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Leverage, balance-sheet size and wholesale funding

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ABSTRACT

Positive co-movements in bank leverage and assets are associated with leverage procyclicality. As wholesale funding allows banks to quickly adjust leverage, banks with wholesale funding are expected to exhibit higher leverage procyclicality. Using Canadian data, we analyze (i) if leverage procyclicality exists and its dependence on wholesale funding, (ii) market factors associated with this procyclicality, and (iii) if banking-sector leverage procyclicality forecasts market volatility. The findings suggest that procyclicality exists and that its degree positively depends on use of wholesale funding. Furthermore, funding-market liquidity matters for this procyclicality. Finally, banking-sector leverage procyclicality can forecast volatility in the equity market.

1. Introduction

In the aftermath of the recent financial crisis, the high levels of leverage among financial institutions has widely been identified as one of the major causes of the crisis. This has focused attention on both how financial institutions manage their leverage ratios (defined as assets divided by equity) and on potential regulatory actions required to prevent the build up of excessive levels of leverage in the financial sector. Given the nature and severity of the recent financial crisis, leverage has quickly become one of the focal points of both academic research and policy-oriented discussions related to financial stability.

While the slow build up of leverage over several years among financial institutions is an important issue, some studies also identify the importance of higher frequency movements of leverage. In this

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regard, one major question has been raised: Does leverage positively co-move with assets, and if so, what are its implications for market volatility? Adrian and Shin (2010) study this relationship between financial institution leverage and assets in the United States and find evidence that such a correlation exists.

One channel in which this positive correlation can be observed is when a financial institution actively manages its balance sheet with respect to changes in the value of equity. For example, when the value of equity increases due to a rise in prices of some marked-to-market assets, a financial institution's leverage ratio decreases. If the financial institution actively manages its balance sheet, it can raise non-equity liabilities and lever up. In this process, the newly-raised liabilities are invested into new assets, leading to a positive relationship between changes in leverage and balance-sheet size. Furthermore, as prices of assets tend to increase during booms and decrease during busts, leverage becomes procyclical to economic activity *in addition to* balance-sheet size.

This paper highlights the interaction of leverage procyclicality with the use of wholesale funding. The degree of procyclicality varies across different types of financial institutions and with respect to changes in macroeconomic and market environments. Financial institutions that use wholesale funding (e.g., institutional deposits, repos, commercial paper and banker's acceptances) display high degrees of procyclicality as these market-based funds are readily available at short notice for quick adjustments to leverage. However, the crisis disrupted short-term wholesale funding markets, revealing the high funding-liquidity risks associated with these funds. With reduced access to wholesale funding, financial institutions lost the ability to adjust leverage easily and quickly, which dampened the degree of procyclicality.

Specifically, we have three main objectives. First, we show that leverage of Canadian financial institutions is procyclical (i.e. positive correlations between leverage and balance-sheet size) and that the degree of procyclicality depends on the usage of wholesale funding. Second, we identify macroeconomic and market variables that are important for the degree of procyclicality. Third, we study if banking-sector leverage procyclicality can forecast aggregate volatility in the equity market. The empirical strategy chosen to achieve the first two objectives is a two-step method, similar to the approach outlined by Kashyap and Stein (2000) in their work on the bank lending channel of monetary policy. The first step cross-sectionally estimates the degree of leverage procyclicality based on monthly *bank-level* balance sheet data for all federally chartered deposit taking institutions in Canada over the period 1994–2009.[1] The analysis for the first objective is derived from the outcome of this step. Then, the second step determines if and how the degree of procyclicality changes over time following macroeconomic and market-wide changes. The results from this step are used for the discussion of the second objective. For the third objective, we construct volatility measures from the Toronto Stock Exchange Broad Index to gauge aggregate market volatility. We regress these volatility measures on banking-sector leverage procyclicality.

With respect to the first objective, we find strong procyclicality of leverage. In addition, we find significantly higher degrees of procyclicality among financial institutions that use more wholesale funding over those that use less. This confirms the findings by Adrian and Shin (2010) that leverage among US investment banks, who mainly rely on market-based wholesale funding to fund their investment activities, is strongly procyclical. They do not find such leverage procyclicality for commercial banks, which rely less on wholesale funding.[2] These results consistently prevail through various robustness checks and model extensions.

Secondly, we find that degrees of procyclicality change with liquidity in short-term wholesale funding markets, where funding-market liquidity is measured as changes in the trading volume of repos and the volume of outstanding commercial paper and banker's acceptances. Specifically, for wholesale funding users, we find that procyclicality is high when the liquidity of these markets is also high. Hence, when these markets become illiquid, wholesale funding users lose the ability to quickly adjust leverage, leading to weaker procyclicality of leverage. This result is consistent with

[1] Availability of high frequency (i.e., monthly) data for Canadian banks is important for the analysis in capturing volatility in short-term funding markets.

[2] However, their results regarding cyclicality of leverage among commercial banks appear to be sensitive to time periods and use of micro vs. macro data. See Berrospide and Edge (2010) and Adrian et al. (2012).

Brunnermeier and Pedersen (2009) who provide a theory linking market liquidity (i.e., the ease with which an asset is traded) with funding liquidity (i.e., the ease with which funds are obtained) through margin requirements for financial intermediaries. Since margin requirements for raising funds (e.g., haircuts on collateral and discounts on bank debts) can increase during downturns, available funds for investment decrease, reducing market liquidity. Such market and funding illiquidity would show up as weaker procyclicality of leverage, as the financial institution's ability to adjust leverage and investment declines. We observe weaker procyclicality with illiquid market conditions only for those financial institutions that rely on short-term wholesale funding markets.

Finally, we find that lagged banking-sector leverage procyclicality forecasts equity market volatility. While this effect is positive and significant during the pre-crisis period, it is insignificant during the crisis period. We interpret this result as the ability for banking-sector leverage procyclicality to forecast overall market volatility during pre-crisis periods. There are, however, multiple other factors that would have contributed to movements in market volatility during the crisis (such as various global and domestic government/central bank interventions), leaving the estimate insignificant.

Our paper is related to a few different strands in the existing literature. Regarding wholesale funding of banks, Huang and Ratnovski (2010) analyze a model with a tradeoff between using wholesale funding vs. retail deposits. On one hand, wholesale funding improves efficiency as uninsured wholesale financiers monitor banks. On the other hand, the monitoring incentives of the financiers depend on the available information set, which could lead to inefficient liquidations. This study is similar to ours in spirit, since it also evaluates the decisions and the riskiness of banks under different funding structures (retail deposits vs. wholesale funding). Our study is also related to the literature on the regulation of bank leverage, since banks in Canada face regulatory leverage limits. Blum (2008) provides a theoretical motivation for leverage limits in a world where a supervisor knows that different types of banks (safe and risky) exist, but without knowing the actual risk types of each bank. In such a setting, self-reporting and assessment of risks (in a manner similar to Basel II) is not optimal, since risky banks have an incentive to understate their risks. Blum (2008) shows that having a simple leverage ratio cap along with capital requirements based on banks' internal risk assessments can result in truthful revelations of banks' risk levels. Geanakoplos (2010) theoretically analyzes adverse effects of leverage fluctuations in an environment where leverage is determined in equilibrium together with interest rates. The paper shows how leverage cycles damage the economy and argues for regulations to control them. Bordeleau et al. (2009) discuss the historical evolution of regulatory leverage limits in Canada and analyze how large Canadian banks manage leverage with respect to these limits. They find that some large banks maintain a buffer between their leverage and the regulatory limit, implying some flexibility to adjust leverage. Finally, The Committee on the Global Financial System (2009) provides some international policy discussions regarding leverage procyclicality.

The rest of the study is as follows: Section 2 presents some basic balance sheet arithmetic to explain the link between asset growth and leverage growth. Section 3 provides a brief discussion of the Canadian banking sector. Section 4 presents the data. Section 5 explains the empirical methodology and Section 6 describes the results for the first two objectives. Section 7 analyzes the relationship between banking-sector leverage procyclicality and market volatility. Section 8 discusses our robustness checks. Finally, Section 9 concludes.

2. Asset changes vs. leverage changes

Our findings of leverage procyclicality are based on positive correlations between asset growth and leverage growth.[3] In this section, we discuss how such a positive correlation can emerge from a bank actively managing its balance sheet. Furthermore, this basic balance sheet arithmetic also demonstrates

[3] However, as mentioned above, prices of certain bank assets and hence the bank's balance-sheet size, tend to increase during booms and decrease during busts. As such, a positive correlation between asset growth and leverage growth can also imply procyclicality of leverage with respect to economic activity.

how the strength of leverage procyclicality is influenced by the funding sources used by a financial intermediary (wholesale funding vs. retail deposits).[4] Consider the simplified balance sheets for two banks that use different funding sources, where Bank 1 is funded by wholesale funding and Bank 2 by retail deposits:

Bank 1				*Bank 2*			
Assets		Liabilities		Assets		Liabilities	
Total Assets	200	Retail Deposits	0	Total Assets	200	Retail Deposits	190
		Wholesale Funding	190			Wholesale Funding	0
		Equity	10			Equity	10

The leverage ratio of a bank is $L = A/E$, where L is leverage, A is total assets and E is equity. Given these balance sheets, the leverage ratio for both banks is 200/10 = 20. Now suppose that both the value of the asset portfolio and the amount of equity rises by $2 for each bank. Such an increase in assets and equity could be caused by an increase in the price of marked-to-market securities, which is reflected in the banks' net worth as in Adrian and Shin (2010), or by the bank issuing new equity in order to purchase more assets. Under both scenarios, the leverage ratio will become 202/12 = 16.83 for both banks. The result is the following balance sheets:

Bank 1				*Bank 2*			
Assets		Liabilities		Assets		Liabilities	
Total Assets	202	Retail Deposits	0	Total Assets	202	Retail Deposits	190
		Wholesale Funding	190			Wholesale Funding	0
		Equity	12			Equity	12

It is, however, possible that the banks will not remain passive and decide to "actively manage" their balance sheets. During economic booms (which likely cause the initial price increase of the bank assets), banks expand their balance sheets as they typically face low funding rates and increasing investment opportunities. Suppose Bank 1, having access to liquid market-based wholesale funding, raises $62 and purchases more assets (e.g., securities). On the other hand, since Bank 2 depends exclusively on retail deposits, it will be less able to quickly raise funds, given the "sluggish" nature of retail deposits. Assuming that Bank 2 is only able to raise a smaller amount of the required funds ($50) in a given period, the balance sheets of these two institutions become[5]:

Bank 1				*Bank 2*			
Assets		Liabilities		Assets		Liabilities	
Total Assets	264	Retail Deposits	0	Total Assets	252	Retail Deposits	240
		Wholesale Funding	252			Wholesale Funding	0
		Equity	12			Equity	12

[4] Besides the channel described here, any balance-sheet adjustments that do not involve an adjustment in equity will also lead to a positive correlation between changes in assets and leverage. Our findings again imply that funding sources are important for these adjustments.

