Staff memo

How does the Riksbank's monetary policy affect the Swedish economy: does inflation rise when the policy rate is raised?

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Summary

Although there is broad consensus that inflation falls when the central bank raises its policy rate, there are mechanisms and channels that may potentially lead to the opposite effect. For example, it is well known that the policy rate also constitutes a cost for households and firms that, when it rises, can cause higher inflation, or relative prices, instead of the desired decrease.

In this Staff Memo, we first describe the challenges faced when measuring the effects of monetary policy and some well-known solutions. We take into account the difficulties that exist with a new measure of monetary policy interest rate adjustments that takes into account both conventional policy rate decisions and the effects of asset purchases. We then use the new measure to examine how monetary policy affects inflation and the various components of inflation. We are particularly interested in whether monetary policy interest rate changes cause certain prices to rise – for example through a cost channel.

We find that monetary policy has a tangible and significant negative effect on inflation. Consumer prices fall by between 2 and 4 percentage points at most, about a year after a sustained interest rate hike of 1 percentage point. As for the cost channel, it is important for the price index for housing. Interest costs for households rise in a similar way to the policy rate after a rate rise. However, the total effect on inflation is negative.

Our calculations reflect part of the Riksbank's overall assessment of the effects of monetary policy. Different approaches yield slightly different results and this study should not be interpreted as an overall assessment by the Riksbank of the effects of monetary policy on the Swedish economy. The Riksbank's forecasts and analyses include a number of other factors that, in different situations, influence the assessment of the impact of monetary policy.

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1 Introduction

It is difficult to measure and estimate the effects of monetary policy interest rate changes and asset purchases. This is because monetary policy is not conducted in a random way regardless of what happens to the economy. Distinguishing cause and effect is complicated because the central bank reacts to changes in inflation and resource utilisation by changing its policy rate and also, in some cases, carrying out asset purchases. The correlation between inflation and different monetary policy tools can then obscure the actual effects of the rate rise.

Although there is broad consensus that inflation falls when the central bank raises its policy rate, there are mechanisms and channels that may lead to the opposite effect.[2] For example, it is well known that the policy rate also represents a cost for households and firms that, when it rises, can cause higher inflation, or relative prices, instead of the desired decrease. The fact that the Riksbank changed target variable in 2017 was a consequence of precisely such an effect in the consumer price index (CPI). Recently, similar reasoning has been put forward in the economic debate as an argument against continued policy rate rises. The arguments are not new. For example, Congressman Wright Patman, who chaired the Joint Economic Committee, argued that using the interest rate to combat inflation would be as logical as "throwing gasoline on fire to put out the flames."[3] After Sweden's transition from the gold standard in September 1931, the discount rate was mainly used as the leading tool in monetary policy.[4] Gunnar Wetterberg notes in his book on the history of the Riksbank (page 314) however that the view of the discount rate changed during, and a couple of decades after, the Second World War, where it came to be regarded more as a cost factor than as a way of influencing economic activity.

The so-called cost channel is based on the premise that monetary policy can also affect inflation without first affecting demand. Since firms partly fund their operations with borrowed funds, a change in interest rates can also affect firms' costs. An increase in the policy rate that increases lending rates can then increase the funding costs of firms, which in turn are forced to raise their prices as compensation. The cost channel may act in the opposite direction on inflation compared to the traditional channels.

In this Staff Memo, we first describe the challenges faced when trying to measure the effects of monetary policy and some well-known solutions. We construct a new measure of monetary policy interest rate adjustments that takes these difficulties into account and that considers conventional interest rate decisions as well as the effects of asset purchases. We then use the new measure to examine how monetary policy affects inflation and the various components of inflation. We are particularly interested

[2] In this Staff Memo, we are primarily thinking of what is known as the cost channel. In a monetary policy regime where the fiscal policy framework is not credible and public debt is high, rate rises can lead to higher inflation. See, for example, Sims (2016) and Caramp and Silva (2023). We are not thinking of the so-called Neo-Fisherian hypothesis, which questions the traditional view of the relationship between nominal interest rates and inflation; see Uribe (2022).

[3] Seelig (1974) and Barth and Ramey (2001).

[4] Berg and Jonung (1999).

in whether monetary policy interest rate changes cause certain prices to rise – for example through a cost channel.

We find that monetary policy has a tangible and significantly negative effect on inflation. Inflation falls by between 2 and 4 percentage points at most, about a year after a sustained policy rate hike of 1 percentage point. The effects may appear relatively large but depend on the fact that the interest rate changes we analyse are both larger and more persistent than previous studies on Swedish data. The strength of the interaction between monetary policy and inflation thus largely depends on how lasting an interest rate change is expected to be. The reason for this is that a rate increase that is more persistent has larger and longer-lasting effects on the interest rates offered to households and firms. Consequently, the interest rate change has greater effects on the overall demand in the economy, but also on the exchange rate. As for the cost channel, it is important for the price index for housing. Interest costs for households rise in a similar way to the policy rate after a rate rise. However, the total effect on inflation is negative.

2 How can the effects of monetary policy interest rate adjustments be measured?

The answer to this question may seem both obvious and well-known, but it has been a recurring theme in the macroeconomic research literature. The reason for the recurring interest may possibly, at least in part, be linked to the difficulty of isolating (identifying) the effects of monetary policy events from events where the central bank is reacting to various changes in financial, economic and political conditions to stabilise inflation and resource utilisation.[5] Two simple examples illustrate how an estimate of the effects of monetary policy risks being inaccurate: Assume that the central bank is targeting inflation and is fully successful in its intentions to stabilise it. In this case, inflation would be almost completely stable, while the policy rate varies to prevent inflation from moving away from the inflation target.[6] The correlation is then virtually non-existent despite the fact that monetary policy is effective and the central bank is successful in its mission. On the other hand, in a situation where firms that plan to reduce their output first reduce their demand for cash, wholesale funding or bank loans, interest rates may rise before output falls even if the central bank has not been involved at all.[7] The effects of monetary policy can then be overestimated if this is not taken into account. Similar phenomena apply to the evaluation of other economic policy measures. Quite simply, it is difficult to identify cause and effect in social sciences.

Natural sciences have effective methods of investigating cause and effect

As far as scientific methods are concerned, controlled experiments are a fundamental method, indeed one of the most important methods and procedures of the scientific

[5] See also Hassler, Krusell and Seim (2023) for a brief discussion.
[6] See, for example, Kareken and Solow (1965) and McLeay and Tenreyro (2020).
[7] See, for example, Tobin (1970) and King and Plosser (1984).

revolution. A controlled experiment, as the name suggests, involves isolating and controlling different variables to investigate the causal relationship between them. This is done by systematically changing one variable (the independent variable) and measuring what happens to another variable (the dependent variable). All other variables are kept constant. The general research question in experiments is: How does the dependent variable depend on the independent variable? By analysing the measurement data, the relationship between these variables can then be described in different ways, which can then constitute an answer to the question.[8]

With regard to monetary policy (or, for that matter, many economic) issues, it is quite difficult, but not impossible, to carry out controlled experiments. Nowadays, for example, there is an entire research area that performs so-called field experiments.[9] An alternative to controlled experiments or field experiments is to instead search for different forms of 'natural experiments' – that is, situations where it can be claimed that the change in the object of study is large or otherwise 'natural' in relation to other potential explanatory factors. Such monetary policy measures are, of course, rare. However, searching over a long period and many countries may make it possible to assemble a number of convincing events that can provide causal insights into the effects of monetary policy. A well-known example of this approach is Friedman and Schwartz (1963) (FS), who studied the monetary history of the United States and tried to localise events that can be likened to natural experiments.

FS demonstrate that three monetary policy actions taken in the interwar period by the Federal Reserve System (Fed) (a) were of major magnitude and (b) cannot be regarded as necessary or unavoidable economic consequences of contemporary changes in incomes and prices. They further claim that "like the results of natural experiments for the scientific researcher, the results are so consistent and sharp that

[8] A well-known example of a controlled experiment is the Rutherford scattering experiment (1911). The purpose of the experiment was to explore the inner structure of the atom. The method used by Ernest Rutherford and his associates was to shoot alpha particles (which are positively charged) against very thin gold foil and observe how these particles were deflected. The outcome showed that most of the alpha particles passed right through the foil, suggesting that most of an atom is empty space. However, some alpha particles were deflected at wide angles, which was unexpected. This showed that there is a very small, but massively heavy and positively charged nucleus at the centre of an atom, which deflected some of the incoming alpha particles. This discovery of the nucleus of the atom laid the foundation for the modern atomic model. Another very well-known controlled experiment is the discovery of the Higgs boson in 2012. The natural sciences, as these examples generally show, have effective methods for identifying cause and effect. But there are situations in which science also faces challenges. In ecological or climate-related studies, the many interacting variables can make it difficult to isolate individual causes of observed phenomena. In medical research, experiments that put people at serious risk cannot be carried out, which can make it difficult to determine cause and effect definitively. The study of the history of the Earth, such as palaeontology and geology, cannot always use experimental methods. Instead, researchers must rely on the observation and interpretation of historical data, which can lead to uncertainty about causation.

[9] Field experiments in economics aim to test economic theories in real-world environments rather than in controlled laboratory environments or through pure data analysis. For example, Economics Nobel Laureates Esther Duflo and Abhijit Banerjee and their colleagues have performed several field experiments on microcredits. One such experiment, for example, tested the effects of microcredits on small business owners and households in India. To do this, the researchers collaborated with a microcredit institution in India. They selected a number of neighbourhoods and randomly divided them into treatment and control groups. In the treatment groups, microcredits were introduced, while the control groups did not have access to these loans. After a certain period of time, the researchers compared the outcomes in the two groups. They looked at things like household consumption, investment in small businesses, income levels and other socio-economic indicators. In monetary policy, experiments have been conducted in which researchers test how different forms of communication affect public expectations about future interest rates, inflation and other economic conditions.

they leave little doubt as to how they can be interpreted". The dates of these events were January–June 1920, October 1931 and July 1936–January 1937. FS thus realised the importance of separating cause from effect. They used historical documents to find these "natural experiments" and pioneered the so-called narrative identification of monetary policy decisions.[10]

Narrative ways of identifying monetary policy "natural experiments"

However, FS may have been selective in their choice of documents to review and did not offer an analytical or statistical method to estimate the size of the effects. Romer and Romer (1989) (RR) built on the insights of FS and argued that the Fed's internal documents and forecasts can be used to identify natural experiments in a more systematic way. They also developed statistical methods to measure the effects of the natural experiments they identified from the Fed's internal documentation.[11] In their 1989 paper, RR identified six episodes of major changes in monetary policy that they considered unrelated to inflation or the real economy. They then added a seventh date in a 1994 paper. In a follow-up paper from 2023, they revisit the historical dates and offer some new potential dates. They also discuss the impact of a final date, namely July 2022.

While this narrative approach to identifying monetary policy dates or disturbances is promising, it comes with some challenges. First, narrative shocks are (often) selected by a rather fuzzy methodology. This means that the results may be difficult to replicate. Second, with only seven to ten data points, it is possible that by chance some other factor is correlated with the monetary policy shocks. In cases with dozens or hundreds of identified shocks, it is likely that a random correlation with any other factor will be small on average. Hoover and Perez (1994) argue that Romer and Romer's dates are strikingly temporally correlated with the dates of oil shocks. Third, narrative shocks often turn out to be predictable, suggesting the possibility of endogeneity. Indeed, in the case of RR's 1989 paper, Shapiro (1994) and Leeper (1997) showed that this was the case.

