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The impact of monetary policy on household borrowing - a high-frequency IV identification*

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Abstract

This paper combines identification of monetary policy shocks from high-frequency financial market data with local projections IV to study the effects of monetary policy on household borrowing using Swedish data. The results are uncertain but indicate that the stock of household loans is 1.6 percent lower two years after a 1 percentage point shock to the repo rate. This is a relatively modest effect considering that the stock of household loans on average grew by 7.8 percent per year over this period.

Keywords: Monetary policy, Household credit, High-frequency identification, External instrument, Local projections.

JEL codes: C26, E51, E52, G14.

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1 Introduction

The objective of this study is to investigate how monetary policy affects household borrowing from the banking sector. There are at least two reasons to study the effect of monetary policy on household borrowing. The first reason is that it helps us better understand the monetary policy transmission mechanism in the short to medium term. If credit markets are an important channel for transmitting changes in monetary policy instruments to the real economy, changes in credit market functioning can have important consequences for the overall monetary policy transmission mechanism. The second reason is that a rapid credit growth may be related to the build-up of financial risk in the economy as suggested by Schularick and Taylor [2012]. An eventual materialization of these risks in the form of a financial crisis can have a significant impact on the real economy many years into the future. This concern underlies the idea that central banks should react to movements in asset prices and credit, beyond what such movements imply for short-run aggregate demand and inflation, by implementing so-called *leaning against the wind* policies.

There are both neoclassical and non-neoclassical theories explaining why credit markets may be an important part of the monetary policy transmission mechanism as explained by Boivin et al. [2010]. According to neoclassical theory, the interest rate channel works through an effect on the user cost of capital and hence, on the amount of investment spending by firms and households. To the extent that investment is debt-financed, changes in the monetary policy rate will affect the demand for loans. For households, changes in short-term interest rates also create incentives for intertemporal substitution in consumption with consequences for savings and borrowing.

The non-neoclassical channels generally involve some type of friction in credit markets. The bank capital channel predicts that contractionary monetary policy reduces credit quality and the value of bank assets. This leads to a decline in bank capital which has a negative impact on lending capacity. The balance sheet channel focuses on the role of collateral in mitigating asymmetric information and enforcement problems. Contractionary monetary policy reduces collateral values which makes lenders less willing to provide funds in the face of moral hazard and adverse selection.

Altogether, these theories predict that stricter monetary policy leads to a contraction of credit, whereas expansionary monetary policy leads to an expansion of credit. However, the size of these effects is likely to vary across countries and institutional settings. This study is based on data from Sweden which is representative of an institutional setting where banks dominate the financial system, variable-rate loans are common and the bank has recourse to an individual's assets and cash-flow in case of default.

To estimate the causal effects of monetary policy, I use a measure of unexpected changes in the Riksbank monetary policy rate, the repo rate, based on event studies of high-frequency financial market data. These unexpected changes can, under certain assumptions, be interpreted as exogenous monetary policy shocks. An advantage of the high-frequency shock identification is that all relevant information is used to separate exogenous monetary policy changes from endogenous reactions of the central bank. Thus, it solves the problems of omitted variable bias and time-varying parameters associated with the estimation of policy rules.

The measured monetary policy shocks are used to instrument for changes in the monetary policy rate in an IV framework estimating the effects of monetary policy on household credit growth and other macro variables. The method used is local projections as proposed by Jordà [2005] and the method is henceforth called "local projection IV".

The time period of study spans from 2003, when the relevant high-frequency financial market data became available, until 2014, before the start of the Riksbank's quantitative easing program.[1] This is a period in which Sweden experienced a rapid rise in house prices and an increase in household indebtedness. Therefore, it is of particular interest to investigate what role monetary policy played in this development. To the best of my knowledge, there are no other studies using high-frequency

[1]Since January 2015, the Riksbank has conducted so-called quantitative easing in the form of large-scale purchases of Swedish government bonds.

identification of monetary policy shocks to identify the effect of monetary policy on credit.

The estimated effects of monetary policy on macro variables are economically meaningful which confirms that a high-frequency identification of monetary policy shocks in combination with local projection IV is a useful method for estimating the impact of monetary policy. The stock of credit is estimated to be 1.6 percent lower two years after a 1 percentage point shock to the repo rate. This is a relatively modest effect considering that the stock of credit on average grew by 7.8 percent per year during the sample period. However, the estimated effect on credit is however not statistically significant at the 95 per cent level.

The estimated response of credit to monetary policy is somewhat lower than the response of GDP. This indicates that contractionary monetary policy is not an efficient tool for reducing the credit-to-GDP ratio, at least not in the short run.

Section 2 presents an overview of related literature whereas Section 3 discusses measures of monetary policy shocks. Section 4 presents the estimated effects of these shocks on household borrowing and Section 5 concludes the paper.

2 Literature on monetary policy shocks and credit

The literature studying the impact of monetary policy on borrowing is not new but has expanded since the recent financial crisis which occurred on the back of the rapid credit expansion in the Unites States and many European countries.

Vector autoregressive models have been used to study the dynamic effects of monetary policy on credit since the 1990's. In an early contribution, Bernanke and Blinder [1992] use a four-variable monthly VAR to study the effects on bank balance sheets of a shock to the federal funds rate. They find that banks initially react to a contractionary monetary policy shock by selling off securities but, in the long run, the entire adjustment in bank assets falls on loans. More recently, Assenmacher-Wesche et al. [2008] use data from 18 OECD countries for the period 1986-2008 in a panel VAR. They find that the effect of monetary policy on credit is mostly small and uncertain but with significant cross-country differences.

Robstad (2016) studies the effect of monetary policy on credit in Norway by extending the Bayesian VAR of Björnland and Jacobsen (2010). The results show that monetary policy has a moderate effect on credit, which is robust across several identification schemes, but that the credit-to-GDP ratio actually rises after a contractionary monetary policy shock. In contrast, Laséen and Strid [2013] estimate a Bayesian VAR on Swedish data and find that a positive monetary policy shock leads to a fall in both real household debt and the debt-to-GDP ratio.

Bernanke and Blinder [1992] and most subsequent VAR studies identify the effects of monetary policy by making assumptions about the central bank information set and the functional form of the central bank reaction function. By assuming a linear reaction function, monetary policy shocks can be estimated as the fitted residuals from an OLS regression of the central bank's policy instrument on variables in the assumed information set. The typical structural VAR specification assumes that the central bank's information set is captured by relatively few macro variables. However, factor-augmented VARs can include factors based on hundreds of variables, which potentially allows for a much richer information set.

Most commonly, a recursiveness assumption is applied to identify the dynamic responses to monetary policy shocks. It assumes that these shocks do not have a contemporaneous effect on the economic variables included in the VAR (Christiano et al. [1999]). Other prominent approaches involve sign restrictions on the responses of other variables (see, for example, Uhlig [2005])

In addition, monetary policy shocks can be obtained from a narrative analysis of historical records (see, for example, Romer and Romer [2004]) and from the calibration or estimation of dynamic stochastic general equilibrium models. Ramey [2016] provides an excellent survey of the identification of macroeconomic shocks in general and monetary policy shocks in particular.

