Staff memo

The effects of monetary policy in Sweden during the inflation targeting period: estimates with structural VAR models

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Staff Memo

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Summary

In this staff memo, we present estimates of the effects of monetary policy in Sweden over the inflation targeting period, from 1995 to the end of 2022, with structural vector autoregressive (SVAR) models and short-run restrictions to identify the monetary policy shocks. This is a common method for calculating the effects of monetary policy, and it is one of several approaches used by the Riksbank. However, research studies on Swedish data using similar approaches were typically done 10-20 years ago and we now have considerably more data for the inflation targeting period, which makes it timely to update previous estimates and document the new results.

Our estimated effects of monetary policy on GDP are slightly larger than in previous studies on Swedish data, while the effects on inflation are in line with previous studies. We show that the effects on CPIF inflation have been stable over time, while the effects on GDP, housing investment, consumption, house prices and household debt have probably increased over time. These observations could be explained by various structural changes that have increased household indebtedness and made the Swedish economy more interest-rate sensitive during the inflation targeting period. The fact that the effects of monetary policy on inflation have not become larger despite larger effects on the real economy could be due to the fact that the sensitivity of prices to changes in costs has simultaneously decreased, i.e. the Phillips curve has become flatter. On the contrary, during the inflation surge in 2022, data indicate that businesses have raised their prices more than usual relative to how costs have evolved, but this short period has no visible impact on our calculations.

There is considerable uncertainty about the effects of monetary policy and the estimated effects are affected by a number of different assumptions. It is important to highlight this uncertainty and to discuss the plausibility of various assumptions made. We therefore devote a relatively large amount of space to sensitivity analyses that highlight local model uncertainty, i.e. uncertainty within the framework of the SVAR model. This analysis can also guide other studies of the effects of monetary policy with similar methods.

Our calculations are part of the Riksbank's overall assessment of the effects of monetary policy. Different methods yield slightly different results and the study can therefore not be interpreted as the Riksbank's overall assessment 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 pass-through of monetary policy.

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1 Introduction

The objective of monetary policy in Sweden is to maintain sustainably low and stable inflation, in concrete terms a CPIF inflation rate of 2 per cent. As it takes time for monetary policy to fully affect the real economy and inflation, monetary policy is guided by forecasts of economic developments. The forecast for the Riksbank's policy rate is an assessment of the monetary policy required for inflation to reach the inflation target within a reasonable time. And to make that assessment, the effects of monetary policy on various macroeconomic variables need to be considered.[2]

There are several different methods for empirically estimating the effects of monetary policy on the economy.[3] On the basis of such estimates, the Riksbank makes an assessment of which policy rate path is compatible with well-balanced forecasts for various variables, primarily inflation, and also what the forecasts would look like with a different monetary policy (so-called monetary policy scenarios).

In this staff memo, we use structural vector autoregressive (SVAR) models estimated with Bayesian methods and short-run restrictions (or recursiveness assumptions) to study the effects of changes in the policy rate on a large number of Swedish macroeconomic variables, and also how these effects have changed over time. This approach is still often described as the 'standard approach' or 'workhorse model' in the field.[4] Our aim is to use a well-established method to calculate and document the effects of monetary policy in Sweden and also for these estimates to serve as a reference point for studies of the effects of monetary policy using methods based on high frequency data.[5] Regular estimates with SVAR models have been one input among others that have formed the basis for the Riksbank's assessments of the effects of monetary policy during the inflation targeting period. However, most research studies using this method on Swedish data were published 10-20 years ago (and in several cases use data from the period before the monetary policy regime change in the early 1990s), which means that one contribution here is also to present more up-to-date estimates.

We first estimate a baseline model with some key macroeconomic variables (GDP, inflation and policy rates abroad and in Sweden, and unemployment and the real exchange rate for Sweden) and show that the qualitative effects of an unexpected change in the policy rate (a so-called monetary policy shock) on the various variables

[2] For a qualitative description of how monetary policy affects the economy (the so-called monetary policy transmission), see for example Hopkins et al. (2009) or the Riksbank's website (www.riksbank.se). See Nyman and Söderström (2016) for a discussion of how the Riksbank's inflation target affects the forecasts for inflation and the policy rate.

[3] A fundamental difficulty in calculating the effects of monetary policy is to distinguish between, on the one hand, genuine monetary policy events and, on the other, occasions when monetary policy reacts to events in the economy. See, for example, Ramey (2016) for an overview of different methods for estimating the effects of monetary policy. See also Laséen and Nilsson (2024) for a discussion of the issues that need to be taken into account when calculating the effects of monetary policy and how these can be handled.

[4] See, for example, Christiano et al. (1999) for a review of the method. A classic criticism of this approach is Rudebusch (1998). See also Englund et al. (1994) for some references to the early research literature in the field and a discussion of these.

[5] Examples of studies that use more modern methods based on high-frequency data to estimate the effects of monetary policy in Sweden are Sandström (2018), Laséen (2020) and Laséen and Nilsson (2024).

are those that can be expected according to standard macroeconomic theory (Chapter 2).[6] We then study how the effects of monetary policy have changed over time (Chapter 3). After that, we extend the model to include a large number of macroeconomic variables, one or a few at a time, and study the effects of monetary policy on them (Chapter 4).

Overall, our findings can be summarised as follows:

- An unexpected increase in the policy rate by one percentage point leads to GDP falling by at most 0.8 per cent (after about two years) and CPIF inflation falling by at most 0.5 percentage points (after slightly more than a year).
- The effect on GDP is slightly larger than in previous studies on Swedish data using similar methods. We show that the differences are probably mainly due to the fact that the effects on GDP have become larger over time.
- The impact on inflation is in line with previous studies. Our estimated effects on CPIF inflation have been remarkably stable over time.
- Our estimates of how the effects of monetary policy have changed over time fit well overall into a narrative of increased indebtedness and a more interest rate-sensitive economy. For example, we show that the effects on housing investment and consumption, and thus GDP, as well as house prices and household debt are likely to have increased over time.[7] The fact that the effects on inflation have not become larger despite larger effects on the real economy could be due to the fact that the sensitivity of prices to changes in costs has simultaneously decreased.

As regards the effects of policy rate changes on other variables, we highlight the following observations that we find particularly interesting:

- The effects on housing investment are large, accounting for about one-third of the effects on GDP (while its share of GDP has been between 3 and 6 per cent over our sample period).
- Changes in the policy rate affect labour input via employment (the extensive margin) rather than via average hours worked (the intensive margin) and, furthermore, the effects on the labour force are small.
- Interest expenditure and rents in the CPI rise when the policy rate is raised, while other components of the CPI fall.

[6] In Appendix D, we conduct a comprehensive sensitivity analysis to highlight the impact of different assumptions on the estimated effects within the framework of the SVAR model with the recursiveness assumption. An important limitation is thus that we only study one approach for identifying the monetary policy shocks. The closest approaches are alternative identification assumptions within the framework of the SVAR model, such as long-run or sign restrictions, see for example Ramey (2016) for references to research papers using such assumptions.

[7] In the concluding discussion, we briefly compare these results with the predictions from structural models.

2 Effects of monetary policy in a baseline model

2.1 Effects of monetary policy 1995Q1-2022Q4

In this section, we study the effects of a monetary policy shock in a Bayesian VAR model that includes a few key macroeconomic variables. A brief description of the model and data is given here and more detailed information is provided in Appendices A (data) and B (the model). The appendix also contains a comprehensive sensitivity analysis that justifies the assumptions we make for the baseline model and shows how the results are affected if we make alternative assumptions about the model specification (see Appendix D).

In the model, we have quarterly data for three foreign variables and five Swedish variables. The foreign variables are trade-weighted measures of log-transformed GDP, the quarterly change in the CPI and the policy rate in level.[8] The domestic variables are log-transformed GDP, unemployment, the quarterly change in the CPIF, the policy rate and the log-transformed real exchange rate. All variables except foreign and domestic price indices are thus included in level.[9] Our model specification is simple in the sense that it does not contain any deterministic trends (e.g. linear trends) or dummy variables. We estimate the model with K=4 lags for the period 1995Q1-2022Q4.[10] The monetary policy shock is identified so that it is allowed to affect the nominal exchange rate (and thus also the real exchange rate), but no other variables, in the same quarter as the policy rate changes.[11] More generally, this can be expressed as financial variables being assumed to be affected immediately by monetary policy, while macroeconomic variables are affected with a lag. These assumptions are often described as "standard assumptions" in the literature.[12] Swedish monetary policy is assumed to have no impact on the foreign variables, which is a typical assumption for a small country like Sweden (the assumption of a small, open economy). With

[8] The foreign variables are KIX-weighted and consist mainly of countries whose currency is the euro. KIX (krona index) is a trade-weighted index, where the weights are based on total flows of processed goods and commodities for 31 countries. Countries with which Sweden trades more have a greater weight. We have also tried to include the change in the oil price (Brent) among the foreign variables, but this does not significantly affect the estimates of the effects of monetary policy.

[9] We thus estimate the model in log levels for GDP abroad and in Sweden and the real exchange rate, but without explicit modelling of any co-integrating relationships between the variables.

[10] A reasonably stable monetary policy regime is a necessary condition when we estimate the effects of monetary policy.

[11] As Swedish monetary policy is not assumed to affect foreign variables and as CPIF inflation is not affected in the same quarter as the interest rate change, any initial effect on the real exchange rate must be entirely attributed to an effect on the nominal exchange rate. It is therefore also more natural to express the assumption in terms of the nominal exchange rate.

[12] See, for example, Björnland and Jacobsen (2010). Identification of the monetary policy shock with the recursiveness assumption is described in detail in, for example, Christiano et al. (1999). An obvious disadvantage of these assumptions is that we do not estimate the initial effects on GDP, unemployment and inflation, but we show in the appendix that the estimated effects are similar if we instead allow these variables to react in the same quarter.

this identification, we assume, alternatively expressed, that the central bank's reaction function in the model is such that the policy rate in Sweden reacts to simultaneous and lagged values of the foreign variables, and Swedish GDP, unemployment and inflation and lagged values for the policy rate and the real exchange rate.[13] The monetary policy shock is given by the deviation between the actual policy rate and the policy rate given by this reaction function.