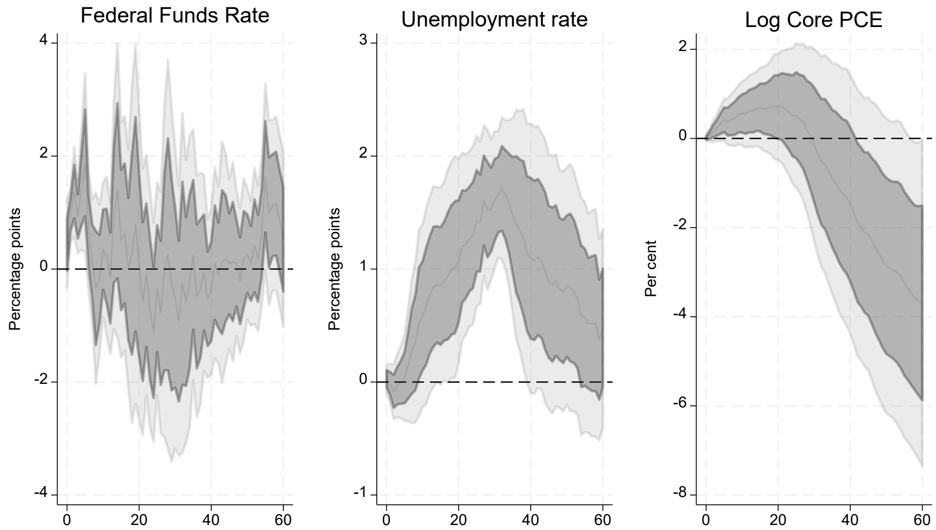
The narrative method is one of several possible methods that can be used to measure and identify the effects of monetary policy on the economy. As we noted, the method has several advantages but also some disadvantages. New capabilities to automatically search through large amounts of text mean that the process of finding relevant

[10] See Nakamura and Steinsson (2018) for a discussion and more information.

[11] Romer and Romer (1989) use the term "narrative" to describe their methodology because they examine the actual descriptions or "stories" that the Federal Reserve provides for its decision-making processes. Romer and Romer wanted to isolate the part of interest rate changes that was pure monetary policy, unrelated to information about future economic activity. To do this, they reviewed the Federal Reserve's "Greenbooks", which are internal forecasts that are not released to the public for several years. By reviewing these Greenbooks and other documents, they tried to decode the motives behind each decision. They looked for evidence that the Federal Reserve was acting in response to expected inflation or unemployment, rather than in response to actual economic changes. By isolating these "causal" changes in monetary policy, they tried to create a more pure set of monetary policy shocks. Coglianese et al (2023) is a recent example of a study that uses a "natural experiment" to analyse the effects of monetary policy on the labour market. The authors analyse a monetary quasi-experiment in Sweden from 2010–2011, when the Riksbank raised the interest rate substantially. They argue that this increase was unrelated to labour market conditions, driven instead by new concerns at the Riksbank about financial stability. The authors show that this monetary tightening led to a substantial economic contraction, raising unemployment by 1–2 percentage points.

episodes can be streamlined. RR discuss this possibility in their 2023 article. Similar "narrative" approaches have been used by several researchers at the Riksbank. For example, Apel and Blix Grimaldi (2014) use text analysis to measure the sentiment and tone of the Riksbank's minutes. The questions that these papers try to answer using text analysis are sometimes slightly different from those addressed by RR. However, the idea behind the identification itself is quite closely related.

Figure 1. Replication of Romer and Romer (2023): the effects of monetary policy in the United States on policy rates, unemployment and inflation.
Percentage points and per cent



Note: The figure shows estimates of β in equation (1) when the respective dependent variable has been shifted between 0 and 60 months ahead. Monthly data. Unemployment: Jan. 1948–Dec. 2022, Federal funds rate: July 1954–Dec. 2022, PCE (personal consumption expenditures): Jan. 1959–Dec. 2022. Standard errors are calculated using Newey-West.

Sources: Romer and Romer (2023) and own calculations.

How can the information be used to evaluate the effects of monetary policy?

Once dates for when the monetary policy decisions (the shock/surprise) can be considered to be independent of inflation, resource utilisation and other information (they are exogenous) have been unearthed from the archives, it is relatively easy to calculate the effects of these changes on inflation, unemployment and other variables of interest. All that needs to be done is to estimate the following equation using the method of least squares (since the monetary policy shock, s_t, is hopefully completely exogenous and not correlated with the residual (ε_t):

$$y_t = c + \beta s_t + \varepsilon_t \quad (1)$$

An estimate of β shows how interest rate changes caused by monetary policy affect the variable y_t – which can be unemployment or inflation in period *t*. Period *t* is the same time period in which the interest rate change occurs. If we then estimate the equation with the variable y in period *t+1* (but still with the shock dated in period *t*), an estimate of β shows what happens to the variable y in period t+1 when the shock occurs in period t. If we do this for several periods ahead, we obtain a path for how monetary policy affects the variable y in the future – that is, an impulse response function. The impulse is the change in interest rates and the response is the impact on inflation, for example. This is exactly what RR do in their paper. It may be worth noting that the variable s_t in the case of RR's dates is a dummy variable that takes the value 1 or –1 on the dates where the policy is identified as exogenous and 0 otherwise. There are obviously other empirical approaches that could be used instead of a simple dummy variable. For example, one could try to scale the dummy variable in some way – perhaps by the change in interest rates during the episode or by using the same narrative sources to classify the "strength" of the shock.

If you know the dates identified by the RR, it is easy to replicate their results. Figure 1 shows the results of such an exercise. We have used monthly data for three variables: the federal funds rate, the unemployment rate and the personal consumption deflator (PCE). The figure shows estimates of β from 0 to 60 months after RR's date. The results are very similar to those shown by RR in their paper. Interest rates rise by just under one percentage point, unemployment rises by 1.5 percentage points and inflation (the price level) falls by about 4 per cent after 4–5 years. As with Romer and Romer, the price level rises before it falls. A not entirely uncommon result is thus for inflation to rise for a period of time before falling. This used to be called the 'price puzzle'. Thus, in some empirical studies, an unexpected increase in the monetary policy rate – which would be expected to lead to a decrease in inflation – leads to an initial increase in inflation instead. Several explanations and theories have been proposed to understand this result: (a) Some researchers believe that the price puzzle may be due to measurement errors or poor modelling specifications. Incorrect identification of monetary policy shocks or omitted variables may lead to misleading results; (b) One argument is that an unexpected increase in interest rates may increase firms' financing costs (through the cost channel). Businesses can respond by immediately increasing their prices, leading to a temporary increase in inflation. It should be mentioned, however, that while the price puzzle is interesting and challenging, more recent research with more advanced models and datasets has not found this phenomenon or has found it to a lesser extent.[12]. For example, in recent research RR show that the price level falls when they control for expectation effects in the narrative disturbances.[13]

Control for confounding factors that reduce the conflation of causality

Although the narrative approach seems simple and easy to apply to the activities of different central banks, probably the most common method to identify variation in monetary policy is to control for (hold constant) so-called 'confounding factors' in various ways. These factors can be news, events, data and statistics that can explain why the central bank chooses to change the policy rate or conduct asset purchases. Much

[12] See, for instance, Bauer and Swanson (2023).

[13] Romer and Romer (2004).

of the literature using so-called vector autoregressions uses this approach.[14] The concept is to try to explain the central bank's policy rate adjustments with several possible explanatory variables (such as production, the exchange rate and inflation). What is not explained (the residual) can, under additional assumptions, be regarded as monetary policy interest rate changes that are not a reaction to economic policy events and information.

However, it is often assumed that a handful of variables capture all endogenous variation in monetary policy decisions. In practice, it may seem rather unlikely that only a few variables explain central bank policy rate adjustments. Central banks base their policy decisions on a large amount of data that also varies over time. Different considerations (in some cases very specific) influence interest rate decisions at different times. These include stress in the banking system, large and sudden changes in commodity prices and terrorist attacks. Each of these considerations can only influence policy in a meaningful way on a small number of occasions, and the number of such occasions and events is so large that it is not feasible to include them all in a regression. But omitting any of them will result in a monetary policy 'shock' that the researcher considers exogenous but is in fact endogenous. Rudebusch (1998) is a classic discussion of these concerns.

Discontinuity-based identification

An alternative way to identify monetary policy events that are (or at least assumed to be) independent of other causal factors is to use a so-called discontinuity-based identification (RD). Discontinuity-based identification was mainly, or at least first, developed in labour market research but has since been applied to monetary policy and other research areas.[15].

RD was first introduced by Thistlethwaite and Campbell (1960) as a way to estimate the effects of receiving a certificate of merit on future academic performance. The main idea was to compare the future academic performance of those awarded a certificate of merit with the future academic performance of those individuals who had not been awarded such a certificate but were on the verge of receiving one. This means that the individuals being compared are basically the same except that one group has received a certificate of merit. RD thus utilises a predetermined threshold or cut-off point (e.g. a cut-off score on a test), where individuals on one side of the threshold are treated differently from individuals on the other side. Researchers are therefore investigating how the outcome measure (e.g. performance afterwards) changes at this interruption point. It is assumed that individuals close to the cut-off

[14] Vector autoregression (VAR) is a statistical model used mainly in econometrics to analyse several time-dependent series simultaneously.

[15] Both discontinuity-based identification (often called 'Regression Discontinuity Design' or RDD) and Difference-in-differences (DiD) are research designs and methodologies in econometrics that aim to estimate causal effects. However, they have different starting points and utilise different types of variation in the data to identify these effects. Discontinuity-based identification utilises a discontinuity at a particular breakpoint or threshold of a 'control variable' to identify the effect of a treatment. DiD compares changes over time in a group exposed to an intervention with changes in a group not exposed to the intervention. It utilises variation both over time and between groups to estimate the treatment effect. A critical assumption for DiD is 'parallel trends', meaning that in the absence of the treatment, the outcomes of the treatment and control groups would have followed the same trends over time.

point are similar in all respects except for the treatment, allowing causal conclusions to be drawn about the effect of the treatment.

RD has thus become a useful tool in economic research to try to isolate causal effects, especially when it is difficult or impossible to conduct randomised controlled experiments. In the field of monetary policy research, RD has become particularly useful for studying the effects of central bank decisions and communication.

A well-known example of the use of RD in monetary policy is the work of Cook and Hahn (1989). This study used RD to evaluate how unexpected changes in the Federal Reserve's federal funds rate affected market interest rates. By focusing on the time around the Federal Reserve's monetary policy announcements, they used the timing of the announcements as a 'cut-off point'. They thus exploit the fact that a disproportionate amount of monetary policy news is revealed at the time of the regularly scheduled monetary policy meetings each year. The way in which monetary policy news is revealed allows for identification based on discontinuity. They found that unexpected changes in the federal funds rate had a direct and tangible effect on market interest rates. To summarise, potential applications of RD in monetary policy include:

1. When the central bank decides on interest rates or other monetary policy tools, the date of this decision can act as a cut-off point. Analysing market reactions before and after this date can provide insight into the impact of these decisions.

2. Analysing the impact of different central bank statements or press conferences on financial variables by using the time before and after these statements as a cut-off point.

3. Some monetary policy tools or programmes may have qualification criteria (e.g. a certain level of capital or liquidity). By comparing entities (such as banks) just above and below these thresholds, researchers can estimate the impact of these programmes.

In general, to the extent that there are clear and well-defined thresholds or cut-off points in monetary policy, RD can be an effective way to isolate and study causal effects.

In the next section, we use a discontinuity-based identification, similar to that used by Cook and Hahn, to estimate the effects of policy-induced interest rate increases on inflation and its various components. One question that we will study a little more closely is whether interest rate increases caused by monetary policy mean that inflation rises due to households' or firms' interest costs rising – which in turn may mean that inflation also rises.