The emergence of high-frequency financial market data has allowed for new methods of identifying unexpected changes in monetary policy as explained in detail by Kuttner [2001]. Under certain assumptions, these monetary policy surprises can be interpreted as exogenous monetary policy shocks. Various methods are used to extract these shocks and combine them with dynamic low-frequency macro models. For example, Bagliano and Favero [1999] construct a shock series based on a continuous-zero coupon yield curve for the US and Germany and include it as an exogenous variable in a VAR model. Cochrane and Piazzesi [2002] use unexpected changes in euro-dollar rates to construct a daily shock series and include the monthly sum of shocks in a VAR. Barakchian and Crowe [2013] use factor analysis to extract the common components of six monthly federal funds futures rate contracts and use shocks to the level factor as a proxy for monetary policy shocks in a monthly VAR.

Using Swedish data, De Rezende [2017] and Brubakk et al. [2017] derive shocks to the Riksbank repo rate as well as to the repo rate path.

The current study is similar in spirit to Gertler and Karadi [2015] who employ the so-called *external instrument* or proxy SVAR method developed by Stock and Watson [2016]. However, whereas their method uses the externally identified shock series to instrument for shocks derived from a traditional VAR, I use the externally identified shock series to instrument for actual monetary policy changes in line with Stock and Watson [2017]. This is due to the properties of the externally identified shock series as discussed in the next section.

3 Measuring monetary policy shocks

This section discusses the assumptions needed to identify exogenous monetary policy shocks using data on market interest rates and presents a shock measure based on Swedish data.

3.1 Assumptions needed to measure exogenous monetary policy shocks from market data

In order to estimate the causal effect of monetary policy, we need to identify an *exogenous* variation in monetary policy.[2] These exogenous changes represent deviations from the expected central bank reactions to the state of the economy. A starting point for finding exogenous changes in monetary policy is therefore to look for *unexpected* monetary policy changes.

To identify unexpected monetary policy changes, we exploit the efficient market hypothesis which states that asset prices reflect all available information including expected future monetary policy. This means that monetary policy expectations of financial market partcipants can be measured via market interest rates that are close proxies for forecasts of the monetary policy stance. For example, Kuttner [2001] shows that Federal funds futures provide good forecasts of the Federal funds rate. To distinguish between expected and unexpected changes in monetary policy, we consider a sufficiently short time period after a monetary policy announcement such that the announcement is the only new information becoming available to the market during that time. Movements in market interest rates observed in that time window should then only reflect new information presented in the monetary policy announcement. Hence, it should only reflect changes in monetary policy that are unexpected by financial market participants.

Assuming that we want to measure the unexpected component of the Riksbank's main monetary policy instrument, the repo rate, we want to find:

$$\Delta i_s^{unexpected} = i_s^{repo} - E_{s-1} i_s^{repo} \tag{1}$$

where s refers to the time of the monetary policy announcement.

As pointed out by Barakchian and Crowe [2013], four assumptions need to be fulfilled for these unexpected movements in market interest rates to be interpreted

[2] As pointed out by Ramey [2016], what the monetary policy literature refers to as "shocks" are not necessarily primitive economic shocks but rather exogenous instruments for changes in monetary policy.

as exogenous monetary policy shocks. The first assumption is that we can observe a market interest rate which is a close proxy for the expected monetary policy rate. In practice, this observed interest rate may not be a perfect measure of expected future monetary policy, but is likely to contain a small risk premium. The second assumption is that there is no systematic variation in the risk-premium part of the observed interest rate at the time of monetary policy announcements. The presence of unsystematic measurement error can also be a problem since it leads to a classical errors-in-variables problem. An attenuation bias resulting from unsystematic measurement error leads us to understate the estimated effects of monetary policy on macro variables.

The third assumption is that no other news affecting market interest rates is systematically released in the time window in which the monetary policy shock is measured. This assumption may be incorrect if the central bank publishes new data in its monetary policy report. To the best of my knowledge, no new data is published in the monetary policy reports of the Swedish central bank.

Even if we can identify unexpected changes in interest rates which are related to monetary policy announcements, this does not necessarily imply that they are *exogenous*. The fourth and perhaps most problematic assumption is that the measured policy shocks do not reflect the central bank's private information about the future state of the economy. If the central bank has access to information about the economy that is not available to financial markets, future economic developments may be interpreted as a consequence of an exogenous policy shock whereas, in reality, policy was changed in anticipation of those future economic developments. For example, if the Riksbank cuts interest rates in anticipation of an economic recession which could not be forecasted by the market, we may see a fall in economic activity following the negative monetary "policy shock". Once more, this bias will lead to an underestimation of the effects of monetary policy on the economy. However, with the wide availability of economic information, it is plausible to assume that the Riksbank has no more information about the future state of the economy than market partcipants.

Assuming that the above requirements are fulfilled, we can use measures of unexpected changes in monetary policy as measures of exogenous monetary policy shocks. However, the question still remains why exogenous monetary policy shocks would exist in modern economies where central banks normally claim that monetary policy decisions are endogenous responses to economic developments. Nevertheless, there are multiple ways in which a central bank can adjust its monetary policy instruments endogenously to economic developments. The fact that there is no universal rule on how monetary policy should be conducted leaves room for shocks to the monetary policy reaction function. A change in the composition of the monetary policy committee or a monetary policy-maker updating her views on how monetary policy should respond to the economy are examples of events that can generate exogenous monetary policy shocks. Our shocks can thus be interpreted as changing preferences of the monetary authority, which are not known by financial markets before the monetary policy announcement.

3.2 Conceptual differences between high-frequency and VAR shocks

The conceptual difference between high-frequency shock measures and shock measures generated from a recursive VAR can be illustrated by the following example. Let us assume that the central bank follows the policy rule:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y y_t. \tag{2}$$

However, from time $t+1$ and onwards, the central bank decides to also give some weight to the exchange rate fx in its monetary policy decision. Hence, there is a shift in central bank preferences such that the time $t+1$ policy rule is:

$$i_{t+1} = \rho + \phi_\pi \pi_{t+1} + \phi_y y_{t+1} + \phi_{fx} fx_{t+1}. \tag{3}$$

If this change in preferences is revealed at the time of the monetary policy decision, the high-frequency event-study identification method will classify the observed movements in financial market prices as the results of an exogenous monetary policy shock. However, if the change in preferences is announced before a monetary policy meeting, financial market prices will adjust before the meeting and this adjustment will not be identified as a monetary policy shock by the high-frequency event-study approach. Some exogenous monetary policy shocks may thus be classified as endogenous monetary policy changes. Any actual adjustment of monetary policy instruments to the exchange rate $\phi_{fx} fx_{t+1}$ taking place at later monetary policy meetings will be correctly classified as part of endogenous monetary policy (endogenous to the decision rule prevailing at time $t+1$).

In contrast, a recursive VAR based on the previous policy rule will identify a deviation ϵ_{t+1} from the monetary policy rule

$$i_{t+1} = \rho + \phi_\pi \pi_{t+1} + \phi_y y_{t+1} + \epsilon_{t+1} \tag{4}$$

where $\epsilon_{t+1} = \phi_{fx} fx_{t+1}$ will be classified as an exogenous monetary policy shock. The VAR based on the previous policy rule will also classify all subsequent central bank responses to the exchange rate as monetary policy shocks, although the exchange rate is now part of the central bank reaction function. Some arguably endogenous monetary policy changes will thus be classified as exogenous monetary policy shocks. Thus, we can expect to measure larger and more frequent monetary policy shocks based on the VAR-framework as compared to the high-frequency event study approach.

Assuming that the four conditions for identifying high-frequency financial market shocks listed above are fulfilled, the high-frequency event-study method will identify shocks that are truly exogenous. However, the method will fail to identify all exogenous monetary policy shocks. The VAR model is, on the other hand, likely to classify endogenous monetary policy shocks as exogenous changes in monetary policy which is a more serious problem. Table 1 presents a summary of ability of alternative methods to correctly classify exogenous and endogenous monetary policy changes.

