Monetary Policy, Private Debt, and Financial Stability Risks*

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Can monetary policy be used to promote financial stability? We answer this question by estimating the impact of a monetary policy shock on private-sector leverage and the likelihood of a financial crisis. Impulse responses obtained from a panel VAR model of eighteen advanced countries suggest that the debt-to-GDP ratio rises in the short run following an unexpected tightening in monetary policy. As a consequence, the likelihood of a financial crisis increases, as estimated from a panel logit regression. However, in the long run, output recovers and higher borrowing costs discourage new lending, leading to a deleveraging of the private sector. A lower debt-to-GDP ratio in turn reduces the likelihood of a financial crisis. These results suggest that monetary policy can achieve a less risky financial system in the long run but could fuel financial instability in the short run. We also find that the ultimate effects of a monetary policy tightening on the probability of a financial crisis depend on the leverage of the private sector: the higher the initial value of the debt-to-GDP ratio, the more beneficial the monetary policy intervention in the long run, but the more destabilizing in the short run.

JEL Codes: E52, E58, C21, C23.

*We would like to thank Oscar Jordà, Jim Hamilton, Harrison Hong, Alexander Ueberfeldt, and seminar participants at the 2016 IJCB Annual Research Conference, Bank of Finland, Bank of Italy, Bank of Spain, Bundesbank, European Central Bank, and Universitat Pompeu Fabra for helpful comments. Graeme Westwood provided outstanding research assistance. The views expressed in this paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada or the Bank of Finland. Corresponding author: eleonora.granziera@gmail.com.

1. Introduction

In the wake of the recent financial crisis, policymakers have disagreed about whether central banks should extend their inflation-targeting mandates to promote financial stability. The supporters of "leaning against the wind" policies argue that low-for-long policy rates may help contribute to the buildup of debt that ultimately poses a risk to financial stability. This is particularly true in the housing market, where low rates may encourage households to take on larger mortgages and spur house price overvaluation (Taylor 2007, 2010). Because of these concerns, some have argued that monetary authorities should raise interest rates more than is warranted by contemporaneous price and output stability objectives alone (Borio 2014).

As monetary policy has a wide impact on both the economy and financial markets, setting interest rates higher than suggested by the central bank monetary policy rule might be costly in terms of lower inflation and lower output. For this reason, other policymakers believe that financial stability should be achieved separately through targeted financial regulation and supervision (e.g., Svensson 2014). Monetary policy should then be used at most to "clean"; i.e., policy should stabilize output and inflation after the bust in asset prices has occurred (Greenspan 2002, Mishkin 2011).

There is a middle ground: even if monetary policy is viewed as the last line of defense, there might be a case for monetary policy intervention to address financial stability concerns when large financial imbalances affect the short-term outlook for output and inflation. Moreover, when a low interest rate environment has encouraged the buildup of broadly based—as opposed to sector-specific—imbalances, monetary policy might complement macroprudential policy and directly contribute to financial stability.[1] However, this view relies on the efficacy of leaning when imbalances are higher than normal.

[1] See Smets (2014) for a detailed summary of the views on the role of monetary policy and macroprudential policies in promoting the soundness of the financial system.

In all of these cases, the rationale for central bank intervention rests on the assumptions that monetary policy is able to reverse the buildup of excess leverage and that "leaning against the wind" policies can be beneficial. However, the effect of monetary policy interventions on key risk indicators—such as the debt-to-GDP ratio—is a priori ambiguous: on the one hand, contractionary policies might lower both debt and the probability of a future crisis over the medium run, while on the other hand, they might have a negative impact on inflation and real activity in the short run. Thus, there are a number of outstanding questions facing policymakers. How effective is monetary policy in lowering the leverage of the private sector along with the subsequent likelihood of a financial crisis? Does this happen over the short or long run? Is leaning better undertaken when financial imbalances are low, or should it occur only when the likelihood of a crisis has become more apparent?

In this paper we contribute to the debate on the leaning versus cleaning roles of monetary policy by investigating whether monetary policy can achieve less leveraged and ultimately less risky economies. We structure our analysis in two steps. In the first step, we assess whether monetary policy can successfully decrease the leverage of the private sector, measured via the private debt-to-GDP ratio. As individual countries have experienced only a small number of financial cycles and financial crises during the last forty years, it would be difficult to determine the impact of a monetary policy shock on financial stability using data from a single country alone. For this reason we consider a broad cross-section of countries that have experienced financial cycles and crises of varying amplitude, size, and timing. In particular, we construct a comprehensive data set for eighteen advanced economies from 1975:Q1 to 2014:Q4. The data include measures of real economic activity, prices, credit, and financial variables. We obtain an aggregate impulse response function of the private debt-to-GDP ratio to a monetary policy shock by averaging impulse responses estimated from individual country VARs. In contrast to most of the existing studies, we use sign restrictions to identify a contractionary structural monetary policy shock while remaining agnostic about the response of the private debt-to-GDP ratio.

In the second step, we relate the private-sector leverage to the likelihood of a financial crisis occurring in the future by using a cross-country panel logit regression. Conditional on the response of the variables to the monetary policy shock and on the panel logit estimates, we can then evaluate the effects of the unanticipated tightening on the subsequent likelihood of a crisis. Some recent studies have analyzed the effect of monetary policy shocks on private debt, while others have focused on the determinants of financial crises. To the best of our knowledge, this is the first empirical paper that studies the effects of monetary policy on private debt and its repercussions for the likelihood of financial crises in a unified framework.

Our results provide new evidence on the questions posed above. A sizable, contractionary monetary policy shock causes real private debt (in deviation from trend) to rise on impact, as nominal debt barely responds and inflation falls. As output shrinks, the debt-to-GDP ratio increases in the short run. In the medium to long run, output recovers and debt decreases, ultimately resulting in a decline in the debt-to-GDP ratio. However, as the probability of a financial crisis increases with the debt-to-GDP ratio, we find that initially a crisis becomes more likely. A contractionary policy is thus risky in the short run. Eventually, as the cumulative response of the debt-to-GDP ratio turns negative, the probability of a crisis drops to a lower value than it was before the shock. Our analysis thus suggests the existence of an intertemporal trade-off that is new to the literature: while an unexpected monetary policy tightening might reduce leverage and promote financial stability in the long run, it might actually generate financial fragility in the short run. This inverse J-curve pattern indicates that additional macroprudential tools may be required or the economy may have to experience short-term pain to achieve long-term gain.

A further novel result is that the effectiveness of monetary policy in mitigating the probability of a financial crisis depends on the current leverage of the economy. In general, an unexpected tightening will ultimately be more effective the higher is the initial debt-to-GDP ratio with respect to trend, but in the short term, it will be more destabilizing. Waiting until financial imbalances are quite high before increasing policy rates can be risky. This result helps policymakers evaluate the trade-off between starting to lean sooner rather than later.

Our paper is related to two growing strands of the literature that discuss the role of monetary policy and financial stability. The first strand examines the role of monetary policy and private debt. From a theoretical perspective, Gelain, Lansing, and Natvik (2015) and Alpanda and Zubairy (2017) use a dynamic stochastic general equilibrium (DSGE) model to find that an unexpected tightening of policy rates affects real private debt through the housing sector by increasing mortgage rates and discouraging new lending. However, it also directly affects the non-housing sectors of the economy. In these models, only new loans respond to a monetary policy shock. As these loans represent a small fraction of total debt, the response of real debt is negative but moderate, implying an increase in the debt-to-GDP ratio in the short run. Svensson (2013) reaches the same conclusion using a partial equilibrium model of household debt dynamics calibrated to the Swedish economy. We include a national house price index in our model to help account for the importance of housing market dynamics. Our findings confirm empirically the results in these structural studies using a broad cross-section of country experience.

The existing empirical evidence on the effect of monetary policy on private debt is limited and focuses mostly on single-country estimates (e.g., Angeloni, Faia, and Lo Duca 2015 for the United States, Laséen and Strid 2013 for Sweden, and Robstad 2017 for Norway). Goodhart and Hofmann (2008) argue that estimates from individual countries might be imprecise, and they conduct a panel VAR analysis of house prices, money, and credit for a sample of industrialized economies. In all of these studies, real debt decreases after a contractionary monetary policy shock, but there is no consensus about the response of the debt-to-GDP ratio. Most of these studies use short-run zero restrictions to identify a monetary policy shock and constrain debt so as not to respond to a monetary policy shock on impact.

There is a growing interest in evaluating the role of private-sector leverage as a potential source of financial instability. Babecký et al. (2012), Gourinchas and Obstfeld (2012), Schularick and Taylor (2012), and Aikman et al. (2015) show that private domestic credit expansion is a significant predictor of financial crises. However, these papers do not investigate how monetary policy can affect credit. To the best of our knowledge, we provide the first empirical assessment of how monetary policy shocks translate into changes in leverage that affect the likelihood of a financial crisis.

Finally, a small number of recent papers use structural models to weigh the benefits and costs of "leaning against the wind" policies. Ajello et al. (2016) and Alpanda and Ueberfeldt (2016) introduce DSGE models for the United States and Canada, respectively, where the economy faces an endogenous probability of a financial crisis that is a function of private credit conditions. Svensson (2016) constructs an analytic model—calibrated to the Schularick and Taylor (2012) likelihood of a crisis—to show that leaning can be expensive, as it implies that when a crisis commences, the economy is already bearing a higher level of unemployment. Gerdrup et al. (this issue) construct a New Keynesian model in which the likelihood of the economy entering a financial crisis follows a Markov-switching process that depends on credit growth. Leaning is also found to be expensive, as it generates more volatile output and inflation in non-crisis periods. These calibrated studies have highlighted an intertemporal trade-off faced by monetary authorities: stabilization of output and inflation in normal times versus decreasing the probability and costs of a future financial crisis. We show new dynamics for the risk of contractionary policies and detail whether these policies should be implemented earlier or later in the cycle.