[5] This assumption features the key difference between wholesale funding and retail deposits.

Now the leverage ratio of Bank 1 is 264/12 = 22, whereas the leverage ratio of Bank 2 is 252/12 = 21. Furthermore, if the initial change in the value of equity is the result of an asset price change with marked-to-market accounting, it would affect all banks with the same marked-to-market assets on the balance sheet. As a result, many banks demanding more assets together can lead to further appreciation in the price of these assets, triggering another round of adjustments as described above. This is the "feedback effect" discussed by Adrian and Shin (2010) (or similarly the "spiral effect" by Brunnermeier and Pedersen (2009)) since the increase in the value of the marked-to-market assets (and the bank's desire to actively manage its balance sheet) is the cause of the adjustment process and the possible spiral that follows.

This example illustrates two things: leverage is procyclical and leverage procyclicality is stronger for banks that use wholesale funding (Bank 1). In the first stage of the example, the change in assets and leverage is identical for both banks: a relatively small increase in assets (1%) leads to a fairly large drop in leverage (approximately 16%). In the second stage, however, both balance-sheet size and leverage increase at a fast rate for Bank 1, since it is able to raise more funds. The growth rates for assets and leverage both equal 31%, approximately. On the other hand, assets and leverage grow at a slower pace for Bank 2, since it is unable to raise as much funding as Bank 1. For Bank 2, the growth rates of assets and leverage both approximately equal 25%. Given that the growth rates were identical for the two banks in the first stage and higher for Bank 1 in the second stage, it is clear that the correlation between asset growth and leverage growth will be higher for Bank 1 ({1%, −16%}, {31%, 31%}) than for Bank 2 ({1%, −16%}, {25%, 25%}). When extended to additional stages, a feedback effect can generate a series of observations which will confirm positive correlations for both banks (i.e., leverage procyclicality) and a higher correlation for Bank 1, the wholesale-funded bank. This is solely due to the fact that Bank 1 is able to quickly raise funds to adjust its leverage.[6]

Fig. 1 shows four scatter-plots of monthly leverage growth and asset growth rates for all banks, high wholesale funding, low wholesale funding and no wholesale funding banks between January 1994 and December 2009.[7] Each point corresponds to a bank-month combination. A positive correlation is observed when the points are scattered along a positively sloped line–assets and leverage change in the same direction. All graphs display differing degrees of points scattered along a positively sloped line. The calculation of an unconditional correlation coefficient reveals a high correlation at 0.76 for all banks. The strength of this correlation coincides with wholesale funding use, as the coefficients are 0.86, 0.73 and 0.48 for high, low and no wholesale funding banks, respectively.[8]

Adrian and Shin (2010) present a similar scatter-plot for the average growth rates of assets and liquidity for US brokers-dealers and commercial banks between 1963 to 2006. Their graphs show positive correlations for brokers-dealers but no observable relationship for commercial banks. Furthermore, similar scatter-plots presented by Panetta and Angelini (2009) do not show a positive asset growth-leverage growth relationship in Germany, France, Italy and Japan. Interestingly, Panetta and Angelini (2009) do observe a positive relationship between asset growth and leverage growth in the United Kingdom.

The discussion of bank equity so far has focused on its book value with an adjustment for marked-to-market assets. Throughout the paper, we will use this notion of equity rather than its market capitalization, reflecting the present value of future dividends. Focus on the former notion fits our purpose of studying bank balance-sheet management. First, balance-sheet risk management is an important objective of banks. Book values of equity are a measure of buffer against losses in asset values. Hence, bank's asset portfolio decisions, considering potential loan defaults and losses in values of securities, would directly factor in book values of equity. Second, various regulatory requirements such as minimum capital ratios and caps on leverage ratios are typically specified with respect to book values

[6] Intuitively, the correlations would be positive in this example because the contribution from the initial movements in assets and leverage (i.e., a decrease in leverage and an increase in assets, a potential source of negative correlation) is small as the asset change is very small.

[7] See below for the definition of the wholesale funding categories.

[8] Regardless of wholesale funding usage, it is possible that only a few banks drive the positive correlations by always changing assets and leverage together, while many other banks have no or negative correlation. We rule this out by calculating the correlation coefficient conditional on a bank. A simple average of bank-specific correlation coefficients across banks in each category gives similar results: 0.69 for all banks and 0.83, 0.69 and 0.54 for high, low and no wholesale funding banks, respectively.

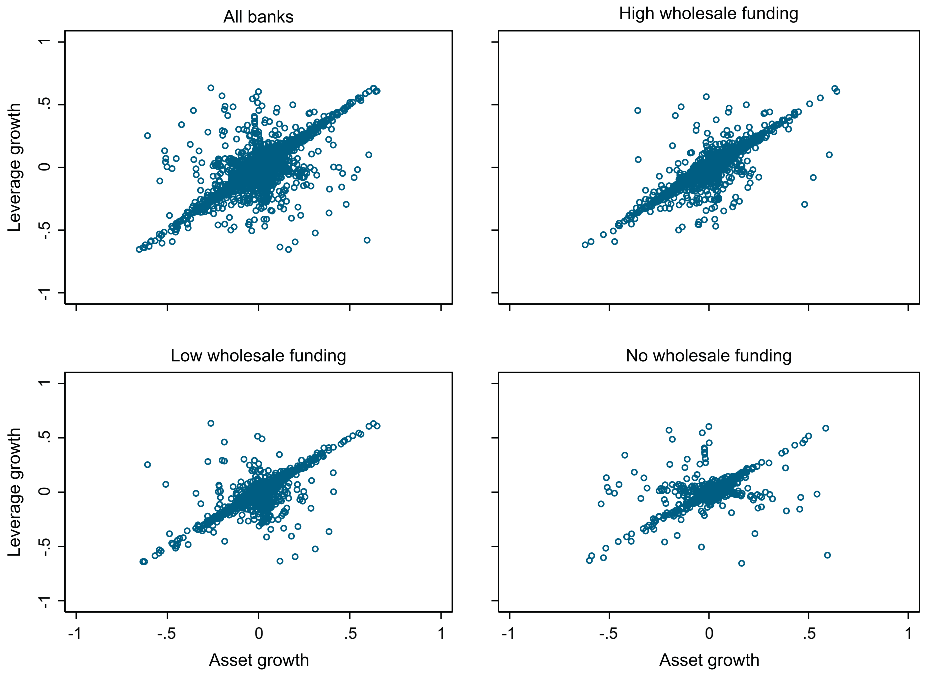

Fig. 1. Monthly change in assets and leverage in Canada (1994–2009).

(with current market-value adjustments to assets) of bank equity. This is again because book values of equity work as a direct buffer against risks associated with bank assets. Based on these considerations, book values of equity are more relevant than its market valuation in our analysis of bank balance-sheet management.

3. Canadian banking sector

In this section, we briefly discuss the Canadian banking sector and provide an overview of important regulatory developments (particularly the "asset-to-capital multiple" or ACM limit) in Canada. Following this overview, the empirical analysis presented in Section 4 below will further examine the positive relationship between asset growth and leverage growth in Canada.

3.1. Overview

It can be argued that the Canadian banking sector has always had a relatively stable structure. Prior to 1980, the financial system had five segments: chartered banks, trust and loan companies, securities dealers, co-operative credit institutions, and life insurance companies. Of these, federally chartered banks were historically involved in commercial lending, whereas trust and loan companies specialized in collecting term deposits and making residential mortgage loans. Co-operative credit institutions, which are chartered and regulated by the provinces, have traditionally concentrated on retail deposits, residential mortgages and personal loans (Allen and Engert, 2007).

Due to nationwide branch banking arrangements, the sector has always been dominated by a few very large banks. Currently, around 88.5% of all banking sector assets are held by six large banks, known as the "Big Six."[9] A number of smaller foreign or domestically-owned banks provide competition

[9] They are: Bank of Montreal (BMO), Bank of Nova Scotia, Canadian Imperial Bank of Commerce (CIBC), National Bank of Canada, Royal Bank of Canada (RBC) and TD-Canada Trust.

to these six very large banks in certain geographic areas (e.g. Western Canada and Quebec) or lines of business (e.g. internet-only banks competing for small retail deposits). Therefore, the Canadian banking sector can be characterized as having a dominant core and a competitive fringe.

3.2. Important change in regulatory environment

An important feature of the Canadian banking sector is that the Bank Act, the legislation that governs banks, includes a requirement for a periodic and formal review process of the rules and regulations regarding financial institutions. This “sunset provision” has led to a number of important legislative amendments since 1980 (Allen and Engert, 2007). One such regulation is directly relevant for our analysis. The 1987 Amendments to the Bank Act allowed banks, which could already have subsidiaries in the areas of venture capital and mortgage lending, to own securities dealers and enter the securities market. Since then, all of the large and some of the small chartered banks eventually acquired or founded a securities dealer. As a consequence, no large, independent Canadian securities dealers remained by the mid-1990s. Thus, the financial institutions in our analysis can own investment banking subsidiaries. Our data consist of regulatory reports which give consolidated financial information and do not separately provide activities of different divisions and subsidiaries.[10]

3.3. Leverage ratio limits and their evolution

Another important feature of the Canadian banking sector is the presence of a regulatory leverage ceiling. As discussed by Bordeleau et al. (2009), Canada is one of the few countries that has had a long-standing limit on leverage ratios. The leverage ceiling, known as the ACM limit, was introduced in 1982, following a period of high leverage ratios among major Canadian banks. Leverage is measured using the following regulatory definition in Canada:

$$\text{Leverage} = \frac{\text{Total balance-sheet assets} + \text{Certain off-balance-sheet assets}}{\text{Total regulatory capital}}$$

The evolution of the ACM limit between 1994 and 2009 can be divided into two distinct periods. During the 1990s, a formal limit of 20 was applied quite uniformly across all institutions, although the supervisors used their discretionary powers to impose lower limits on smaller and/or newly founded financial institutions. The supervisory bank data used in this study contains the ACM limits for 26 banks and 22 trust and loan companies from 1997Q4 to 1999Q4 (ACM limit data is unavailable for 1994Q1–1997Q3). Most of these institutions had an ACM limit of 20 during the entire period between 1997Q4 and 1999Q4, although some reported an ACM limit below 20.