3 Does inflation rise when the Riksbank raises the policy rate?

To answer this question, we must first of all choose a method to identify monetary policy interest rate changes that is as independent as possible from other causal factors. In this Staff Memo we rely, as mentioned, on a discontinuity-based identification.

One challenge with a discontinuity-based method is that the Riksbank has used several monetary policy instruments since 2015. Analysing market reactions in only short-term market interest rates before and after monetary policy announcement dates, as was common until 2015, may be too limiting if several measures were announced at the same time. Simultaneous announcements of interest rate changes in the policy rate, the policy rate path, purchases of government bonds and later also purchases of other assets quite simply present a challenge.

Which method do we choose to distinguish between cause and effect?

We address this challenge by using an approach that attempts to take into account all types of announcements, as proposed by Bu, Rogers and Wu (2021) (BRW). The BRW approach has several advantages. The measure bridges periods of conventional and unconventional monetary policy. It does not require access to a host of complicated financial contracts. The measure is not predictable and does not include so-called information effects. One such information component may be that the central bank may have more, or more in-depth, information about how the economy is developing than market participants have. A monetary policy tightening may then contain several causal factors that are mixed together. This is not the case with the measure used in this paper.

As we have sorted out the interest rate changes that are causally linked to monetary policy decisions, we refer to our measure as 'monetary policy interest rate changes' or 'monetary policy shocks'. By these terms we mean that the causal relationships have been clarified and that the changes are caused by the monetary policy decisions and not by other factors.

The method we use is based on the assumption that the change in government bond yields on the days when the Riksbank announces monetary policy decisions is affected both by news and information not related to monetary policy and also by a specific component, or shock, related only to the monetary policy decision. The general idea behind the method is to use the Fama and MacBeth (1973) two-stage regression method to estimate the monetary policy specific component. The first step is a temporal regression to determine the sensitivity of interest rate changes to the monetary policy component. The second step is a cross-sectional regression to estimate the monetary policy component. The method is a partial least squares method (PLS) and is similar to the principal component method.

Since monetary policy decisions are not only related to changes in the policy rate but also to changes in the policy rate path and to purchases and sales of assets, mainly government bonds, we assume that the monetary policy component is not only present in short-term interest rates but also in longer-term interest rates. The sensitivity of different interest rates to the monetary policy component/shock may vary for different maturities. For two different maturities, the relationship is as shown in these equations:

$$\Delta R_{3M,t} = \alpha_{3M} + \beta_{3M} e_t + \epsilon_{3M,t},$$

$$\Delta R_{1Y,t} = \alpha_{1Y} + \beta_{1Y} e_t + \epsilon_{1Y,t}.$$

$\Delta R_{3M,t}$ and $\Delta R_{1Y,t}$ are the observable changes in a 3-month and 1-year zero-coupon government bond at each monetary policy meeting between January 2001 and September 2023 (we exclude dates where other central banks also announce decisions). $\epsilon_{i,t,}$ are all other factors not related to monetary policy. The objective is to estimate e_t, which is not observable, on the days that the Riksbank announced its decisions. We use the uneven distribution of information about monetary policy and monetary policy decisions as a cut-off point to estimate e_t.

Note that if we knew the values of β_{3M}, β_{1Y} etc. we could use these to estimate e_t. For each monetary policy announcement, the shock is the same for all maturities. It is the variation in government bond yields and the cross-sectional differences between β_{3M}, β_{1Y} etc. that identify the size and signs of the shock at a given monetary policy meeting. For a given monetary policy meeting and observations of government bond yields and the parameters β_i, the value of e_t is what minimises the loss function,

$$\min_{e_t} \sum_{i=3M}^{5Y} \left(\Delta R_{i,t} - \beta_i e_t\right)^2.$$

The estimated coefficient in each regression per announcement is then an estimate of e_t. In other words, one can say that the monetary policy shock roughly captures the weighted average change in the yield curve on the days when the Riksbank announces monetary policy decisions. If the observed interest rate change in all maturities were identical to the respective maturity's parameters β_{3M}, β_{1Y} etc., the shock would be estimated at one percentage point (e_t=1). A one percentage point shock then means that the loss function is zero. If only short-term interest rates rise after a monetary policy decision, the common component will be smaller and the estimated disturbance will also be smaller. Since we do not know the values of β_i, the first step is to estimate these coefficients.

Consequently, we start by estimating the sensitivity of the change in government bond yields at different maturities to changes in the monetary policy component/shock. We do this using a heteroscedasticity-based time series approach where we assume that the coefficient on a one-year government bond, β_{1Y}, has a one-to-one relationship with e_t ($\beta_{1Y} = 1$). One can choose to normalise against other maturities. It does not have much impact on the final result. We also assume that the variance in the monetary policy component increases on days when the Riksbank announces monetary policy decisions, while the non-monetary policy shocks are unaffected and have the same variance. More specifically, we estimate a time series regression by maturity. Here we show such a regression model for three-month and two-year maturities.

$$\Delta R_{3M,t} = \theta_{3M} + \beta_{3M}\Delta R_{1Y,t} - \beta_{3M}\epsilon_{1Y,t} + \epsilon_{3M,t},$$

$$\Delta R_{2Y,t} = \theta_{2Y} + \beta_{2Y}\Delta R_{1Y,t} - \beta_{2Y}\epsilon_{1Y,t} + \epsilon_{2Y,t}.$$

The reason why we estimate the equation using a heteroscedasticity-based time series method is that the residual in the regression is correlated with the independent variable. The estimates of β_i will be inconsistent if we do not take this into account.

Once we have estimated the sensitivity for all government bond yields with different maturities ($\beta_{3M}, \beta_{6M}, \beta_{1YM}, \dots, \beta_{5Y}$), we use the estimated coefficients in the way described earlier, namely in a series of cross-sectional regressions on a meeting-by-meeting basis. The estimated coefficients in these regressions constitute our measure of e_t. The advantage is thus that our estimate is independent of other information contained in $\epsilon_{i,t}$ and that we include monetary policy changes that also affect longer-term interest rates.

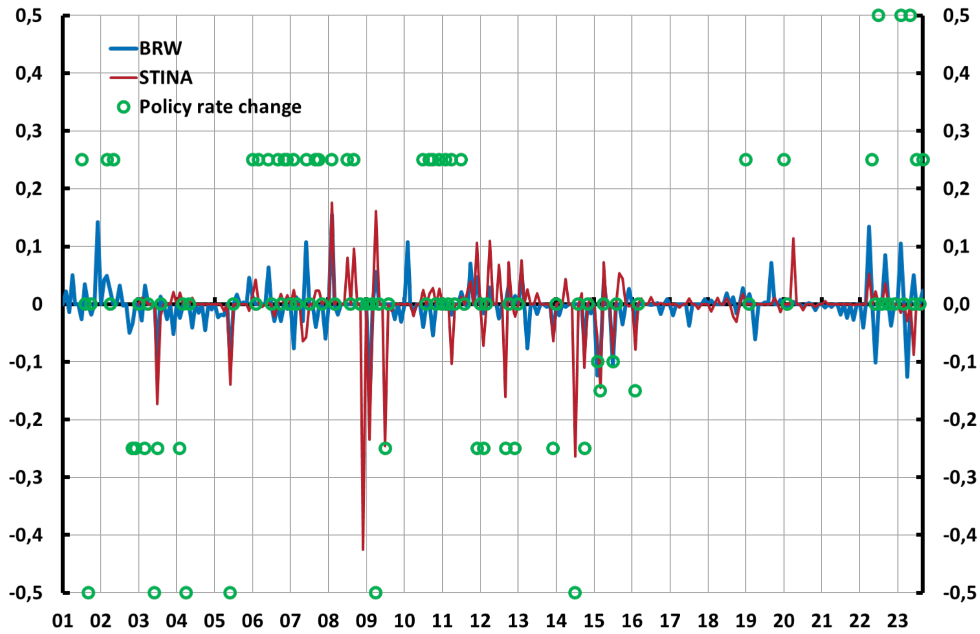
Figure 2 compares our new measure of monetary policy shocks (red line) with a measure that uses only changes in short-term swap contracts (Tomorrow/Next Day STIBOR Swap) (STINA).[16]. The measures are correlated, but perhaps the most important difference is that we can also measure monetary policy rate changes after 2015. Here the old measure becomes less and less informative. The variation in the red line in Figure 2 decreases noticeably between 2016 and 2020.

To show how our measure can be interpreted and how it captures different monetary policy decisions, it may be instructive to discuss a couple of examples. We have selected two decisions in 2019 that are interesting because they did not involve a change in the policy rate, but changes in the interest rate path and additional asset purchases.

[16] See for example Fransson and Tysklind (2016) and Iversen and Tysklind (2017).

Figure 2. Comparison of our new monetary policy instrument (BRW) with a previously used instrument based on STINA contracts and actual policy rate changes.

Percentage points



Note: Monthly data, January 2001 – September 2023. Interest rate changes of more than 0.5 and less than -0.5 percentage points (2008/09 and 2022) are not shown in the figure to clarify the comparison with the relatively small monetary policy rate changes/instruments.

Source: Riksbank, Bu, Rogers and Wu (2021) and own calculations.

On 5 September 2019, our measure indicates a monetary policy rate increase despite the policy rate being kept unchanged at -0.25 per cent and the interest rate path being lowered. Short-term rates were relatively unchanged but longer-term rates rose, which our measure captures as a positive monetary policy rate increase. The Riksbank's announcement to stick to a rate hike in late 2019 or early 2020 was considered 'hawkish'.

On 25 April 2019, the Executive Board decided to hold the repo rate unchanged at -0.25 per cent. The rate was expected to be raised towards the end of the year or at the beginning of 2020. The Executive Board also decided that the Riksbank would purchase government bonds for a nominal value of SEK 45 billion from July 2019 to December 2020. Deputy Governors Martin Flodén and Henry Ohlsson entered reservations against the decision to purchase government bonds. They considered that further purchases would not contribute to attaining monetary policy targets in a clear way, but that there were risks associated with additional purchases. Government bond yields at all maturities except the shortest fell by almost 10 basis points. This is captured by our measure of monetary policy rate changes with a reduction of just under 8 basis points.

What are the effects of monetary policy rate changes?

We do not use our estimated monetary policy rate changes directly in a regression as in equation (1) above but we use them as an instrument.[17] See, for example, Stock and Watson (2018) and Amberg, et al. (2022) for a description of the same method but with different instruments. We estimate the following panel data regression model,

$$100\left(y_{g,t+h} - y_{g,t-1}\right)w_{g,t-1} = c_g + \beta^{g,h}\Delta\widehat{R_t} + \gamma^h \boldsymbol{x}_t + \varepsilon_{g,t+h}, \qquad (2)$$

where $g = 1, \ldots, G$ indicates groups in the CPI and $t = 1, \ldots, T$ indicates time periods in months between January 2001 and September 2023.[18] $y_{g,t+h}$ is the logarithmic price level in different groups (g) in the CPI in period $t + h$, $w_{g,t-1}$ is the weight of group g in the CPI, $\Delta\widehat{R_t}$ is the change in a one-year government bond rate instrumented with our monetary policy shocks, $\boldsymbol{x}_t$ is a vector of control variables such as the exchange rate, inflation expectations, the GDP indicator, commodity prices, an index of financial conditions in Sweden, Nordpool electricity prices and the New York Fed Global Supply Chain Pressure Index.[19] Since we have weighted the CPI components by the weight of each component in the CPI, this means that all estimated effects on individual CPI groups (i.e. estimates of $\beta^{g,h}$ for $h = 0, \ldots, 24$) add up to the effect on the total CPI. Estimating the effect of monetary policy interest rate changes on the CPI can thus be done in two ways. The first is to estimate (2) as shown above where all components that make up the CPI are included in the dependent variable $y_{g,t+h}$. The second way is to estimate (2) as a time series model instead of a panel data model with total CPI as the dependent variable. The panel data estimation estimate of $\beta^{g,h}$ for $h = 0, \ldots, 24$ measures the average effect of a monetary policy interest rate increase on all weighted CPI components between 0 and 24 months after the interest rate change.[20].