In interpreting our results, we stress that we are not conducting a welfare analysis to weigh the benefits and costs of monetary policy tightening. In addition, we do not provide a metric to weigh short-term losses against long-term gains. Furthermore, our identified monetary policy shock is not directly interpretable as a systematic "leaning against the wind" policy. These considerations can be addressed in the context of general equilibrium models such as in Ajello et al. (2015) and Alpanda and Ueberfeldt (2016). Therefore, we provide an answer to the question of whether monetary policy *could*, rather than *should*, be used to promote financial stability.

The paper is organized as follows: Section 2 provides some stylized facts regarding the evolution of private debt and the occurrence of financial crises. Section 3 describes the panel VAR model and shows the impulse responses to a monetary policy shock. Section 4 reports the effects of leverage dynamics on the probability of a crisis and evaluates the impact of an unanticipated monetary policy tightening on the likelihood of a crisis. Section 5 concludes.

2. Private Debt and Financial Crises: Stylized Facts from Cross-Country Evidence

In this paper, we consider private-sector leverage as an indicator of financial stability and show that it acts as an important channel through which monetary policy can affect the probability of a financial crisis. We start by detailing the data on debt and then turn to our definitions of financial crises.

2.1 Private Debt

We focus on leverage, as excessively leveraged economies might be less resilient to shocks and have lower loss-absorption capacities. Private-sector leverage is measured as the ratio of nominal private debt to nominal output. Private debt is defined as total credit provided by domestic banks to the domestic, private, non-financial sector.[2] We base our analysis on private credit provided by banks, as Jordà, Schularick, and Taylor (2016) stress that bank credit is the predominant form of private-sector borrowing in advanced economies. The data for all countries in our analysis are collected by the Bank for International Settlements (BIS) and cover the sample 1975:Q1 to 2014:Q4.[3]

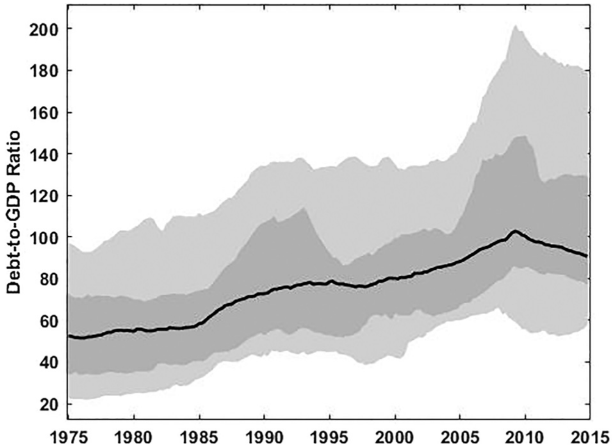
Figure 1 shows the weighted average of the debt-to-income ratio across countries where weights are given by countries' shares of output.[4] In each quarter, the light grey area spans the range of values

[2]The private non-financial sector includes non-financial corporations, households, and non-profit institutions serving households. The series capture the outstanding amount of credit at the end of the reference quarter. Credit covers loans as well as debt securities.

[3]The countries included in our sample are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States. We consider the longest sample for which credit is available for all countries.

[4]We compare our data on credit with the aggregate private bank credit to the private non-financial sector as percentage of GDP shown in Jordà, Schularick, and Taylor (2016), available at the annual frequency from 1870. The series provided by Jordà, Schularick, and Taylor shows the same dynamics as the (unweighted) average of our series. The levels of both series are about 55 percent in 1975, and rise throughout the sample. They dip slightly to 80 percent in 1995, reach a peak of almost 120 percent in 2008–09, and plummet in 2010.

Figure 1. Private Debt-to-GDP Ratio, 1975:Q1–2014:Q4



Notes: Private debt-to-GDP ratio for eighteen advanced economies over the sample 1975:Q1–2014:Q4. The black line shows the weighted average across countries, where countries are weighted by their share of output. The light grey shaded area delimits the range of values of the individual country ratio; the dark shaded area, the 20 percent and 80 percent percentiles.

(minimum and maximum) across countries, while the dark shaded area delimits the 20th and 80th percentiles.

Private debt as a fraction of GDP has risen rapidly and substantially across countries, increasing from an average of about 55 percent in 1975:Q1 to 90 percent in 2014:Q4. The strong rise in leverage can be attributed primarily to a substantial increase in mortgage credit, which represented one-third of bank assets at the beginning of the twentieth century and constitutes about two-thirds today (Jordà, Schularick, and Taylor 2015). At the same time, household borrowing was facilitated by higher levels of financial development (Chen et al. 2015). The level of the debt-to-GDP ratio shows a high degree of heterogeneity across countries which increased substantially during the financial crisis. The cross-sectional distribution of the debt-to-GDP ratio can be explained by different legal and economic institutions, including legal enforcement of contracts (e.g., the time needed to repossess a house (Bover et al. 2016)).

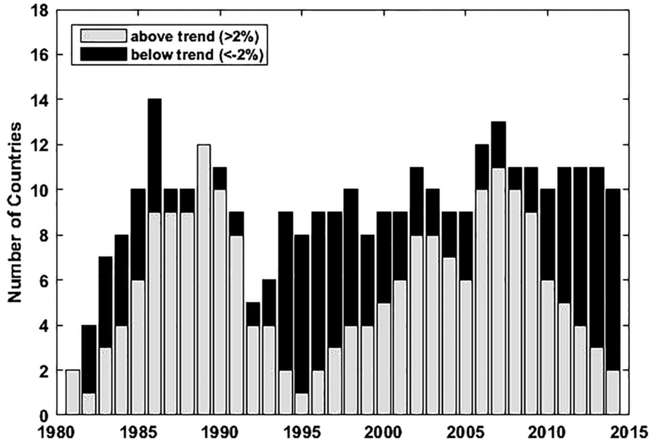
The upward trend in the debt-to-GDP ratio poses some challenges for empirical analysis. Moreover, the literature that studies the determinants of financial crises finds that the short-term dynamics of credit or the deviations of debt-to-GDP from trend, rather than the level, are significant predictors of crises (e.g., Babecký et al. 2012, Gourinchas and Obstfeld 2012, Schularick and Taylor 2012, and Drehmann 2013). We therefore use the debt-to-GDP gap, measured as deviation from a one-sided Hodrick-Prescott (HP) filter trend, in the analysis that follows. To account for the fact that credit cycles are characterized by longer duration and larger amplitude than those of traditional business cycles (Aikman et al. 2015, 2016), we use a much larger smoothing parameter ($\lambda = 400{,}000$) than the one commonly used for quarterly data. The resulting trend is thus very slow moving. This definition of the debt-to-GDP gap is also adopted under Basel III for the implementation of countercyclical capital buffers (Drehmann 2013).

While the trend is often ascribed to financial deepening, as financial innovations granted access to credit markets to previously unserved households and businesses, gaps in debt-to-GDP ratio may reflect several causes. For example, credit expansions may be driven by active risk-taking of financial intermediaries due to incentives that may not be fully aligned with those of shareholders (e.g., Allen and Gale 2000 and Bebchuk, Cohen, and Spamann 2010). Alternatively, shareholder risk appetite may be elevated (Danielsson, Shin, and Zigrand 2012; Adrian, Moench, and Shin 2013). Widespread optimism may be shared by financial intermediaries and other agents in the economy (Reinhart and Rogoff 2009; Gennaioli, Shleifer, and Vishny 2012, 2013; Barberis 2012). In these environments, banks might have an incentive to underwrite poor-quality loans and seek risk, posing threats to financial stability. In the analysis that follows, we implicitly interpret large positive deviations from trend as reflecting expansions in "bad" credit due to the incentives just described.

While there seems to be an upward trend in the ratio for all of the economies considered, the short-term dynamics of individual countries are quite heterogeneous.[5] Figure 2 shows the number of

[5]For example, while some countries—such as Ireland, Spain, and the United States—have gone through a large leveraging-deleveraging episode during the recent financial crisis, others—such as Canada, Switzerland, and Sweden—are still experiencing an increase in borrowing relative to income.

Figure 2. Financial Cycles, 1975:Q1–2014:Q4



Notes: Number of countries with debt-to-GDP ratio on average at least 2 percent above (below) trend in grey (black) in a given year. The trend is constructed using a one-sided HP filter with smoothing parameter of 400,000.

countries in which the debt-to-GDP gap is higher or lower than 2 percent in a given year. The figure suggests that while cyclical fluctuations might be correlated, they are not perfectly synchronized.[6] For example, even during the recent financial crisis, when most countries experienced an increase in debt-to-GDP ratio well above trend, some countries were deleveraging.

Moreover, looking at individual cross-country correlations, in some cases debt-to-GDP gaps are strongly positively correlated—e.g., Finland and Sweden (0.83), Australia and New Zealand (0.86), or Ireland and Spain (0.88)—while in others, the gaps are negatively correlated, as in Japan and the Netherlands (–0.70) or Germany and Sweden (–0.79).

In our data, private-sector credit is strongly procyclical, as the average contemporaneous correlation between the growth rates of real output and real private debt is 50 percent. This confirms a similar result in Jordà, Schularick, and Taylor (2016).

[6]This finding is consistent with other studies; e.g., Baron and Xiong (2016).