After 2000, banks that satisfy a certain set of criteria have been allowed to increase their ACM limit to as high as 23. The standard ACM limit of 20 is still maintained, although the regulators apply a lower ACM limit to certain institutions. The available data confirms that there was much less uniformity in the ACM limits set on individual banks after 2000. Currently, ACM limit data exists for 23 banks and 29 trust and loan companies for the period 2000Q1 and 2009Q4. Of these, the majority of banks and about half of trust and loan companies reported having an ACM limit of 20 during the entire period. Several institutions had a limit above 20 for at least part of the period, while others reported a limit below 20 at least once (or sometimes for the entire period). Overall, the ACM limit appears to have been more variable during this period, with more financial institutions having a leverage limit either above or below the standard limit of 20.

In their study of regulatory leverage constraints in Canada, Bordeleau et al. (2009) argue that the major Canadian banks prefer not to operate too close to their limit. Instead, these banks tend to keep a “leverage buffer” in order to minimize the risk of balance-sheet volatility (such as trading activity) pushing leverage above the limit. The presence of such a buffer between a bank’s leverage and its leverage limit can play a role in determining the link between asset growth and leverage growth. This issue will be discussed further below.

[10] This fact puts some of these financial institutions closer to investment banks analyzed in Adrian and Shin (2010).

4. Data

The bank balance sheet data used in this study comes from the Tri-Agency Database System (TDS) of the Bank of Canada, Office of the Superintendent of Financial Institutions (OSFI) and the Canadian Deposit Insurance Corporation (CDIC). The TDS database contains monthly balance sheet and off-balance sheet information, along with quarterly income statement information, reported by all federally chartered financial institutions. Although there exist data going back to January 1981, some series did not begin until after 2000, while other series were terminated and/or replaced due to accounting rule changes. As a result, only certain broad measures, such as total assets, total equity, retail deposits, wholesale deposits, total loans and total securities, can be tracked across the entire sample period. Most of the subitems under these broad categories only become available much later than 1981. This imposes some constraints on the design of the empirical analysis, which will be discussed below. Nevertheless, TDS is an extensive database and it has the advantage of providing balance sheet data at a higher frequency than the data used in other studies in the literature. This study uses data that covers the period January 1994 to December 2009.[11]

Although TDS provides data on a universe of 224 domestic banks, foreign bank subsidiaries, foreign bank branches and trust and loan companies (active or inactive), some of these institutions had to be eliminated from the study. The foreign bank branches that were established in Canada following the regulatory changes in 1999 had to be eliminated, since they do not report any equity (making it impossible to calculate their leverage ratio). Also, banks and trust and loan companies that are fully-owned subsidiaries of a chartered bank or a trust and loan company were also eliminated, since their parent institution already reports a consolidated balance sheet.[12] Given that TDS does not contain data on co-operative credit institutions, these are also excluded from our study. The remaining 136 Canadian banks and trust and loan companies (which are referred to as "financial institutions" or "banks" from now on) form the sample that was used in the study.[13] Overall, the data set contains 12,949 bank-month combinations.

The bank-level balance sheet data is also supplemented by macroeconomic and financial market variables, such as GDP growth rate, and market liquidity measures. These variables were all obtained from the "Bank of Canada Banking and Financial Statistics."[14]

5. Empirical analysis: methodology

As discussed above, the first two objectives of this study are (i) to identify the link between leverage growth and asset growth among Canadian financial institutions, and to determine how this link interacts with banks' funding (specifically their use of wholesale funds) and (ii) to examine whether shocks in macroeconomic and market conditions affect the asset growth-leverage growth relationship. The empirical strategy chosen to achieve these goals is a two-step method, similar to the approach outlined by Kashyap and Stein (2000) in their work on the bank lending channel of monetary policy and subsequently used by Campello (2002) and Cetorelli and Goldberg (2008).

In broad terms, the outline of the two-step approach is as follows: in the first step, the sensitivity of leverage growth to asset growth, i.e., the *degree* of leverage procyclicality, ($\partial\Delta$Leverage/$\partial\Delta$Assets) is cross-sectionally estimated using *bank-level* balance sheet data only. Then, the second step of the analysis aims to determine if and how these sensitivities change over time following macroeconomic and

[11] Availability of balance sheet data at the monthly frequency is not typical. For example, Call Reports in the United States – used by Kashyap and Stein (2000) and Campello (2002) – are only available at the quarterly frequency. One focus of our analysis is market-based funding of banks. Markets for these types of funding are fairly sensitive to economic conditions and hence more volatile than, say, the markets for retail deposits. Hence, use of high frequency data is desirable.

[12] However, if a bank or a trust and loan company operated independently any time between 1994 and 2009 before being acquired, then it was included in the sample for the period during which it was an independent entity. There were 13 such cases.

[13] We also consider a sample consisting solely of the "Big Six" in the Appendix, available at http://www.bankofcanada.ca/wp-content/uploads/2013/06/Appendix-JFI.pdf.

[14] Available at http://www.bankofcanada.ca/en/bfsgen.html.

Table 1
"Transition matrix" showing switching patterns of banks among the different wholesale funding use categories.

Group at t	Group at $t + 1$ (%)		
	High WSF	Low WSF	No WSF
High WSF	96.29	3.51	0.2
Low WSF	3.56	94.22	2.22
No WSF	0.05	3.84	96.11

market-wide liquidity shocks, i.e., *changes* in the degree of procyclicality over time. Therefore, only *macroeconomic and market-wide financial variables* are used in this second step.

While identifying the link between leverage growth and asset growth, we also consider the degree of heterogeneity among Canadian banks' funding portfolios. It is possible that banks with access to liquid wholesale funding markets can adjust their leverage ratios more quickly, compared to banks that rely on illiquid funding sources (such as retail deposits) or equity, which can be more costly to raise. Accordingly, Canadian banks were categorized based on how much wholesale funding they use. "Wholesale funding use" of a bank is thereby defined as:

$$\%\text{WSF} = \frac{\text{Non-personal deposits} + \text{Repos} + \text{Banker'sAcceptances}}{\text{Total Liabilities} + \text{Equity}}$$

Using this definition, Canadian banks can be divided into three categories: (a) high degree of wholesale funding users – High WSF, (b) low degree of wholesale funding users – Low WSF, and (c) banks that do not use wholesale funds – No WSF.

For banks that do use wholesale funding, the median of the %WSF ratio was calculated for each month, and banks above (below) the median were placed in the High WSF (Low WSF) group. This categorization was individually performed for each of the 192 months in the sample (January 1994 to December 2009).

Such a categorization naturally raises the issue of a bank's "access" to wholesale funding markets vs. its "use" of such funds. Specifically, a bank that chooses not to raise any wholesale funds would be in the No WSF group along with a bank that has no access to wholesale funding markets. The former bank, however, can decide at any time to access wholesale funding markets, switching either to the Low WSF or High WSF group.

The patterns in the data, however, suggest that banks do not frequently change their intensity of wholesale funding use. Table 1 presents a simple "transition matrix" showing the probability of a bank remaining in the same category vs. switching to a different category between time t and $t + 1$. As seen from this transition matrix, switches between categories are relatively rare events: out of a total of 12,949 bank-month combinations, there are only 604 cases where a bank switches categories between t and $t + 1$. As such, the concerns related to frequent switches between categories appear to be alleviated for the Canadian case.[15]

Table 2 below presents some summary statistics for the entire sample of banks, along with different groups of banks based on their wholesale funding use. In addition to the number of banks, summary statistics for leverage, leverage growth (ΔLeverage) and asset growth (ΔAssets) are also presented. The variation in the number of banks within the No WSF group during the sample period is due to the nature of the data set. TDS does not contain balance sheet data for trust and loan companies before January 1996. Since many trust and loan companies do not hold wholesale funding, their absence from the data set during the January 1994 - December 1995 period causes the No WSF category to have very few observations. Once the trust and loan companies enter the data set in January 1996, most of this variation is eliminated. The summary statistics in Table 2 suggest that No WSF banks have lower leverage ratios compared to the rest, but the leverage behavior of the High WSF and Low WSF banks are similar. Although the average monthly rates of changes in

[15] As the threshold level of wholesale funding use changes over time, this categorization captures macroeconomic and market-wide movements fairly well. As a result, many banks stay in the same category with high probabilities.

Table 2
Summary statistics for all banks in the sample and each individual group of banks.

	Mean	Median	Std. dev.	Min	Max
All banks					
# of banks	67.44	69	4.04	54	75
Leverage	9.33	9.40	5.38	0.96*	24.15
ΔLeverage	−0.001	0.00	0.09	−0.66	0.63
ΔAssets	0.006	0.004	0.08	−0.63	0.65
High WSF					
# of banks	26.59	26	3.69	20	33
Leverage	10.56	9.93	4.47	1.58	24.15
ΔLeverage	−0.003	0.002	0.10	−0.62	0.63
ΔAssets	0.004	0.006	0.09	−0.62	0.64
Low WSF					
# of banks	26.06	26	3.65	19	32
Leverage	10.749	11.57	4.71	1.00	23.75
ΔLeverage	0.0004	0.001	0.08	−0.64	0.63
ΔAssets	0.009	0.007	0.07	0.63	0.65
No WSF					
# of banks	14.79	13	7.97	1	30
Leverage	4.57	1.30	5.30	0.96[a]	22.92
ΔLeverage	−0.0004	0.00	0.07	−0.66	0.60
ΔAssets	0.004	0.002	0.07	−0.60	0.59

[a] Some observations display leverage ratios less than 1. This is because some liability items can have negative values. For example, "Income Taxes Payable" (a liability item) can be negative, implying income tax refunds.

assets and leverage are smaller than ±1%, there is some variation both within and between different groups of banks, which is elaborated in the empirical analysis below.