Figure 1 shows the effects of an unexpected increase in the policy rate by one percentage point initially.[14] We use this normalisation of the effect on the policy rate throughout the paper so that the effects from different model estimates can be easily compared. The policy rate then returns to its normal level after about two years. We first see that the qualitative effects (i.e. the signs of the responses) on all variables are those expected according to economic theory. We also see that the estimated effects mean that monetary policy is neutral - we have no long-term effects of the policy rate change on GDP, unemployment or the real exchange rate.[15] GDP has decreased by a maximum of 0.8 per cent after 8 quarters and the effect on unemployment is greatest after 9 quarters when it has increased by 0.7 percentage points (this refers to the median effects). The effects of monetary policy on the real economy are thus gradual, with the largest effects occurring with a time lag. We also see that the effects on unemployment are much more persistent than the effects on GDP. The real exchange rate is affected relatively quickly and has appreciated by at most 3 per cent after about a year. This effect is larger than the effect that can be expected from the effect on the real policy rate and real interest rate parity with other countries.[16] CPIF inflation (which is consistently shown as an annual percentage change) declines by 0.5 percentage points, with the maximum effect occurring after 5-6 quarters.[17] We find no support for a so-called price puzzle, i.e. that an increase in the policy rate would initially lead to an increase in consumer prices (and thus the "wrong" sign for the inflation response). It also follows from the effects on the real exchange rate and CPIF inflation that the nominal exchange rate depreciates by approximately (3+0.5=) 3.5 per cent after one year.

[13] Lindé et al. (2008) use a similar model and similar identification assumptions to estimate the effects of a monetary policy shock on data for Sweden over the period 1986-2002. See, for example, Bernanke and Blinder (1992) or Rudebusch (1998) for further discussion of the monetary policy reaction function in the VAR model. The latter criticises the assumptions made about the reaction function on various grounds, including the fact that it is estimated on (revised) data that were not available to the central bank at the time of the decision.

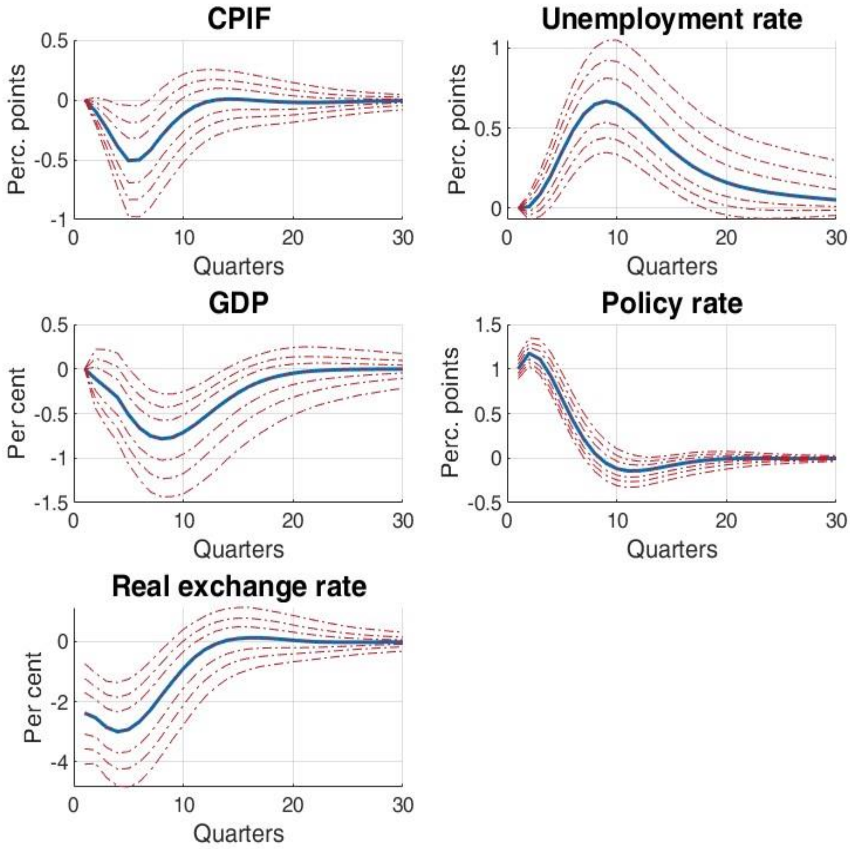
[14] A monetary policy shock of the magnitude of one standard deviation raises the policy rate by around 0.2 percentage points. We scale this effect up to one percentage point to make it easier to compare the effects with other estimates and other studies. The normalisation is arbitrarily chosen and has no impact on the analysis as the model is linear.

[15] One disadvantage of specifying the VAR model in levels (without explicit modelling of co-integration) is that we cannot impose long-run restrictions, for example restrictions on how monetary policy affects different variables in the long run, see for example Kilian and Lutkepohl (2017). But we note that the assumption of monetary policy neutrality is nevertheless fulfilled in our estimate.

[16] The effect on the real policy rate and real interest rate parity implies that the real exchange rate should appreciate by 1.7 per cent immediately and then depreciate. This also means that the effect on the real exchange rate is larger in our BVAR model than in structural models that incorporate some form of interest rate parity, such as the Riksbank's DSGE model, MAJA (see Corbo and Strid (2020)).

[17] The maximum effect on the quarterly change in the CPIF already comes in the quarter after the policy rate is raised.

Figure 1. Effects of an increase in the policy rate in the baseline model



Note. The figure shows the effects of a monetary policy shock in the baseline model, where the initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the response and the blue line shows the median response (50th percentile).

In Figure 1 we also show probability intervals of size 50, 70 and 90 per cent to illustrate the uncertainty in the estimated effects (see dashed red lines). For example, the probability that the effect lies between the extreme lines - the 5th and 95th percentiles of the distribution - is 90 per cent. For all variables, we see that the probability that the maximum effect is different from zero is at least greater than 95 per cent, and in this sense the effects can be said to be statistically significantly different from zero. [18] For example, the probability that a positive monetary policy shock (raising the policy rate) causes lower inflation is greater than 95 per cent. This uncertainty about the effect highlights the parameter uncertainty conditional on a particular model. The sensitivity analysis in Appendix D and comparisons with the results of other studies

[18] By "statistically significant" we mean throughout this paper that the probability is high, and more specifically that it is at least 90 per cent and often greater than 95 per cent.

also shed light on model uncertainty, for example how the effects are affected if the model contains other variables or a different lag length.

2.2 Comparison with other studies on Swedish data

In Table 1 we compare our estimated effects for GDP and inflation with those of some other research studies using Swedish data. In the comparison, we include a number of articles that use methods similar to those we use, i.e. SVAR models, as well as results for four dynamic stochastic general equilibrium (DSGE) models that have been used by the Riksbank and the National Institute of Economic Research over the past 20 years or so.[19] To illustrate how these estimates on Swedish data compare with similar estimates on data for the US and the euro area, we also include the average effects for a large number of models estimated for these regions. [20] We have normalised the effects in the various studies so that they refer to an unexpected increase in the policy rate by one percentage point initially. However, it is important to note that the persistence of the policy rate response may differ slightly across studies, which means that the comparison is not entirely accurate.[21]

[19] In Figure 12 in the appendix, we show a comparison of the effects for all variables in the model with those in MAJA, a general equilibrium model used by the Riksbank. In Figure 13 in the appendix, we show a comparison of the estimated monetary policy shocks in the two models and the correlation between the two series is 0.7. Alexius and Holmlund (2008) is an example of a study that estimates the effects of a monetary policy shock on unemployment on Swedish data with a structural VAR model. They use an composite measure of monetary policy (monetary condition index, MCI) and their estimated effects on GDP and unemployment are much smaller than those we report here - an unexpected increase in the real interest rate by one percentage point results in 0.1 percentage points higher unemployment.

[20] See Laséen et al. (2022), who have compiled the effects of monetary policy in 57 models for the euro area and the US.

[21] The more persistent the interest rate change, the greater its effects on the other variables. See, for example, Laséen et al. (2022) for a discussion of how the duration of the policy rate change affects its impact on the economy. As our comparison in Table 1 is based on the reading of effects in charts in the different research papers, normalising the initial effect is the best we can do to make the effects as comparable as possible. But this means that the comparison should be seen as approximate and not exact.

Table 1. Maximum effects of monetary policy on GDP and inflation in Sweden in a selection of research studies

Article	Model	GDP Value	Quarter	Inflation Value	Quarter
Jacobson et al. (2001)	VAR	-0,3	1	-0,3	8
Villani and Warne (2003)	BVAR	-0,7	3	-0,3	4
Adolfson et al. (2008)	Ramses (DSGE)	-0,5	7	-0,4	5
Lindé et al. (2008)	VAR	-0,3	6	-0,2	8
Hopkins et al. (2009)	VAR	-0,5	5	-0,2	6
Hopkins et al. (2009)	BVAR	-0,1	5	-0,1	5
Björnland and Jacobsen (2010)	VAR	-0,7	5	-0,7	8
Christiano et al. (2011)	Ramses 2 (DSGE)	-0,4	5	-0,1	5
Laséen and Strid (2013)	BVAR	-0,4	8	-0,4	6
Di Casola and Iversen (2019)	BVAR	-0,8	7	-0,3	5
Corbo and Strid (2020)	MAJA (DSGE)	-0,7	5	-0,2	4
The National Institute of Economic Research (2023)	SELMA (DSGE)	-0,5	4	-0,2	4
Lyhagen andl Shahnazarian (2023)	BVAR	-0,3	9	-0,2	10
Median		**-0,5**	**5**	**-0,2**	**5**
Median VAR models		**-0,4**	**5**	**-0,3**	**6**
This article	***BVAR***	***-0,8***	***8***	***-0,5***	***6***
Laséen et al. (2022)	57 models (United States and euro area)	-0,5	missing	-0,2	missing

Note. The effects in the table refer to GDP (or the cyclical component of GDP) in level and inflation in annual percentage change. Inflation refers to the main measure of inflation used in each article. The effect on the policy rate is normalised to one percentage point initially. Where results are reported for several different assumptions in a study, we have chosen the one we perceive as most comparable to our study. In most cases, the effects have been read visually from figures, which entails a risk of misreading. DSGE means that the model is a dynamic stochastic general equilibrium model.