The evolution of the housing market might be an important factor that can explain leveraging and deleveraging episodes. In fact, overvaluations in house prices might reflect high investor risk appetite and over-optimism, possible sources of large and rapid credit expansions. Indeed, in our sample, the contemporaneous correlation between debt-to-GDP ratio and real house prices ranges from 18 percent in Germany to 65 percent in the United States. Moreover, mortgage loans represent the majority of bank assets. Therefore, in the analysis that follows, we model the evolution of house prices and credit dynamics jointly.

2.2 Financial Crises

In our analysis, we construct two alternative measures of financial crises. In the first, we consider systemic banking crises that involve a large number of banks and therefore pose a threat to the entire economy. To identify the crises, we use the classification provided by Caprio and Klingebiel (2003) and Laeven and Valencia (2012). In data extending to 2003, Caprio and Klingebiel (2003) identify financial crises as periods of significant and systemwide financial distress in the banking system. In a longer data set, Laeven and Valencia (2012) impose an additional requirement that the distress must be followed by widespread insolvencies or significant banking policy interventions.[7] In our application, we combine the two data sets. However, even after the two classifications have been combined, this definition of financial crises delivers only a small number of episodes in our sample. Moreover, the crises are difficult to date accurately, and most episodes coincide with the latest financial crisis of 2008–11.

For these reasons, we consider a second measure of financial stability risk: large bank equity corrections. Following Baron and Xiong (2016), we define a large bank equity correction as a decrease in the realized excess return on the national bank equity index of at least 25 percent over one quarter, or of at least 35 percent over two quarters. This definition identifies episodes of distress in the banking sector that might not lead to a fully fledged systemic banking

[7]Significant banking policy interventions include, for example, extensive liquidity support, bank nationalization, asset purchase, deposit freezes, or bank holidays.

Table 1. Comparisons: Systemic Banking Crises and Large Equity Corrections

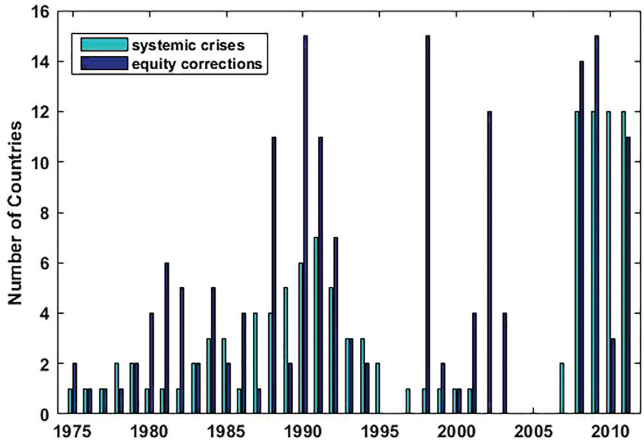
	Systemic Banking		Equity Corrections
	LV	LV + CK	BX
Frequency and Duration			
Proportion of Quarters in a Crisis	0.11	0.18	0.14
Number of Crisis Episodes	18	26	88
Average Number of Quarters in a Crisis	16	19	4
Losses			
Cumulative Output Change (%)	−2.9	−1.2	0.5
Excess Return on Bank Equity (%)	−92.8	−66.3	−36.1
Non-Crisis Average			
Cumulative Output Change (%)	2.6	2.7	2.6
Excess Return on Bank Equity (%)	7.9	8.9	11.6

Notes: LV refers to the Laeven and Valencia (2012) classification, LV + CK refers to an integrated data set from Laeven and Valencia (2012) and Caprio and Klingebiel (2003), and BX refers to the episodes identified as in Baron and Xiong (2016). Losses are computed on the first four quarters following the start of the crisis.

crisis. However, they clearly show an impaired financial sector and likely translate into a reduction of the supply of financial services to the private sector. A monetary policy shock that reduces debt and leverage might decrease the likelihood of these tail episodes.

Table 1 shows the frequency, duration, and losses associated with the two definitions of crises. We count twenty-six episodes of systemic banking crises occurring over the sample 1975:Q1–2011:Q4, of which ten occur during 2007:Q3–2011:Q4. The stricter Laeven and Valencia (2012) classification identifies eighteen crisis events; using this definition, most countries have experienced only one crisis, two have experienced two crises (Sweden and the United States), and three have never experienced any (Australia, Canada, and New Zealand). Systemic banking crises are accompanied by large output losses with a cumulative decline in GDP in the first year of the crisis of 2.9 percent on average for the Laeven and Valencia (2012) data and a decline of 1.2 percent for the integrated data set. This compares with GDP growth rates of 2.6 (2.7) percent per annum on average in non-crisis periods. Using the two combined data sets, the average duration of the crises is nineteen quarters.

Figure 3. Frequency of Systemic Banking Crises and Bank Equity Corrections, 1975–2011



Notes: Number of countries in a systemic banking crisis or large bank equity correction in a given year. A country is counted as having experienced a crisis episode in a given year if it has experienced a crisis episode in at least one quarter of that year. The classification of systemic banking crisis is based on Caprio and Klingebiel (2003) and Laeven and Valencia (2012). We follow Baron and Xiong (2016) for large bank equity corrections.

Large bank equity corrections are more frequent than systemic banking crises, with eighty-eight occurrences of the former. However, they are shorter lived, lasting an average of only four quarters. They are also less severe disruptions to the financial system: while the excess rate of return on bank equity is –36.1 percent during the first year of a correction, this is smaller than the 92.8 percent and 66.3 percent declines recorded during the two types of systematic crises. GDP grows by a scant 0.5 percent during the first year of a bank equity correction compared with 2.6 percent growth during all non-crisis periods. Thus, bank equity corrections are far more numerous but less costly.

Figure 3 shows the frequency of systemic banking crises and large bank equity corrections for each year in our sample. Large bank equity corrections are more evenly distributed than systemic banking crises. In general, systemic banking crises are accompanied by large equity crashes, at least in the first year. We also observe episodes of large bank equity drops that were not followed by systemic banking crises, such as the crashes in the early 2000s, contemporaneous to the stock market downturn of 2002.

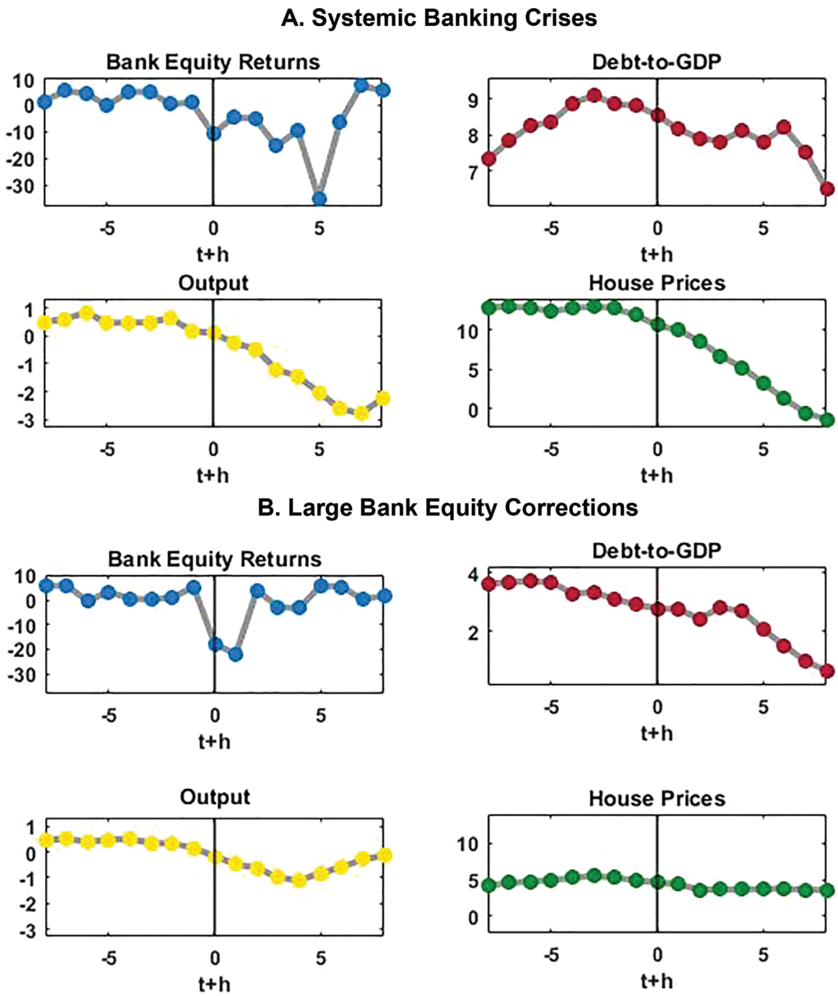
To provide additional insight, we conduct an event-study analysis in which we show the dynamics of bank equity returns, debt-to-GDP gaps, output gaps, and house price gaps during an event window that runs from eight quarters before to eight quarters after a crisis episode. Figure 4 shows the average of variables around a systemic banking crisis (panel A), and a bank equity correction (panel B). The qualitative patterns of the variables are very similar across the two types of crisis episodes. Bank equity returns fall with the beginning of the crisis, but the largest drop occurs after five quarters in the case of systemic banking crises. Returns are both lower and more volatile following the crisis. In the run up to a crisis, debt-to-GDP gaps are positive and large, especially for systemic banking crises. While we observe some deleveraging right before the onset of the crisis, the speed of the adjustment in the debt-to-GDP ratio increases in the aftermath of the crisis. Both types of crises are associated with a significant decline in the output gap, which fails to close within the first two years. However, the recovery is more sluggish for systemic banking crises. As in the case of debt-to-GDP gaps, house prices are higher than trend before the crisis, but they start to decline two to three quarters before the onset of both types of crises and continue to correct after that. While the dynamics are qualitatively similar across crises, the magnitude of the drops in output gaps, bank equity returns, and house prices suggests that systemic banking crises are more costly than large bank equity corrections.