Finally, Table 3 provides weighted average balance-sheet portfolios of all banks and for each wholesale funding group over the sample period. The weighting is done by combining the balance sheets of all banks in a category in a given month, finding the balance-sheet share of each item for the combined group and averaging these shares across time. The average bank has above half of its assets in loans and the rest in cash, securities and other assets. On the funding side, 95% of assets are funded by non-equity funding, with retail deposits and wholesale funding each taking up 48% and 30%, respectively. The percentage of wholesale funding accordingly changes across wholesale funding groups by design. The average bank in the High WSF group funds 60% of assets by wholesale funding, while this ratio is 30% for the Low WSF group. Retail deposits are the important source of funding for the Low WSF group, amounting to 50% of total assets. The No WSF group tends to finance assets mostly by retail deposits and other types of debts. Loans make up most of the asset side with 57%, 66% and 75% of total assets for High, Low and No WSF banks, respectively. The High WSF group owns a higher fraction of riskier non-mortgage loans than safer mortgage loans (42% vs. 14%), relative to the Low and No WSF groups (33% vs. 33% for Low WSF and 64% vs. 11% for No WSF). Private sector securities and derivative related securities are among the assets most subject to market-price risk. The High and Low WSF groups have 20% and 12% of their total assets, respectively, in these assets.

5.1. Empirical analysis: first step

In the *first step* of the empirical analysis, we run two sets of regressions. The procyclicality of leverage is analyzed for all banks together in the first set (Eq. (1)) and for three groups in the second (Eq. (2)). These two sets of regressions are independently run for *each month*:

Table 3
Weighted average balance-sheet portfolios for each group of banks in percentage of total assets, January 1994–December 2009.

	All banks	High WSF	Low WSF	No WSF
Total Assets	100	100	100	100
Cash	6	8	6	10
Loans	58	57	66	75
Mortgage	21	14	33	64
Non-mortgage	37	42	33	11
Securities	29	27	23	12
Public sector	8	8	11	9
Private sector	15	14	9	3
Derivative related	6	6	3	0
Other assets	7	8	5	3
Total liabilities	95	95	94	79
Retail deposit	30	19	50	32
Wholesale funding	48	60	30	0
Other liabilities	18	16	14	47
Equity	5	5	6	21

$$\begin{aligned}\Delta \ln(\text{Leverage})_{i,t} &= \psi_t \\ &+ \alpha_{1,t} \cdot \Delta \ln(Assets)_{i,t} \\ &+ \alpha_{2,t} \cdot \ln(ACM\ Limit)_{i,t} \\ &+ \alpha_{3,t} \cdot Liquid_{i,t} \\ &+ \alpha_{4,t} \cdot Merger_{i,t} \\ &+ \alpha_{5,t} \cdot \ln(Leverage)_{i,t-1} + \epsilon_t,\end{aligned} \tag{1}$$

$$\begin{aligned}\Delta \ln(\text{Leverage})_{i,t} &= \psi_{1,t} + \psi_{2,t} \cdot Low_{i,t} + \psi_{3,t} \cdot No_{i,t} \\ &+ \beta_{1,t} \cdot \Delta \ln(Assets)_{i,t} \\ &+ \beta_{2,t} \cdot \Delta \ln(Assets)_{i,t} \cdot Low_{i,t} \\ &+ \beta_{3,t} \cdot \Delta \ln(Assets)_{i,t} \cdot No_{i,t} \\ &+ \beta_{4,t} \cdot \ln(ACM\ Limit)_{i,t} \\ &+ \beta_{5,t} \cdot Liquid_{i,t} \\ &+ \beta_{6,t} \cdot Merger_{i,t} \\ &+ \beta_{7,t} \cdot \ln(Leverage)_{i,t-1} + \epsilon_t,\end{aligned} \tag{2}$$

where $Leverage_{i,t}$ = ($\text{Assets}_{i,t}$/Total Regulatory $\text{Capital}_{i,t}$) and $Assets_{i,t}$ is the total balance sheet assets of bank *i* at time *t*. This *first step* regression is similar to the regressions run by Adrian and Shin (2010), since the dependent variable is the growth rate of leverage, and both the lagged leverage ratio (in logs) and the growth rate of assets are included as independent variables. However in Eq. (2), in order to account for heterogeneity in the link between leverage and asset growth among banks, $\Delta\ln(Assets)_{i,t}$ is also interacted with the wholesale-funding group dummies, where the High WSF group is the omitted category.

The first step regressions given in Eqs. (1) and (2) also include a number of control variables. A bank with a liquid asset portfolio might be more likely to increase its leverage ratio, since it would be able to quickly sell assets if it were unable to refinance some of its debt in the future. Therefore, $Liquid_{i,t}$ = (-Securities $\text{owned}_{i,t}$/$\text{Assets}_{i,t}$) is included as a control variable. $Merger_{i,t}$ is a dummy variable that takes the value one if the bank was involved in a merger or acquisition during the previous six months, since such activity is likely to impact leverage.

[16] Results of these regressions are available upon request.

The final independent variable is $\ln(ACM\ Limit)_{i,t}$, which is the log of the leverage ratio ceiling placed on a bank at time t. As discussed above, the data used in this study does not contain information on the ACM limits of individual banks for 1994Q1–1997Q3, while for the period between 1997Q4 and 2009Q4, ACM limits are observed only for some banks. In order to include the ACM limit in the first step regression, the missing ACM limit data was generated using a simple procedure that uses Tobit regressions. This procedure involves regressing the ACM limits observed in the data set on a number of bank-specific variables and using the regression coefficients to generate fitted values for the missing ACM limits.[16]

The estimation of Eqs. (1) and (2) separately for each month involves running 192 individual regressions per equation. The estimated coefficients for $\Delta\ln(Assets)_{i,t}$ and its interactions are then used as dependent variables in the second step regression discussed below. In this setting, α_1 from Eq. (1) measures the correlation between asset growth and leverage growth for all banks combined. In addition, β_1 from Eq. (2) is the correlation between leverage and asset growth for high wholesale funding users, whereas $(\beta_1 + \beta_2)$ and $(\beta_1 + \beta_3)$ capture this relationship for the low wholesale funding users and no wholesale funding users, respectively. In essence, the first step of the analysis generates the estimates of a separate time series of $\partial\Delta$Leverage/$\partial\Delta$ Assets for all banks combined and for each wholesale funding group, with 192 observations in each time series.

5.2. Empirical analysis: second step

This second step involves the estimation of the following time series regression, separately, *for all banks combined* and *for each WSF group*:

$$\xi_{j,t} = \eta + \sum_{q=0}^{1}\theta_{1q} \cdot \Delta\ln(Repo)_{t-q} + \sum_{q=0}^{1}\theta_{2q} \cdot \Delta\ln(CP + BA)_{t-q} + \sum_{q=0}^{1}\theta_{3q} \cdot \Delta\ln(GDP)_{t-q} + \sum_{q=0}^{1}\theta_{4q} \cdot \Delta TED\ Spread_{t-q} + \epsilon_{j,t}, \quad (3)$$

where j represents the different groupings of Canadian banks: $j = 1$ for all banks and $j = 2$, 3, and 4 based on their wholesale funding use, high, low and non, respectively. $\xi_{j,t}$ is constructed from the estimates in the first step such that $\xi_{1,t} = \alpha_{1,t}$, $\xi_{2,t} = \beta_{1,t}$, $\xi_{3,t} = \beta_{1,t} + \beta_{2,t}$, and $\xi_{4,t} = \beta_{1,t} + \beta_{3,t}$. As discussed above, the second step of the empirical analysis only uses macroeconomic and market-wide financial variables to estimate the relationships between these variables and *changes in the degree* of leverage procyclicality.

As illustrated in the balance sheet examples in Section 2, leverage procyclicality would be influenced by how easily a bank can raise funds, i.e., funding liquidity. Hence, we introduce two sets of regressors that contain information on funding liquidity. The log change in the total volume of transactions in the repo market ($\Delta\ln(Repo)$) and the log change in the amount of outstanding banker's acceptances plus outstanding short-term corporate paper ($\Delta\ln(CP + BA)$) indicate the degrees of funding-market activities and hence the ease of raising funds for banks.[17] Both of these variables are normalized by the money supply (M2), in order to capture relative changes in the size of repos, banker's acceptances (BA) and commercial paper (CP) markets relative to the more "traditional" source of liquidity, namely money. If the repo, CP and BA markets are growing faster than the money supply, this can signal "market-based financial intermediaries" playing a larger role in financial intermediation.[18] As such, these variables are of particular interest in the second step of the analysis.

Furthermore, the monthly growth rate of GDP ($\Delta\ln(GDP)$) is included in the second step, since higher growth rates could reduce the costs of rolling over short-term debt, resulting in more assets being purchased by debt. Under this scenario, higher rates of GDP growth will strengthen the asset

[16] Results of these regressions are available upon request.

[17] In Canada, large and established banks use BA as an important source of funding. Also, separating outstanding commercial paper volumes into asset-backed vs. not asset-backed commercial paper can be illustrative; unfortunately, such disaggregated data is not available.

[18] For example, Adrian et al. (2010) look at the importance of financial intermediaries in excess returns of various assets.

growth-leverage growth relationship in the Canadian banking sector. Finally, the monthly change in the TED spread, defined as (3-month CDOR rate) – (3-month Canadian T-Bill rate), is added as a measure of credit market risk.[19]

Before we present the results, it is helpful to discuss why this particular method was chosen. The obvious alternative to the two-step procedure is to nest Eq. (3) into Eq. (2) (or Eq. (1)) and run a panel regression. Kashyap and Stein (2000) and Campello (2002) discuss the benefits of the two-step methodology that allows for a different shock to have a time-dependent impact on leverage in each month. Therefore, it becomes less likely that the results of the first step (coefficients of $\Delta\ln(Assets)_{i,t}$ and its interactions) are influenced by unobserved factors. For example, the two-step procedure is able to account for a shock that leads to an increase in the leverage ratios of all banks in a given month. Furthermore, nesting Eq. (3) into Eq. (2) would force the variables in Eq. (3) to effect leverage growth in a linear fashion, creating a more restricted structure. Finally, the two-step approach allows for the link between asset growth and leverage growth (i.e., the degree of procyclicality) to vary across time. Given the relatively long time-span of this study, it is reasonable to assume that the relationship between leverage and asset growth has changed over time. Some evidence of the coefficients of $\Delta\ln(Assets)_{i,t}$ and its interactions varying across time will be presented below, further validating the two-step approach. However, the two-step specification also tends to have lower statistical power compared to a one-step method, as discussed by Kashyap and Stein (2000). Therefore, results of a one-step, panel data specification that nests Eq. (3) into Eq. (2) is also discussed in the Appendix.[20]

6. Results

6.1. First step results

As discussed above, the first step of the analysis involves the estimation of Eqs. (1) and (2) for each month. During the estimation, in a manner similar to Campello (2002), observations where $|\Delta\ln(Leverage_{i,t})| \geqslant 0.67$ and/or $|\Delta\ln(Assets_{i,t})| \geqslant 0.67$ were eliminated. This ensures that the results are not driven by outliers. Furthermore, the first six months of observations after an entry and the last six months of observations before an exit were eliminated, since the periods immediately following an entry or immediately preceding an exit can involve large swings in assets and equity. The number of observations in each regression varied between 54 and 75 banks, as shown in Table 2.