Table 1: Methods' classification of monetary policy changes

	Recursive VAR		High-frequency	
	Expected	Unexpected	Expected	Unexpected
END reactions to info in VAR	correct	correct	correct	correct
END reactions to info not in VAR	incorrect	incorrect	correct	correct
EXO monetary policy changes	correct	correct	incorrect	correct

END refers to endogenous and EXO refers to exogenous. Expected refers to the fact that the change was expected by financial market participants and Unexpected refers to the change not being expected by financial market participants.

3.3 A shock measure based on interest-rate swaps

Short-dated so-called STINA-swaps can be used to measure expectations of the Riksbank repo rate.[3] The STINA swap-rate represents the exchange of a fixed and a floating rate where the floating rate is STIBOR T/N, that is the interbank rate from tomorrow to the day after tomorrow. The fixed rate should therefore represent the expected average STIBOR T/N over the duration of the contract which is between 1 month and 1 year. The expected average interbank rate should be a close proxy for the expected repo rate over the same time horizon, especially for the 1-month contract for which the credit risk is normally low.[4] An advantage of the STINA contract is that intraday data are available which makes it possible to measure STINA swap rates shortly before and shortly after the monetary policy announcement. In this way, we can better separate the effect of monetary policy news on financial market prices from the effects of other events occurring on the same day.[5] One drawback is that intraday data on the STINA swap rate are only available since 2003, which gives

[3]STINA stands for Stockholm Tomorrow Next Interbank Average.

[4]The Stibor T/N generally trades at the repo rate plus a fixed risk premium of 10 basis points.

[5]Monetary policy announcements generally take place at 9:30 am. In practice, we observe changes in the STINA rate between 9:15 and 12:15 to ensure that we have captured the full adjustment to the monetary policy news announcement.

a rather short time period for this study.

The STINA 1-month contract should reflect the average expected repo rate during the month, but repo rate changes are always implemented on the first Wednesday after the monetary policy announcement, which means that each contract covers a period in which the old repo rate prevails. Hence, based on the methodology in use at the Riksbank, the following adjustment is made to measure an unexpected monetary policy shock (see appendix A for details):

$$shock_s = \Delta i_s^{unexpected} = \frac{[i_s^{STINA} - i_{s-1}^{STINA}](\tau_1 + \tau_2)}{\tau_2} \tag{5}$$

where s is the time of the monetary policy announcement, τ_1 is the number of days until the implementation of the new repo rate and τ_2 is the number of days from the implementation of the new repo rate until the maturity of the contract. This means that $\tau_1+\tau_2$ is the total length of the contract. Fransson and Tysklind [2016] show that a shock measure based on the STINA 1-month swap rate has a large and significant impact on both shorter and longer bond rates as well as on lending rates to firms and households.

3.4 From daily to quarterly shock measures

In Section 4, I use the monetary policy shock measures as instruments in the empirical models linking monetary policy to credit. An important question is how to combine the daily series of measured shocks with quarterly macro data. One option would be to aggregate all shocks occuring in each quarter to a quarterly shock. However, this method may not work well since the effect of a policy shock on the economy will differ depending on whether it occurs early or late in the quarter.

Following Gertler and Karadi [2015], I therefore create a measure of the intensity of the shock in each quarter. This measure is obtained by first calculating a series of cumulated daily shocks over the full sample where the cumulated shock at day d is

$$shock_d^c = \sum_{s=1}^{d} shock_s. \tag{6}$$

Then, I create a quarterly average of the cumulated series where the observation at quarter t is

$$qa_t = \frac{\sum_{d=d_t^1}^{d_t^T} shock_d^c}{d_t^T - d_t^1}, \tag{7}$$

where T is the number of trading days in quarter t.

The difference in quarterly averages is used as measures of quarterly monetary policy shocks

$$shock_t = qa_t - qa_{t-1}. \tag{8}$$

This shock measure is meant to capture the change in the average policy rate between two subsequent quarters that is due to monetary policy shocks.

3.5 Properties of the monetary policy shock series

Descriptive statistics of the derived daily and quarterly monetary policy shock series are summarized in Table 2. Both the daily and the quarterly series are slightly negative on average (-0.02 and -0.03 percentage points, respectively) coinciding with an overall downward trend in interest rates globally. The negative averages are somewhat surprising since, in a rational expectations equilibrium, market participants would be right on average. However, a t-test indicates that the mean of the series is not statistically different from zero. We also see that the quarterly shock series has a lower minimum value than the daily series, reflecting several occasions of unexpected monetary policy easing in the same quarter.

Table 2 shows that the daily and quarterly shock series are positively correlated with actual monetary policy changes. More surprisingly, they are also positively correlated with expected monetary policy changes. This is further confirmed by Figure 1 showing actual changes of the monetary policy rate and the derived measures of quarterly monetary policy shocks. Two things can be noted from Figure 1. First, there is an asymmetry between repo rate hikes and repo rate cuts. The repo rate increases in 2006-2007 and in 2010-2011 were largely in line with the market expectations. In contrast, the Riksbank has sometimes surprised the market by a more expansive monetary policy than expected by market participants. Second, we see that unexpected repo rate cuts are often accompanied by expected repo rate cuts. This shows that market participants have generally been right about the direction of monetary policy changes but have underestimated their magnitude. One interpretation of this phenomenon is that the Riksbank has continuously changed its policy rule to conduct a more expansive monetary policy than expected by the market participants, based on their previous knowledge of the Riksbank's reaction function. This may reflect continuously shifting preferences of central bank policy-makers towards a more expansionary monetary policy. The alternative is that market participants do not understand central bank preferences, which means that our measures of exogenous monetary policy shocks are invalid.

Table 2: Descriptive statistics of monetary policy shock series

Descriptive statistics (percentage points)					
	Mean	Median	Min	Max	Std. dev.
Daily	-0.02	0.00	-0.42	0.18	0.10
Quarterly	-0.03	0.00	-0.60	0.11	0.14

Correlation coefficients		
	Corr($\Delta i_t^{unexpected}$, $\Delta i_t^{expected}$)	Corr(Δi_t, $\Delta i_t^{unexpected}$)
Daily	0.45	0.69
Quarterly	0.51	0.72

The daily shock series refers to unexpected monetary policy changes on days of monetary policy meetings. Expected monetary policy, $\Delta i_t^{expected}$, refers to the difference between actual and unexpected monetary policy changes.

Figure 1 shows large negative shocks in Q4 2008 and Q1 2009, which reflect the large unexpected monetary policy easing at the height of the financial crisis. On the one hand, these shocks are much larger than the normal variation in the series, which could justify removing them altogether if we are only interested in the effects of monetary policy under more normal circumstances. On the other hand, they are possibly the most important observations of unexpected monetary policy changes in this time period and I have therefore included them in the sample.

3.6 Incorporating the shock series in a dynamic model

If the series measuring monetary policy changes that are unexpected by market participants represents an exogenous component of monetary policy, it is a candidate instrumental variable for monetary policy. Stock and Watson [2017] list the conditions that need to be met for our shock series to be a valid instrument. The instrument relevance condition and the instrument exogeneity conditions are familiar from the microeconometric literature. The positive correlation between unexpected and actual repo rate changes displayed in Table 2 implies that the instrument relevance condition is met. The instrument exogeneity condition follows from the assumption that we have identified exogenous shocks to monetary policy. A third assumption is that the instrument needs to be uncorrelated with past monetary policy shocks. It turns out that the shock series lagged by one to eight quarters are not statistically significant predictors of the current shock series. This means that the effect of monetary policy on macro variables can be estimated by 2SLS with our measured shock series as an instrument for endogenous monetary policy changes.