The median of the maximum (peak) effects on GDP and inflation in the Swedish studies are -0.5 per cent and -0.2 percentage points respectively, and they occur after slightly more than one year for both variables. For the studies using VAR models, these effects are -0.4 per cent and -0.3 percentage points respectively. Furthermore, the maximum effects in the Swedish studies are in line with the effects obtained with models (estimated or calibrated) on data for the US and the euro area. We also see that the effects are well in line with the effects in the models currently used by the Riksbank (MAJA) and the National Institute of Economic Research (SELMA). The ratio between the maximum effects on GDP and inflation (sacrifice ratio) in the different studies varies between 1 and 4, with the median being slightly greater than 2.[22]

Overall, we see that our estimated maximum effects of an interest rate increase on GDP and inflation are slightly larger than the median of the effects in the studies reported in Table 1. The fact that our estimated effects on GDP are larger than in most previous studies is probably mainly due to the effects having become larger over time

[22] For example, the ratio is relatively high in the MAJA model, which can be linked to the fact that the Philip curves that determine CPIF inflation in the model are flat.

(see further analysis and discussion in Chapter 3). As regards the effects on inflation, a more detailed comparison shows that our effects are broadly in line with previous studies, and in particular those that are most similar to ours in approach.[23] The relationship between the effects on GDP and inflation is also roughly in line with the ratio in previous studies. The maximum effect on GDP occurs somewhat later in our estimates than in previous studies, while the timing of the maximum effect on inflation is in line with previous studies.

A common belief is that monetary policy affects the economy with a lag and that the time between a change in interest rates and its effect can vary over time ("long and variable lags" as Milton Friedman put it). For example, in a well-known study on US data, the maximum effect on GDP occurs after 5-6 quarters while the price level *starts to* fall only after 6 quarters.[24] The timing of the maximum GDP effect in the studies on Swedish data is roughly in line with this (although it obviously differs between different studies), while the maximum effect on inflation in the Swedish studies generally comes much more quickly and without any longer lag (see Table 1).[25] The results of the Swedish studies could be interpreted as companies being forward-looking when they set their prices, i.e. that expected lower demand in the future means that they are already lowering prices today. Another important explanation for the rapid effects on inflation is probably that the relative importance of the exchange rate for inflation is greater in a small, open economy like Sweden compared with the US.[26]

2.3 Estimates with alternative assumptions

An important part of our study is to shed light on how different assumptions affect the estimated effects, partly to justify the assumptions we make in the baseline model, and partly to know how robust the results are for other assumptions. This type of analysis is presented in Appendix D. We study and compare models with variables in different transformations (level or difference), with or without deterministic trends, with or without restrictions on stationarity, different numbers of lags, different assumptions about the short-run restrictions, and with different sets of foreign variables. We also estimate the model with maximum likelihood (instead of Bayesian

[23] When we estimate the effects of monetary policy over time, we usually get a maximum effect of -0.4 percentage points (rather than -0.5, which is the maximum effect for the sample 1995Q1-2022Q4), see Figure 2 below. This is in line with the median of the maximum effect in studies based on VAR models (-0.3, see Table 1). And when we compare our estimated effects for GDP and inflation with the two studies closest to ours in methodology, Laséen and Strid (2013) and Di Casola and Iversen (2019), we find that our results are well in line with these two studies(see more in Section 3 below).

[24] See Christiano et al. (1999).

[25] Note that if the maximum effect on the annual percentage change in prices comes after 5 quarters (the median in the studies on Swedish data), the maximum effect on the CPIF in quarterly change typically occurs 1-3 quarters after the interest rate change (under the assumption that inflation cannot be affected contemporaneously).

[26] The fact that monetary policy has large effects on the exchange rate and that the maximum effects on inflation come quickly are also two of the main conclusions of a relatively recent study by Laséen and Nilsson (2024), which uses other methods to identify the effects of monetary policy. In DSGE models such as MAJA, the effects on inflation are rapid because businesses are assumed to be forward-looking when setting prices, i.e. they react quickly to changes in expectations about future economic developments that affect their pricing behaviour.

methods), with monthly data (instead of quarterly data) and highlight how the estimates are affected if we take into account the Riksbank's asset purchases since 2015. The analysis generally shows that our estimated effects of monetary policy are relatively robust for a number of alternative assumptions.

3 Have the effects of monetary policy changed over time?

To study whether and how the effects of monetary policy have changed over time during the inflation-targeting period, we estimate the model for different sub-periods during the period 1995Q1-2022Q4.[27] The aim is to obtain estimates that are based to varying degrees on older or more recent data over the inflation-targeting period. We first estimate the model on samples with a fixed starting quarter and varying ending quarters (expanding samples). The first sample is from 1995Q1 to 2009Q4 inclusive and the last is from 1995Q1 to 2022Q4 inclusive. We then estimate the model on samples with a varying starting quarter and a fixed ending quarter (shrinking sample). The first sample is 1995Q1 to 2022Q4 inclusive and the last is 2008Q1 to 2022Q4. If we add all the estimates together, we then get estimates that are based to different degrees on earlier and later data, which makes it possible to say something about how the effects have changed over time. A simple way to summarise the 'freshness' of the different samples is to indicate the centre of the sample. For example, the midpoint for the whole period 1995Q1-2022Q4 is given by the turn of 2008-2009.[28] The fact that we choose this approach to study how transmission has changed over time is mainly due to the fact that we are already studying a relatively short period of time at the outset.[29]

In Figure 2 we show how the estimated peak effect of a monetary policy shock on the different variables has changed over time, where the time on the x-axis indicates the centre of the sample.[30] In all cases, these are calculated for an unexpected increase in the policy rate of one percentage point initially.[31] The maximum effects for samples with greater weight on older data (expanding samples) are shown in blue and the maximum effects for samples based on newer data (shrinking samples) are shown in red. The further right (left) we move in the figure, the greater the weight of more recent (older) data. The point where these two lines meet thus shows the estimate of

[27] More advanced alternatives to this approach that have been used to study time variation in the monetary policy transmission mechanism are models with time-varying parameters or regime switching, see for example Boivin et al. (2010) for a discussion and further references.

[28] We choose to estimate the model on expanding and shrinking samples instead of rolling samples to use the data as efficiently as possible. Culling et al. (2019) estimate DSGE and VAR models on expanding samples to study how the effects of monetary policy in New Zealand have changed over time.

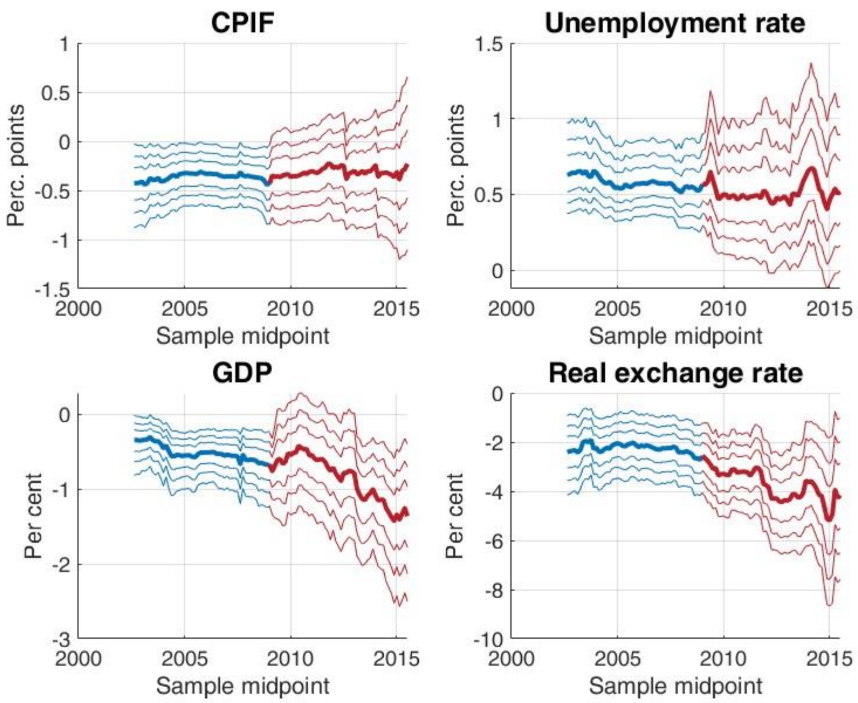
[29] The inflation-targeting period is too short to split into non-overlapping samples. And using rolling samples (instead of expanding and shrinking) would mean that the samples would be relatively short.

[30] The maximum effect always refers to the maximum effect in absolute terms. For example, the maximum effect on inflation is approximately -0.4 percentage points.

[31] This normalisation does not capture the fact that the persistence of the policy rate response may have changed over time, which could affect the estimated effects on the variables, see, for example, Ramey (2016). We have therefore compared the results with those obtained if we (i) normalise the maximum effect on the policy rate to 1 or (ii) normalise the average effect on the policy rate in the first year to 1. However, the picture of how the effects have changed over time is not affected if we instead use one of these alternative normalisations and we therefore do not show these results here.

the maximum effect for the entire sample period 1995Q1-2022Q4. (These maximum effects can also be discerned in Figure 1). Overall, we see that the effects on inflation and unemployment are relatively stable over time, while the effects on GDP and the real exchange rate have become larger over time.

Figure 2. Maximum effects of an increase in the policy rate in the baseline model estimated for different samples



Note. The BVAR model is estimated for different samples and the figure shows how the maximum effect on different variables has changed over time. The initial effect on the policy rate in all estimates is normalised to one percentage point. The thin red and blue lines are the 5th, 15th, 25th, 50th (median, in bold) 75th, 85th and 95th percentiles of the probability distribution of responses. The model is first estimated with a start period of 1995Q1 and an end period varying from 2009Q4 to 2022Q4 (expanding sample), see blue lines. The model is then estimated with the start period moved forward, 1995Q1 to 2008Q1 and the end period 2022Q4 (shrinking sample), see red lines. The x-axis shows the midpoint of the sample period.