While analyzing the first step results, three important questions will be addressed: (a) What is the relationship between asset growth and leverage growth in the Canadian banking sector (or is there procyclicality of leverage)? (b) Does the relationship differ by wholesale funding use (or does the degree of procyclicality differ by groups)? (c) Does the relationship between leverage growth and asset growth evolve over time (or does the degree of procyclicality change over time)?[21]

Fig. 2 displays most relevant estimation results as time series of the point estimates and the two standard-error band of $\alpha_{1,t}$ from Eq. (1), and $\beta_{1,t}$, $\beta_{2,t}$ and $\beta_{3,t}$ from Eq. (2). The point estimates are relatively more stable for $\alpha_{1,t}$ (all banks) and $\beta_{1,t}$ (High WSF) at around 1. The estimates of the marginal effects (above that of High WSF), $\beta_{2,t}$ (Low WSF) and $\beta_{3,t}$ (No WSF), are more volatile over time and with wider error bands. This implies that high wholesale funding banks tend to exhibit leverage procyclicality more consistently than other banks.

To elaborate on differences in leverage procyclicality among banks, Table 4 summarizes the results of the coefficient estimates. The table shows the the median, mean and standard error of 192 sets of

[19] All variables in the second step regressions are seasonally adjusted to remove any month effects. In addition, as seen in Eq. (3), the first lag of all independent variables are included in the analysis as well. Studies such as Campello (2002) tend to include longer lags, but since some of our data is unavailable for before January 1994, including additional lags places a burden on both the number of observations and degrees of freedom.

[20] Available at http://www.bankofcanada.ca/wp-content/uploads/2013/06/Appendix-JFI.pdf.

[21] The answer to this question would justify the two-step approach, which allows the coefficients of $\Delta\ln(Assets)_{i,t}$ and its interactions to vary across time. That is, if leverage procyclicality is time dependent, the second-step will allow us to observe macroeconomic and market conditions associated with the changes in procyclicality over time.

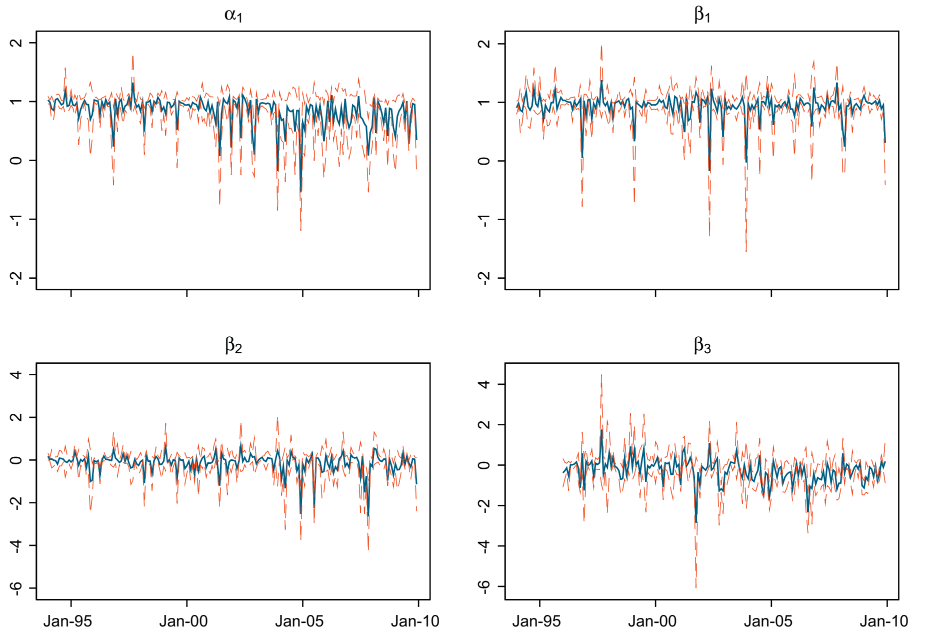

Fig. 2. Time series of the point estimates and the two-standard-error band: α_1 from Eq. (1) (All banks), and β_1 (High wholesale funding), β_2 (Low wholesale funding) and β_3 (No wholesale funding) from Eq. (2). Since the number of no wholesale funding banks is very small during January 1994 and December 1995, the estimated coefficients for these 24 months are not shown.

the estimated coefficients from Eqs. (1) and (2) for all banks and by wholesale funding groups, respectively.[22] Since we focus on the estimates of $\alpha_{1,t}$, $\beta_{1,t}$, $\beta_{1,t} + \beta_{2,t}$, and $\beta_{1,t} + \beta_{3,t}$, we mainly discuss these results. First, we focus on the means and interpret as follows. For all banks, when assets change by 1%, leverage changes by 0.833% in the same direction on average across time. Among High WSF banks, leverage changes by 0.933% with an asset change of 1%, whereas leverage of Low WSF and No WSF banks changes by 0.787% (=0.933 − 0.146) and 0.654%, respectively.[23] As these are all positive numbers, leverage and assets move together on average, indicating that leverage is procyclical. Furthermore, as wholesale funding use increases, leverage and assets move more closely to each other (i.e., the number becomes closer to 1), implying that *degree* of procyclicality increases with wholesale funding.[24]

Second, Table 4 also indicates that dispersions of some parameter estimates across time are high, especially those of $\beta_{2,t}$ and $\beta_{3,t}$ from Eq. (2). Fig. 3 visually shows dispersions of relevant parameters.

[22] The number of estimated coefficients for the no wholesale funding user banks is 168. Since the number of No WSF banks is very small during January 1994 and December 1995, the estimated coefficients for these 24 months are mostly driven by movements in the leverage ratios of one or two banks. As a result, the asset growth-leverage growth sensitivities for this group are not taken into consideration either in the first or the second step of our analysis.

[23] Note that the mean estimate for No WSF is not 0.661% (=0.933 − 0.272). In Table 4, 0.933 is the mean coefficient of $\Delta\ln(\textit{Assets})$ for the entire sample (192 months), while −0.272 is the mean coefficient of $\Delta\ln(\textit{Assets}) \cdot \textit{No}$ for 168 months only, leaving a direct comparison of the two numbers invalid. Table 5 provides the right calculation of the mean coefficient, 0.654, by calculating $\Delta\ln(\textit{Assets}) + \Delta\ln(\textit{Assets}) \cdot \textit{No}$ for each of the 168 months and then taking the average.

[24] Another potentially important determinant of leverage growth in the Canadian banking sector is the ACM limit. The mean of the coefficient estimate on ln(*ACM Limit*) in Table 4 suggests that the ACM limit has some positive impact on how banks adjust their leverage. When ln(*ACM Limit*) increases by one unit, the average increase in leverage is about 0.015% under both Eqs. (1) and (2). The "buffer" that some banks keep between their actual leverage ratios and the leverage ceiling (as discussed by Bordeleau et al. (2009)) is a possible explanation for this finding. If most banks keep such a buffer, then they could increase their leverage with their balance-sheet size without worrying about violating their ceiling. In times of decreasing leverage in the banking sector, it is natural that the ceiling has no impact on the (negative) rate of leverage growth. This may be a reason that the 192 estimates of the coefficient of ln(*ACM Limit*) display high volatility over time in both equations, i.e., the high variances relative to the means in Table 4. See Section 8.2 for more analysis regarding ACM limits.

Table 4
Summary of the 192 individual first-step regression results. Medians, means and standard errors for all coefficients except "$\Delta\ln(Assets) \cdot No$" are calculated across the 192 individual regressions. These descriptive statistics for "$\Delta\ln(Assets) \cdot No$" do not include the 24 estimated coefficients for the years 1994 and 1995, since this group had very few banks during this period.

	All banks			WSF groups		
	Median	Mean	Std. err.	Median	Mean	Std. err.
$\Delta\ln(Assets)$	0.918	0.833	0.018	0.968	0.933	0.014
$\Delta\ln(Assets) \cdot Low$				−0.032	−0.146	0.033
$\Delta\ln(Assets) \cdot No$				−0.169	−0.272	0.045
$\ln(Leverage)_{-1}$	−0.004	−0.005	0.001	−0.004	−0.006	0.001
Liquid	0.008	0.005	0.004	0.006	0.008	0.005
Merger	−0.001	−0.008	0.004	−0.002	−0.006	0.003
ln(*ACM Limit*)	0.007	0.014	0.01	0.003	0.015	0.012
Low				−0.0006	−0.0004	0.001
No				−0.003	−0.001	0.002

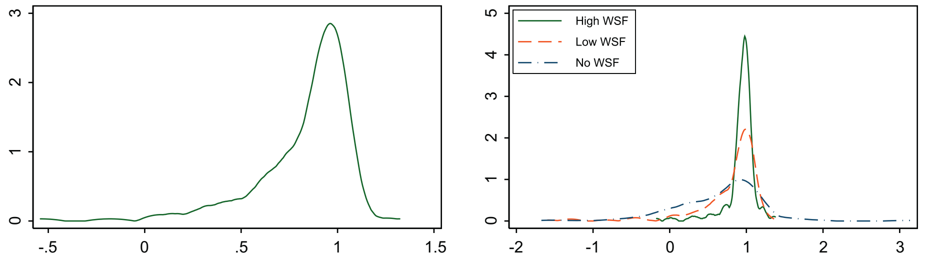

Fig. 3. Kernel Density Estimates of α_1 from the regression model (1) on the left panel; and β_1 (High WSF), $\beta_1 + \beta_2$ (Low WSF) and $\beta_1 + \beta_3$ (No WSF) from the regression model (2) on the right panel.