An alternative approach would be to estimate the effect of monetary policy by directly regressing the variable of interest on the derived monetary policy shock series similar to Romer and Romer [2004]. However, the positive correlation between unexpected and expected monetary policy changes displayed in Table 2 implies that the estimated effects of unexpected monetary policy changes would also capture the response to expected monetary policy changes. Hence, the resulting omitted variable bias would lead to an overestimation of the effects of monetary policy.

4 Estimating the impact of monetary policy on household borrowing

The primary interest lies in the impact of monetary policy on household credit but the effects on output and inflation are also presented to facilitate the comparison with other studies and methods.

4.1 Local projection IV

The objective is to explain how household credit depends on current and past changes in the repo rate instrumented by the measured shock series. The fact that shocks are identified outside of the model means that monetary policy is allowed to have an immediate impact on macro variables.

The approach taken is a local projection method as presented by Jordà [2005], which implies that a separate equation is estimated for each time horizon. The advantage of the linear projection method is that it is more robust to non-linearities in the responses to monetary policy shocks.

The local projection IV can be represented as a two-equation model where Equation 9 aims at separating repo rate changes into their endogenous and exogenous components and Equation 10 describes the structural relationship between monetary policy and the variable of interest y_t which represents household credit growth, GDP growth and inflation, respectively:

$$\Delta repo_t = \theta shock_t + u_{1,t}, \tag{9}$$

$$y_{t+h} = \beta_h \Delta repo_t + u_{2,t+h}. \tag{10}$$

If the shock series measures truly exogenous monetary policy changes, there is no reason to expect any correlation between these shocks and other variables. Therefore, no additional control variables should be needed. The error term $u_{1,t+h}$ is serially correlated for all horizons except $h = 0$ which requires a correction of standard errors. For each regression of horizon h, I obtain the HAC weighting matrix according to

Newey-West with a maximum lag-lenght h.

The quarter-on-previous-quarter growth rate of household credit, depicted in Figure 2 is derived from the nominal stocks recorded in the Financial accounts.[6] GDP growth is measured as the seasonally adjusted quarter-on-previous quarter growth rate of real GDP. Figure 3 shows a sharp drop in GDP growth in Q4 2008 during the global financial crisis and a dummy variable has been added to account for this event. Inflation is represented by the year-on-year consumer price inflation, net of changes in the interest rate. The yearly, and not quarterly, inflation rate is used since the central bank inflation target is formulated in terms of a yearly rate. This time series is depicted in Figure 4.

As described above, we can measure STINA-based monetary policy shocks using intraday data from Q1 2003 and this determines the starting date of the sample. In order to focus on the period when monetary policy was primarily conducted by changes in the repo rate as well as communication about future repo rate changes, the sample ends in Q4 2014. Hence, I exclude the period since January 2015 when the Riksbank has conducted so-called quantitative easing in the form of large-scale purchases of Swedish government bonds. This means that there are in total 48 quarterly observations. Because of the short sample length, I limit the forecast horizon h to eight quarters. The model parameters are estimated using 2SLS and the coefficient β_h gives the effect on y_{t+h} of a monetary policy shock occurring in quarter t. In the VAR terminology, β_h represents the impulse-response of y at horizon $t+h$ to a shock occuring in time t.

The impulse-response of credit growth to a 1 percentage point monetary policy shock is displayed in Figure 6. It shows a negative effect of monetary policy on credit growth with the largest response, -0.5 percentage points, occuring after three quarters. The effect is relatively modest considering that the average credit growth has been 1.9 percent per quarter in this time period. It is also within one standard deviation of credit growth (0.65 percentage points). The cumulative effect after two

[6]It should be noted that there is some measurement error in the time series since stock changes also represent banks' sales and purchases of loans.

years is -1.6 percent on the total stock of credit. Also this is a relatively modest effect considering that the stock of credit on average grew by 7.8 percent per year. The estimated coefficients are not statistically significant at the 95-percent level.

The response of GDP growth depicted in Figure 7 displays the hump-shaped pattern typically associated with impulse-responses to monetary policy shocks. The sharp drop in GDP growth after four quarters is both statistically and economically significant. The maximum effect on GDP growth of -1.3 percentage points is large compared to the average quarterly GDP growth rate of 0.5 percent. It is also more than one standard deviation (1.08 percent) of GDP growth.

The cumulative effect on GDP over two years is -2.2 percent. If omitting the initial large increase in GDP, the cumulated response of GDP is larger. However, the borderline statistically significant initial increase in GDP indicates that the identified shocks may partly be unexpectedly big responses to, rather than the causes of, GDP developments which may indicate an endogeneity problem.

Figure 8 shows that inflation starts to fall after three quarters with no apparent price puzzle and this drop in inflation is statistically significant. After two years, the price level is -1 percent lower than what it would have been in the absence of the monetary policy shock.

4.2 Robustness analysis

4.2.1 Linear dependence on shocks

An alternative to the linear projection method is to assume that macro variables depend linearly on current and past monetary policy changes similar to Romer and Romer [2004]. If the true relationship between the variables is linear, this approch will imply a more efficient estimation. Once more, I implement this method in a two-equation model of the form:

$$\Delta repo_t = \theta shock_t + u_{1,t}, \tag{11}$$

$$y_t = \sum_{j=0}^{8} \beta_j \Delta repo_{t-j} + u_{2,t}, \quad (12)$$

where y_t represents household credit growth, GDP growth and inflation, respectively. Also, in this case, a dummy variable is included to account for the sharp drop in GDP in Q4 2008 following the global financial crisis. Once more, the parameters are estimated by 2SLS.

The estimated impulse-responses are presented in Figures 9, 10 and 11. Confidence intervals are based on the unrestricted residuals bootstrap as described by Davidson and MacKinnon [2010] with the formula presented in appendix B.[7]

We see that the impulse-responses for all three variables are relatively similar to the local projection results but the effects of monetary policy are somewhat more muted and more erratic. The drop in GDP growth is statistically significant whereas the effects of monetary policy on credit and inflation are not.

4.2.2 Vector autoregressive model

As discussed in Section 2, the most common method used to identify monetary policy shocks in the VAR literature is by the recursiveness assumption (Christiano et al. [1999]). It is therefore interesting to compare the above results with the results generated from a recursive VAR estimated on the same sample.

Figure 12 shows the impulse-response functions of a recursive VAR with the cholesky ordering; inflation, GDP, loan growth and the monetary policy rate. By ordering the interest rate last, we assume that monetary policy does not have a contemporaneous effect on any of the other variables. Two lags of the variables are included as well as a dummy variable to account for the financial crisis.

The overall pattern of the variables is relatively similar to the local projection findings except for inflation which now displays a price-puzzle. The magnitudes of the effects are, however, slightly different with monetary policy having a larger negative effect on credit but the effect on GDP is only half compared to what we found with

[7]Bootstrap methods for hypothesis tests often perform better than tests based on asymptotic theory in small samples where the error term is not necessarily normally distributed.

the local projection IV method. The estimated impulse-response of credit is now statistically significant, whereas the effects of monetary policy on other variables are not.