The maximum effect of a monetary policy shock on CPIF inflation (in annual percentage change) is negative in all estimates and stable over time. The maximum effect is close to -0.4 percentage points over the whole period (this figure and those that follow refer to the median effect, shown by the bold line in the figure). The effect on unemployment is also stable over time, around 0.6 percentage points, but the variation in the estimate increases when we use later data. The maximum effect on the level of GDP increases over time from around 0.3 per cent to over 1 per cent in the latest samples. (In Section 4.2 below, we further examine which parts of GDP are more affected by monetary policy). The effect on the real exchange rate has also increased over time from a maximum appreciation of the real exchange rate of 2-3 per cent to effects around 4 per cent. Our estimated effects are also in line with two previous studies that estimate the effects of monetary policy in Sweden with a similar model.[32] The changes in the relative effects of the different variables over time are consistent with a lower coefficient in an Okun relationship (relating unemployment to GDP) and a reduced exchange rate pass-through to inflation.[33]

The time at which the maximum effect occurs has also remained stable over time, but with some evidence that the effects have occurred more quickly for samples that have greater weight on more recent data. For GDP, the maximum effect typically occurs after 8 quarters and for unemployment the effect typically peaks after 9 quarters, which means that the estimate for the entire sample period 1995Q1-2022Q4 can be said to be typical in this respect. This is in line with the usual pattern that labour market activity is affected with a lag relative to output. However, for both GDP and unemployment, the maximum effect in samples with more recent data has occurred a couple of quarters earlier than in the oldest samples. The effect on the real exchange rate is greatest in the first year after the policy rate is raised, while the maximum effect on inflation typically occurs after five quarters.

In Figure 2 we also show probability intervals for the effects and how these have changed over time. These intervals illustrate the uncertainty in the estimates of the effects and can also be used to say something about whether the changes in the effects over time are statistically significant. Based on these intervals and approximate probability calculations, we conclude that there is a very low probability that the effects of monetary policy on inflation or unemployment have changed during the inflation-targeting period. However, it is highly likely that the effects on GDP and the real exchange rate have become larger over time.[34]

We also see that the probability intervals are generally wider for samples that are centred on later data. One partial explanation is that the estimates further to the right of the figure (and also to the left) are based on shorter samples than those in the centre. However, this is probably also explained by the fact that macroeconomic volatility is higher for these samples - for example, the global financial crisis of 2007-09 and the turbulent period in the early 2020s (the coronavirus pandemic and then high inflation) have a greater weight in these samples.[35]

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[32] Laséen and Strid (2013) estimate a BVAR model similar to the one we use on Swedish data for the period 1995Q1-2013Q1 (the sample's midpoint is then approximately 2004) and find maximum effects on GDP and inflation of -0.4 per cent and -0.4 percentage points respectively. We see that these effects are in line with those shown in Figure 2. Di Casola and Iversen (2019) estimate a BVAR model similar to the one we use on Swedish data and for three periods, from 1995 to 2007, 2015 and 2018 respectively. Our results on how the effects of policy rate changes on GDP, CPIF inflation and the real exchange rate have changed over time are in line with their results.

[33] However, in Section 3.3 below, we note that the effects on hours worked and employment appear to have increased slightly over time, although these effects are not statistically significant.

[34] In Appendix C we make an approximate probability calculation to show this.

[35] However, we note that there has been little variation in the policy rate since the global financial crisis, and particularly in the latter part of the 2010s.

The 2020-2021 Covid pandemic raised the question of how to deal with a sequence of extreme observations when estimating a VAR model. [36] We have therefore also specifically examined the impact of the 2020-2022 data on our estimates. We then instead estimate the model on shrinking samples ending in 2019Q4, i.e. before the pandemic, instead of 2022Q4 (not shown here). This gives broadly the same overall results as those reported above for GDP (larger maximum effects over time), the CPIF (stable effects) and the real exchange rate (larger effects). However, the effect on unemployment, which is stable in Figure 2, appears to have decreased over time when the end point of the sample is 2019Q4 instead of 2022Q4. One interpretation of this is that the pandemic and the post-pandemic period have rather limited effects on the analysis of how the effects changed over time in the baseline model.

4 Effects of monetary policy on other macroeconomic variables

In this chapter we study the effects of monetary policy on a broader set of macroeconomic variables. The discussion is divided into five different themes or topics: interest rates, GDP and its components, labour market, prices and house prices and debt. Starting from the baseline model above, we extend the model by one or a small number of variables at a time and study the effects of monetary policy on them.

4.1 Interest rates

In this chapter we study how different interest rates in the economy are affected when the policy rate changes, what is commonly referred to as the "first stage of transmission". Changes in the policy rate affect market rates (e.g. the STIBOR interbank rate) and, via banks' funding costs, the interest rates faced by households and businesses.[37] The extent to which different interest rates are affected by a change in the policy rate is captured by the interest rate pass-through, which is the ratio of the change in the interest rate in question to the change in the policy rate. [38] Common methods for estimating the pass-through are event studies and various regression models. Here, we use our structural VAR model to calculate the pass-through.

We start from the baseline model (see Chapter 2), add one interest rate at a time to the model and study the effects of an unexpected change in the policy rate on the

[36] Lenza and Primiceri (2020) show that excluding the observations from the pandemic may be acceptable if the purpose, as in our study, is parameter estimation with VAR models. Another way to deal with the pandemic is to include dummy variables for 2020Q1 and 2020Q2 when the movements in the time series were the largest, or a dummy variable for the whole period from 2020Q1 onwards. However, there is no major difference in results when we include the dummy variables and we therefore choose to estimate the model with data for the pandemic as well, as they do not have a major effect on the results in the baseline model.

[37] See Vredin and Åsberg Sommar (2023) for a general description of how monetary policy is implemented in practice. During the period we are studying, the Riksbank has had two different operational frameworks. The first between 1994 and 2019, see Sellin and Åsberg Sommar (2014) for a description, and the second which applies today and is described in Hansson and Wallin-Johansson (2023).

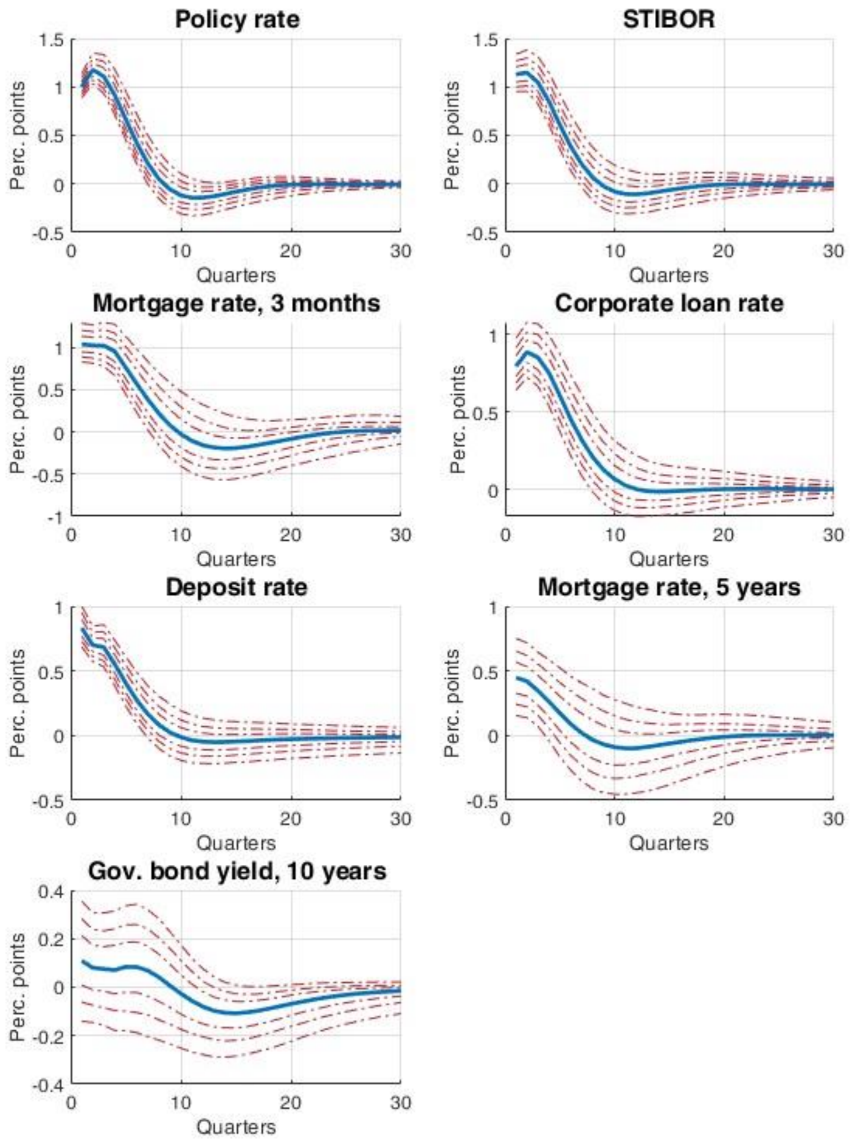
[38] See Sveriges Riksbank (2023) and Fransson and Tysklind (2016) for an in-depth discussion of the operational framework and how the general level of interest rates is affected by monetary policy.

various interest rates.[39] The interest rates we study are the three-month STIBOR, three-month and five-year mortgage rates, the average interest rate on loans to companies, the average deposit rate for households and a 10-year government bond rate. The sample allows us to examine the effect on a number of key short- and long-term interest rates faced by households and businesses, but also rates set in financial markets. All interest rates included in the analysis are central rates in the economy - for example, Swedish households' mortgages account for approximately 80 per cent of total household debt and three-month fixed-rate loans have accounted for between half and three-quarters of mortgages since the early 2000s. The models are estimated for the period 1995Q1-2022Q4.[40] We assume that the various interest rates can be affected in the same quarter as the policy rate changes and otherwise make the same assumptions about the identification of the monetary policy shock as in the baseline model.

[39] We study seven different interest rates and thus estimate seven different VAR models. The effects of an interest rate increase on the variables included in the baseline model are not significantly affected when we add these different interest rates to the model.

[40] For mortgage rates, the model is estimated for the period 1997Q2-2022Q4 due to the availability of data for these.