The figure contains kernel density estimates based on 192 estimates of $\alpha_{1,t}$ on the left panel, and $\beta_{1,t}$, $\beta_{1,t} + \beta_{2,t}$, and $\beta_{1,t} + \beta_{3,t}$ on the right panel. We observe a long left tail over negative values in all figures, implying that in some months, assets and leverage moved in opposite directions. As seen in Section 2, this can happen through passive balance sheet management or alternatively when asset purchases are funded by equity. On the right panel in Fig. 3, we also observe that the estimates of $\beta_{1,t}$ (i.e., for High WSF banks) show less variation than those of $\beta_{1,t} + \beta_{2,t}$ (i.e., for Low WSF banks), and the estimates of $\beta_{1,t} + \beta_{3,t}$ (i.e., for No WSF banks) show the most variation among three groups.

Tables 5 and 6 further summarize the main findings of the first-step regressions and provide some answers to the evolution of leverage procyclicality over time. Table 5 presents the mean of the estimated asset growth-leverage growth sensitivities (i.e., the degree of leverage procyclicality) for all banks and each wholesale funding group, during the entire sample period, and during two sub-sample periods (the 1990s and 2000s). Also presented are statistical tests comparing the means and variances of the estimated sensitivities for the *same* category across *different* time-periods.

The analysis of the two sub-periods in Table 5 suggests the asset-leverage link weakened over time, especially for banks with little or no wholesale funding. This observation is confirmed by the tests comparing the mean sensitivities across different time periods. The null hypothesis of equal means across different sub-periods is rejected for these banks. Furthermore, for the Low WSF group, the null hypothesis of the estimated coefficients ($\beta_{1,t} + \beta_{2,t}$) having equal variance across time is also rejected. This time-variation in the means and the variances of the estimated coefficients across time for all three categories confirms the benefits of the two-step approach over the one-step approach.

Table 6 presents comparisons of mean asset growth-leverage growth sensitivities across different wholesale funding categories for different periods. The comparisons confirm differences in the asset-leverage link across the different groups over the entire sample period, especially during the 2000s. As

Table 5
Summary of first step regression results, continued. Mean (μ) and variance (σ^2) for the estimated leverage growth-asset growth sensitivities are reported for the entire sample period and two sub-periods. The last two rows present tests for the equivalence of the means (μ) and variances (σ^2) of the estimated coefficients for the same category but across different subperiods. $H_0 : \sigma^2_{90} = \sigma^2_{00}$ reports the chi-squared test statistic for a Bartlett's test for equal variance across the two sub-periods. H_0: $\mu_{90} = \mu_{00}$ reports the results of a F* test for the equality of the sub-sample means (robust to $\sigma^2_{90} \neq \sigma^2_{00}$). The mean leverage growth-asset growth sensitivities for the No WSF group do not include the estimated coefficients for 1994 and 1995, since this group had very few banks in it during this period.

	All	High WSF	Low WSF	No WSF
Mean (μ)				
Whole sample (μ_{whole})	0.833	0.933	0.787	0.654
1990s (μ_{90})	0.930	0.952	0.872	0.915
2000s (μ_{00})	0.774	0.921	0.735	0.550
Variance (σ^2)				
Whole sample (σ^2_{whole})	0.062	0.039	0.193	0.319
1990s (σ^2_{90})	0.023	0.029	0.078	0.257
2000s (σ^2_{00})	0.076	0.045	0.256	0.309
$H_0 : \sigma^2_{90} = \sigma^2_{00}$	13.79***	4.41**	26.84***	0.549
H_0: $\mu_{90} = \mu_{00}$	25.36***	1.23	5.90**	16.74***

** Significant at 5%.
*** Significant at 1%.

Table 6
Comparison of mean leverage growth-asset growth sensitivities across different size categories for (i) the entire sample and (ii) two sub-sample periods. The differences in the mean sensitivities are calculated as "Row j – Column i" and a Welch's *t*-test is performed with the null hypothesis of "Mean difference = 0" (robust to unequal sample variances). The mean difference tests involving the No WSF group only include observations from January 1996 and onwards, since this group had too few banks in it prior to January 1996.

	Low WSF	No WSF
Panel A: Entire sample		
High WSF	0.146***	0.272***
Low WSF		0.117**
Panel B: The 1990s		
High WSF	0.080**	0.028
Low WSF		−0.053
Panel C: The 2000s		
High WSF	0.186***	0.370***
Low WSF		0.184***

** Significant at 5%.
*** Significant at 1%.

seen in Panel B of Table 6, the differences between the mean sensitivities of the three groups were not as significant during the 1990s, suggesting that most of the divergence occurred sometime during the 2000s. Whether these changes were due to macroeconomic or financial shocks will be the focus of the second step of the empirical analysis. Nevertheless, the large differences between the High WSF group and the other two groups are not very surprising. Based on the balance sheet examples discussed above, the link between asset growth and leverage growth is likely to be stronger for banks that are able to change their leverage ratio quickly. Banks that access wholesale funding markets can raise or retire debt more quickly, since wholesale funding markets tend to be more liquid compared to retail deposit markets during normal times.[25]

[25] The significant variations across these different groups of Canadian banks also validate the inclusion of the interaction terms with respect to the use of wholesale funding in the first step of the analysis.

In summary, the first step of the analysis suggests that the relationship between asset growth and leverage growth in the Canadian banking sector (a) is positive, i.e., leverage is procyclical,[26] (b) is dependent on wholesale funding use of banks, i.e., the degree of procyclicality increases with wholesale funding use,[27] and (c) has evolved over time.

Specifically, during the 1990s, changes in leverage ratios of all Canadian banks were relatively more procyclical and sensitive to changes in balance-sheet size (as seen in Table 5, mean sensitivities are higher than 0.85 for all three categories during this sub-period). There was a divergence in the 2000s, caused by the weakening of the asset growth-leverage growth relationship among banks that use little or no wholesale funding. Changes in leverage ratios of banks that use high levels of wholesale funding, however, continued to be very sensitive to changes in balance-sheet size. It is possible that the asset growth-leverage growth correlations have a negative time trend, due to the expansion of non-intermediated funding markets reducing the traditional growth opportunities of banks (such as commercial loans) and limiting balance sheet growth rates. However, for the high wholesale funding banks, the development of wholesale funding markets and the use of these funds may have given them new growth opportunities and kept them from lowering their sensitivities relative to other banks. In the second step, we analyze these possibilities.

6.2. Second step results

The second step of the empirical analysis investigates the macroeconomic and market-wide variables associated with the change in the degree of leverage procyclicality of Canadian banks over time. This involves the time-series estimation of Eq. (3) separately for each bank group: All, High WSF, Low WSF and No WSF banks.

The results of the second step are given in Table 7 which contains three panels: Panel A with both *Repo* and *CP* + *BA* funding liquidity variables, Panel B with only *Repo* and Panel C with only *CP* + *BA*. These results strongly suggest that funding-market liquidity matters for changes in the degree of leverage procyclicality in the Canadian banking sector. In Panel A, the degree of leverage procyclicality for all banks increases when the liquidity of the *Repo* and the *CP* + *BA* markets contemporaneously increases (i.e., the positive and significant coefficient of $\Delta\ln(Repo)$ and $\Delta\ln(CP + BA)$). Specifically, as the repo market transaction volume increases by 1%, the co-movement of assets and leverage (measured by the estimated coefficients of $\Delta\ln(Assets)$ in Eq. (1)) increases by 0.004. Similarly, the co-movement increases by 0.013 for an 1% increase in the outstanding *CP* + *BA*, in addition to an increase by 0.01 from a lagged effect of *CP* + *BA*. An increase in *GDP* tends to occur together with higher leverage procyclicality and the increase in *TED Spread* with lower procyclicality, although these relationships are not significant.

Regarding the results by wholesale funding groups, changes in liquidity in the repo market have positive and significant coefficients on leverage procyclicality for High WSF banks. This finding confirms Adrian and Shin (2010), who argue that the active management of a financial institution's balance sheet requires frequent access to repo markets. This is especially true for US investment banks, whose asset growth-leverage growth relationship is highly positive. The positive and significant coefficient of $\Delta\ln(Repo)$ suggests that more liquid repo markets make it easier for banks relying heavily on wholesale funding to take positions in financial markets, perhaps fueling the "feedback effect" of Adrian and Shin (2010) in some parts of the Canadian banking sector.

For the Low WSF group, the asset growth-leverage growth relationship is significantly stronger (more positive) when the *CP* + *BA* markets are more liquid, i.e. the amount of outstanding CP and BA increases. Higher liquidity in CP and BA markets can also signal easier access to funding markets for these institutions, which can then be used to purchase assets, leading to higher procyclicality.

[26] A panel data analysis only with the Big-Six-bank sample confirms that there is no evidence of the behavior of "atypical" small banks driving this finding of a high correlation between asset growth and leverage growth. See the Appendix for a robustness check, available at http://www.bankofcanada.ca/wp-content/uploads/2013/06/Appendix-JFI.pdf.

[27] Wholesale funding banks could also hold high fractions of marked-to-market securities, fueling leverage procyclicality through adjustments in equity values. An analysis explicitly incorporating securities holdings shows that the result is robust to this concern. See the Appendix, available at http://www.bankofcanada.ca/wp-content/uploads/2013/06/Appendix-JFI.pdf.

Table 7
Second-step regression results. Heteroscedasticity and autocorrelation corrected Newey-West (one lag) standard errors. The regression for the No WSF group includes estimated asset growth-leverage growth sensitivities from January 1996 and onwards only.

