write open banking takes it a step further, and allows, for example, an app to modify customer data, including making payments.

Suppose that it becomes legal to create and use open banking apps to which individuals can delegate the right to move their money from bank to bank, perhaps on a daily basis.[16] With permission, the app would gather information

16 The federal government is just beginning to examine open banking and its regulation (see Canada 2019). It has not yet made any proposals regarding payments functionality.

on the amount of the individual's deposits in all chequing and savings accounts – and perhaps money market mutual funds and commercial paper as well. Given this account information, what the individual shared on upcoming planned payments and the app's knowledge of bank (and other) interest rates and account requirements, the app would move the individual's money to maximize interest earnings.

In principle, then, if such apps were widely adopted, retail accounts would no longer be "sticky," and cash management at banks would become more difficult. More important, bank runs could become more likely – in response to errors banks make in posting their interest rates and account rules or to errors apps make in interpreting the information. (Such runs, one hopes, would be short lived, but could lead to rumours and contagion at a time when there is financial stress for other reasons.) As well, regulatory liquidity requirements likely would be harder to set because the degree of stickiness of deposits initially would be hard to gauge, as competition likely would cause interest rates (and many of the account requirements) across institutions to converge.

All this suggests that regulators might want to move slowly in some areas of open banking, especially those that could lead to large increases in liquidity risk.

Implications for Actions by Canadian Prudential Regulators

The above analysis suggests that Canadian prudential regulators should require the explainability of models used in lending decisions – typically with allowance for overrides by real people. The analysis also suggests, as just noted, that regulators exercise much care with some extremes of what open banking could mean, because of the link to liquidity risk for deposit-taking institutions.

In addition, macroprudential regulators should ensure that they have sufficient timely data to understand how financial innovations are affecting credit growth and short-term financing. To prepare for potential problems in the financial system as a whole, they need to undertake stress tests to understand how rapid growth in credit and short-term financing outside the banking system can lead to financial instability.[17]

Improving Data Collection on NBFIs

Canadian macroprudential regulators need to take seriously the fact that they have little or no data on many types of financial institutions that are not regulated for prudential purposes. These tend to be non-deposit-taking institutions and fall under Statistics Canada's definition of non-bank financial intermediaries, which includes, importantly, non-bank credit intermediaries (Statistics Canada 2019a, 2020).[18] Regulators should ensure that quarterly data on lending and short-term financing are gathered for each type of lender, whether regulated for prudential purposes or not.

Economic history suggests that these data should be gathered for each type of lending (consumer credit, residential mortgage credit, non-residential mortgage credit and other business lending) and for each type of short-term financing (asset-backed commercial paper, other commercial paper, bankers' acceptances, repo loans, securities lending and others). The data are needed – and

17 As a referee pointed out, another important issue for regulators is how to deal with firms that cut across banking, insurance, securities and more. Canada's current regulatory system, especially its federal-provincial dimension, makes this difficult.

18 Non-bank credit intermediaries comprise mortgage investment corporations, mortgage finance corporations, consumer and business transportation leasing and other leasing and financing companies.

likely will become more important in a world of rapid financial innovation and open banking – to analyze potential instability in the financial sector as a whole that might have implications for the overall economy that could feed back to affect the deposit-taking sector as well. Even though many of the non-deposit-taking lending sectors are currently small, there is no guarantee that they will remain that way in a world of rapid financial innovation. When a sector starts to grow rapidly, one wants to have the ability to understand what is going on immediately. This implies the need for quarterly data, short publication lags after the end of the quarter and sufficient disaggregation to understand which categories of lending and short-term financing are being affected. This allows for follow-up to understand changing business models in a given type of financial institution. It will be important to explain clearly the rationale for increased data collection to all the relevant players engaged in non-bank financial intermediation. There will be value to them in understanding what is happening to the growth of various types of credit and short-term financing across the economy, as well as in their own subsectors.

Some improvements have been made recently to Statistics Canada's annual "non-bank financial intermediation economic account" to show explicitly data for mortgage investment corporations and mortgage finance corporations, as well as some leasing companies. The Bank of Canada has been closely monitoring the rapid growth in lending by mortgage investment corporations (Bank of Canada 2019). However, data for 2018 on this sector only became available in mid-January 2020 (Statistics Canada 2020). The disaggregation of the lending and short-term financing data is also not sufficient to understand what is happening in the NBFI sector overall – for example, mortgages are not disaggregated between residential and non-residential. Data have also been enhanced on quarterly flows and stocks of securities (Statistics Canada 2019b). Unfortunately, however, there is insufficient disaggregation across types of financial institution.

A new source of lending being closely watched is lending by Big Tech – the Googles and Amazons of this world – especially to small and medium-sized businesses (Bank for International Settlements 2019; Financial Stability Board 2019). This kind of lending differs from traditional trade credit as it does not primarily finance the payment of bills to the Big Tech companies themselves. As this lending has the possibility of growing rapidly and becoming a significant source of finance for Canadian small and medium-sized businesses, Statistics Canada and macroprudential regulators should ensure that data on such loans are gathered separately, not just subsumed in other categories of lending.[19] Online peer-to-peer lending for both households and businesses is another area that should be watched carefully, as it too has potential for accelerating credit growth.

It takes time to institute new or improved Statistics Canada surveys, so the time to design and fund the needed new surveys is now, not when the beginning of an episode of financial stability is already suspected to be underway. It is now more than ten years since the heart of the global financial crisis, which was partly due to behaviour by NBFIs. It should not have taken so long to ensure that all of the relevant data were gathered. The Senior Advisory Committee to the minister of finance should also be considering whether, for systemic risk reasons, it should have access to the types of data mentioned above on significantly

19 Big Tech companies could grow to become international, systemically important financial institutions, which would raise the question of their supervision and regulation.

large individual NBFIs. This could be done in conjunction with provincial regulators.

Extending What Stress Tests Cover

Rapid growth in overall credit, especially household credit, coming from the non-bank sector potentially poses problems for the macro economy and for the banking sector as well. Therefore, Canadian macroprudential authorities would be well advised to construct and carry out stress tests that incorporate such a scenario. For example, this scenario could incorporate substantial new borrowing in the form of uninsured mortgages from institutions that are not prudentially regulated. This scenario would need to incorporate all the relevant connections among different parts of the financial sector, including any bank lending to the financial institutions providing the new mortgages, as well as the effects of changes in the macro economy on the banking sector. While not necessary, timely data collection would help in the construction of the scenario.

Conclusion

Economic history gives us many examples of instances when financial innovations, rapid growth in credit supply and increased reliance on short-term financing have led to financial instability and crises. Therefore, at a time of rapid changes in the financial sector, it is important that regulators pay close attention to what is happening and take appropriate action.

Canadian prudential supervisors should require the explainability of machine-learning models used for lending decisions. The major steps macroprudential regulators should take are as follows: take care not to rush into open banking regulations that could increase the likelihood of bank runs; collect better and more timely data by type of financial institution on types of credit and short-term financing; and extend the coverage of stress tests to examine stresses related to rapid new borrowing from financial institutions that are not prudentially regulated.

Microprudential supervisors will have to weigh closely the costs of new regulations against the benefits of financial innovations. At the macroprudential level, however, the steps suggested in this *Commentary* should have little or no effect on the vast majority of digital financial innovations that are underway or contemplated in the near future. Therefore, there would be no real trade-off between the increased stability coming from these actions and the increased competition, efficiency and range of financial services that should come from digital financial innovation.

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