3. Monetary Policy and Financial Cycles

3.1 VAR Model

We conduct a cross-country analysis that yields an estimated average response of the debt-to-GDP ratio to a typical monetary policy shock across countries and across time. Rather than estimating a panel VAR which assumes that countries are "similar enough" to pool their credit cycles, we estimate individual country VARs and pool the individual impulse responses. We thus do not impose

Figure 4. Event Study



Note: Average of selected variables around crisis episodes: systemic banking crises (panel A); large bank equity corrections (panel B).

dynamic homogeneity, which can deliver biased estimates of the autoregressive coefficients in dynamic panel models even when T is large (Pesaran and Smith 1995). Dynamic heterogeneity might be induced by cross-country variation in the degree of financialization and other idiosyncratic characteristics that affect the transmission mechanism of monetary policy.

The eighteen country-i VARs each take the form

$$Y_{i,t} = A_i + \sum_{l=1}^{p} B_{i,l} Y_{i,t-l} + \varepsilon_{i,t} \qquad i = 1, \ldots, 18,$$

where $Y_{i,t}$ is a $K \times 1$ vector of endogenous variables, A_i is a $K \times 1$ vector of country-specific intercepts, $B_{i,l}$ is a $K \times K$ matrix of autoregressive coefficients, and $\varepsilon_{i,t}$ is a $K \times 1$ vector of errors with $\varepsilon_{i,t} \sim N(0, \Sigma_i)$. The vector of endogenous variables includes real output, inflation, a short-term interest rate, the real national house price index, and the private debt-to-GDP ratio. Real variables are obtained by deflating nominal variables by the CPI (all items). Output, house prices, and the debt-to-GDP ratio are expressed in percentage deviation from the trend calculated using a one-sided HP filter. Inflation is the quarter-over-quarter log-difference in CPI (all items). The short-term interest rate is the three-month Treasury-bill (T-bill) rate.

We estimate the model by least squares with a lag length of two over the sample period 1975:Q1–2014:Q4. A monetary policy shock is identified via sign restrictions as in Uhlig (2005). We impose the restriction that after a contractionary monetary policy shock (an increase in the short-term interest rate, normalized to a 100 basis point response on impact), both the output gap and inflation do not increase. In order to capture the effects in the housing market, the response of property prices is also restricted to be non-positive. The restriction imposed on real house prices is consistent with DSGE models that incorporate a housing sector such as Iacoviello (2005) or Iacoviello and Neri (2010) and the semi-structural model of Svensson (2013). Responses of all variables are constrained only on impact.

We remain agnostic about the behavior of the debt-to-GDP ratio by not restricting its response. For the numerator, an increase in the interest rate will likely discourage lending by increasing borrowing costs. However, a higher policy rate will also lower the inflation rate, further increasing the real cost of borrowing on the one hand, but increasing the real value of the existing debt stock on the other. Therefore, the total effect of a monetary policy shock on real debt will depend on how monetary policy interventions transmit to both mortgage rates and inflation. For the denominator, the shock will cause output to decline. Thus, the response of the debt-to-GDP ratio is a priori unclear and depends on the relative size of the responses of debt and output.

In the case of sign restrictions, inference is complicated by the fact that the impulse responses are not point identified, but only set identified; i.e., impulse responses are bounded up to an interval (Moon and Schorfheide 2012). While most of the existing literature uses Bayesian methods to derive the highest posterior density intervals in these models, we conduct inference using the novel frequentist procedure outlined in Moon, Schorfheide, and Granziera (2013), which is based on a Bonferroni approach. We prefer the frequentist approach, as the Bayesian approach for set-identified models is sensitive to the choice of priors even in large samples (Moon and Schorfheide 2012, Giacomini and Kitagawa 2015). Average impulse responses across countries are obtained by pooling individual country responses with weights corresponding to the country share of output.

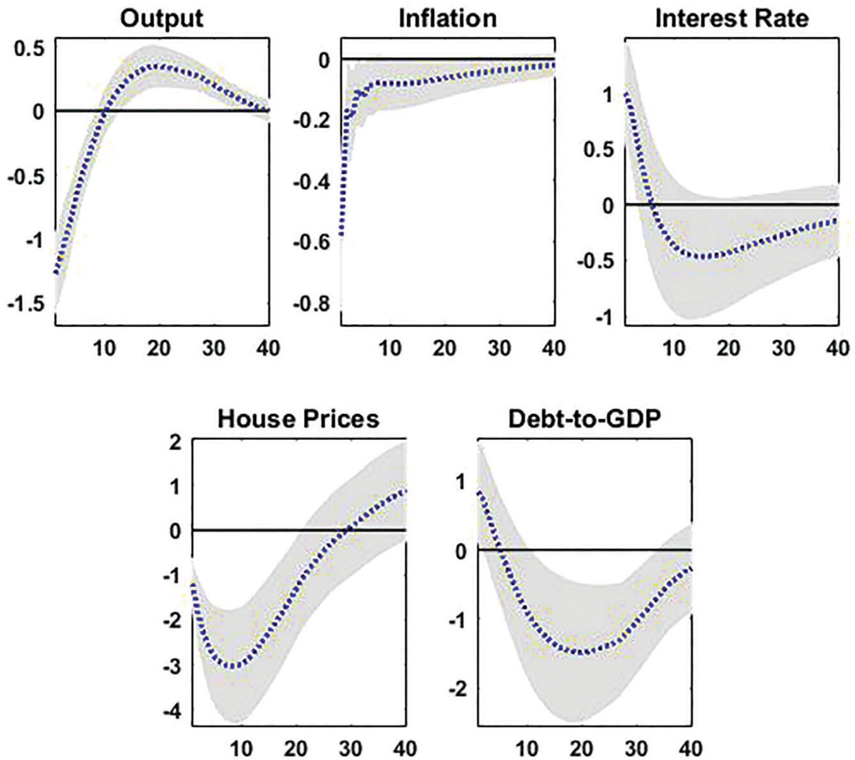
3.2 Impulse Responses

Figure 5 shows the impulse response functions of each variable after an unanticipated 100 basis point increase in the short-term rate. We show the 68 percent confidence interval for the impulse responses as well as the average of the confidence set.

After a sizable, contractionary monetary policy shock, output falls below potential for about ten quarters. Inflation also falls, but by less than output, and the response becomes insignificant after one year. The private debt-to-GDP ratio increases on impact, although the response is only slightly significantly different from zero. The ratio falls below trend in the medium and long run.

To help with the interpretation of this latter result, we also compute the impulse responses of the real private debt and nominal private debt in deviation from a one-sided HP-filter trend. The responses are obtained from analogous structural VAR models where the real or nominal debt is used in place of the private debt-to-GDP ratio. These additional exercises, shown in figure 6, reveal that the monetary policy shock causes only a moderate reduction in nominal debt on impact. Similar to the results in Svensson (2013)

Figure 5. Responses to a Monetary Policy Shock

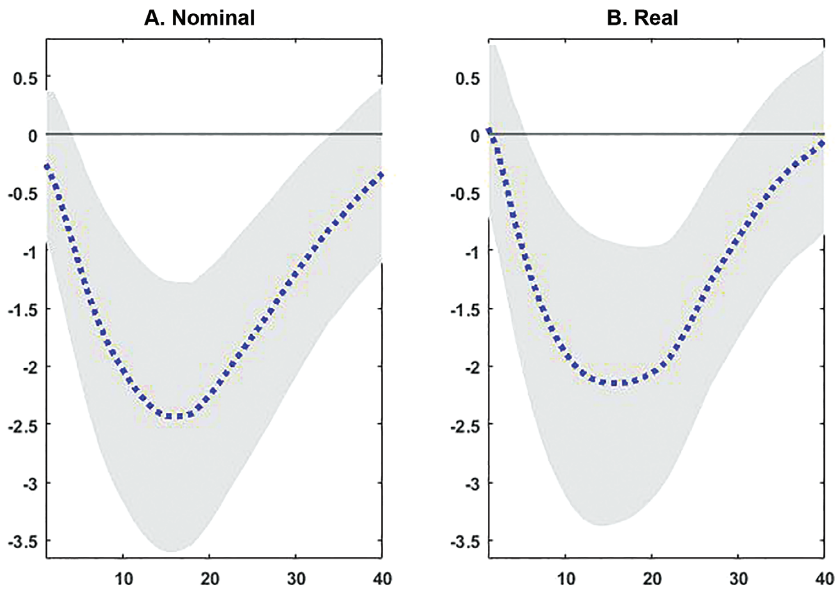


Notes: Impulse response functions after a 100 basis point contractionary monetary policy shock. Dashed lines indicate the average response; shaded areas indicate 68 percent confidence set obtained with the frequentist procedure in Moon, Schorfheide, and Granziera (2013).

and Gelain, Lansing, and Natvik (2015), the stock of nominal debt exhibits considerable inertia, as agents find it difficult to change existing contracts. Given that the fall in inflation is larger than the reduction in nominal debt, after a monetary policy shock real debt rises on impact. As nominal debt further decreases and inflation quickly rebounds, real debt falls below trend from the first quarter after the shock.