	All banks		High WSF		Low WSF		No WSF	
	Coef	S. E.	Coef	S. E.	Coef	S. E.	Coef	S. E.
Panel A: Repos, bankers' acceptances and commercial paper								
$\Delta\ln(Repo)$	0.388**	0.172	0.327**	0.142	0.298	0.260	−0.016	0.387
$\Delta\ln(Repo)_{-1}$	0.045	0.132	−0.048	0.121	−0.027	0.211	0.342	0.352
$\Delta\ln(CP+BA)$	1.323**	0.617	0.452	0.580	0.186	1.373	0.180	1.443
$\Delta\ln(CP+BA)_{-1}$	0.982*	0.565	0.0445	0.548	4.143**	1.776	−0.209	1.533
$\Delta\ln(GDP)$	0.062	0.042	0.032	0.033	−0.023	0.064	0.123	0.097
$\Delta\ln(GDP)_{-1}$	0.017	0.040	−0.063*	0.036	−0.075	0.073	0.309***	0.095
$\Delta TED\ Spread$	−0.094	0.060	−0.059	0.076	−0.169	0.111	−0.232	0.191
$\Delta TED\ Spread_{-1}$	−0.008	0.057	−0.009	0.053	0.077	0.123	−0.129	0.146
F-stat	3.85***		1.56		1.73*		2.12**	
No. of obs.	190		190		190		168	
Panel B: Repos only								
$\Delta\ln(Repo)$	0.382**	0.177	0.324**	0.141	0.309	0.259	−0.017	0.383
$\Delta\ln(Repo)_{-1}$	0.069	0.136	−0.035	0.117	−0.082	0.223	0.353	0.349
$\Delta\ln(GDP)$	0.083**	0.041	0.036	0.032	0.021	0.059	0.122	0.088
$\Delta\ln(GDP)_{-1}$	0.042	0.041	−0.057*	0.034	−0.036	0.072	0.309***	0.090
$\Delta TED\ Spread$	−0.109*	0.060	−0.065	0.077	−0.161	0.113	−0.237	0.181
$\Delta TED\ Spread_{-1}$	−0.024	0.061	−0.010	0.052	0.021	0.140	−0.125	0.139
F-stat	2.72**		1.87*		0.81		2.77**	
No. of obs.	190		190		190		168	
Panel C: Bankers' acceptances and commercial paper only								
$\Delta\ln(CP+BA)$	1.121*	0.612	0.174	0.518	−0.047	1.370	0.765	1.542
$\Delta\ln(CP+BA)_{-1}$	1.133**	0.539	0.255	0.524	4.319**	1.760	−0.695	1.436
$\Delta\ln(GDP)$	0.0549	0.041	0.025	0.034	−0.031	0.062	0.130	0.097
$\Delta\ln(GDP)_{-1}$	0.024	0.038	−0.056	0.036	−0.069	0.070	0.300***	0.095
$\Delta TED\ Spread$	−0.096	0.061	−0.059	0.081	−0.169	0.107	−0.215	0.193
$\Delta TED\ Spread_{-1}$	−0.003	0.064	−0.002	0.062	0.082	0.121	−0.136	0.139
F-stat	3.94***		0.87		2.18**		2.51**	
No. of obs.	190		190		190		168	

* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Alternatively, higher turnover can also cause an appreciation in the value of CP or BAs held by Low WSF banks, which may again exacerbate the feedback effect. Taken together, the coefficients for $\Delta\ln(Repo)$ and $\Delta\ln(CP+BA)$ point to easier access to wholesale funds (i.e. when the markets are more liquid) resulting in more assets being financed with debt and a higher correlation between asset growth and leverage growth.[28]

Regarding macroeconomic variables, positive impacts of GDP on leverage procyclicality are limited to the No WSF group. The asset growth-leverage growth relationship is positively correlated with lagged GDP growth. This could be capturing easier access to retail deposits and an abundance of growth opportunities during an economic boom. High WSF banks, however, show lower leverage procyclicality with respect to lagged GDP growth at the 10 per cent significance.[29] TED spreads appear to have negative coefficients. Although insignificant, this result is inline with the intuition that the banking

[28] The finding regarding leverage procyclicality of High and Low WSF banks being sensitive to liquidity in only one of the two funding markets is interesting. Although further analysis on this issue is beyond the scope of this paper, this finding is likely due to differences in business models of the two groups involving both sides of the balance sheet.

[29] This may be a result of High WSF banks taking profits with respect to their security holdings as the price of securities increase during booms. Note, however, that contemporaneous GDP growth (although insignificant) are positively related to leverage procyclicality.

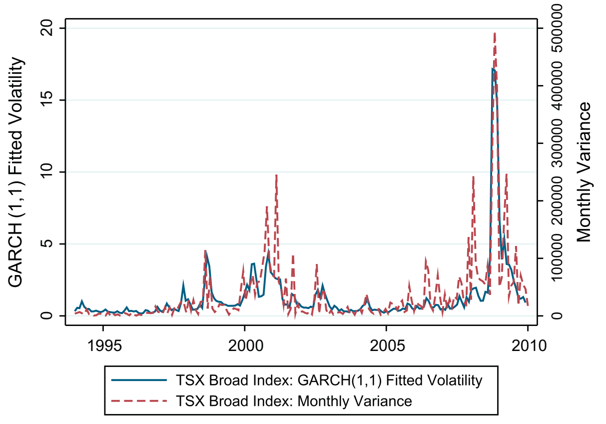

Fig. 4. GARCH fitted volatilities and monthly variance of Toronto Stock Exchange Broad Index.

sector reduces risk-taking activities through active balance-sheet management (e.g., lower leverage procyclicality) when perceived risk is high.

Results found in Panel B and C generally confirm those from Panel A. Although the funding-market liquidity measures, *Repo* and *CP* + *BA*, may be correlated to some extent, Panel B and C independently find similar results to those in Panel A with respect to these variables. Overall, the second step of the analysis suggests that the degree of leverage procyclicality among Canadian banks is significantly impacted by funding-market liquidity variables. Liquidity in the repo, CP and BA markets plays at least some role in determining the magnitude of this relationship, depending on the degree of wholesale funding use. For High WSF, the repo market matters and the CP and BA markets matter for Low WSF. Since these banks might be pursuing active trading strategies, their ability to use funding markets to take trading positions can impact their leverage behavior.

7. Leverage procyclicality and aggregate volatility

Regarding the third objective of the study, this section analyzes how banking-sector leverage procyclicality can forecast aggregate volatility. For instance, leverage procyclicality of individual banks could be linked to aggregate volatility in equity markets. This section studies empirical evidence for these potential links. Specifically, suppose an initial change in the balance sheet in Section 2 is caused by a change in the price of bank assets (i.e., the Adrian and Shin channel). Due to the balance-sheet adjustments explained in Section 2, overall demand for bank assets increases. Given that the initial price change affects all banks with similar portfolios, the banking-industry demand for assets increases. This feeds back into additional increase in the asset price, leading to another round of balance-sheet adjustments and increased demand for assets. Hence, small fluctuations in price could amplify asset price volatility for the industry or in the aggregate through an individual bank's balance-sheet adjustments.

In order to investigate whether this potential link between leverage procyclicality and aggregate or industry-wide volatility exists in Canada, we analyze if the banking-sector co-movements of assets and leverage can forecast aggregate volatility by estimating the following regressions:

$$Volatility_t = \phi_0 + \phi Correlation_{t-1} + \xi_t \quad (4)$$

$$Volatility_t = \lambda_0 + \lambda_1 Correlation_{t-1} + \lambda_2 Correlation_{t-1} \cdot Crisis_t + \lambda_3 Crisis_t + \upsilon_t \quad (5)$$

where $Volatility_t$ is the aggregate equity market volatility, measured in two ways: (i) by the volatilities implied by a GARCH(1,1) model, which is standard in the finance literature (Engle, 2001), and (ii) by monthly variance of observed daily index. We consider the volatility of the Toronto Stock Exchange

Table 8
Leverage procyclicality – aggregate volatility regressions. Dependent variable: (i) GARCH-implied volatility in the TSX Broad Index and (ii) monthly variance of the daily TSX Broad Index. Heteroscedasticity and autocorrelation corrected Newey-West (two lags) standard errors.

Variable	(i) GARCH-Implied volatility				(ii) Realized volatility			
	Coef	S. E.	Coef	S. E.	Coef	S. E.	Coef	S. E.
Correlation	0.949*	0.529	0.487**	0.229	32,491	20,413	17,637*	9,087
Crisis			2.558**	1.202			80,563***	23,390
Correlation · crisis			0.937	1.857			31,075	64,030
Constant	1.287***	0.246	0.868***	0.102	36,293***	5,693	23,082***	3,234
Observations	191		191		191		191	
F	3.216*		3.210**		2.534		7.633***	

* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

(TSX) Broad Index as our aggregate equity market index. The GARCH-implied volatility is calculated using daily returns for the period January 1990–December 2009 and are averaged over a month. Although our bank data set starts in January 1994, we use daily returns extending back to January 1990, in order to improve the estimation of GARCH-implied volatility for the earlier months in the sample. Fig. 4 presents the two volatility series.

In Eqs. (4) and (5), $Correlation_t$ is the correlation between the asset growth and leverage growth rates of Canadian banks in each month and proxies the degree of leverage procyclicality. Although the first-step regression coefficients from Section 6.1 also capture the degree of leverage procyclicality, they are unsuitable to be included as independent variables in Eqs. (4) and (5) due to the "generated regressor" problem. Instead, the following procedure was used to calculate $Correlation_t$: for each month, the correlation between $\Delta ln(Assets)$ and $\Delta ln(Leverage)$ is calculated across banks. We weight individual bank observations by the amount of wholesale funding used by each bank.[30] Averaging the weighted individual bank correlations yields the banking sector-wide asset growth-leverage growth correlation coefficient used in Eqs. (4) and (5) (with one lag).

In addition, Eq. (5) includes a dummy for the recent financial crisis ($Crisis_t$) that equals one for the months between July 2007 and December 2009. This crisis dummy is also interacted with $Correlation_{t-1}$ in order to investigate the impact of leverage procyclicality on aggregate market volatility during periods of financial stress.

The estimation results for Eqs. (4) and (5) are given in Table 8. The left panel of the table presents the estimation results with GARCH-implied volatility of the TSX Broad Index as the dependent variable and the right panel with the monthly variance of the daily TSX Broad Index. First, the estimation results of Eq. (4) show that higher leverage procyclicality (i.e., higher *Correlation* term) weakly forecasts higher GARCH-implied TSX Broad Index volatility, implying a potential positive link between bank leverage procyclicality and aggregate volatility. Furthermore, the results from Eq. (5) suggest that this positive link is more significantly observed during the pre-crisis period than during the crisis period, as the lagged *Correlation* term has positive and significant (at 5%) while the interaction term, *Correlation · Crisis*, exhibits positive but non-significant effects. Results with the monthly variance on the right panel of the table show similar effects, implying that leverage procyclicality forecasts aggregate market volatility, especially, during the pre-crisis period.