Figure 3. Effects of an increase in the policy rate on other interest rates



Note. The figure shows the effects of a monetary policy shock from SVAR models where the initial effect on the policy rate has been normalised to one percentage point. The models are estimated for the period 1995Q1-2022Q4 for all variables except for mortgage rates, where the estimation starts in 1997Q2 instead. All variables are in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the response and the blue line shows the median response (50th percentile).

In Figure 3 we show the effects of a monetary policy shock on the various interest rates when the policy rate is initially raised by one percentage point. We define the pass-through of the policy rate to other interest rates as the maximum (peak) effect on that rate divided by the maximum effect on the policy rate.[41] For example, the pass-through for the 3-month mortgage rate is 1 divided by 1.2, i.e. around 0.8. We see that the pass-through for shorter maturities is larger, around 0.7-1, while the pass-through for longer maturities is smaller, around 0.1-0.4. We also see that a change in the policy rate has a rapid impact on other interest rates. With regard to the effects on the individual interest rates, we can see that an increase in the policy rate has a pass-through to STIBOR of just over 1. The pass-through of the 3-month short-term mortgage rate and the average deposit rate faced by households is around 0.8 and 0.7 respectively. For the average interest rate on loans to businesses, the pass-through of a policy rate increase is 0.8 per cent. For interest rates with longer maturities, the 5-year mortgage rate and the 10-year government bond rate, we obtain a pass-through of just over 0.4 and 0.1 per cent respectively.

We also show the probability intervals of size 50, 70 and 90 per cent in the figure (see dashed red lines). For all interest rates, the effect of a policy rate increase is statistically significantly different from zero, with the exception of the 10-year government bond rate. We also have relatively wide probability intervals for the 5-year mortgage rate, which means that the estimated pass-through is uncertain.

In Figure 4 we show how the interest rate pass-through has changed over time. The method is the same as that used above for the baseline model, with the difference that we choose to normalise the maximum effect (instead of the initial effect) on the policy rate to 1.[42] We see there that the pass-through of the policy rate to the various interest rates has been relatively stable over time. The pass-through to STIBOR has been close to 1 over time. The pass-through between the three-month mortgage rate and the corporate loan rate has been slightly below 1 and appears to have increased over time. The pass-through of the policy rate to the average deposit rate faced by households has declined over time.[43] For the 5-year mortgage rate, the pass-through appears to have increased over time, and with more recent data the effect is statistically different from zero. The pass-through for the 10-year government bond rate is clearly the lowest among all the rates analysed and is not significantly different from zero.

Our method of studying the pass-through of the policy rate to other interest rates does not seem very common in the research literature, but the results are in line with studies using more high-frequency data. Our results for the short-term market rate and short-term interest rates to households and businesses are in line with the results in Tysklind and Fransson (2016), who showed a significant pass-through for these rates, for example their estimated pass-through to a 3-month mortgage rate is just over 0.9. Their estimates for longer-term market rates are also in line with our results;

[41] We choose to calculate the pass-through in this way because the policy rate response is not greatest initially.

[42] We choose this option here because it gives a better picture of the interest rate pass-through to relate the maximum effects.

[43] One reason for the reduced pass-through may be that no Swedish banks introduced negative deposit rates for households during the period when the Riksbank cut the policy rate below zero.

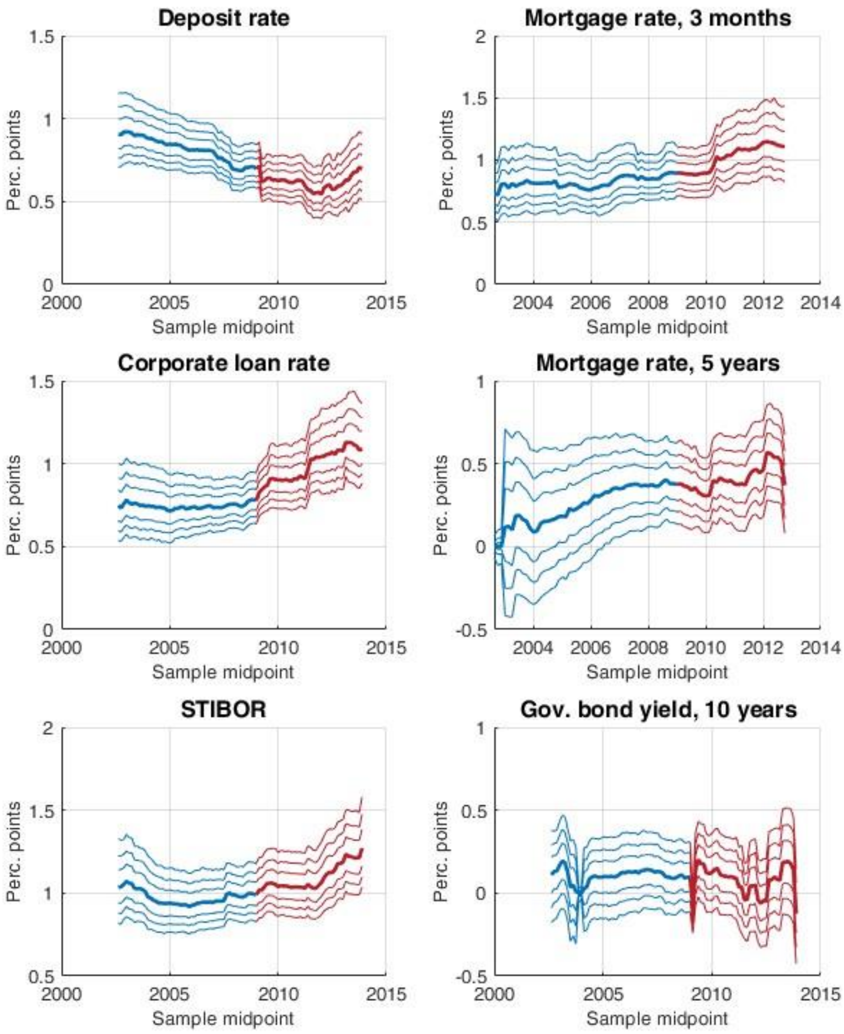
for example, the pass-through for the ten-year rate is relatively limited.[44] Kaplan and Njie (2024) find an average pass-through of around 0.9 to the variable mortgage rate when they examine different episodes of policy rate changes over the period 2006-2023. [45] Our results are also in line with international studies on the pass-through of the interest rate. For example, a meta-study by Gregora et al. (2019) that the pass-through to lending rates when the policy rate changes is 0.8 on average. [46]

[44] Tysklind and Fransson (2016) conducted a similar but more comprehensive analysis with many more interest rate variables. The authors use a simple regression to estimate how different interest rates are affected by a policy rate decision. The model includes both the expected and unexpected change in the policy rate.

[45] Kaplan and Njie (2024) examine the relationship between the policy rate and the variable mortgage rate by identifying the factors that drive the mortgage rate. They also analyse the impact of the policy rate on the variable mortgage rate for different periods between 2006 and 2023. To study this, the authors develop an analytical framework that takes into account all bank funding. They find that the pass-through of a policy rate change has decreased in the latest rate hike cycle compared with previous cycles.

[46] Gregora et al. (2019) reviews the empirical literature on interest rate pass-through and systematises it through meta-analysis and meta-regressions. They analyse 52 studies and pick out 1,040 coefficients for the estimated interest rate pass-through. When they control for country-specific institutional factors, for example, the estimated pass-through drops to 60 per cent. Furthermore, they find that the estimates for longer-term interest rates and average lending rates to households tend to be significantly lower.

Figure 4. Maximum effects of an increase in the policy rate on other interest rates estimated for different samples



Note. BVAR models with the different variables in the figure are estimated for different samples and the figure shows how the maximum effect on different variables has changed over time. The 5th, 15th, 25th, 50th (median, in bold), 75th, 85th and 95th percentiles of the maximum effect distribution are shown. The maximum effect on the policy rate is normalised to one percentage point in all estimates. All variables are in level. The model is first estimated with a start period of 1995Q1 and an end period varying from 2010Q1 to 2022Q4 (expanding sample), see blue lines. The model is then estimated with the start period moved forward, 1995Q1 to 2008Q1 and the end period 2022Q4 (shrinking sample), see red lines. The x-axis shows the midpoint of the sample period.

4.2 GDP and its components

In this chapter, we estimate the effects for the different components of GDP and then compare the results with other studies. We start from the baseline model described in Section 2.1. We then add the following variables to the model, one at a time: consumption, investment, housing investment, exports and imports.[47] All variables are (like GDP) in level and log-transformed and we assume that a monetary policy shock cannot affect them in the same quarter as the interest rate is raised.

Figure 5 shows the effects of monetary policy on the components of GDP when the different models for the components are estimated for the period 1995Q1-2022Q4. In all cases, the policy rate is assumed to be raised by one percentage point initially.[48] We see there that the maximum effect on consumption (-0.3 per cent) is about half the size of the effect on GDP (-0.8 per cent), while the effect on investment is about twice the size of GDP (-1.6 per cent). These relationships are in line with the relative volatility of these variables in the data. Since the consumption response is affected to some extent by data for the period 2020-2022, we also show the response when the model is estimated for the period before the pandemic, 1995Q1-2019Q4 (see light blue line). The effect on housing investment (-7.3 per cent) is significantly larger than the effect on non-housing investment (-1.0 per cent) and means that about a third of the effect on GDP falls on housing investment, despite the fact that it accounts for a relatively small share of GDP.[49] Both exports (-1.6 per cent) and imports (-2.1 per cent) fall, but as imports decline more than exports, the effect on net exports is negative. However, the initial effect on net exports in our model estimates is positive, which is in line with what is usually described by the so-called J-curve - that is, net exports increase after an appreciation of the exchange rate and then decrease.[50] As with GDP, the responses for the different variables are hump-shaped and the maximum effects occur in most cases, as with GDP, after about two years.[51]

[47] Net exports are the difference between exports and imports. Non-housing investment refers to private investment excluding housing investment, thus also excluding public investment which is included in the measure of total investment (here only referred to as investment).