The somewhat different results are not surprising when comparing the shock series derived from financial market data to the residuals from the interest rate equation of the recursive VAR. The two series, displayed in Figure 13, have a positive correlation of 0.44 which suggests that they classify the same monetary policy changes as exogenous shocks to a relatively high degree. However, Figure 13 shows that the recursive VAR to a much larger extent classifies monetary policy changes as exogenous shocks, which is also expected based on the discussion in Section 3. That monetary policy is exogenous to such a large degree is hardly consistent with the idea of modern central banks devoting considerable resources to economic analysis and tailoring policy responses to economic conditions.

4.3 Discussion of results

The estimates obtained from the local projection IV method are mostly economically resonable which confirms that this is an interesting new method for estimating the impact of monetary policy on macro variables. However, the estimated impulse-response functions are surrounded by uncertainty which is not surprising given the limited data sample available for the study. A longer time series with larger monetary policy shocks would possibly improve the conditions for statistical inference.

Table 3 shows a comparison of the estimated impact of monetary policy on household credit and GDP in studies of Swedish data. The estimated effect on credit in the local projection IV framework is of the same magnitude but somewhat larger than the findings of Laséen and Strid [2013] and somewhat smaller than the findings of Assenmacher-Wesche et al. [2008].[8]

However, the estimated impact of monetary policy on GDP varies significantly more across the studies. The local projection estimates above indicate that the cu-

[8]However, the results are not entirely comparable since Assenmacher-Wesche et al. [2008] are considering real credit.

mulated response of credit is somewhat weaker than the cumulated response of GDP which suggests that contractionary monetary policy may not help reduce the credit-to-GDP ratio, at least not in the short run. However, this finding is contrary to the other results displayed in Table 3. The differences in estimates imply that choices of identifying assumptions and estimation methods are important for our conclusions about the effects of monetary policy. Further comparison of results based on high-frequency identification and local projection IV to results based on other methods is an interesting area for future research.

Table 3: Effect on levels after 2 years (percent)

	household credit	GDP
This paper local projection	-1.6	-2.2
This paper VAR	-2.7	-2.6
Laséen and Strid [2013]	-1.4	- 0.4
Assenmacher-Wesche et al. [2008]	-2.0	-0.8

Effects of a 1 percent positive monetary policy shock. The reported results from other studies are based on a visual inspection of figures.

5 Conclusion

The aim of this study is to shed light on some of the intermediate steps in the monetary policy transmission mechanism by investigating the effect of monetary policy on household borrowing in Sweden. The investigation is carried out by combining high-frequency monetary policy shocks with a local projection IV framework.

The estimated effects are mostly economically meaningful which confirms that this is an interesting new method for studying the impact of monetary policy on macro variables. The stock of credit is estimated to be 1.6 percent lower two years after a 1 percentage point shock to the policy rate. This is a relatively modest effect considering that the stock of credit on average grew by 7.8 percent per year. However, the estimated effect on credit is not statistically significant at the 95 per cent level.

Moreover, the estimated response of credit is somewhat weaker than the response of GDP. This indicates that contractionary monetary policy may not be an efficient tool for reducing the credit-to-GDP ratio, at least not in the short run.

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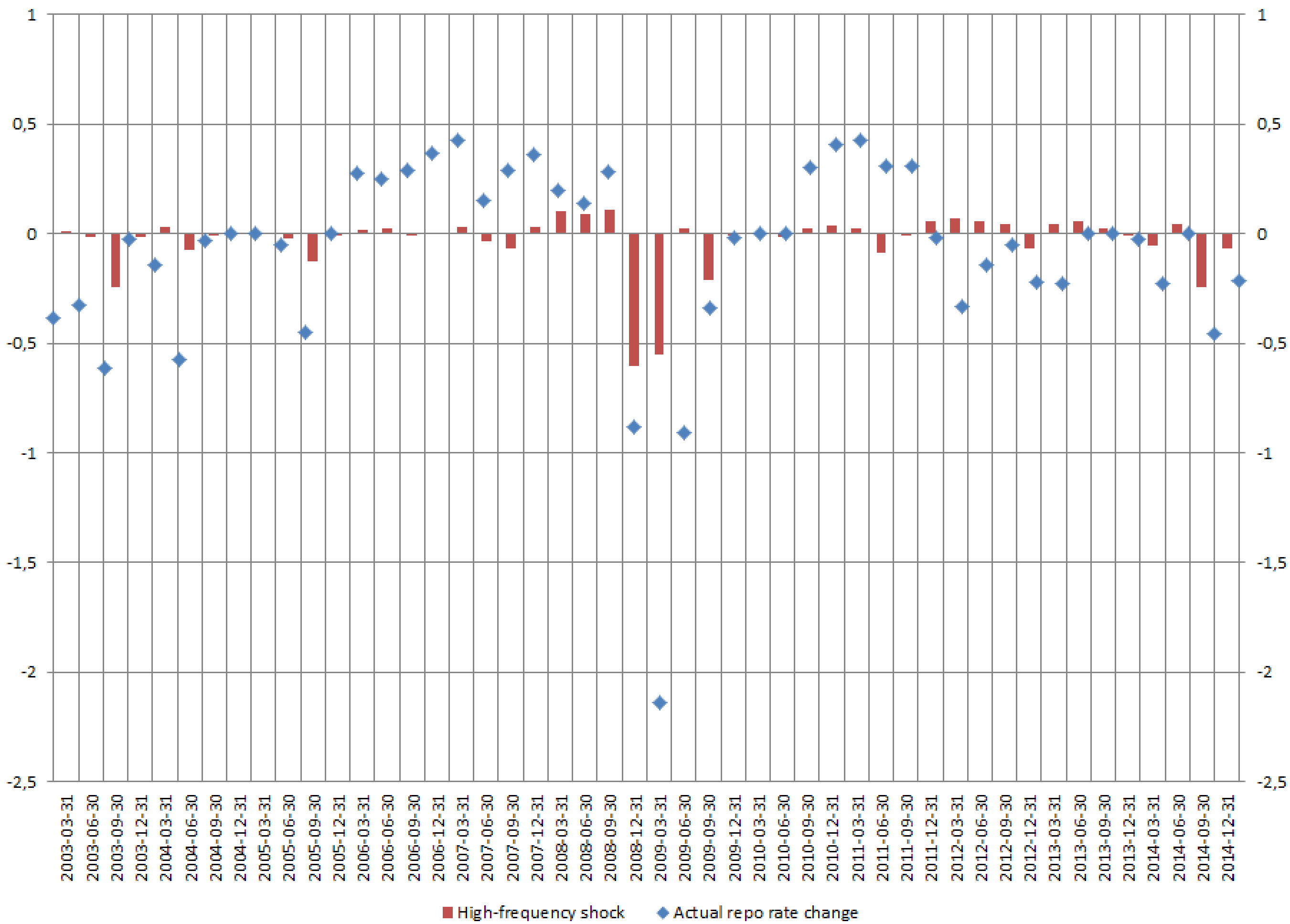
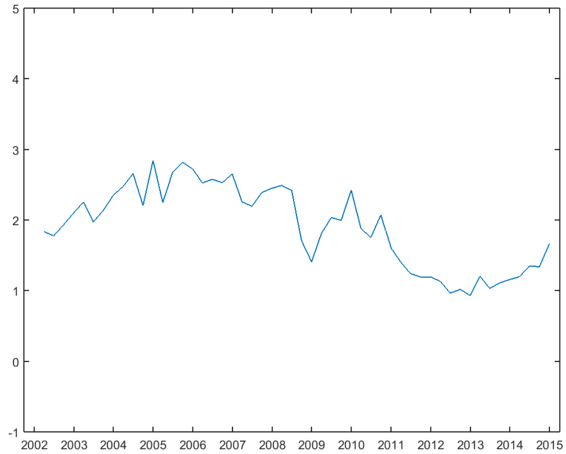
Figure 1: Actual repo rate changes and measured monetary policy shocks (percentage points)