As output shrinks on impact, the debt-to-GDP ratio rises by about 0.85 percent (figure 5). However, starting from the first

Figure 6. Responses to a Monetary Policy Shock: Nominal Debt and Real Debt



Notes: Impulse response functions of nominal debt (panel A) and real debt (panel B) after a 100 basis point contractionary monetary policy shock. Dashed lines indicate the average response; shaded areas indicate 68 percent confidence sets.

quarter after the shock, debt decreases and the output gap becomes smaller (in absolute terms). As the decline in the debt is larger than the fall in output, a tightening of monetary policy will decrease the debt-to-GDP ratio in the medium run and long run, starting after approximately six quarters. After five years from the initial tightening, the debt-to-GDP ratio is about 14 percent lower in percentage deviation from trend than before the tightening.

The effect of the monetary policy shock is more pronounced on house prices than it is on either real output or real debt. While house prices and output respond by roughly the same magnitude on impact, after two quarters the response of house prices is more than twice as strong as that of output. This result is consistent with other structural panel VAR studies such as Assenmacher-Wesche and

Gerlach (2008). House prices dip by about 3 percent one year after the shock and recover only in the long run.

Our results can be compared with a number of others from the literature. Using Norwegian data that runs from the mid-1990s to 2013, Robstad (2017) finds that the debt-to-GDP ratio rises following a contractionary monetary policy shock. However, Laséen and Strid (2013) conduct a similar analysis using Swedish data and report a decline in the debt-to-GDP ratio after a tightening. Using a pre-financial crisis sample of U.S. data, Angeloni, Faia, and Lo Duca (2015) find that both industrial production and household debt decline over all horizons considered. Although they do not provide the response of the debt-to-GDP ratio, the relative changes in the household debt and industrial production suggest that the debt-to-GDP ratio increases slightly in the short run but falls, although only moderately, in the long run. All of these studies are based on single-country evidence and restrict real debt not to change on impact in response to a contractionary monetary policy shock.

Our results are more comparable with those of Goodhart and Hofmann (2008), who estimate a panel VAR on seventeen countries over the 1970–2006 period. They do not restrict the contemporaneous response of debt. As in our analysis, after a 100 basis point increase in the interest rate, real debt and the debt-to-GDP increase on impact. However, while both debt and output decline from the second quarter after the shock, the response of debt is much stronger than the response of output. This leads to a substantial decline in the debt-to-GDP ratio in the medium and long run. The response of the debt-to-GDP ratio in our paper is qualitatively consistent with the structural studies of Svensson (2013), Gelain, Lansing, and Natvik (2015), Chen and Columba (2016), and Alpanda and Zubairy (2017).

3.3 Robustness Analysis

In this subsection we present a series of robustness checks on the VAR model. The characteristics of residential mortgage markets may affect the transmission of monetary policy (Assenmacher-Wesche and Gerlach 2008; Garriga, Kydland, and Sustek 2013). In particular, the proportion of fixed versus variable mortgage rates matters for the response of house prices, residential investment, and output to a monetary policy shock. We therefore investigate whether the responses of debt gaps and debt-to-GDP gaps differ according to the mortgage scheme by estimating the panel VAR on two subsamples of countries which are grouped according to their prevailing mortgage structure (Tsatsaronis and Zhu 2004). Panel A of figure 7 shows that the effect of a monetary policy tightening on the debt-to-GDP ratio is qualitatively and quantitatively very similar across the two samples.

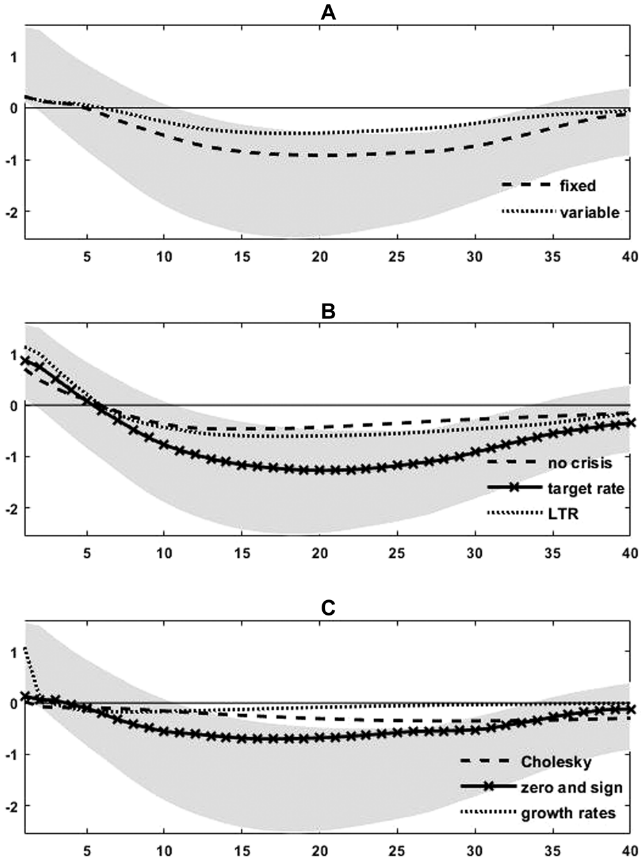
We have examined a number of alternative specifications of the model. In the benchmark specification we prefer using the three-month rate rather than the target rate to mitigate the issues associated with the zero-lower-bound constraint, binding at the end of our sample. In a second experiment, we repeated our estimation with the policy rate in place of the three-month rate. Long-term interest rates are relevant for debt dynamics, as they will affect mortgage subscriptions. Hence, in a third exercise we add long rates to the variables in our baseline VAR specification. As the transmission of monetary policy might have been distorted during the financial crisis, in a fourth experiment we limit our estimation sample to 2006:Q4.

The results of these additional exercises are shown in panel B of figure 7. The impulse response functions are generally well within the confidence bounds of the baseline model throughout all horizons considered.

Despite its long-standing tradition in macroeconomics, the HP filter presents some drawbacks. Specifically, it generates spurious dynamic relations and is subject to the end-of-sample problem, i.e., the filter produces a trend component that is close to the observed data at the beginning and at the end of the sample. For these reasons, we have tried using data detrended by taking log-differences for output, house prices, and the debt-to-GDP ratio. We find that on impact the debt-to-GDP ratio in log-differences rises by more than the debt-to-GDP gap. However, the response for log-differences quickly converges to zero, as it is less persistent than the response of the gap. Log-differenced data would imply a permanent effect of monetary policy shocks on the level of the variables. Therefore we prefer working with HP-filtered series.

As further checks on the robustness of our results, we tried different identification strategies of the monetary policy shock. First,

Figure 7. Impulse Response Functions: Robustness Analysis



Notes: Impulse response functions of debt-to-GDP in deviation from trend after a 100 basis point contractionary monetary policy shock. Dashed lines indicate the average responses from different robustness experiments; shaded areas indicate the 68 percent confidence set for the impulse responses obtained from the baseline VAR.

we added a zero restriction on impact for output to the sign restrictions imposed on the other variables. While the qualitative response did not change, imposing a zero response on output dampens the impact of the monetary policy shock on the debt-to-GDP gap, as shown in panel C of figure 7.

Finally, we try to identify the monetary policy shock, resorting to short-run restrictions. In a first experiment where house prices and debt-to-GDP are ordered after the interest rate, we find qualitatively similar results to the ones obtained using sign restrictions for house prices, and the debt-to-GDP ratio, although the response is muted (panel C of figure 7). In a further experiment where the interest rate is ordered last and therefore debt cannot respond to monetary policy shocks on impact, we find that, differently from the sign-restriction identification strategy, in the short run debt-to-GDP ratio does not increase, while the medium- and long-run response is analogous to the one generated via sign restrictions.

We conclude that our specification is robust to a number of alternative scenarios.

4. Leverage Dynamics and Financial Stability Risks

We have shown that a monetary policy tightening decreases the debt-to-GDP gap, at least in the medium to long run. Although the magnitude of the decrease seems moderate, to evaluate its importance we should understand how the dynamics of the ratio affect the soundness of the financial system. The recent literature finds that a rapid expansion in credit is associated with a higher likelihood of experiencing a systemic banking crisis or a financial crisis recession (Gourinchas and Obstfeld 2012; Jordà, Schularick, and Taylor 2015). Baron and Xiong (2016) show that rapid credit growth may also lead to a large correction in bank equity prices.

The mechanism at work is the following: a large and rapid expansion of bank credit might drive funds to private-sector borrowers with poor credit quality, exposing banks to a higher number of defaults in case of adverse shocks. Such shocks may lead to a sharp drop in banks' equity prices. Because of the leading role played by banks in providing credit to the private sector, a sizable correction in the bank equity index might cause a decline in the supply of credit as leverage constraints become binding. Large drops in equity prices and the consequent depletion of bank capital might then trigger a systemic banking crisis which might require government interventions.

In this section we evaluate how reductions in leverage will translate into a less risky financial system by quantitatively assessing the linkages between deviations of debt-to-GDP from trend and the likelihood of a banking crisis.

4.1 Assessing the Likelihood of a Crisis

In order to understand the role of excessive credit as a source of financial instability, we estimate its impact on the probability of a systemic banking crisis or a large bank equity correction occurring in the near future using a panel logit regression framework. We follow Schularick and Taylor (2012) in using a cross-country panel, as the number of episodes for each country is limited and inference conducted on a single country may be misleading.