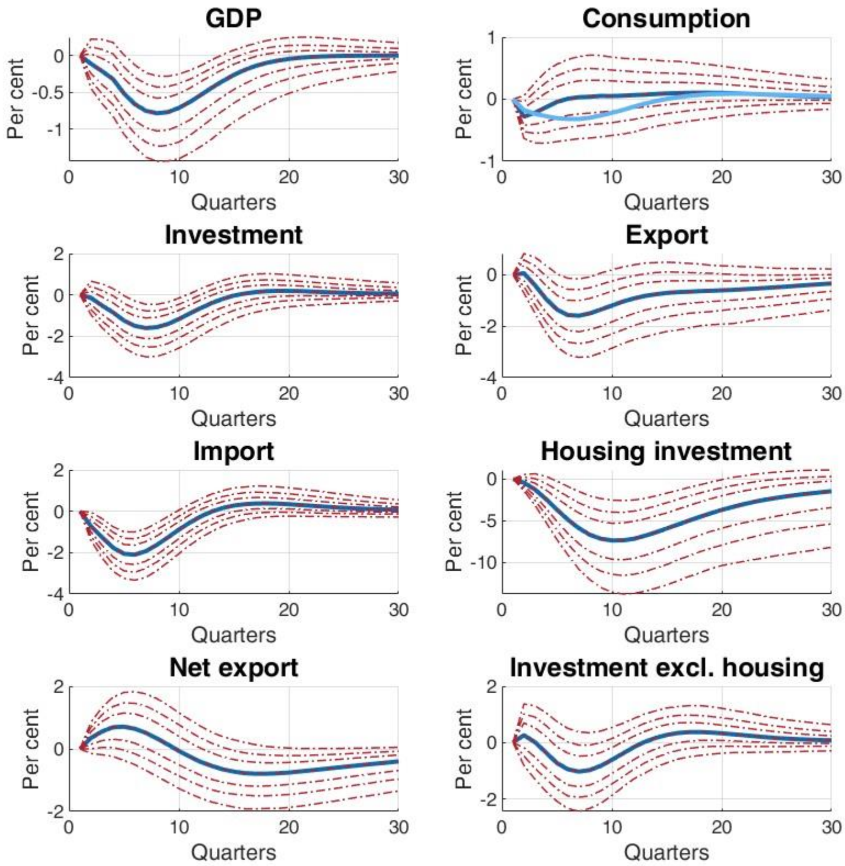
[48] We note that the response for the policy rate differs slightly in the different estimates. However, these differences are so small that they do not affect the analysis in any significant way.

[49] The share of housing investment in GDP has been around 4 per cent on average during our sample period and the contribution to the GDP effect based on the maximum effects is then 7.3*4%/0.8.

[50] The J-curve is commonly used to describe the change in the trade balance following a depreciation of the currency as the current account first falls and then rises. In this study, the real exchange rate appreciates when the interest rate is raised, causing the J-curve to move upside down. The effect is not unique to Sweden, see Camacho and Lindström (2021), but as value chains have become more globalised, the relationship has become weaker in recent years, see Frohm (2018).

[51] Correlations between GDP growth rates and different components of GDP are typically strongest at around the same time.

Figure 5. Effects of an increase in the policy rate on GDP components



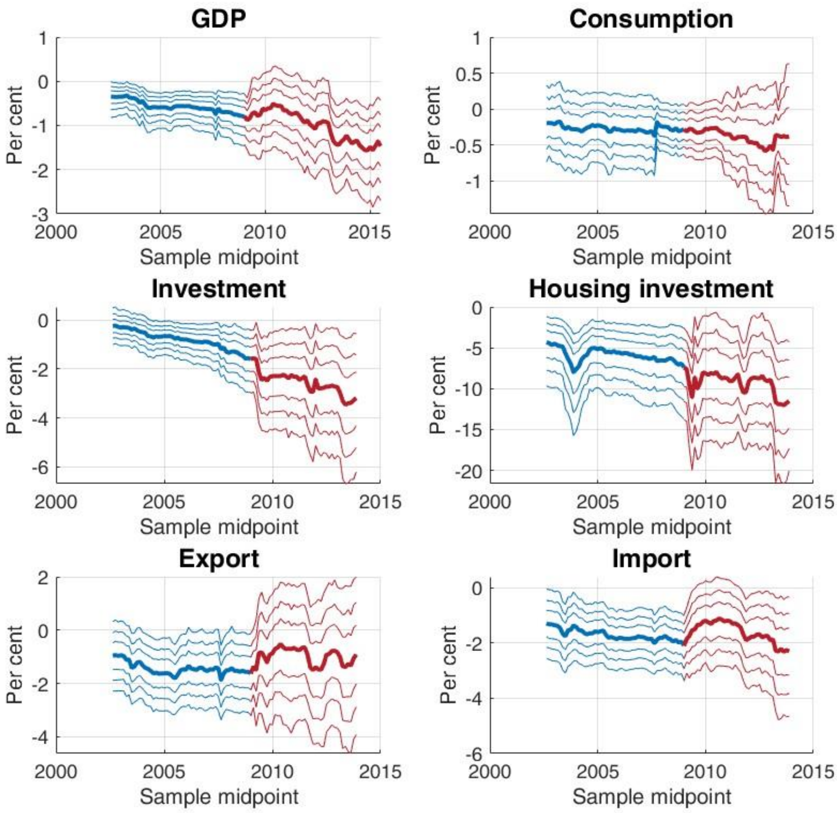
Note. The figure shows the effects of a monetary policy shock from SVAR models where the initial effect on the policy rate has been normalised to one percentage point. The models are estimated for the period 1995Q1-2022Q4 for all variables. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the response and the blue line shows the median response (50th percentile). The model with consumption has also been estimated for the period 1995Q1-2019Q4, see light blue line.

In Figure 2 in Chapter 3, we saw that the effects of a change in interest rates on GDP have become larger over time. In Figure 6 we show how the maximum effects of the GDP components have changed over time. We see that this is mainly related to a larger effect on housing investment. The effect on housing investment has roughly doubled from around -5 per cent in the early samples to around -10 per cent in the samples that put most weight on later data. The effects on consumption also appear to have increased somewhat over time. However, we note that neither the changes in the effects on housing investment nor consumption are statistically significant. The effect of a change in interest rates on non-housing investment has declined over time, and according to our estimates, the effects are virtually non-existent for later samples (not shown here).

The fact that the effects of monetary policy on consumption and housing investment, and hence GDP, have increased over time is in line with the predictions of general equilibrium models with housing and indebted households. For example, higher indebtedness means that households' interest expenditure, and thus their consumption, become more sensitive to a given change in the loan rate.[52]

[52] See Chen et al. (2023), Di Casola and Iversen (2019) and Finocchiaro et al. (2016) for comparisons of the effects of monetary policy with different debt levels in general equilibrium models with housing and indebted households. In these articles, the effects of policy rate changes are calculated with different assumptions about household debt levels in steady state. For example, different debt levels can be calibrated by assuming different loan-to-value (LTV) ratios for household mortgages. All three articles show that the effects of monetary policy on consumption become greater with higher debt and Chen et al. (2023) also shows that the impact on housing investment will be larger.

Figure 6. Maximum effects of an increase in the policy rate on GDP components estimated for different samples



Note. BVAR models with the different variables in the figure are estimated for different samples and the figure shows how the maximum effect on different variables has changed over time. The 5th, 15th, 25th, 50th (median, in bold), 75th, 85th and 95th percentiles of the maximum effect distribution are shown. The initial effect on the policy rate is normalised to one percentage point in all estimates. All variables are in level. The model is first estimated with a start period of 1995Q1 and an end period varying from 2010Q1 to 2022Q4 (expanding sample), see blue lines. The model is then estimated with the start period moved forward, 1995Q1 to 2008Q1 and the end period 2022Q4 (shrinking sample), see red lines. The x-axis shows the midpoint of the sample period.

The impact of monetary policy on the different components of GDP - the relative quantitative contributions of the different components to GDP - is an issue that appears to have received rather limited attention in the research literature.[53] We compare the estimated effects with those in three general equilibrium models estimated

[53] Angeloni et al. (2003) estimate the effects of monetary policy for the US (1960-2001) and the euro area (1970-2000) with, among other things, VAR models and show that private sector demand in the US is relatively affected quite considerably by consumption, while it is affected more by investment in the euro area. They refer to this difference as the 'output composition puzzle'. Lindé (2003b) shows that in a general equilibrium model these differences can be explained by parameters governing adjustment costs for investment and capacity utilisation and households' consumption habits. For example, the effect on consumption in the euro area is relatively smaller in relation to investment, as the habit persistence of consumption is greater there than in the US.

on Swedish data used by the Riksbank over the past 20 years, as responses of the various components of GDP to a monetary policy shock are available for these models. The three models are Ramses 1, Ramses 2 and MAJA. The effect of a monetary policy shock on GDP is quite similar in these models and somewhat smaller than in our BVAR model. In all three models, the effect on consumption is about the same size as the effect on GDP, while the consumption effect in the BVAR model is instead about half the size of the GDP effect. However, the effect on investment relative to the effect on consumption (or GDP) is quite different in the three models. Overall, the effects on consumption, investment and GDP in MAJA are most in line with those in the BVAR model. An important explanation is probably that MAJA is estimated on approximately the same sample period as the BVAR model. But the large differences in the responses for investment in the three models cannot be explained solely by different sample periods - the fact that the effects on investment are significantly larger in Ramses 2 than in the other models is largely due to the fact that it contains financial frictions.

Our estimates imply that the effects of monetary policy via housing investment are an important channel for the effects on GDP. The relatively large effects of an interest rate increase on housing investment is in line with estimates for the euro area, the US and Canada.[54] But our estimated effects are significantly larger than those in a general equilibrium model with a housing sector estimated on Swedish data.[55]

Our estimated effects on consumption are significantly smaller than in two relatively recent studies on Swedish data. We have examined the differences and found that the consumption effects are sensitive to relatively small differences in the choice of sample period.[56] If we omit data for 1995 and/or data from 2020 onwards, the estimated effects on consumption become larger and more in line with those in Stockhammar et al. (2022). In Figure 6 , for example, we see that the consumption responses estimated on data to 2022Q4 and 2019Q4 are clearly different.[57] But above

[54] Battistini, Chiaie and Gareis (2023) estimate a BVAR model with housing investment for the euro area and the US for the period 1995-2022. A monetary policy shock that raises the policy rate by one percentage point causes housing investment to fall by a maximum of around 5 and 8 per cent respectively, and the maximum effect occurs after 3-4 years. Luciani (2015) estimates a dynamic factor model with 109 variables for the US for the period 1982-2010 and shows that a monetary policy interest rate increase of one percentage point causes housing investment to fall by 8-9 per cent after 4-5 years. Chernis and Luu (2018) use narratively identified monetary policy shocks and direct regression models (local projections) to estimate the effects of monetary policy on, for example, housing investment in Canada during the period 1974-2015. A monetary policy interest rate increase of one percentage point causes housing investment to fall by around 5 per cent and the maximum effect comes within a year.