Before we study the effects on the CPI and on the CPI components to see if CPI inflation, or any components, actually rise after a monetary policy rate increase, we begin to look at the effects on the Riksbank's policy rate and some other macroeconomic and financial variables. Figure 3 shows the estimated effects of a monetary policy rate

[17] When trying to assess causality between an explanatory variable (e.g. education) and a dependent variable (e.g. income), it can be problematic if the explanatory variable is correlated with the error term in the model (i.e. it is endogenous). In such situations, it can be difficult to draw conclusions about causality. One solution to this problem is to use an instrument variable. The idea is to use a third variable, the instrument, which affects the explanatory variable but is not directly related to the explanatory variable (that is, it affects the dependent variable only through the explanatory variable). There are two requirements for instrument variables: A. the instrument must be correlated with the potentially endogenous explanatory variable (relevance) and B. the instrument must not be correlated with the error term in the original regression.

[18] Note that the sample includes both the periods before and after 2022 with low and high inflation, respectively. We do not include a time series break but control for variables that were significant for the dynamics of inflation throughout the entire selection period. Note that the sample size decreases by one month for each time period h.

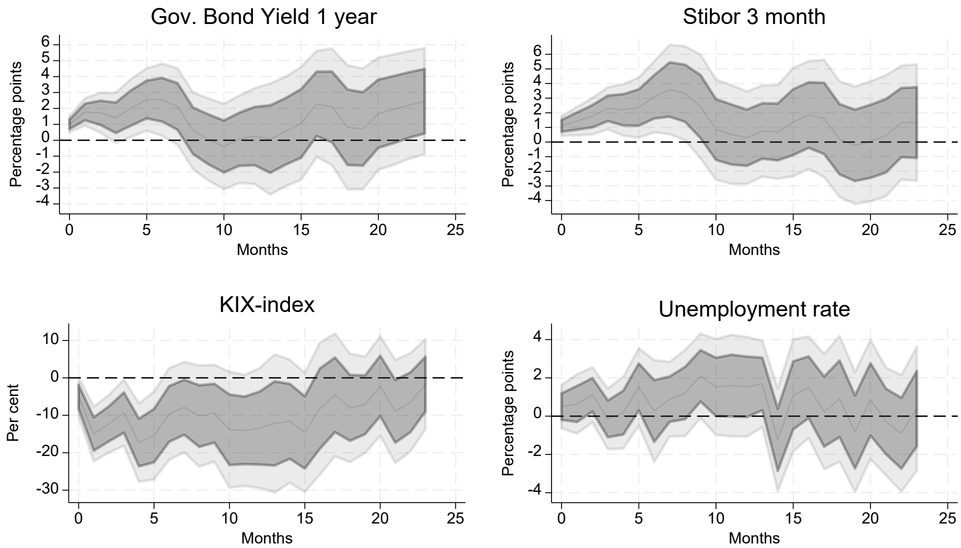
[19] We use the CPI at the logarithmic level as the dependent variable. The results are quantitatively unchanged if we instead use the CPI in annual percentage change. The variables included in $\boldsymbol{x}_t$ have been chosen to control for both demand and supply factors, open economy aspects, and expectation effects.

[20] Since all components included in the CPI are weighted, the panel data estimates must be multiplied by the number of groups, G, to obtain the total effect on the CPI.

increase on the policy rate, a government bond rate, the exchange rate and the unemployment rate.

Figure 3. Economic impact of a monetary policy rate increase between January 2001 and August 2023.

Percentage points and per cent



Note: The figure shows estimates of β^h for $h = 0, .. ,24$ where instead of the CPI as the dependent variable, we use the policy rate, the government bond rate, the KIX index (nominal trade-weighted exchange rate) and the unemployment rate as dependent variables. Note that it is the result of a time series estimation and not a panel data estimation that is shown in the graph. The shaded areas indicate 1 and 1.65 standard deviation (68 and 90 per cent) confidence intervals. Standard errors are calculated using Driscoll and Kraay whenever panel data estimation is employed. Otherwise, we use Newey-West standard errors. This applies to all figures unless otherwise stated.

Source: Own calculations.

The policy rate, and other interest rates, are lastingly affected by a monetary policy rate increase. Hence, our instrument is relevant – it is correlated with the explanatory variable. All effects are normalised so that a 1 year government bond yield rises by one percentage point in the first period. This applies to all results below. Interest rates then rise by around two to three percentage points over several years. The uncertainty in the estimate is relatively large. It is well known that the direct method used in this paper involves a fairly large estimation uncertainty. There are ways to take this into account and reduce uncertainty, but we leave this to further studies.[21].

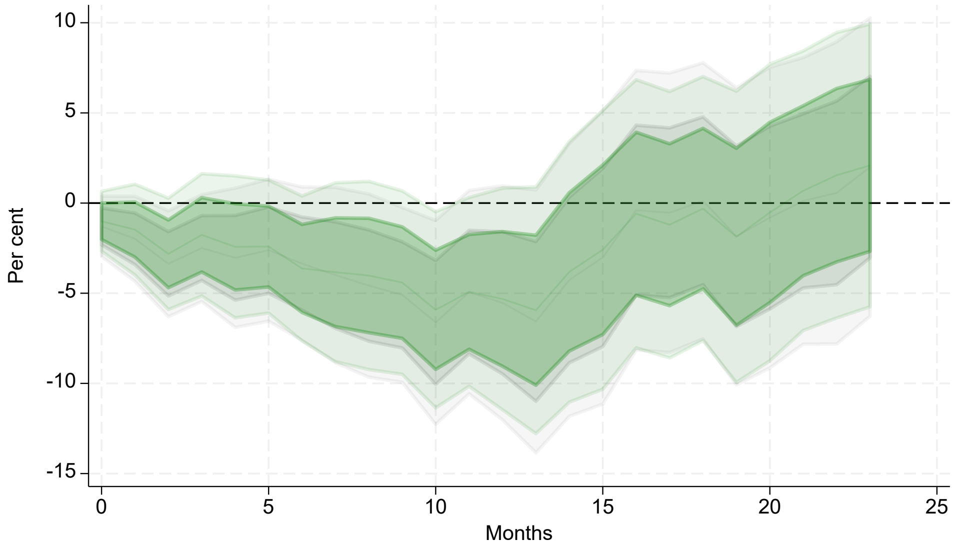
The effects on the exchange rate are the most significant and the exchange rate appreciates by around 10 per cent when the policy rate and other interest rates are raised lastingly by one percentage point in the first month. This agrees well with estimates where the effect is only studied on the days when the Riksbank announces

[21] See, for example, Jorda (2023) and Powell (2023).

monetary policy decisions. The disadvantage of these studies is that they do not show what happens to the exchange rate in the coming months and years, as we do here.

Figure 4. Effects on the consumer price index of a monetary policy rate increase between January 2001 and August 2023.

Per cent



Note. The graph shows estimates of β^h for $h = 0,..,24$ in equation (2) for a time series estimation (grey bands) where the CPI index (100xlogarithm) is the dependent variable and a panel data estimation (green bands) where the CPI index 9 main groups is the dependent variable. The shaded areas indicate 1 and 1.65 standard deviation (68 and 90 per cent) confidence intervals. The monetary policy rate increase giving rise to the effect on CPI inflation is shown in Figure 3.

Source: Own calculations.

The effect on the unemployment rate is uncertain but still clearly positive in the first year after the interest rate increase. The order of magnitude is that unemployment rises by about 2 percentage points.

Figure 4 shows the effects of a monetary policy rate increase on CPI inflation. The effects are negative and statistically significant. Consumer prices fall by about 4 percentage points after about a year. The effects are temporary, and the consumer price index returns to its original level after about one and a half years. We have not assumed these effects; they are entirely empirical effects of the interest rate changes we study. It is interesting to note that the results from the time series estimation where only total CPI inflation is the dependent variable are consistent with the panel data estimation where all nine main components of the CPI are dependent variables. The results are apparently quantitatively larger than those found by previous Swedish studies[22]. Two important reasons for this are firstly that we study more lasting monetary policy rate changes that also affect interest rates with longer maturities. Previous papers

[22] See for example Corbo and Strid (2020) and Laséen (2020). However, compared to Bu, Rogers and Wu (2021), the effects are smaller.

mainly study very short-term changes in interest rates. Secondly, it is important that the comparison is based on the same monetary policy rate – that is, the rate instrumented in equation (2). The size and duration thus differ from previous studies and, if this is taken into account, the results are well in line with previous Swedish studies.

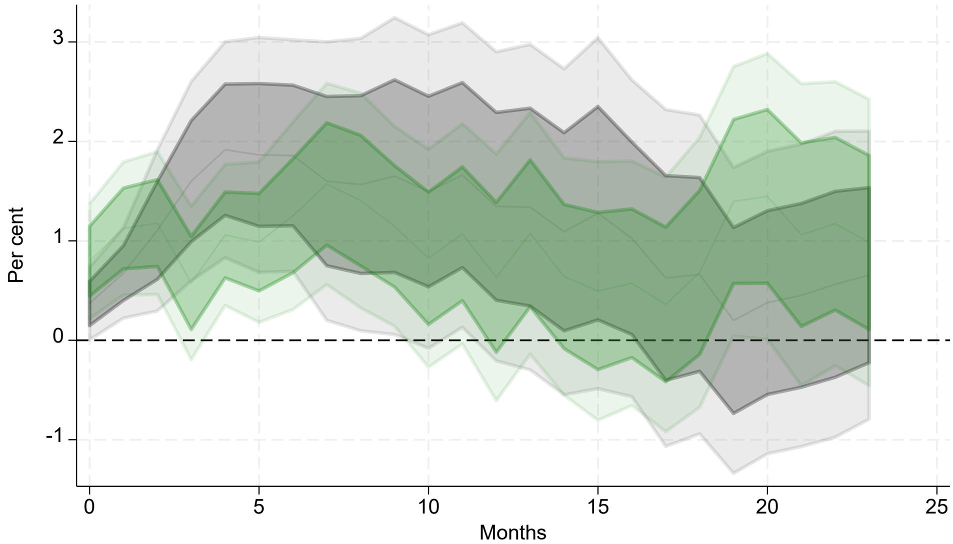
In the appendix, we show that the size of the impact on inflation is due to the greater persistence of the interest rate increase under our new instrument. The increase in interest rates is also significantly larger. We see this both when we compare with structural macro models but also when we compare the effects with alternative instruments on monetary policy rate changes used in previous studies. The differences in the size of the effects with different choices of instruments for monetary policy rate changes can also be illustrated if we use the same interest rate that is instrumented, and with which we standardise the effects. When we use STINA, we have used STIBOR as the monetary policy interest rate variable (variable that is instrumented). If we instead use a 1-year government bond rate as the interest rate variable that is instrumented, we show that the size of the effects is now relatively similar.