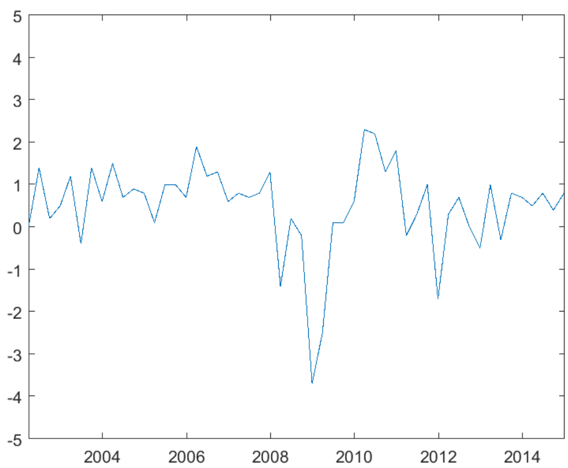
The actual repo rate changes refer to changes in the average quarterly repo rate. The high-frequency shock is the quarterly shock derived from STINA interest swaps with 1-month maturity.

Figure 2: Household credit growth (percent)



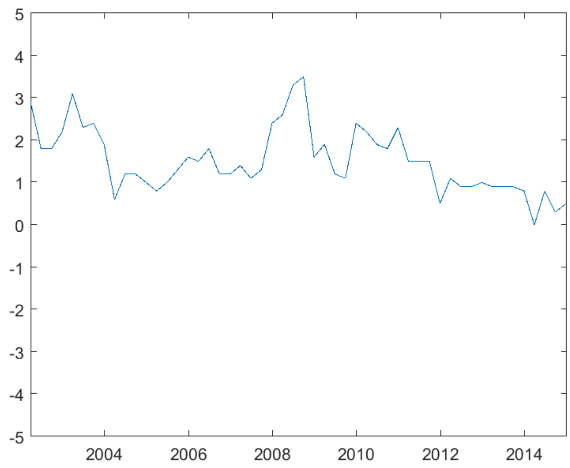
Quarter-on-previous-quarter growth rate of Swedish monetary financial institutions' lending to households. Nominal values. Seasonally adjusted with Eviews X13.

Figure 3: GDP growth (percent)



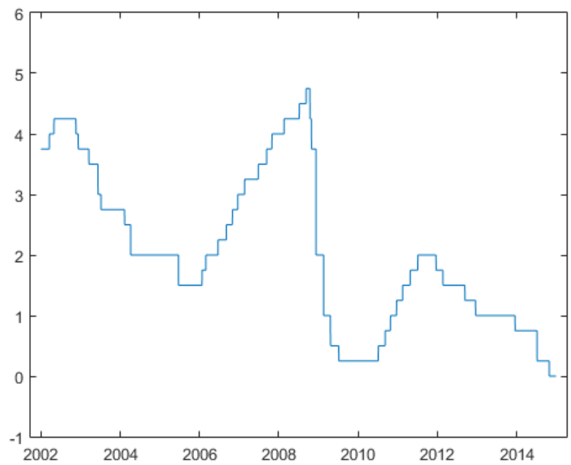
Quarter-on-previous-quarter growth of real GDP. Seasonally adjusted.

Figure 4: Inflation (percent)



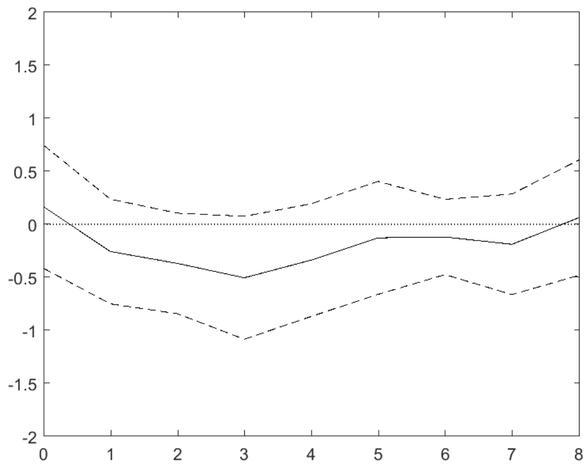
Year-on-year inflation net of interest rate changes.

Figure 5: Riksbank repo rate (percentage points)



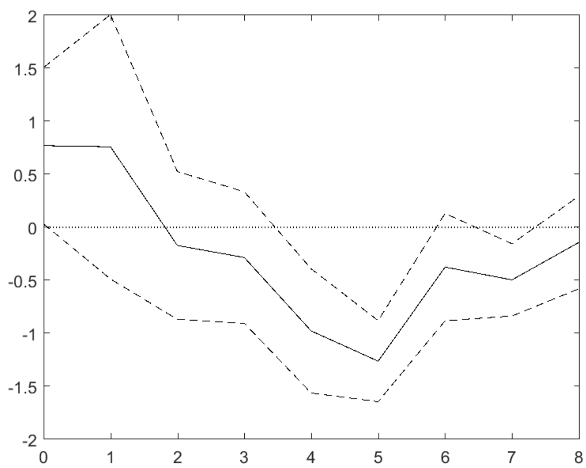
Quarterly average of Riksbank repo rate.

Figure 6: Impulse-response of household credit growth - local projection IV



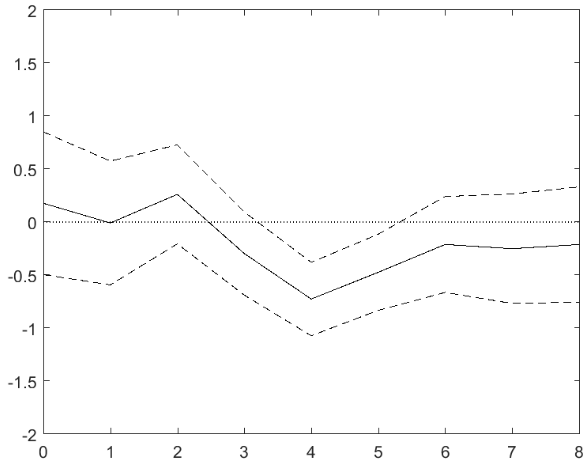
Effect of a 1 percentage point exogenous repo rate increase. The dashed lines indicate a 95 percent confidence interval.

Figure 7: Impulse-response of GDP growth - local projection IV



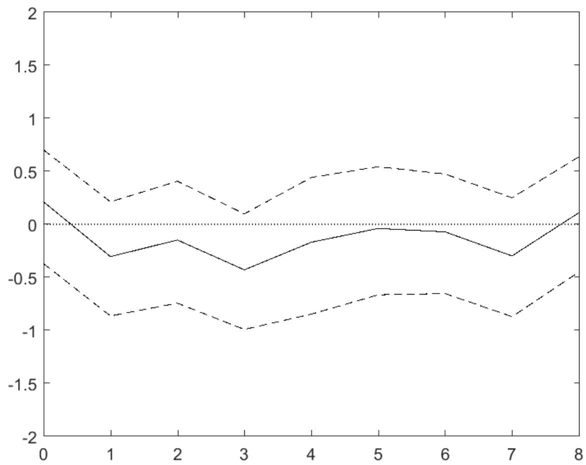
Effect of a 1 percentage point exogenous repo rate increase. The dashed lines indicate a 95 percent confidence interval.