Following Gourinchas and Obstfeld (2012) and others, we construct a forward-looking dummy variable for crisis events as follows. Define $f_{i,t}^{k}$ to be the dummy variable that takes the value of 1 if a financial stability risk episode of type k starts within the next eight quarters in country i. The variable $k = \{sb, ec\}$ indicates the two types of crises that were detailed in section 2.2, where "sb" denotes a systemic banking crisis and "ec" an equity correction. We consider a horizon of eight quarters, which is of interest to monetary policy authorities. To reflect the uncertainty in the dating of the crisis episodes, we let $f_{i,t}^{sb}$ take the value of 1 in the first year of the crisis also.

Thus, our panel logit regression takes the form

$$\Pr\left(f_{i,t}^{k} = 1 \mid \delta_i^k, x_{i,t}\right) = \frac{\exp\left(\delta_i^k + \beta_k x_{i,t}\right)}{1 + \exp\left(\delta_i^k + \beta_k x_{i,t}\right)},$$

where $x_{i,t}$ is the set of explanatory variables. All specifications include country-specific fixed effects (δ_i^k) to allow for cross-country, time-invariant heterogeneity. Note that we run two separate regressions: in the first one the endogenous variable is a dummy indicating an upcoming systemic banking crisis ($k = sb$), while in the second it is a dummy indicating a future bank equity index correction ($k = ec$). Further, for both of these crisis-type events, we consider two regression models: one that includes only the debt-to-GDP ratio in deviation from trend, and a second one that includes all of the variables used in the VAR. By including only the debt-to-GDP ratio in the first regression, we impose that the other

Table 2. Panel Logit Regressions

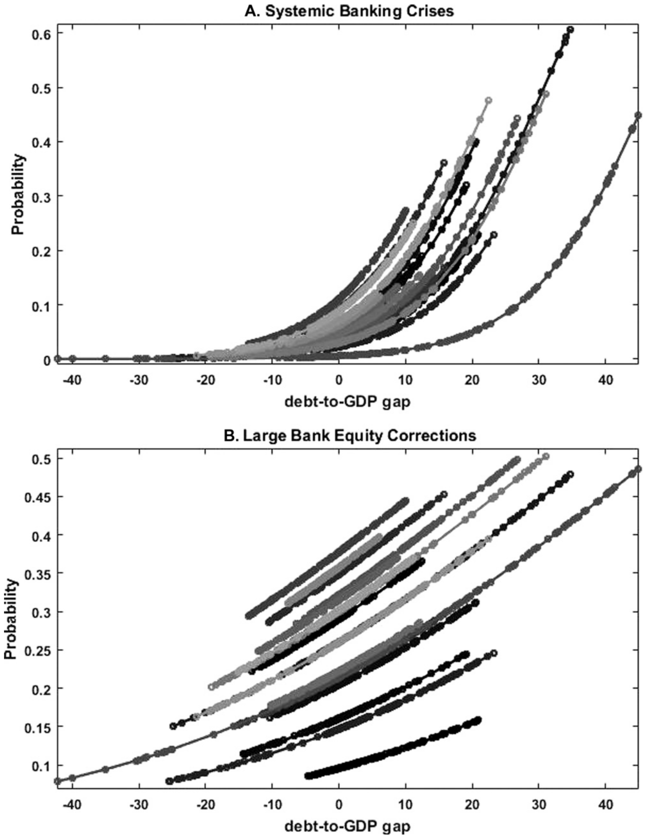
	Systemic Banking Crises		Bank Equity Corrections	
	(1)	**(2)**	**(3)**	**(4)**
$debt/gdp_{t-1}$	0.128***	0.128***	0.027**	0.031**
	(0.0359)	(0.0410)	(0.0136)	(0.0144)
gdp_{t-1}		0.0136		0.145*
		(0.127)		(0.076)
inf_{t-1}		0.0575		−0.324**
		(0.241)		(0.127)
i_{t-1}		0.0493		−0.034
		(0.0725)		(0.0344)
rhp_{t-1}		0.0287		0.003
		(0.0207)		(0.009)
Observations	2,324	2,284	2,455	2,415
R^2	0.167	0.223	0.014	0.064
χ^2	12.626	18.312	4.089	19.313
p-value	0.000	0.003	0.043	0.002
Hit Rate	0.650	0.658	0.589	0.593
Standard Error	0.007	0.007	0.009	0.016
Quadratic Probability Score	0.163	0.153	0.357	0.344
Standard Error	0.015	0.016	0.002	0.017
AUROC	0.715	0.757	0.624	0.678
Standard Error	0.018	0.017	0.012	0.012

Notes: Estimates of a panel logit with country fixed effects. The dependent variable is the occurrence of a systemic banking crisis (columns 1–2) or large equity corrections (columns 3–4) between horizon $t + 1$ and horizon $t + 8$ quarters. "Systemic banking crises" refers to the integrated LV + CK data set, while "bank equity corrections" is defined similarly to Baron and Xiong (2016). Debt-to-GDP ratio is expressed in percentage deviation from an HP-filtered trend. Significance levels at 10, 5, and 1 percent are denoted as *, **, and ***, respectively. R^2 refers to the pseudo R-squared. Robust standard errors are obtained using the multiway clustering (country and time) of Cameron, Gelbach, and Miller (2011).

variables affect the probability of a crisis only through their effects on leverage.

Table 2 shows the results of the panel logit model for the two types of crises and the two sets of regressors. We focus on systematic banking crises first. The debt-to-GDP ratio is a positive, highly significant predictor of systemic banking crises (table 2, column 1). As the other variables from the VAR are not statistically significant predictors (column 2), we will use the debt-to-GDP ratio as the sole predictor in the subsequent analysis (section 4.2).

Figure 8. Financial Crisis Predicted Probabilities



Notes: Probabilities are obtained from a panel logit regression in which the dependent variable is a dummy taking the value of 1 if a systemic banking crisis (panel A) or a large bank equity correction (panel B) occurs within the next eight quarters. The logit models, described in detail in section 4, include only the country fixed effect and the lagged debt-to-GDP ratio.

It is important to assess the fitted value of the model to understand the adjustments to the likelihoods that result from monetary policy innovations. Panel A of figure 8 shows the fitted values of the model for systemic banking crises across the countries in the sample, over the range of debt-to-GDP ratios experienced in sample. The graph shows that when the debt-to-GDP ratio is at its trend level, the estimated probability of a crisis starting sometime in the next two years ranges from approximately 1 to 12 percent. When the ratio is below this value, the probabilities compress to low levels. What is more interesting is the sharp increase in the likelihood of the onset of a financial crisis when the debt-to-GDP ratio moves above trend. For example, when the debt-to-GDP ratio is 20 percent above trend, the likelihood of a financial crisis for some countries can be quite high, at 30 percent or higher. At larger deviations of the ratio, the likelihoods can increase to 60 percent.

A similar exercise for the model to predict large bank equity corrections can be undertaken. The coefficient on the debt-to-GDP ratio is again positive and statistically significant (table 2, column 3). When the other variables from the VAR are added, we obtain significant coefficients on the inflation and output gap measures. However, the fitted values from the two specifications are similar, so we focus on the model containing only the debt-to-GDP ratio. It is interesting to note that the fitted values of this model display a more linear relationship between the debt-to-GDP ratio and the likelihood of an equity correction (figure 7, panel B). However, we note that the estimated levels may be quite high for this model as well. For example, when the ratio is at its trend value, the likelihood of a correction ranges from approximately 5 percent up to 35 percent. When the ratio is 20 percent above trend level, the likelihood may increase to 15 to 45 percent.

The ability of the debt-to-GDP ratio to forecast both systemic financial crises and bank equity corrections can be assessed using the area under the receiver operating characteristic curve (AUROC). This statistic estimates the likelihood of making correct decisions (Schularick and Taylor 2012, Jordà 2014). The area varies between 50 and 100 percent. In the results here the values of the AUROC statistic for models that contain only the debt-to-GDP ratio are 62.4 and 71.5 percent, suggesting that the ratio is more successful in predicting financial crises and corrections than is a random coin toss. We note that the values of these statistics are in line with those in Schularick and Taylor (2012), where the model to predict financial crises using the growth of private credit has an AUROC statistic of 67 percent.

4.2 Monetary Policy and Financial Stability Risks

In the previous sections, we completed two separate exercises. In the first, we derived the response of the leverage of the private sector (i.e., the debt-to-GDP ratio) to an unexpected monetary policy tightening. Then, we showed that the ratio, in deviation from trend, is a significant predictor of systemic banking crises and large bank equity corrections.

We are now in a position to answer the question as to how monetary policy can ultimately impact financial stability. We assess how an unanticipated monetary policy tightening affects the probability of a financial crisis through its effect on the debt-to-GDP ratio. The estimated impulse response of the debt-to-GDP ratio to a tightening can be calculated from the VAR model. The panel logit regression tells us how this affects the probability of a crisis. Given these two estimates, we compute the changes in the probability of a financial crisis that can be attributed to the unanticipated monetary policy shock.

The experiment is conducted as follows. We first compute the probability of a financial crisis occurring within the next two years for an initial, given deviation of the debt-to-GDP ratio from trend. This probability is obtained from the estimated panel logit model in table 2 that includes only the country fixed effects and the debt-to-GDP gap as predictors.[8] Next, given the cumulative responses of the debt-to-GDP ratio (in deviation from trend),[9] we can compute the value of the debt-to-GDP gap after the shock and the corresponding probability of a financial crisis. Finally, by comparing the probability of a financial crisis before and after the shock, we can assess whether the tightening has resulted in an increase or a decrease in financial stability risks.

For example, if we assume that the debt-to-GDP ratio is at trend before the shock hits, the results of the panel logit

[8]In this exercise, for all the initial debt-to-GDP gap values considered, we set the country fixed-effect parameters to their cross-country mean value. We are thus analyzing the effect of the tightening on the financial stability of a "typical" country.