Before we go on to study how different groups in the CPI are affected by monetary policy, it may be informative to ask how important it really is to study identified effects of monetary policy interest rate changes that are independent of changes in inflation and the economy as a whole? To illustrate this, we replace the identified monetary policy interest rate change ($\Delta\widehat{R_t}$) in equation (2) with actual interest rate changes in the Riksbank's policy rate and in a one-year government bond rate. We thus study how changes in observable interest rates directly relate to CPI inflation. Figure 5 shows the results of such an estimation. As shown in the figure, inflation rises as interest rates rise. So here the causal relationships are not clearly identified and what is shown is a correlation and not a causal relationship. The fact that inflation rises when interest rates are raised can thus easily be confused with the central bank reacting to unexpectedly high inflation by raising interest rates.

In figure 5, the causal relationship between the interest rate change and inflation is not clarified. This is precisely the point of figure 5. We now return to studying causal relationships where the interest rate change is caused by the central bank. The question now is which groups in the CPI are most affected by monetary policy interest rate changes and whether some groups in the CPI rise instead of falling. Figures 6-8 show the effects of a monetary policy rate increase on the main CPI groups. All impulse responses shown represent each group's contribution to the overall CPI effect shown in Figure 4. However, the responses of all groups shown in the figure do not necessarily add up to the total impact on the CPI as some groups are included in others. For example, the group 'Goods' includes both 'Domestically produced goods and services' and 'Imported goods and services'. Each group should thus be interpreted as its contribution to the total effect of monetary policy interest rate changes on the CPI.

Figure 5. Effects on the consumer price index of a change in the policy rate and a change in a one-year government bond yield between January 2001 and August 2023.

Per cent



Note. The figure shows estimates of β^h for $h = 0,..,24$ in equation (2) for a time series estimation (green bands) where CPI inflation is the dependent variable and the change in the policy rate is the independent variable, and an estimation (grey bands) where the change in a one-year government bond rate is the independent variable. The shaded areas indicate 1 and 1.65 standard deviation (68 and 90 per cent) confidence intervals.

Source: Own calculations.

Starting with the breakdown between goods and services (Figure 6), it can be noted that the impact of a monetary policy rate increase is almost twice as large on goods prices compared to services prices. The annual percentage change in goods prices falls by almost 3 percentage points, while services prices fall by at most one percentage point. In turn, the largest contribution in the product group comes from imported goods (Figures 7 and 8). The result that goods prices react much stronger than service prices is well in line with micro price studies showing that the prices change more often in the goods sector.[23]

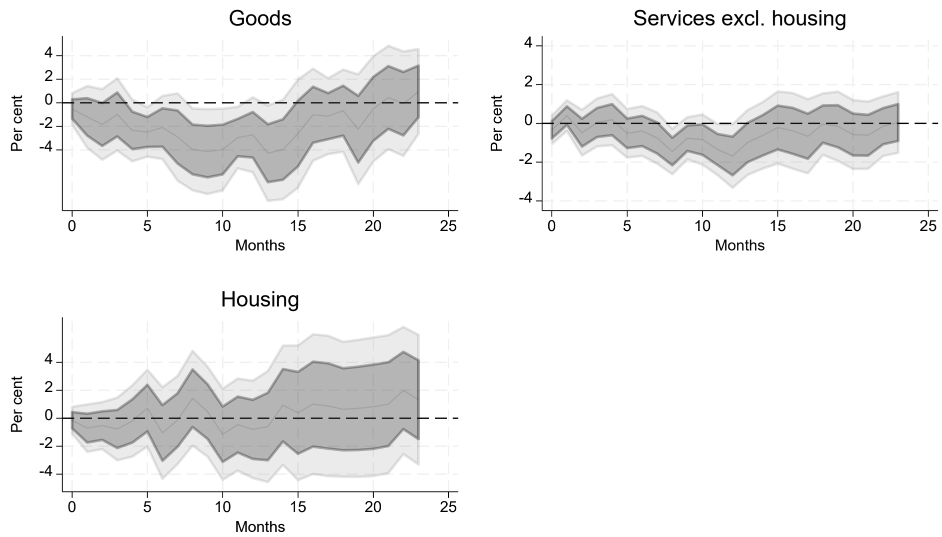
The group 'Housing' is less affected by a monetary policy interest rate increase than goods and services excluding housing. One reason for this is that the prices included in the group Housing are affected in different ways by changes in interest rates. This is evident for the group 'Interest on owner-occupied houses' and 'Other houses' where prices are rising. For most other sub-groups within Housing, such as basic rent, heating, water and sewage, prices are falling but, as mentioned, this is offset by higher interest costs and other owner-occupied housing prices. The rise in the interest cost component is an expected effect of monetary policy interest rate increases. This characteristic was an important reason why the Riksbank changed the target variable from the CPI to the consumer price index with a fixed interest rate (CPIF). A new result is

[23] See for example Klenow and Malin (2010) and Dhyne et al. (2006).

that prices in the group 'Other owner-occupied houses' are rising. These are mainly electricity, which actually rises after a monetary policy interest rate increase. One reason for this may be a cost channel where a higher interest rate increase means higher capital costs, which in turn are passed on in higher electricity prices.

Figure 6. Effects on CPI group price index of a monetary policy rate increase between January 2001 and August 2023.

Per cent



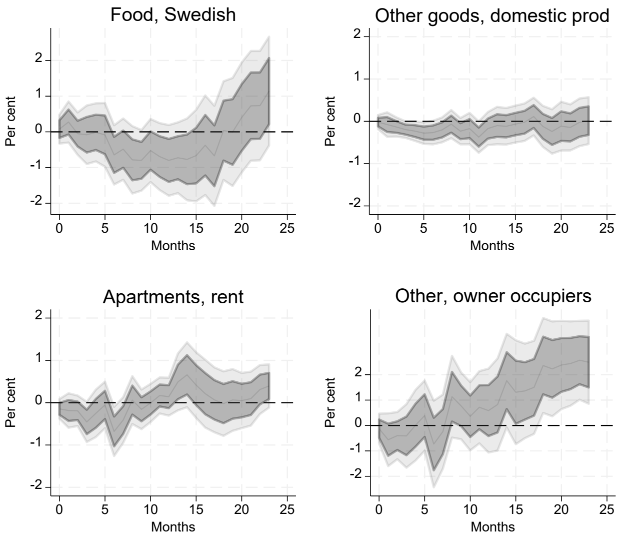
Note. The graphs show estimates of β^h for $h = 0,..,24$ in equation (2) for a time series estimation where CPI inflation in each group is the dependent variable. The shaded areas indicate 1 and 1.65 standard deviation (68 and 90 per cent) confidence intervals. The groups 'Goods', 'Services ex-housing' and 'Housing' can be summed up to the total effect on CPI inflation.

Source: Own calculations.

Figure 8 shows a breakdown of the effects on domestically produced goods and services compared to imported goods and services and mortgage rates. These three groups can be summarised as the total CPI effect. The main contribution to the fall in inflation comes from imported goods and services. Domestic goods and services are affected to a lesser extent and the total effect on the CPI is obtained by adding interest costs that actually increase. The large impact on imported goods and services is perhaps not surprising given that the exchange rate is one of the variables most clearly affected by monetary policy (Figure 3).

Figure 7. Effects on CPI groups of a monetary policy rate increase between January 2001 and August 2023.

Per cent



Note: See Figure 6.

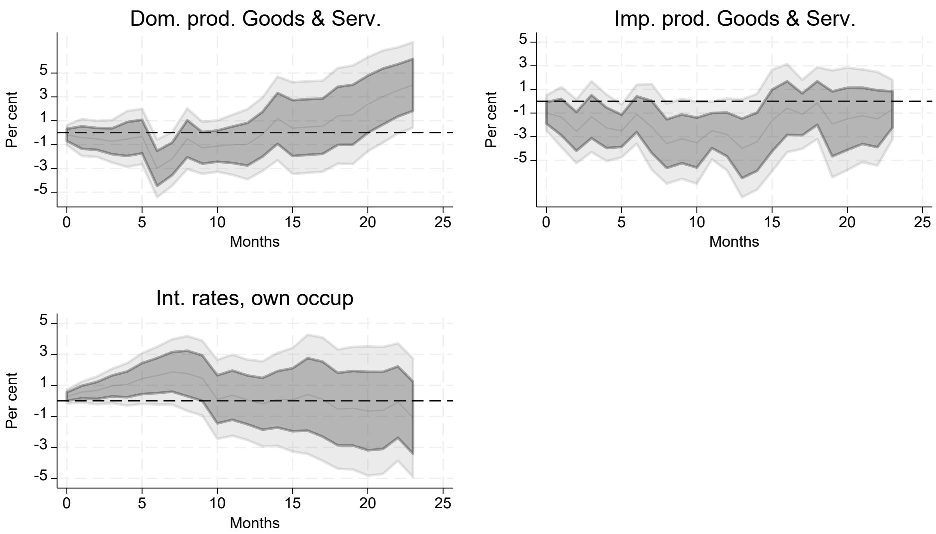
Figure 9 shows even more detailed effects of a monetary policy rate increase on CPI group inflation. All subgroups except 'Housing', which we have already mentioned, show lower inflation after a monetary policy rate increase.

An increase in the policy rate may, both in theory and in practice - at least for some sectors and firms - lead to an increase in firms' operating and capital costs, which in turn may affect firms' pricing behaviour. This can lead to higher prices for goods and services. Süveg (2021) studies the cost channel using data on Swedish firms and shows that a firm with a higher share of working capital, i.e. the share of funds the firm uses to finance its daily operations and manage its short-term financial obligations, raises its prices more than firms with a low share of working capital. However, she does not examine the overall effect, but studies differences between firms. This suggests that the cost channel may be important for some firms' pricing, but overall we show that on average there are few groups of goods and services at the consumer price level where prices rise after an interest rate increase. The result is in line with the conventional view of how monetary policy affects the economy and inflation.[24]

[24] For example, in this year's Geneva report, the authors show a similar result for the United States, see Guerrieri et al. (2023).

Figure 8. Effects on CPI groups of a monetary policy rate increase between January 2001 and August 2023.

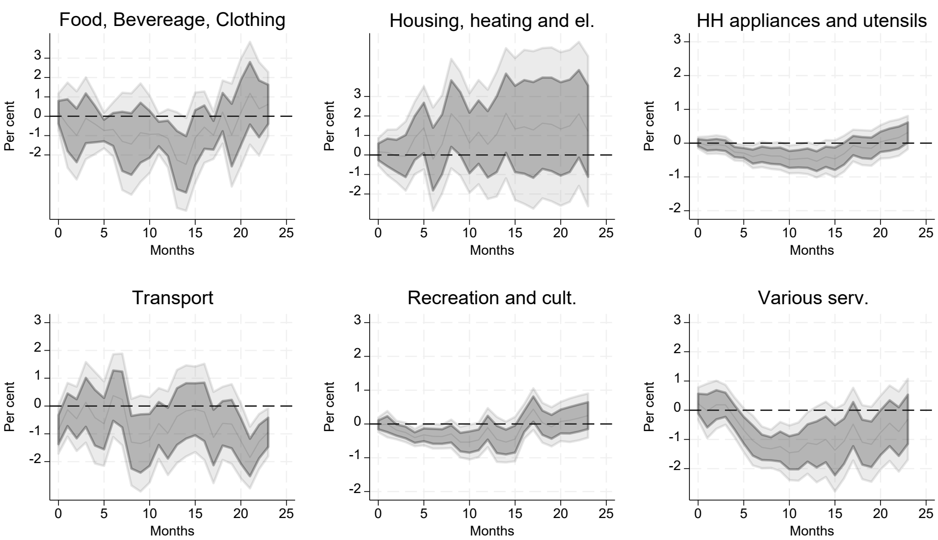
Per cent



Note: See Figure 6. The groups in the figure can be summed up to the total effect on CPI inflation.