Figure 8: Impulse-response of inflation - local projection IV



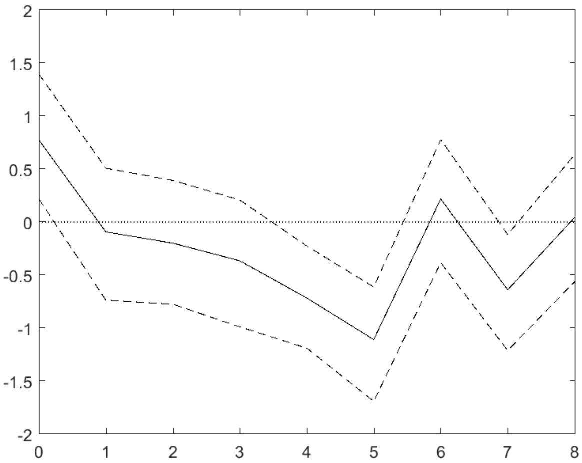
Effect of a 1 percentage point exogenous repo rate increase. The dashed lines indicate a 95 percent confidence interval.

Figure 9: Impulse-response of household credit growth - linear model



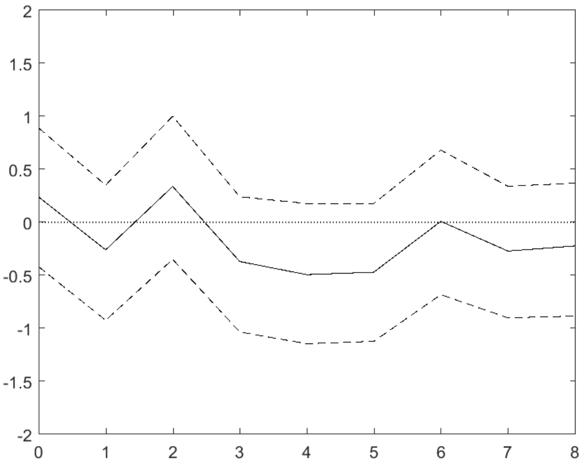
Effect of a 1 percentage point exogenous repo rate increase. The dashed lines indicate a 95 percent confidence interval.

Figure 10: Impulse-response of GDP growth - linear model



Effect of a 1 percentage point exogenous repo rate increase. The dashed lines indicate a 95 percent confidence interval.

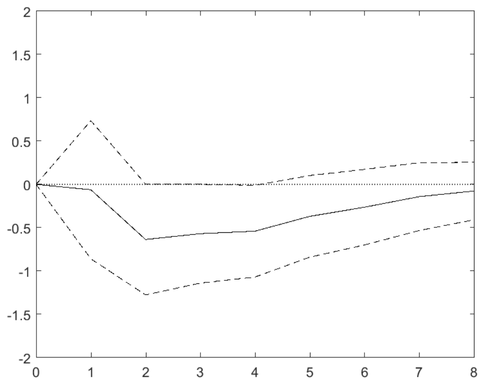
Figure 11: Impulse-response of inflation - linear model



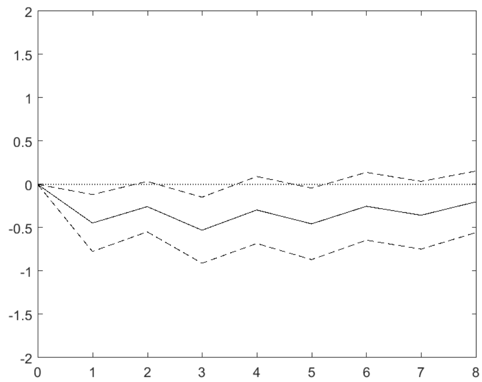
Effect of a 1 percentage point exogenous repo rate increase. The dashed lines indicate a 95 percent confidence interval.