[9]In the case of sign-restricted SVARs, the impulse response can be bounded up to an interval, rather than a point (Moon and Schorfheide 2012). We base our analysis on the mean of the identified interval.

regression imply that the probability of a systemic banking crisis (for an average country) is about 6 percent. The impulse response functions in figure 5 indicate that after a monetary policy shock the debt-to-GDP ratio increases by 0.85 percent, which results in an increase in the likelihood of a financial crisis to about 6.6 percent.

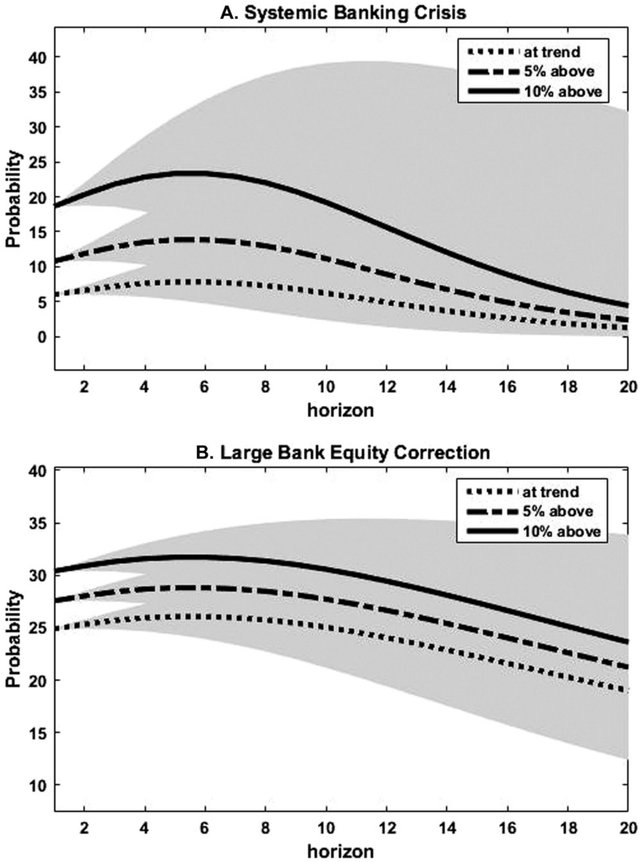
This exercise can be repeated for all of the horizons considered from the panel VAR. In addition, as the panel logit model is non-linear, the effect on the probability of a crisis will depend on the initial level of the debt-to-GDP ratio. To illustrate the non-linearities of the model, we repeat our experiment for different initial levels of the ratio. We thus assume that the debt-to-GDP ratio is at trend, or 5 and 10 percent above trend, before the monetary policy shock occurs. The results will indicate the differences among the effectiveness of tightening at different stages of financial fragility.

Figure 9 shows the probability of a systemic banking crisis (panel A) occurring within the next two years following the unexpected policy tightening. For all initial debt-to-GDP levels considered, the probability of a financial crisis rises after the shock, reaching a maximum increase approximately one year from the tightening. Then, as the debt-to-GDP ratio falls, the probability decreases sharply. As the cumulative effect on the ratio eventually becomes negative, the likelihood of a crisis falls below its initial value. Thus, five years after the shock, the likelihood of a financial crisis hitting the economy is considerably lower than it was before the shock. The magnitudes of the decreases in risk are quite large.

For example, if the initial debt-to-GDP ratio is 10 percent above trend, the likelihood of a financial crisis is approximately 18 percent (figure 9, panel A). Following the monetary policy shock, the decline in the debt-to-GDP ratio causes a decline of approximately 15 percent in the likelihood of a systemic financial crisis. For lower initial levels of the debt-to-GDP ratio, the declines are smaller. Indeed, regardless of the initial debt level, the likelihood of a crisis falls to between 0 and 5 percent, approximately, at the end of five years. Thus, the monetary policy tightening is able to reduce large amounts of tail risk.

A similar inverse J-curve pattern holds for the effect of a tightening on the likelihood of a large bank equity correction (figure 9, panel B). As these corrections are more common, the initial values of the likelihoods are higher than are their counterparts for

Figure 9. Effect of a Monetary Policy Shock on Crisis Probabilities



Notes: Probability of a crisis occurring within the next two years given the responses of the debt-to-GDP ratio, following a 100 basis point monetary policy shock. Probability of a financial crisis is calculated assuming that before the monetary policy shock hits, the debt-to-GDP is (i) at trend, (ii) 5 percent above trend, or (iii) 10 percent above trend. Shaded areas delimit the 68 percent confidence set.

full-fledged financial crises. For example, the likelihood of a large decline in bank equity values starting sometime in the next two years is approximately 31 percent when the debt-to-GDP ratio is 10 percent above trend. After the monetary policy shock, the likelihood declines rapidly, falling to about 24 percent after five years. We note that declines of similar magnitudes are experienced by economies where the initial debt-to-GDP levels are either at trend or 5 percent above trend (figure 9, panel B). However, the terminal values of the probabilities remain higher than for their systemic banking crisis counterparts. The tightening is thus able to substantially reduce the likelihood of an extreme left-tail event (i.e., a fully fledged financial crisis), while it has a much smaller effect on a more moderate episode (i.e., a large decline in bank equity).

4.3 Robustness Analysis

In this section we estimate some alternative specifications to show that our results are robust.

First, we estimate the effect of the debt-to-GDP gap on the probability of experiencing an episode of distress in the financial system, while taking into account that systemic banking crises can be interpreted as more severe events than banking equity corrections. In fact, table 1 and the upper panel of figure 4 show that systemic banking crises are accompanied by large declines in equity indexes. As the two types of crises have a natural ordering, we can estimate an ordered logit regression model that captures the likelihood of either type of crisis simultaneously. We thus construct a dummy variable that takes the value of 1 if a bank equity correction occurs and 2 if a systemic banking takes place. For quarters in which we experience both crises simultaneously, we assign the value 2 to the dummy. Table 3, columns 1–2, shows the results. As in the previous logit regressions, we find that the debt-to-GDP gap is a highly significant and positive predictor of crises. The variable retains its significance when a larger set of regressors is included in the logit model. The coefficient associated with the debt-to-GDP gap is between the value estimated in the logit regression for systemic banking crises and the one estimated for bank equity corrections.

Second, we also estimate the effect of the debt-to-GDP gap on the probability of experiencing either type of crisis; i.e., we investigate the ability of the debt-to-GDP ratio to simultaneously predict both financial crises and large bank equity corrections. In this second exercise we do not distinguish between the two types of financial stability risks based on their severity. We thus run a logit model where the dummy variable takes the value of 1 if we will experience either a

Table 3. Robustness: Logit Regressions

	Ordered Logit		Logit-Pooled Crises Episodes	
	(1)	**(2)**	**(3)**	**(4)**
$debt/gdp_{t-1}$	0.0508***	0.0538***	0.0487***	0.0483***
	(0.016)	(0.014)	(0.017)	(0.016)
gdp_{t-1}		0.117		0.142
		(0.085)		(0.107)
inf_{t-1}		−0.030		−0.038
		(0.106)		(0.127)
i_{t-1}		0.088**		0.149***
		(0.037)		(0.044)
rhp_{t-1}		0.002		0.016
		(0.007)		(0.010)
Observations	2,478	2,438	2,478	2,438
R^2	0.0255	0.0521	0.059	0.127
χ^2	217	357	566	848
p-value	0.000	0.000	0.000	0.000

Notes: Estimates of an ordered logit with country fixed effects (columns 1–2) and a logit model that pools the crisis episodes (columns 3–4). The dependent variable is a dummy variable indicating the occurrence of a crisis between horizon $t + 1$ and horizon $t + 8$. The dummy takes the value of 1 for bank equity corrections and 2 for systemic banking crises (columns 1–2); 1 for either a systemic banking crisis or a large bank equity correction (columns 1–2). Debt-to-GDP ratio is expressed in percentage deviation from an HP-filtered trend. Significance levels at 10, 5, and 1 percent are denoted as *, **, and ***, respectively. R^2 refers to the pseudo R-squared. Robust standard errors are obtained using the multiway clustering (country and time) of Cameron, Gelbach, and Miller (2011).

systemic banking crisis or a large equity correction between horizon $t+1$ and horizon $t+8$: table 3, columns 3–4, presents these results. As can be seen, the debt-to-GDP channel remains significant.

Overall, the results in table 3 corroborate our initial findings.

5. Conclusion

We show that a tightening of monetary policy can have a positive impact on financial stability in the medium to long run, as it is successful in reducing leverage. However, the gains are moderate and occur approximately three years after the shock. In the short run, a tightening might instead generate financial instability, as it would cause further increases in the debt-to-GDP ratio and the probability of a financial crisis occurring. The inverse J-curve pattern indicates that monetary policy might not be sufficient to maintain financial stability in the short run and additional tools, such as macroprudential policies, may be needed.

Our results also point to the fact that initial conditions matter, as the higher the initial leverage, the larger is the increase in the likelihood of a crisis. It may therefore be dangerous to let the debt-to-GDP ratio increase substantially above trend. This in turn suggests that the current debate on the role of monetary policy in promoting financial stability might oversimplify the issue, as the benefits and costs of "leaning against the wind" depend on when the interventions starts.

In interpreting our results, we note that our analysis is based on the average response of variables over time and across countries. However, if the cross-country heterogeneity—for example, in macroprudential regulations—is not fully captured by fixed effects, the transmission mechanisms of monetary policy may differ. Similarly, structural breaks—because of, for example, financial liberalization or changes in the mandate of the monetary authority—might bias our responses.