[55] Walentin (2014) estimates a general equilibrium model with a housing sector where households take on debt to buy a home. The estimated effects of a monetary policy shock on GDP and inflation are roughly in line with those we report, but the effect on housing investment is much smaller. A policy rate increase of one percentage point causes housing investment to fall by about 1.5 per cent,

[56] When we include dummy variables in the same way as for the baseline model, the results are not affected in any notable way than the one presented in the estimation of consumption in Figure 5. If we include two dummy variables (2020Q1 and 2020Q2), the result for consumption is similar to the one when the model is estimated up to 2019Q4 (see light blue line in Figure 5). If we include a dummy variable for the whole period from 2020Q1 onwards, we see no visible impact compared to the run without dummy variables.

[57] Stockhammar et al. (2022) estimates the effects of a monetary policy rate increase with structural BVAR models estimated at different sub-periods during the period 1996Q1-2019Q4. The estimated consumption effect for the whole sample is -0.6 per cent. Di Casola (2023) estimates the effects of a shock to the shadow rate (identified by zero and sign restrictions) with structural BVAR models for 19 countries over the period

all, the picture of the consumption effects becoming larger over time becomes clearer if we let the shrinking samples end in 2019 instead of 2022, see Figure 6.

4.3 Labour market

We start from the baseline model described in Section 2.1. We then add the following variables to the model, one at a time: hours worked, employment, average hours worked, labour force and labour productivity. All variables are in level and log-transformed and we assume that a monetary policy shock cannot affect them in the same quarter as the interest rate is raised.

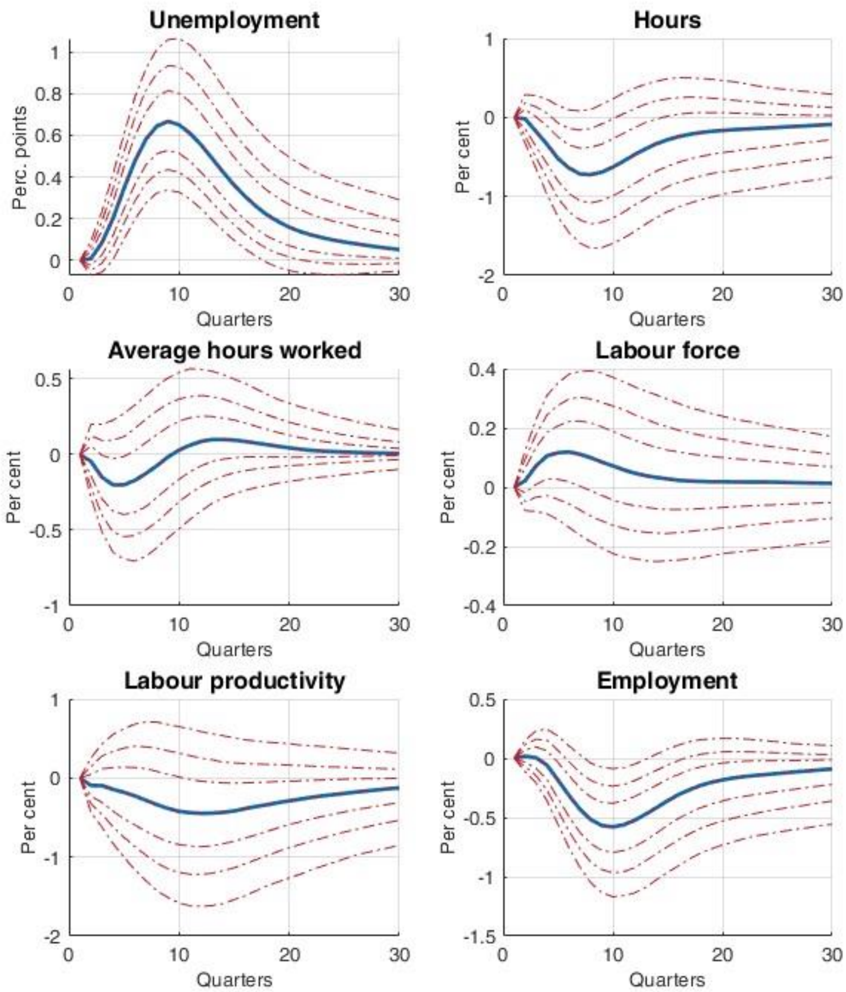
Figure 7 shows the effects of monetary policy on the various labour market variables when the model is estimated for the period 1995Q1-2022Q4. In all cases, the policy rate is assumed to be raised by one percentage point initially.[58] We see there that the effects on employment (maximum effect -0.7 per cent) and hours (-0.6) are approximately equal in size so that the effect on the ratio between these two variables, average hours worked (-0.2), is limited and, above all, not significantly different from zero. This means that monetary policy mainly affects labour input via the so-called extensive margin. We further see that the maximum effect on hours comes after 8 quarters and on employment after 10 quarters. Businesses thus respond to lower demand by first reducing the number of hours per employee and somewhat later by reducing the number of staff. Furthermore, the maximum effect on hours is about the same as the effect on GDP and the effect on the ratio between these variables, labour productivity, should therefore be limited. When we estimate the effect on this variable directly, the effect is surprisingly large (the maximum effect is -0.4) but we also note that it is not significantly different from zero. The effect on the labour force is small and not significantly different from zero. We also note that the effects on unemployment, employment and hours worked are much more persistent than the effects on GDP.[59]

1995Q1-2022Q1. She finds that a shock that raises the shadow rate by one percentage point reduces consumption by almost 2 per cent but also has much larger effects on household debt than we get, which may explain the large differences.

[58] We note that the response for the policy rate differs slightly in the different estimates. However, these differences are so small that they do not affect the analysis in any significant way.

[59] The effects on GDP have largely faded after 5 years (20 quarters), while at least ¼ of the maximum effect remains for these three labour market variables.

Figure 7. Effects of an increase in the policy rate on labour market variables



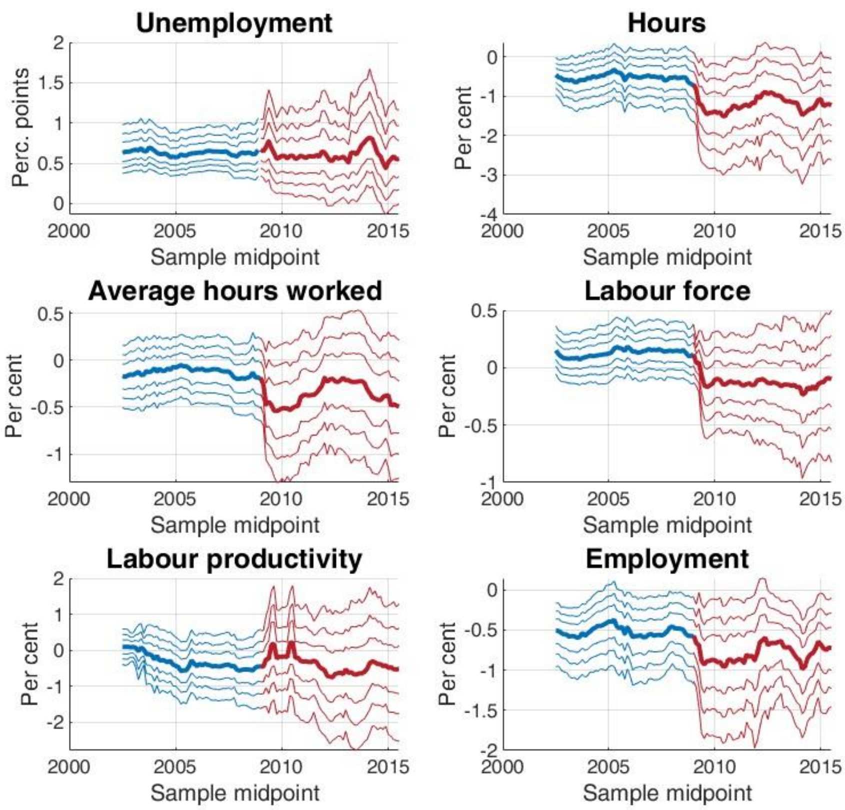
Note. The figure shows the effects of a monetary policy shock from SVAR models where the initial effect on the policy rate has been normalised to one percentage point. The model is estimated for the period 1995Q1-2022Q4 for all variables. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the response and the blue line shows the median response (50th percentile).

In Figure 8 we show how the maximum effects on the labour market variables have changed over time. In Figure 2 we saw that the effects of an interest rate adjustment on GDP have become larger over time, and in Section 4.2 we linked this to larger effects on housing investment and consumption. We see that the effects on hours and employment also seem to have become larger over time, which is in line with what we observe for GDP. But these changes can hardly be said to be statistically significant.[60] For average hours worked and labour productivity, we see no clear changes in

[60] The steep initial drop in the red line for many of the labour market variables in Figure 8 can also be interpreted as the estimates being sensitive to the inclusion of data for the beginning of the sample period, especially data for 1995.

the maximum effects over time. The effect on the labour force changes sign from positive to negative as we put more weight on more recent data. On the one hand, the effect is not statistically different from zero, but on the other hand, there is a high probability that the effect has changed over time.

Figure 8. Maximum effects of an increase in the policy rate on labour market variables estimated for different samples



Note. BVAR models with the different variables in the figure are estimated for different samples and the figure shows how the maximum effect on different variables has changed over time. The 5th, 15th, 25th, 50th (median, in bold), 75th, 85th and 95th percentiles of the maximum effect distribution are shown. The initial effect on the policy rate is normalised to one percentage point in all estimates. All variables are in level. The model is first estimated with a start period of 1995Q1 and an end period varying from 2010Q1 to 2022Q4 (expanding sample), see blue lines. The model is then estimated with the start period moved forward, 1995Q1 to 2008Q1 and the end period 2022Q4 (shrinking sample), see red lines. The x-axis shows the midpoint of the sample period.