Figure 9. Effects on CPI groups of a monetary policy rate increase between January 2001 and August 2023.

Per cent



Note. See Figure 6. The groups in the figure can be summed up to the total effect on CPI inflation.

Source: Own calculations.

Discussion

The answer to the question of whether inflation rises when interest rates are increased depends to a large extent on how well one can distinguish between cause and effect in terms of changes in interest rates. If one does not distinguish between cause and effect but only studies correlations, one may get the impression that a higher interest rate causes higher inflation (Figure 5). However, what is captured may be a correlation that hides the causal relationships. Households and firms react to various events and changes in forecast conditions by changing their behaviour and thus supply and demand and, by extension, inflation and resource utilisation. A central bank with an inflation target also responds to these changing conditions by changing its monetary policy instruments. Failure to disentangle the causes of the change in interest rates and inflation may give the impression that a higher interest rate causes higher inflation when only a correlation is captured. In this Staff Memo, we try to distinguish interest rate changes caused by monetary policy from interest rate changes caused by other events. When we do that, we can show that interest rate increases cause lower inflation, not higher inflation. However, some CPI groups are more or less affected by interest rate changes and the interest rate component for Owner-occupied housing and Other owner-occupied housing are two groups that are positively affected by interest rate changes. Thus, the higher interest costs for households offset lower prices for other goods and services. It is well known that the interest rate component is affected in this way and is an important explanation why the Riksbank changed the target variable from the CPI to the CPIF (consumer price index with a fixed interest rate).

Regarding the more general question of how the economy is affected by the Riksbank's monetary policy, three results are noteworthy:

First, it is interesting to note that the exchange rate appreciates significantly after a monetary policy rate increase. It is well known that the exchange rate strengthens by between seven and ten per cent after a one percentage point increase in interest rates on the days when the Riksbank announces monetary policy decisions, but here we also show that the effects last for up to two years.

Second, it is interesting to note that inflation is apparently falling more than previous studies have found. In the appendix we discuss some reasons for this. We show that the size and duration of monetary policy rate changes are important explanations for the relatively large effects. The strength of the interaction between monetary policy and inflation largely depends on how lasting an interest rate change is expected to be. The reason for this is that a rate increase that is more persistent has larger and longer-lasting effects on the interest rates offered to households and companies, and thus has greater effects on aggregate demand in the economy as well as on the exchange rate. In terms of CPI groups, we show that imported goods and services are particularly sensitive to interest rates. In terms of the breakdown between goods and services, goods are relatively more affected than services.

Third, the impact on inflation is relatively rapid. The impact on inflation peaks after 6-14 months. Again, imported goods and services is the group that is affected relatively quickly.

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APPENDIX

Methodology for computing our new measure of monetary policy instruments.

The methodology used to estimate our monetary policy instruments, or monetary policy shocks, is described in Bu, Rogers and Wu (2021). This section fully follows their formulation. We assume that the monetary policy shock e_t is unobservable. We further assume that the observable changes in Swedish government bond yields around the Riksbank's monetary policy decisions are driven by the monetary policy shock and a non-monetary policy shock as follows:

$$\Delta R_{i,t} = \alpha_i + \beta_i e_t + \epsilon_{i,t}, \quad i = 3m, 6m, ..,5Y; \; t = 1, 2, \dots, T;$$

where $\Delta R_{i,t}$ is the observable change in a zero-coupon government bond with maturity *i*, at each monetary policy meeting between January 2001 and September 2023 (we exclude dates where other central banks also announce decisions). $\epsilon_{i,t,}$ are all other factors not related to monetary policy. The aim is to estimate e_t which is the variable that we will use as an instrument in the econometric model that we are estimating (i.e. equation 2). BRW use the Fama-MacBeth two-step procedure to extract e_t from the common component of $\Delta R_{i,t}$.

In a first step, the method involves estimating the sensitivity of the observable changes in Swedish government bond yields to monetary policy changes (β_i) using time series regressions. To do so, we normalise the shock so that it has a one-to-one relationship with the change in a one-year government bond rate ($\beta_1 = 1$). We can then rewrite the above equation as follows

$$\Delta R_{i,t} = \alpha_i + \beta_i \left(\Delta R_{1,t} - \alpha_1 - \epsilon_{1,t} \right) + \epsilon_{i,t,} = \theta_i + \beta_i \Delta R_{1,t} + \vartheta_{i,t}.$$

Since the residual $\vartheta_{i,t}$ is correlated with the independent variable in the regression ($\Delta R_{1,t}$), the regression cannot be estimated using the least squares method. We follow BRW and estimate the regression with a heteroscedasticity-based instrumental variable estimator. The assumption is that the variance of the monetary policy shocks is greater on the days that the Riksbank announces monetary policy decisions but that all other shocks have the same variance on these days. Once the various coefficients $\hat{\beta}_i$ are estimated, the second step is to estimate cross-sectional regressions for each monetary policy announcement date where $\hat{\beta}_i$ is the independent variable and the observable changes in Swedish government bond yields are the dependent variable:

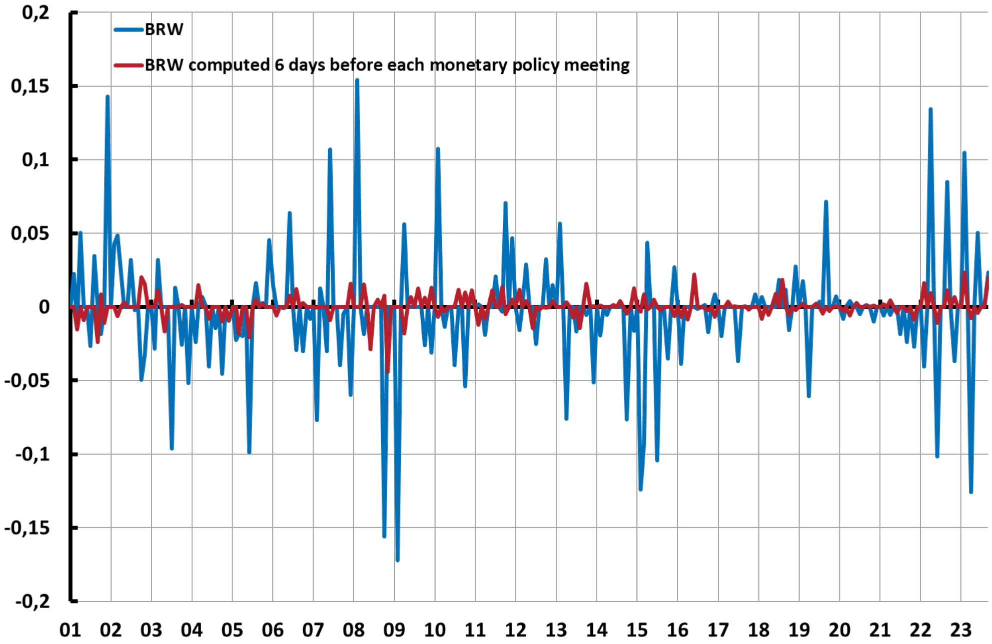
$$\Delta R_{i,t} = \alpha_i + e_t^{aligned} \hat{\beta}_i + v_{i,t}, \quad t = 1, 2, \dots, T,$$

where $e_t^{aligned}$ is the coefficients in these cross-sectional regressions. Our monetary policy shocks thus capture a common variation in the entire interest rate structure between 3 months and 5 years. The blue line in Chart 2 shows the results of this two-step procedure where we have just normalised the shock to have a one-to-one relationship with the change in a one-year government bond rate. The results become very similar if we normalise with other maturities. The only data requirement is daily observations of zero coupon rates with different maturities.

Figure 10 below shows our measure $e_t^{aligned}$ where *t* represents the days on which the Riksbank has announced monetary policy decisions. For comparison, we have also estimated $e_{t-6}^{aligned}$. In other words, we have estimated the monetary policy shock six days before each decision when no monetary policy news has been announced. A measure of e_t on these days should be very small. The figure shows that this is the case. Our assumption that the variance of the monetary policy shock is greater on days when the Riksbank announces its decisions than on other days appears to be correct.

Figure 10. Comparison of our new measure of monetary policy rate changes calculated on days with monetary policy decisions (BRW) with the same measure calculated on days without monetary policy decisions (six days before each decision).

Percentage points



Note: Sum per month of daily estimated disturbances, January 2001 – September 2023.

Source: Sveriges Riksbank, Bu, Rogers and Wu (2021) and own calculations.

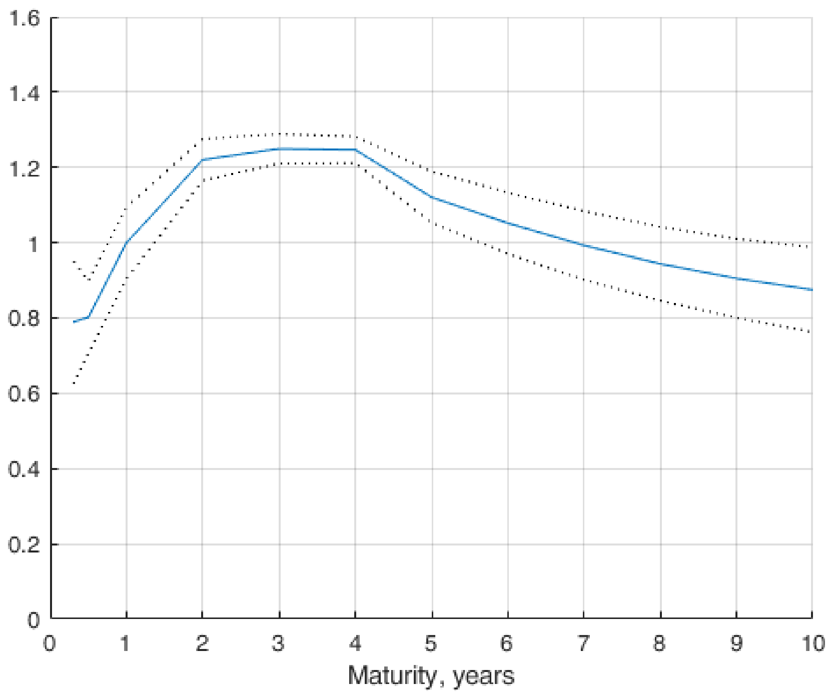
Figure 11 shows how our measure of monetary policy shocks is related to changes in interest rates for different maturities. We estimate the following regression model per maturity *i*,

$$\Delta R_{i,t} = \alpha_i + \beta_i e_t^{aligned} + \epsilon_{i,t},$$

where $\Delta R_{i,t}$ is the observable change in a zero-coupon government bond with maturity i, at each monetary policy meeting between January 2001 and September 2023. The figure shows the estimated coefficients β_i for different maturities.

Our estimated monetary policy shocks are significantly related to interest rate changes at all maturities, but mostly to interest rate changes at maturities of between two and four years. The hump-shaped relationship is very similar to that estimated by BRW for the United States and the euro area. Our measure thus captures changes in the entire yield curve and not just changes in short-term government bond yields.

Figure 11. Our new measure of monetary policy rate changes and the yield curve on days with monetary policy decisions.



Note: The figure shows estimates from a regression of interest rates of different maturities on our new measure of monetary policy rate changes on days with monetary policy decisions. The dashed lines represent a 95-per cent confidence interval. Average effects January 2001 – September 2023.

Source: Bu, Rogers and Wu (2021) and own calculations.

Why are the effects of the new measure on inflation relatively large?