Moreover, we are not conducting a welfare analysis to weigh the benefits and costs—improved financial stability and deviation of real activity and inflation from target, respectively—of a monetary policy tightening. In addition, we are unable to weigh short-term losses against long-term gains regarding financial stability. Still, we provide an important analysis in the debate on the cleaning versus leaning role of central banks by answering the question of whether monetary policy *could* lean against the wind and highlighting the undesired short-term effects of such policies.

References

Adrian, T., E. Moench, and H. S. Shin. 2013. "Dynamic Leverage Asset Pricing." Staff Report No. 625, Federal Reserve Bank of New York.

Aikman, D., M. T. Kiley, S. J. Lee, M. G. Palumbo, and M. N. Warusawitharana. 2015. "Mapping Heat in the U.S. Financial System." Finance and Economics Discussion Series No. 2015-059, Board of Governors of the Federal Reserve System.

Aikman, D., A. Lehnert, N. Liang, and M. Modungo. 2016. "Financial Vulnerabilities, Macroeconomic Dynamics, and Monetary Policy." Finance and Economics Discussion Series No. 2016-055, Board of Governors of the Federal Reserve System.

Ajello, A., T. Laubach, D. Lopez-Salido, and T. Nakata. 2016. "Financial Stability and Optimal Interest-Rate Policy." Finance and Economics Discussion Series No. 2016-067, Board of Governors of the Federal Reserve System.

Allen, F., and D. Gale. 2000. "Bubbles and Crises." *Economic Journal* 110 (460): 236–55.

Alpanda, S., and A. Ueberfeldt. 2016. "Should Monetary Policy Lean Against Housing Market Booms?" Working Paper No. 2016-19, Bank of Canada.

Alpanda, S., and S. Zubairy. 2017. "Addressing Household Indebtedness: Monetary, Fiscal or Macroprudential Policy?" *European Economic Review* 92: 47–73.

Angeloni, I., E. Faia, and M. Lo Duca. 2015. "Monetary Policy and Risk Taking." *Journal of Economic Dynamics and Control* 52 (March): 285–307.

Assenmacher-Wesche, K., and S. Gerlach. 2008. "Financial Structure and the Impact of Monetary Policy on Asset Prices." Working Paper No. 2008-16, Swiss National Bank.

Babecký, J., T. Havranek, J. Mateju, M. Rusnák, K. Smidkova, and B. Vasicek. 2012. "Banking, Debt and Currency Crises: Early Warning Indicators for Developed Countries." ECB Working Paper No. 1485.

Barberis, N. 2012. "Psychology and the Financial Crisis of 2007–2008." In *Financial Innovation: Too Much or Too Little?* ed. M. Haliassos, 15–28 (chapter 2). MIT Press.

Baron, M., and W. Xiong. 2016. "Credit Expansion and Neglected Crash Risk." *Quarterly Journal of Economics* 132 (2): 713–64.

Bebchuk, L. A., A. Cohen, and H. Spamann. 2010. "The Wages of Failure: Executive Compensation at Bear Stearns and Lehman 2000–2008." *Yale Journal on Regulation* 27 (2/3): 257–82.

Borio, C. 2014. "Monetary Policy and Financial Stability: What Role in Prevention and Recovery?" BIS Working Paper No. 440.

Bover, O., J. M. Casado, S. Costa, P. Du Caju, Y. McCarthy, E. Sierminska, P. Tzamourani, E. Villanueva, and T. Zavadil. 2016. "The Distribution of Debt Across Euro-Area Countries: The Role of Individual Characteristics, Institutions, and Credit Conditions." *International Journal of Central Banking* 12 (2): 71–128.

Cameron, A. C., J. B. Gelbach, and D. L. Miller. 2011. "Robust Inference with Multiway Clustering." *Journal of Business and Economic Statistics* 29 (2): 238–49.

Caprio, G., and D. Klingebiel. 2003. "Episodes of Systemic and Borderline Financial Crises." Mimeo, World Bank.

Chen, J., and F. Columba. 2016. "Macroprudential and Monetary Policy Interactions in a DSGE Model for Sweden." IMF Working Paper No. 16/74.

Chen, S., M. Kim, M. Otte, K. Wiseman, and A. Zdzienicka. 2015. "Private Sector Deleveraging and Growth Following Busts." IMF Working Paper No. 15/35.

Danielsson, J., H. S. Shin, and J. P. Zigrand. 2012. "Endogenous and Systemic Risk." In *Quantifying Systemic Risk*, ed. J. G. Haubrich and A. W. Lo, 73–94. University of Chicago Press and NBER. Available at http://www.nber.org/chapters/c12054.pdf.

Drehmann, M. 2013. "Total Credit as an Early Warning Indicator for Systemic Banking Crises." *Quarterly Review* (Bank for International Settlements) (June): 41–45.

Garriga, C., F. E. Kydland, and R. Sustek. 2013. "Mortgages and Monetary Policy." Working Paper No. 2013-037, Federal Reserve Bank of St. Louis.

Gelain, P., K. J. Lansing, and G. J. Natvik. 2015. "Leaning Against the Credit Cycle." Working Paper No. 4/2015, Norges Bank.

Gennaioli, N., A. Shleifer, and R. Vishny. 2012. "Neglected Risks, Financial Innovation, and Financial Fragility." *Journal of Financial Economics* 104 (3): 452–68.

———. 2013. "A Model of Shadow Banking." *Journal of Finance* 68 (4): 1331–63.

Giacomini, R., and T. Kitagawa. 2015. "Robust Inference about Partially Identified SVARs." Mimeo.

Goodhart, C., and B. Hofmann. 2008. “House Prices, Money, Credit, and the Macroeconomy.” *Oxford Review of Economic Policy* 24 (1): 180–205.

Gourinchas, P. O., and M. Obstfeld. 2012. “Stories of the Twentieth Century for the Twenty-First.” *American Economic Journal: Macroeconomics* 4 (1): 226–65.

Greenspan, A. 2002. “Opening Remarks.” In *Rethinking Stabilization Policy.* Proceedings of a symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 29–31.

Iacoviello, M. 2005. “House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle.” *American Economic Review* 95 (3): 739–64.

Iacoviello, M., and S. Neri. 2010. “Housing Market Spillovers: Evidence from an Estimated DSGE Model.” *American Economic Journal: Macroeconomics* 2 (2): 125–64.

Jordà, O. 2014. “Assessing the Historical Role of Credit: Business Cycles, Financial Crises and the Legacy of Charles S. Peirce.” *International Journal of Forecasting* 30 (3): 729–40.

Jordà, O., M. Schularick, and A. M. Taylor. 2015. “Betting the House.” *Journal of International Economics* 96 (Supplement 1): S2–S18.

———. 2016. “Sovereigns versus Banks: Credit, Crises, and Consequences.” *Journal of the European Economic Association* 14 (1): 45–79.

Laeven, L., and F. Valencia. 2012. “Systemic Banking Crises Database: An Update.” IMF Working Paper No. 12/163.

Laséen, S., and I. Strid. 2013. “Debt Dynamics and Monetary Policy: A Note.” Working Paper No. 283, Sveriges Riksbank.

Mishkin, F. S. 2011. “How Should Central Banks Respond to Asset-Price Bubbles? The ‘Lean’ versus ‘Clean’ Debate After the GFC.” *Bulletin* (Reserve Bank of Australia) (June): 59–69.

Moon, H. R., and F. Schorfheide. 2012. “Bayesian and Frequentist Inference in Partially Identified Models.” *Econometrica* 80 (2): 755–82.

Moon, H. R., F. Schorfheide, and E. Granziera. 2013. “Inference for VARs Identified with Sign Restrictions.” NBER Working Paper No. 17140.

Pesaran, H. M., and R. Smith. 1995. "Estimating Long-Run Relationships from Dynamic Heterogeneous Panels." *Journal of Econometrics* 68 (1): 79–113.

Reinhart, C., and K. Rogoff. 2009. *This Time Is Different: Eight Centuries of Financial Folly.* Princeton University Press.

Robstad, O. 2017. "House Prices, Credit and the Effect of Monetary Policy in Norway: Evidence from Structural VAR Models." Forthcoming in *Empirical Economics.*

Schularick, M., and A. M. Taylor. 2012. "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870-2008." *American Economic Review* 102 (2): 1029–61.

Smets, F. 2014. "Financial Stability and Monetary Policy: How Closely Interlinked?" *International Journal of Central Banking* 10 (2): 264–300.

Svensson, L. E. O. 2013. "'Leaning Against the Wind' Leads to a Higher (Not Lower) Household Debt-to-GDP Ratio." Working Paper. Available at http://www.larseosvensson.net.

———. 2014. "Inflation Targeting and 'Leaning Against the Wind'." *International Journal of Central Banking* 10 (2): 103–14.

———. 2016. "Cost-Benefit Analysis of Leaning Against the Wind: Are Costs Larger Also with Less Effective Macroprudential Policy?" NBER Working Paper No. 21902.

Taylor, J. B. 2007. "Housing and Monetary Policy." NBER Working Paper No. 13682.

———. 2010. "Getting Back on Track: Macroeconomic Policy Lessons from the Financial Crisis." *Review* (Federal Reserve Bank of St. Louis) 92 (3, May/June): 165–76.

Tsatsaronis, K., and H. Zhu. 2004. "What Drives Housing Price Dynamics: Cross-Country Evidence." *Quarterly Review* (Bank for International Settlements) (March): 65–78.

Uhlig, H. 2005. "What Are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure." *Journal of Monetary Economics* 52 (2): 381–419.