Figure 12: Impulse-responses from VAR cholesky identification

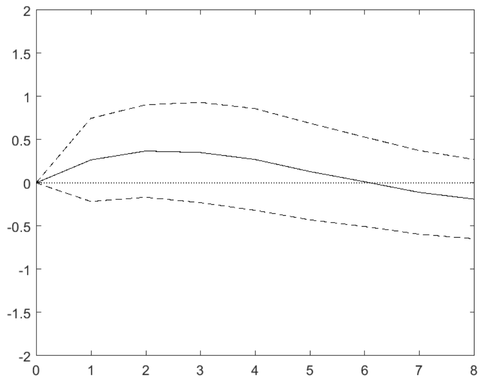
(a) GDP growth



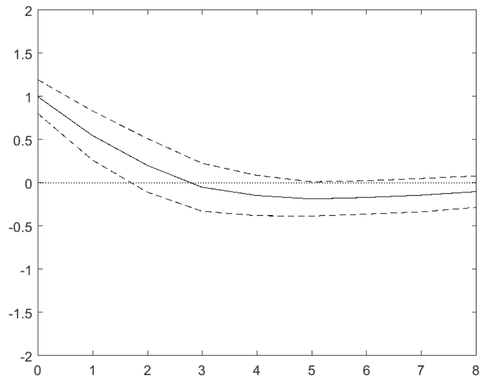
(b) Household credit growth



(c) Inflation

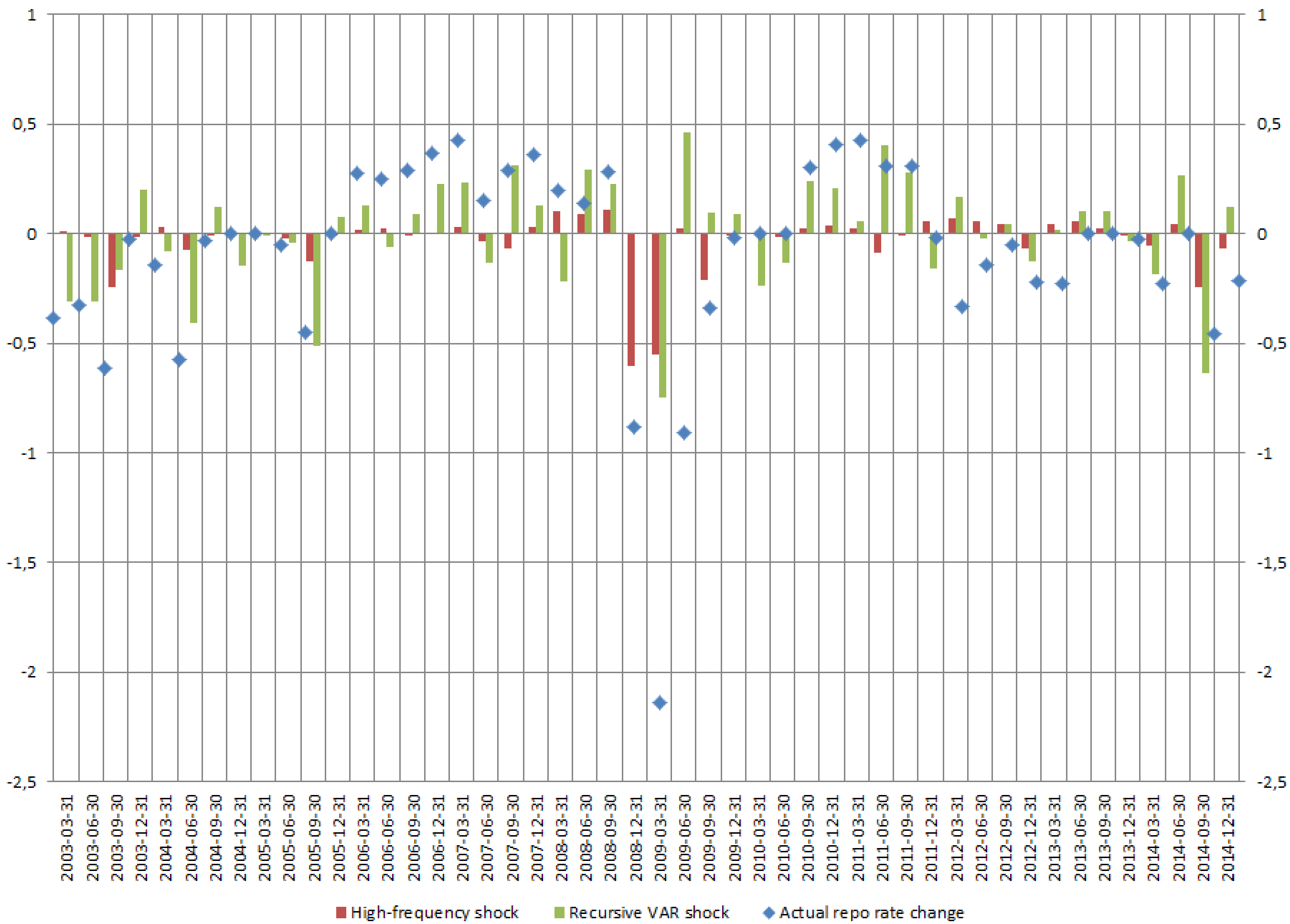


(d) Repo rate



The charts show the effects of a 1 percentage point positive monetary policy shock. The dashed lines indicate a 95 percent confidence interval.

Figure 13: Actual repo rate changes, shock series derived from financial market data and VAR residuals (percentage points)



The actual repo rate changes refer to changes in the average quarterly repo rate. The high-frequency shock is the quarterly shock derived from STINA interest swaps with 1-month maturity. VAR residuals refer to the residuals from the interest rate equation from the recursive VAR.

Appendix A

Derivation of unexpected STINA shock measure

Let s be the time of the monetary policy announcement. Period 1 is the period from the announcement of a (potentially new) repo rate until the implementation of that repo rate. Period 2 is the period between the implementation of the new repo rate until the maturity of the STINA-contract. τ_1 is the number of days in period 1, that is the number of days during which the old repo rate prevails. τ_2 is the number of days in period 2, that is the number of days during which the (possibly) new repo rate prevails. $\tau_1+\tau_2$ is the total lenght of the contract, that is 30 days. Let $i_1^{s/n}$ and $i_2^{s/n}$ represent the average STIBOR t/n in period 1 and period 2, respectively. The STINA rate just prior to the repo rate announcement is denoted i_{s-1}^{STINA}. Then, we have:

$$\left(1+\frac{i_s^{STINA}}{100}\frac{\tau_1+\tau_2}{360}\right)=\left(1+\frac{E_s[i_1^{t/n}]}{100}\frac{1}{360}\right)^{\tau_1}\left(1+\frac{E_s[i_2^{t/n}]}{100}\frac{1}{360}\right)^{\tau_2} \tag{1}$$

By taking logs and using the fact that $ln(1+x)\approx x$ for small x we get:

$$i_s^{STINA}\frac{(\tau_1+\tau_2)}{360}\approx E_s[i_1^{t/n}]\frac{\tau_1}{360}+E_s[i_2^{t/n}]\frac{\tau_2}{360}\Longrightarrow \tag{2}$$

$$i_s^{STINA}(\tau_1+\tau_2)\approx E_s[i_1^{t/n}]\tau_1+E_s[i_2^{t/n}]\tau_2 \tag{3}$$

The STINA swap rate can thus be expressed as the average of the STIBOR T/N over the horizon of the contract $(\tau_1+\tau_2)$.

$$i_s^{STINA}\approx\frac{E_s[i_1^{t/n}]\tau_1+E_s[i_2^{t/n}]\tau_2}{(\tau_1+\tau_2)} \tag{4}$$

or equivalently

$$i_{s-1}^{STINA}\approx\frac{E_{s-1}[i_1^{t/n}](\tau_1)+E_{s-1}[i_2^{t/n}](\tau_2)}{(\tau_1+\tau_2)} \tag{5}$$

The change in the STINA swap rate around the monetary policy announcement is

$$i_s^{STINA} - i_{s-1}^{STINA} \approx \frac{E_s[i_1^{t/n}]\tau_1 - E_{s-1}[i_1^{t/n}]\tau_1 + E_s[i_2^{t/n}]\tau_2 - E_{s-1}[i_2^{t/n}]\tau_2}{(\tau_1 + \tau_2)} \tag{6}$$

Since the repo rate before the monetary policy announcement is known, we have $E_s[i_1^{t/n}]$=$E_{s-1}[i_1^{t/n}]$ and the expression can be simplified to

$$i_s^{STINA} - i_{s-1}^{STINA} \approx \frac{(E_s[i_2^{t/n}] - E_{s-1}[i_2^{t/n}])(\tau_2)}{(\tau_1 + \tau_2)} \tag{7}$$

Since the risk-premium is assumed to be constant, we have

$$\Delta i_s^{unexpected} = E_s[i_2^{t/n}] - E_{s-1}[i_2^{s/n}] \tag{8}$$

so that:

$$\Delta i_s^{unexpected} = \frac{[i_s^{STINA} - i_{s-1}^{STINA}](\tau_1 + \tau_2)}{\tau_2} \tag{9}$$

Appendix B

The bootstrap data generating process is:

$$\Delta repo_t^* = \sum_{j=0}^{8} \hat{\theta}_j shock_{t-j} + \hat{u}_{1,t}^* \tag{1}$$

$$y_t^* = \sum_{j=0}^{8} \hat{\beta}_j \Delta repo_{t-j}^* + \hat{u}_{2,t}^* \tag{2}$$

where

$$\begin{bmatrix} \hat{u}_{1,t}^* \\ \hat{u}_{2,t}^* \end{bmatrix} \sim \; EDF \begin{pmatrix} (n/(n-l))^{1/2} \hat{u}_{1,t} \\ \hat{u}_{2,t} \end{pmatrix} \tag{3}$$

The studentized bootstrap confidence intervals are constructed according to the procedure in Davidson and MacKinnon [2004]. I generate the bootstrap samples y_k^* where k=1,...,B=1000 and compute the bootstrap t-statistic for each β_j:

$$t_k^* = \tau(y_k^*, \hat{\beta}_j) = \frac{\beta_{j,k}^* - \hat{\beta}_j}{s_k^*} \tag{4}$$

where s_k^* is the standard deviation of the parameter estimate in bootstrap sample k. The observed test statistics t_k^* are sorted from the smallest to the largest and the asymmetric equal-tail bootstrap confidence interval can be expressed as:

$$[\beta_{j,l}, \beta_{j,u}] = [\hat{\beta}_j - s_{\beta_j} t_{1-(\alpha/2)}^*, \hat{\beta}_j - s_{\beta_j} t_{(\alpha/2)}^*] \tag{5}$$

where $t_{(\alpha/2)}^*$ is the 25th entry and $t_{1-(\alpha/2)}^*$ is the 975th entry in the sorted list.

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