The effects on CPI inflation that we have reported are quantitatively larger than previously estimated effects on Swedish data. If the policy rate is raised by one percentage point over one year in the Riksbank's Maja model and the NIER's Selma model, the inflation rate falls by an average of just under 0.15 percentage points during the first three years. These effects are much smaller than the ones we report. Laséen (2020) used STINA contracts as instruments for a three-month STIBOR rate to estimate the effects of a monetary policy rate increase. The effect of a one percentage point higher STIBOR rate was a four per cent stronger exchange rate and a half percentage point lower price level (excluding interest and electricity). These effects are also smaller than those we report. However, the effects reported by BRW for the United States are almost twice as large as our results.

An important difference between our results and previous results is that the interest rate change we study is much larger but also more persistent. In this section, we therefore first compare our results with those of Laséen, Lindé and Söderström (2022), who study how the duration of the interest rate change influences the effects of monetary policy rate increases. This is a relevant comparison because the interest rate effects we find are indeed more persistent than in previous studies. We then examine how different types of monetary policy instruments affect the results. We study how the results differ if we use changes in short-term swap contracts (STINA) instead of our new measure, as shown in Figure 2.

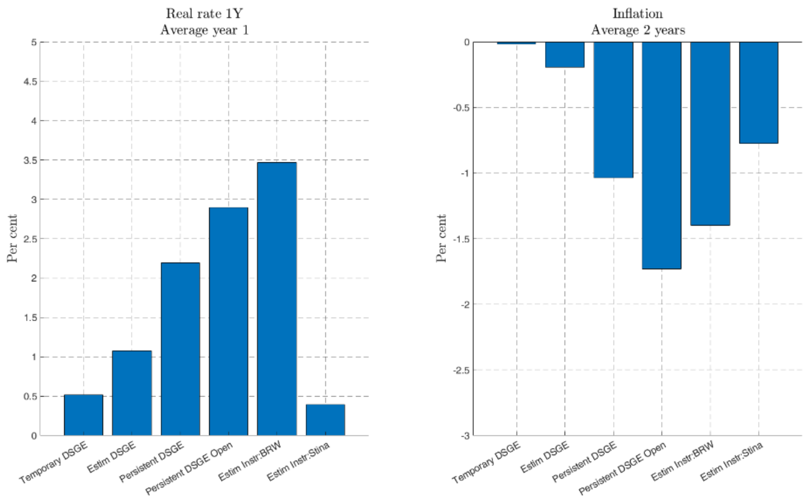
Laséen, Lindé and Söderström (2022) show that the reason why monetary policy has such small effects on inflation in common macro models is that the change in interest rates is not particularly persistent. Interest rates with maturities longer than one year are hardly affected at all in the structural models studied by the authors, as the policy rate is expected to return to its initial position relatively quickly. In Figure 12, we replicate their results but, instead of showing the effects on a 5-year real interest rate, we have calculated the effects on a 1-year real interest rate. We do this because it makes the comparison with our results clearer. The three bars furthest to the left in each panel show the effects of monetary policy on a 1-year real interest rate and on inflation as the median of a large number of different structural models estimated on US and euro area data. The different bars show the effects of assuming different time durations of monetary policy. For example, the bar specifying "Temporary DSGE" shows a rate increase that is highly temporary and thus has very small effects on the 1-year real interest rate. In all three cases, the policy rate is initially raised by an average of one percentage point over a year.

We can see that a temporary increase in the real interest rate has almost no effect on inflation (the right-hand panel of Figure 12). But when the rate increase is expected to become more persistent, the effects are considerably larger: the 1-year real interest rate rises almost twice as much in the different cases (Temporary, Estimated and Persistent), while inflation reacts more than six times as much to monetary policy. The reason for this is that a rate increase that is more persistent has much larger and longer-lasting effects on the interest rates offered to households and firms, and thus has greater effects on aggregate demand in the economy.

However, the models studied by Laséen, Lindé and Söderström (2022) are predominantly large closed economies with a non-existent or weak exchange rate channel. To study how this channel can affect the results, we have modelled the effects of monetary policy as the median of different open economy structural models. The “Persistent DSGE Open” bars show the median of six different structural models where economies have trade and financial relations with the rest of the world. It is clear that the impact on inflation of a sustained increase in interest rates is greater in these models than in models without an exchange rate channel. The effects in these models are comparable to the effects we report. Overall, the effects we report do not appear to be quantitatively larger than previously estimated effects if one takes into account the duration of the interest rate change being studied.[25].

Figure 12. Effects of an interest rate increase with different persistence in a number of models

Per cent



Note. The three bars on the left-hand side of each panel show the median effects in 57 different models of an unexpected increase in the policy rate by an average of one percentage point over one year with varying degrees of persistence. The fourth bar from the left in each panel shows median effects in 6 different models where the economies have trade and financial relations with the rest of the world and flexible exchange rates and thus an exchange rate channel. The two bars on the right of each panel summarise the effects we report when we use our new measure of monetary policy rate changes (BRW) and when we use changes in short-term swap contracts as an instrument for monetary policy rate changes (STINA). In all cases, the nominal interest rate averages one percentage point in the first year.

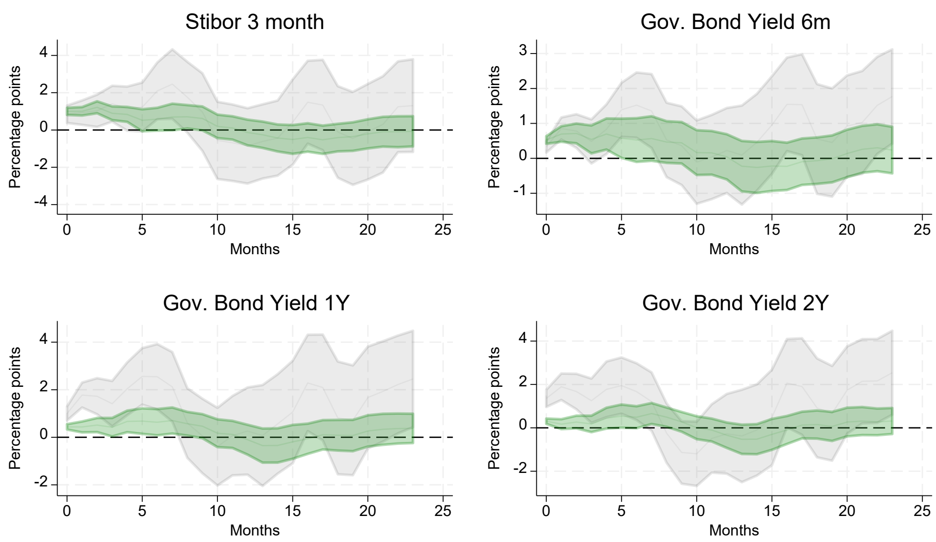
Source: Laséen, Lindé and Söderström and own calculations.

[25] Estimated duration is also affected by the sample used. The duration of monetary policy rate changes is lower if we estimate equation (2) until December 2019, thereby excluding the inflation and interest rate increases of recent years.

We now study whether our new measure, which reflects changes in the entire interest rate structure, is related to the size of the effects. We do this by comparing the effects with an instrument that only captures changes in the shortest interest rates (STINA), which are also closely linked to the Riksbank's policy rate. STINA is constructed by studying interest rate changes in financial instruments that are closely linked to STIBOR, which in turn is closely related to the expected level of the policy rate three months ahead. This measure affects short-term rates to a greater extent and longer-term rates to a lesser extent. Figure 13 shows the effects on government bond yields of a monetary policy rate increase when using our new (BRW) and STINA as instruments. The effects are normalised so that a 1-year government bond rate and STIBOR rise by one percentage point when we use BRW and STINA as instruments. STIBOR has noticeably less lasting effects on all interest rates. Figure 14 shows how a 1-year real interest rate is affected when we use different instruments. The real interest rate increases by about 3.5 percentage points in the first year when we use our new instrument compared to about half a percentage point when we use the STINA instrument (this can also be seen in Figure 12). The real interest rate thus increases six times as much in each case. This needs to be taken into account when comparing the effects.

Figure 13. Average effects on government bond yields of a monetary policy rate increase when BRW and STINA respectively are used as instruments between January 2001 and September 2023.

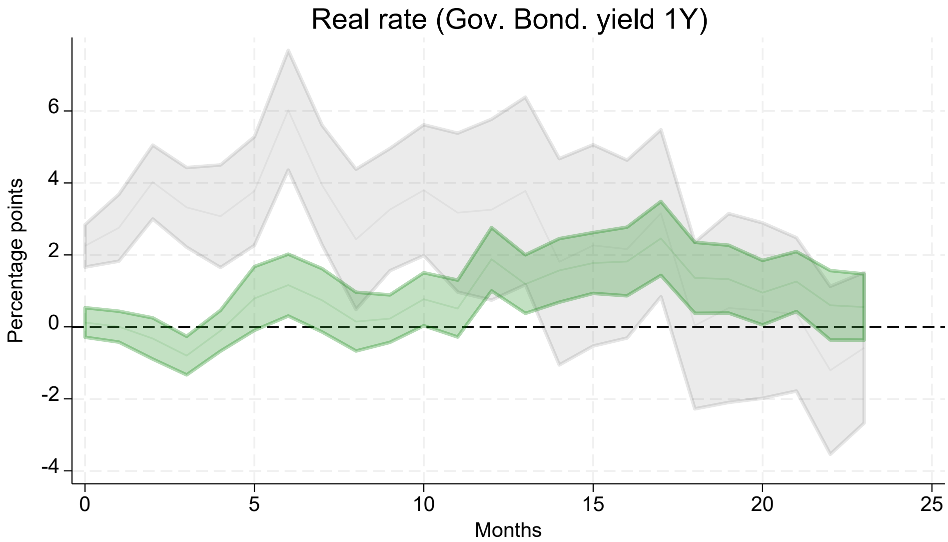
Percentage points



Note: The figure shows estimates of β^h for h=0,...,24 in equation (2) where government bond yields with different maturities are the dependent variable between January 2001 and September 2023. The shaded areas indicate confidence intervals of 1 standard deviation. The grey bands indicate effects estimated with our new measure of monetary policy rate changes (BRW) and the green bands indicate effects estimated with STINA.

Source: Own calculations.

Figure 14. Average real interest rate effects of a monetary policy rate rise based on BRW and STINA between January 2001 and September 2023.



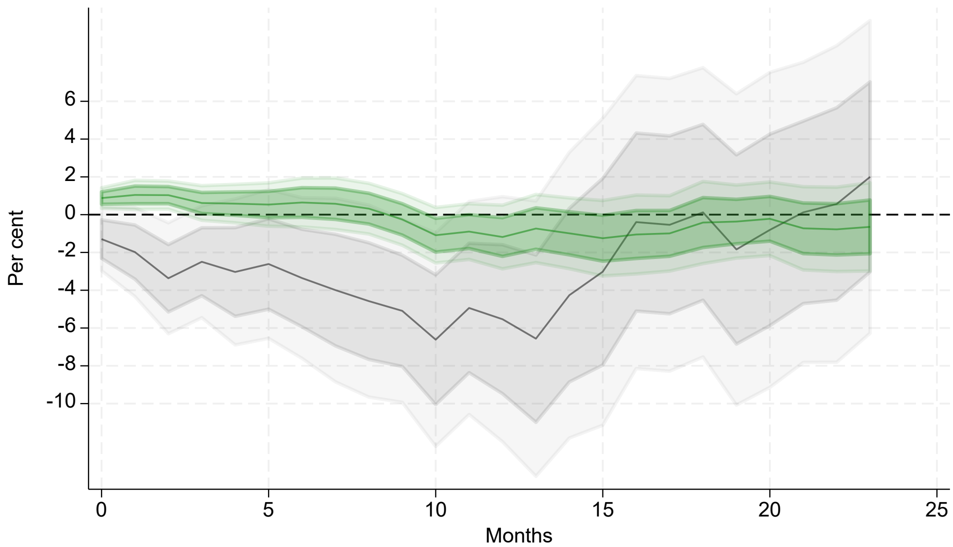
Note: The chart shows estimates of β^h for $h = 0,..,24$ in equation (2) where the real interest rate (nominal government bond rate minus CPI inflation) is the dependent variable between January 2001 and September 2023. The shaded areas indicate confidence intervals of 1 standard deviation. The grey bands indicate effects estimated with our new measure of monetary policy rate changes (BRW) and the green bands indicate effects estimated with STINA.