Overall, these findings suggest that there is a positive link between leverage procyclicality of the banking sector and the volatility of financial markets. This positive link is significant in the pre-crisis period but turns insignificant during the crisis. It is likely that leverage procyclicality (e.g., de-leveraging by asset fire sales) was an important factor in the crisis-time volatility of the economy, however, multiple other factors would also have been important. For example, various domestic and global government/central bank interventions would have contributed to the reduction in volatility observed during 2009 in Fig. 4, independent of banking-sector leverage procyclicality.

[30] Results based on asset-weighted correlations are similar.

Table 9
Summary of the 192 individual first-step regression results when growth rate of loans is used as an explanatory variable. Means and standard errors (in parentheses) for the estimated leverage growth-loan growth sensitivities are reported for the entire sample period. The mean leverage growth-loan growth sensitivities and their standard errors for the No WSF group do not include the estimated coefficients for 1994 and 1995, since this group had very few banks in it during this period.

	All banks	High WSF	Low WSF	No WSF
All loans	0.350	0.398	0.340	0.248
	(0.016)	(0.021)	(0.020)	(0.044)
Mortgages	0.146	0.119	0.192	0.276
	(0.024)	(0.027)	(0.017)	(0.040)
Non-mortgage loans	0.234	0.349	0.152	0.114
	(0.013)	(0.103)	(0.056)	(0.085)

Table 10
Comparison of mean leverage growth-loan growth sensitivities across different size categories for the entire sample period. The differences in the mean sensitivities are calculated as "Column i – Row j" and a Welch's *t*-test is performed with the null hypothesis of "Mean difference = 0" (robust to unequal sample variances). The mean difference tests involving the No WSF group only include observations from January 1996 and onwards, since this group had too few banks in it prior to January 1996.

	All loans		Mortgages		Non-mortgage loans	
	Low WSF	No WSF	Low WSF	No WSF	Low WSF	No WSF
High WSF	0.058*	0.143	−0.073	−0.116	0.197***	0.221***
Low WSF		0.077		−0.066		0.007

* Significant at 10%.
*** Significant at 1%.

8. Robustness and extensions

This section considers robustness of our previous results and some extensions.

8.1. Leverage procyclicality with loans

Findings in this paper on leverage procyclicality may be linked to real economic activities. Since bank loans provide a more direct link between banking activities and real economic activities than non-loan bank assets, we analyze leverage procyclicality based on loans instead of total assets. We estimate a regression model similar to Eqs. (1) and (2) but replace *Assets* with *All Loans*, *Mortgage Loans* or *Non-Mortgage Loans*. Tables 9 and 10 summarize the estimation results.

Table 9 tells us that positive correlations are present between loan and leverage growth. When all banks are considered together, we observe average correlations of 0.35 for all loans, 0.146 for mortgage loans and 0.234 for non-mortgage loans. Although these values are lower relative to those observed with total asset growth, they are still positive. Table 9 also shows that results regarding higher average correlations for wholesale funding reliant banks are preserved with respect to all loans (0.398 for High WSF, 0.340 for Low WSF and 0.248 for No WSF), and non-mortgage loans (0.349 for High WSF, 0.152 for Low WSF and 0.114 for No WSF). Table 10 confirms that differences between the average correlations for High WSF and other groups are significant for non-mortgage loans but not for mortgage loans. Hence, loan-based leverage procyclicality appears to be amplified by use of wholesale funding and mainly driven by non-mortgage loans.

8.2. Regulatory limits on leverage

The assets-to-capital multiple (ACM) is the regulatory definition of the leverage ratio in Canada and the OSFI places a bank-specific regulatory limit on ACM. In this section, we analyze how proximity of bank leverage to the regulatory limit affects leverage procyclicality with a dummy variable (*ACM*

Table 11
Summary of the 192 individual first-step regression results while controlling the bank's proximity to its ACM Limit. Medians, means and standard errors for all coefficients are calculated across the 192 individual regressions.

Variable	Median	Mean	Std. err.
Panel A: Within 5% of ACM Limit			
$\Delta\ln(Assets)$	0.915	0.829	0.019
$\Delta\ln(Assets)\cdot ACM\ Close$	−0.027	−0.366	0.275
ACM Close	0.001	−0.002	0.004
$\ln(Leverage)_{-1}$	−0.003	−0.004	0.001
Liquid	0.008	0.006	0.004
Merger	−0.001	−0.009	0.004
$\ln(ACM\ Limit)$	0.006	0.015	0.011
Panel B: Within 10% of ACM Limit			
$\Delta\ln(Assets)$	0.926	0.831	0.019
$\Delta\ln(Assets)\cdot ACM\ Close$	−0.003	−0.167	0.144
ACM Close	−0.003	−0.003	0.003
$\ln(Leverage)_{-1}$	−0.003	−0.004	0.001
Liquid	0.008	0.005	0.004
Merger	−0.001	−0.009	0.004
$\ln(ACM\ Limit)$	0.005	0.010	0.011
Panel C: Within 20% of ACM Limit			
$\Delta\ln(Assets)$	0.938	0.833	0.019
$\Delta\ln(Assets)\cdot ACM\ Close$	0.000	−0.023	0.038
ACM Close	−0.003	−0.004	0.001
$\ln(Leverage)_{-1}$	−0.002	−0.004	0.001
Liquid	0.008	0.005	0.004
Merger	−0.001	−0.008	0.003
$\ln(ACM\ Limit)$	0.007	0.013	0.011

Close) indicating the proximity of leverage to the ACM limit. We add *ACM Close* and the interaction term ($\Delta\ln(Assets)\cdot ACM\ Close$) to Eq. (1) based on the all-bank specification. Intuitively, when leverage is close to its limit, banks in an attempt to stay within their leverage limits avoid increasing their leverage even if assets grow, reducing the degree of leverage procyclicality.

Table 11 contains three panels, A, B and C, showing results with *ACM Close* = 1 when leverage is within 5%, within 10% and within 20% of its limit, respectively. In all cases, the distribution of coefficient estimates of $\Delta\ln(Assets)$ are similar to that found in Table 4. The main coefficient of interest is that of $\Delta\ln(Assets)\cdot ACM\ Close$. At the mean, they are negative in all three panels and they decrease as the definition of "proximity to ACM limit" loosens from 5% to 10% and to 20% (from −0.286 to −0.164 and to −0.023, respectively). Hence, average co-movements of leverage and assets decline as leverage gets closer to its regulatory limit.

We can intuitively interpret this result as follows. Banks try to avoid violating regulatory limits on leverage by reducing leverage procyclicality (e.g., debt financing of new assets) as leverage approaches the limit. This is an interesting finding that supports the effectiveness of regulatory limits on bank leverage. Regulatory limits not only control the level of leverage (as their primary objective) but also dampen procyclicality of leverage.[31]

It is also possible that changes in the bank's ACM limit have an impact on leverage procyclicality. Accordingly, we create the dummy variables *Limit Up* and *Limit Down*, which capture whether the bank's ACM limit increased or decreased between $t-1$ and t.[32] Changes in the ACM limit are relatively rare; out of 12,949 bank-month observations in our sample, there are only 514 instances of an ACM limit increase and 495 instances of an ACM limit decrease (in most cases, the limit increases or decreases by

[31] We observe, however, that the standard error of these coefficients are high, especially, for Panel A at 0.275. Hence, there may be time periods when leverage procyclicality increases as leverage becomes close to its limit.

[32] Defining *Limit Up* and *Limit Down* according to ACM limit changes during the previous three months ($t-2$ to t) yields similar results.

Table 12
Summary of the 192 individual first-step regression results while changes in the bank's ACM Limit (increase or decrease). Medians, means and standard errors for all coefficients are calculated across the 192 individual regressions.

Variable	Median	Mean	Std. err.
$\Delta\ln(Assets)$	0.923	0.834	0.019
$\Delta\ln(Assets)\cdot$ *Limit Up*	0.047	0.226	0.247
$\Delta\ln(Assets)\cdot$ *Limit Down*	0.024	−0.109	0.104
Limit Up	0.001	0.012	0.011
Limit Down	0.002	0.001	0.004
$\ln(Leverage)_{-1}$	−0.003	−0.005	0.001
Liquid	0.007	0.004	0.004
Merger	−0.001	−0.007	0.004
ln(*ACM Limit*)	0.009	0.010	0.011

one). Nevertheless, adding the interactions of *Limit Up* and *Limit Down* with $\Delta\ln(Assets)$ to Eq. (1) (all-bank specification) allows us to see the link between changes in the regulatory limits on leverage and procyclicality.

The results shown in Table 12 suggest that when the regulatory limit on leverage is increased, leverage procyclicality also goes up, presumably due to the increased distance between the bank's leverage and its limit giving banks more flexibility in actively managing their balance sheets. Similarly, a decrease in the ACM limit seems to lower leverage procyclicality. Overall, these findings are in line with our "proximity to the ACM limit" results.

9. Conclusion

We study the extent of procyclicality of leverage in the Canadian banking sector. The study is motivated by the theory developed by Brunnermeier and Pedersen (2009) and empirically studied in Adrian and Shin (2010) that a link exists between funding liquidity and market liquidity through financial institutions' balance-sheet management. Our analysis utilizes a variation of the two-step empirical estimation method first proposed by Kashyap and Stein (2000). We use monthly balance sheet data covering 15 years and establish that leverage is highly procyclical among Canadian financial institutions. The degree of procyclicality is higher among banks that are more dependent on wholesale funding, e.g., leverage rises as assets increase. Furthermore, the gap in the degree of procyclicality between high wholesale funding users and the rest of the banking sector has grown larger during the 2000s. We then investigate macroeconomic and market-wide variables associated with leverage procyclicality and its divergence between different wholesale funding groups. The result suggests that leverage becomes more procyclical during times of increased liquidity in repo, BA and CP markets. Finally, we argue that banking-sector leverage procyclicality is important for aggregate economy by providing empirical evidence that banking-sector leverage procyclicality forecasts aggregate market volatility in the equity market.

Since procyclicality of leverage could lead to aggregate volatility, current leverage regulations may not adequately address potential consequences of market and funding liquidity risks. Other regulations, such as those being discussed in the Basel Committee on Banking Supervision, that enforce counter-cyclical capital holdings and directly restrict banks' balance-sheet liquidity-risk management have the potential to address this issue. However, potential costs of such regulations need to be taken into account.

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