Source: Own calculations.

The effects on CPI and CPI excluding interest costs and electricity are shown in Figures 15 and 16. The grey and green fields show the effects of using our new measure and STINA as an instrument, respectively. The effects are both faster and quantitatively larger when we use our new measure as an instrument. The size of the effects can thus be partly attributed to differences in how monetary policy rate changes are measured. Interest rate changes that mainly cause short-term interest rates to rise have less impact than if longer-term interest rates are also affected by monetary policy. This is in line with the analysis above where we compare our results with the effects of a wide range of structural macro models.

We note that CPI inflation rises slightly after a monetary policy rate hike using STINA as an instrument. To examine the reason for this and to further facilitate comparisons with previous results, we produce the effects on CPI inflation excluding interest costs and electricity. Previous studies often focus on this particular measure. Figure 16 shows the results of such an exercise. We first note that the increase seen in Figure 15 disappears when we exclude interest costs and electricity. We further note that the effects converge but are still quantitatively larger with our new measure. A certain difference in effects from previous studies thus appears to be due to different studies analysing different measures of inflation. To summarise, so far we can conclude that the effects on inflation are due to the fact that the interest rate increase is more persistent with our new measure. The increase in interest rates is also significantly larger. We see this both when we compare with structural macro models but also when we compare with alternative instruments on monetary policy rate changes. The differences in the size of the effects with different choices of instruments for monetary policy rate changes can also be illustrated if we use the same interest rate as the basis for normalising the effects. When using STINA, we have used STIBOR as the monetary policy interest rate variable. Figure 17 shows the effects on CPI excluding interest costs and electricity if we instead use a 1-year government bond rate as an interest rate variable when using STINA as a monetary policy instrument. The effects reflect a monetary policy interest rate change that causes a 1-year government bond rate to rise by one percentage point on average over 12 months in both cases. It can be noted that the magnitude of the effects is now relatively similar.

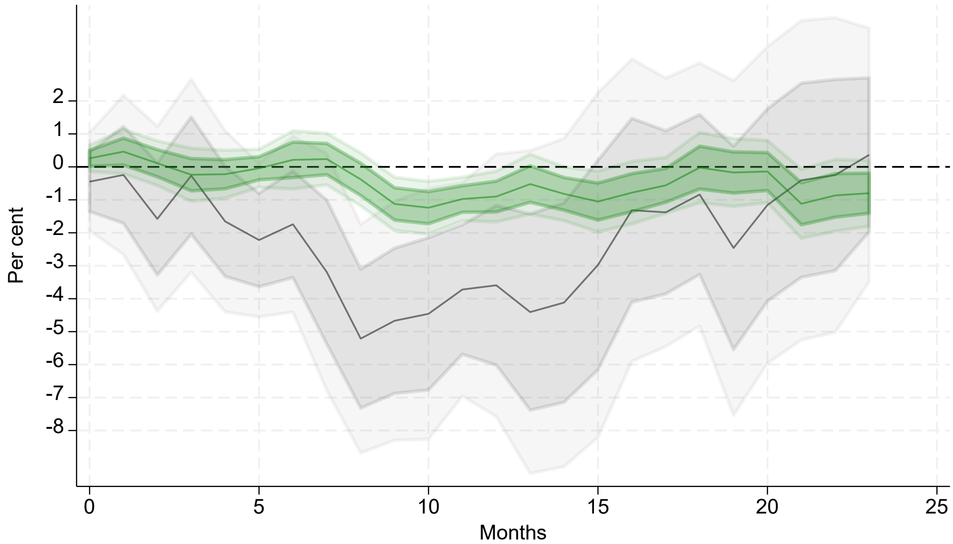
Figure 15. Average effects on the consumer price index of a monetary policy rate increase based on BRW and STINA between January 2001 and September 2023.



Note: The graph shows estimates of β^h for $h = 0,..,24$ in equation (2) where CPI inflation is the dependent variable between January 2001 and September 2023. The shaded areas indicate 1 and 1.65 standard deviation confidence intervals. The grey bands indicate effects estimated with our new measure of monetary policy rate changes (BRW) and the green bands indicate effects estimated with STINA.

Source: Own calculations.

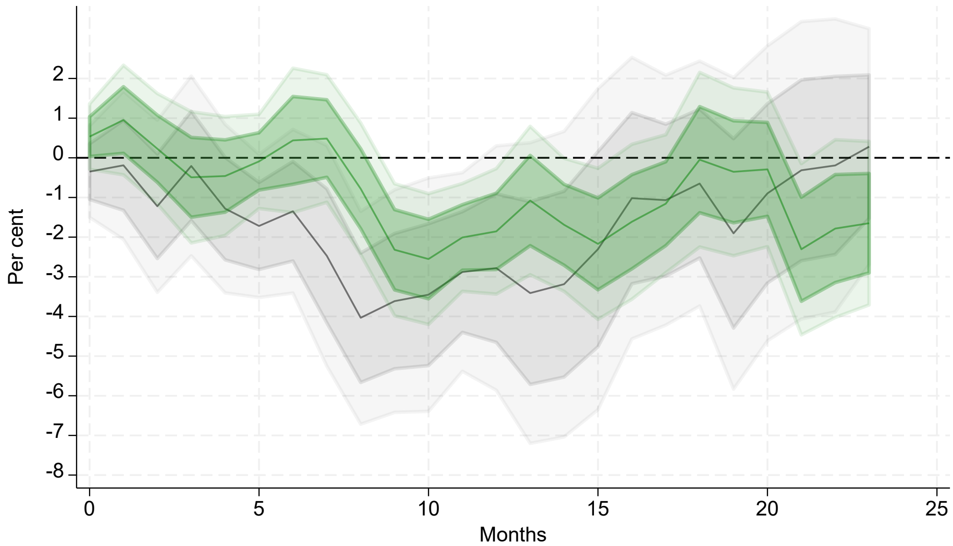
Figure 16. Average effects on the consumer price index and consumer price index excluding interest costs and electricity of a monetary policy rate rise based on BRW and STINA between January 2001 and September 2023.



Note: See Figure 15.

Source: Own calculations.

Figure 17. Average effects on the consumer price index and consumer price index excluding interest costs and electricity of a monetary policy rate rise when a 1-year government bond rate is instrumented with BRW and STINA between January 2001 and September 2023.



Note: See Figure 15.

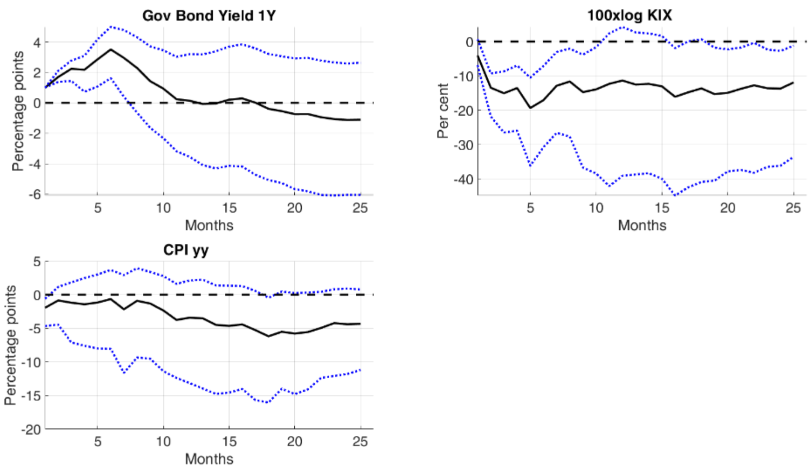
Source: Own calculations.

Do the results stand up if we use other alternative statistical methods?

In this section, we study whether the results we have presented hold up if we use alternative statistical methods. Specifically, we compare our simple local projection method (equation 2), in which we estimate the standard errors with Driscoll and Kraay, with an inversion-robust instrumental variable local projection, in which we estimate the standard errors with GLS (inversion-robust LP GLS IV), and an inversion-robust instrumental variable structural VAR model. The methods are described in Lusompa (2023). We compare with these two methods for two reasons. First, Ramey (2016) has shown that the two methods sometimes produce different results when applied to the same problem. The models represent different trade-offs between bias and efficiency (low variance). This is a well-known trade-off in statistics, where a reduction in bias can lead to an increase in variance and vice versa. Second, it is well known that the residuals in local projection models are autocorrelated. Here we use a new method (GLS) to take this into account.

Figures 18 and 19 show the results of our comparison. Figure 18 shows the results from SVAR-IV and Figure 19 from LP GLS IV. We have included 12 lags of all variables in the models and estimate the standard errors with 20,000 bootstrap draws as in Lusompa (2023). We include five variables in the models, our monetary policy instruments, a one-year government bond rate, the nominal exchange rate, CPI inflation and two-year inflation expectations. The figures show the impact of a one percentage point increase in government bond yields. As can be seen, all effects are significant and qualitatively similar to those presented above.

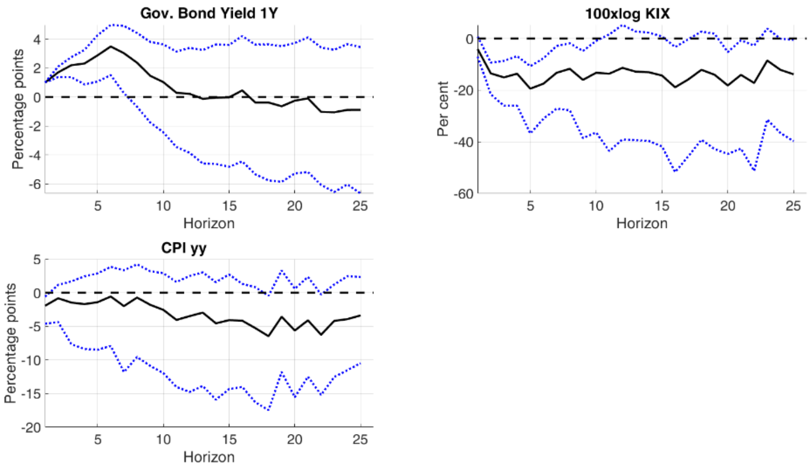
Figure 18. Effects on a one-year government bond yield, nominal exchange rate and CPI inflation of monetary policy rate changes between January 2001 and August 2023 estimated with an inversion-robust SVAR-IV model.



Note: The dashed lines are 90 per cent confidence intervals. The standard errors are calculated using 20,000 bootstrap draws with a block length of 10.

Source: Lusompa (2023) and own calculations.

Figure 19. Effects on a one-year government bond yield, nominal exchange rate and CPI inflation of monetary policy rate changes between January 2001 and August 2023 estimated with an inversion-robust LP GLS IV model.



Note: The dashed lines are 90 per cent confidence intervals. The standard errors are calculated using 20,000 bootstrap draws with a block length of 10.

Source: Lusompa (2023) and own calculations.

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