Our estimated effects of monetary policy on labour market variables can be summarised by saying that monetary policy affects the number of hours worked via employment (the extensive margin), and that the effect on the labour force is relatively small and statistically insignificant. The effect on labour productivity is negative but not statistically significantly different from zero. These observations are essentially in line with the effects in the general equilibrium models used by the Riksbank. MAJA, for example, ignores the effects of monetary policy on average hours worked (the intensive margin) and the effects on labour productivity are limited.

Studies using US data have found that an increase in the policy rate has a significant negative effect on the labour force.[61] For Sweden, we note that the effect may have changed sign from positive (countercyclical) to negative (pro-cyclical) but, more importantly, that it is not statistically significantly different from zero. Thus, in contrast to the evidence for the US, we find no evidence that monetary policy has important effects on the labour force.

4.4 Prices

In this chapter we analyse the impact of monetary policy on inflation and its various components. Above, we have documented that an interest rate increase causes CPIF inflation to fall, that this effect is statistically significant and that it has also been relatively stable over time.

In Figure 9, we show the effects of a monetary policy shock that raises the policy rate by one percentage point initially for various measures of inflation and components of the CPI (where all variables are in annual percentage change). We add the different variables one by one to the baseline model and estimate the effects for each variable.

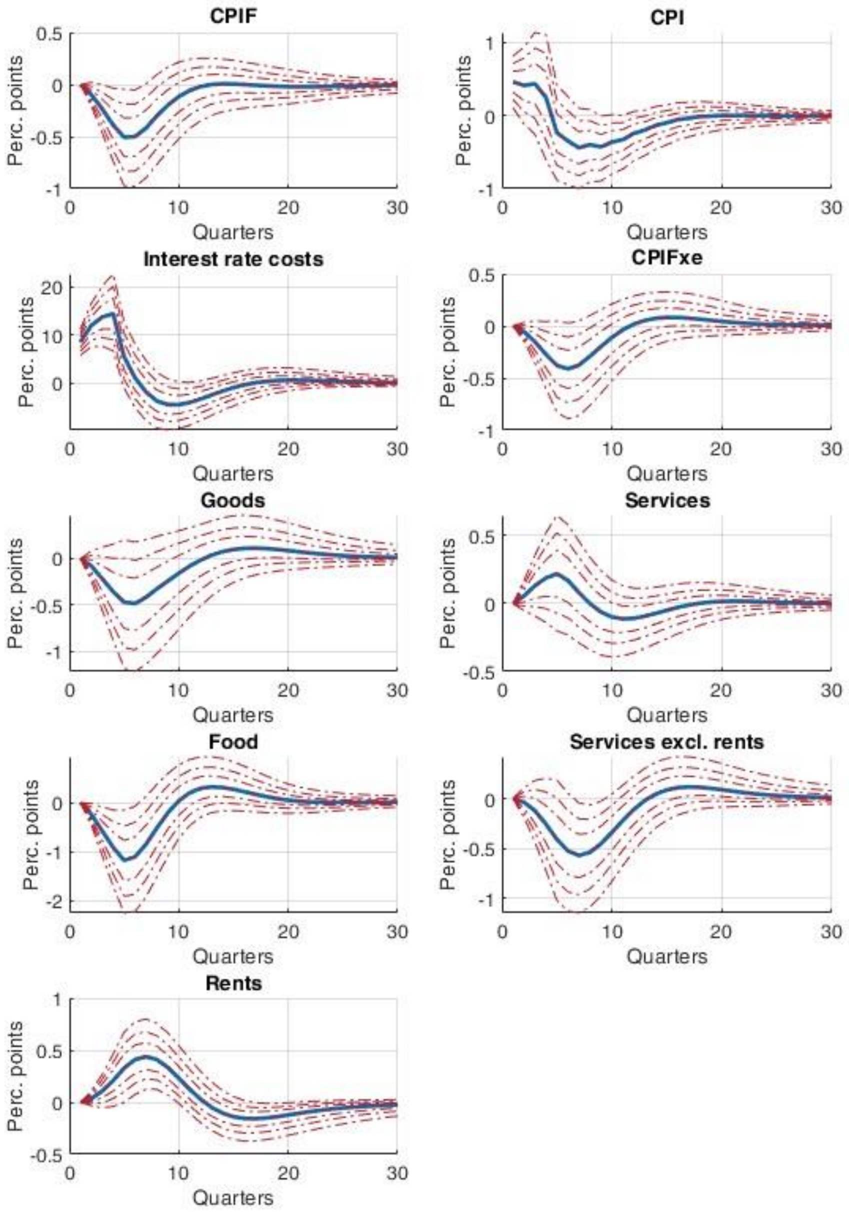
In 2017, the Riksbank changed its target variable from CPI to CPIF. One reason was that changes in the policy rate, via effects on household mortgage rates, affect the CPI in the "wrong direction". In the CPIF, household mortgage rates are instead kept constant. We see in the figure that an increase in the policy rate causes housing costs for owner-occupied homes in the CPI to rise initially, which in turn causes CPI inflation to rise. As policy rate changes have a rapid pass-through to mortgage rates, we allow the policy rate to affect CPI inflation in the same quarter.[62] However, the positive effect on CPI inflation fades and the 2-year response is in line with that of CPIF inflation. The effect on CPIF-XE inflation is also similar to that for CPIF inflation, and the effect on the energy component of the CPI is not significantly different from zero in our estimates (not shown here).[63]

[61] Christiano et al. (2021) estimate a 14-variable VAR model on US data for the period 1951-2008 and find that a monetary policy shock that raises the interest rate has a negative impact on the labour force and the effect is statistically significantly different from zero. Graves et al. (2023) identify monetary policy shocks with high-frequency data for the US and estimates the effects of monetary policy with a six-variable VAR model. A monetary policy shock that raises the 2-year government bond yield leads to a fall in labour force participation.

[62] If we instead assume that CPI inflation is not affected in the same quarter by the interest rate increase, the response is very similar to that for CPIF inflation. But this assumption is not realistic because mortgage rates are affected quickly when the policy rate is adjusted.

[63] We find that the effect on the change in the energy component of the CPI is close to zero and statistically insignificant under two different identification assumptions, i.e. with and without a zero contemporaneous restriction on the effect (these estimates are not shown here).

Figure 9. Effects of an increase in the policy rate on different measures of inflation and components of the CPI



Note. The figure shows the effects of a monetary policy shock from SVAR models where the initial effect on the policy rate has been normalised to one percentage point. The model is estimated for the period 1995Q1-2022Q4 for all variables. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the response and the blue line shows the median response (50th percentile).

We then study the effects on different components of the CPI. We see that price changes for goods and food fall when the interest rate is raised, while services price inflation initially rises. However, for services in the CPI, we have noted that the estimated effects are not robust when we use different sets of inflation variables in the model simultaneously. But the effects become more robust and easier to understand when we exclude rents from services and estimate the effects on services excluding rents and rents separately. We see that a higher interest rate causes rents to rise and the price change for services excluding rents to fall.[64] Rents increase because housing companies' interest costs rise and these costs are to some extent passed on to tenants (a type of cost channel). Rising mortgage rates also causes the cost of owning a home to increase, which leads to a rise in relative demand for rented accommodation, and thus also in rents.

Overall, we see that the maximum effects of an interest rate increase on CPIF inflation and CPIF-XE inflation and on price changes for goods and services excluding rents are fairly similar.[65] We see that the maximum effects for goods and food occur earlier (after about one year) than for services excluding rents (about 2 years), which may be due, among other things, to the fact that the impact via the exchange rate channel is greater for the former two groups.[66]

The effects of monetary policy on rents appears to be an issue that has received limited attention in the research literature. Laséen and Nilsson (2024) find a positive but insignificant effect of a monetary policy rate increase on rents after one year. Our results are in line with a study on US data showing that rent inflation rises when monetary policy is tightened. For US data, this may explain a large part of the so-called price puzzle, i.e. the observation that inflation is influenced in the "wrong direction".[67]

4.5 House prices and debt

The rapid increases in house prices and debt in many countries, including Sweden, in recent decades and the global financial crisis of 2007-09 raised the question of how monetary policy should respond to the build-up of financial imbalances. In Sweden, the discussion was most intense in the years following the financial crisis when the Riksbank raised the policy rate. The emphasis that monetary policy places on such imbalances, such as rapidly growing household debt, in addition to resource utilisation and inflation, has come to be known as "leaning against the wind". Such a policy could reduce the risk of a financial crisis and thus lead to better realisation of inflation and resource utilisation objectives in the longer term. A fundamental condition for such a

[64] We have obtained similar results when we exclude foreign travel from the services in addition to rents. The effect for services excluding rents and international travel is therefore not shown here.

[65] The fact that goods prices are affected more than services prices by a monetary policy interest rate change is also one of the main conclusions in Laséen and Nilsson (2024), but in our case it is thus mainly due to the effect on rents.

[66] For goods and food, we get a large negative effect initially on the quarterly change if we allow for this but thereafter the response is similar to that shown in Figure 9.

[67] Dias and Duarte (2019) estimate the effects of monetary policy on house prices and rents with a proxy-SVAR model and data for a small number of macroeconomic variables for the US over the period 1983-2017.

policy to be meaningful is that monetary policy has the intended effect on debt.[68] And given the close link between developments in house prices and debt, it is reasonable to believe that the effects of monetary policy on these two variables are to some extent related.[69]

Here we estimate a model that includes house prices and household debt in addition to the variables in the baseline model. Both variables are deflated by the CPIF and log-transformed. The model is thus similar to the one used by Laséen and Strid (2013) to study the effects of monetary policy on household debt. We also estimate a variant of the model in which the debt ratio, i.e. debt as a percentage of GDP, is included instead of real debt.[70] We estimate the models for different sample periods in order to study how the effects of monetary policy on the two variables have changed over time.

Figure 10 shows the effects on real house prices and real household debt when the policy rate is raised by one percentage point. When the model is estimated for the period 1995Q1-2022Q4, the maximum effects for both variables are -1.7 per cent and they come after about two years for house prices and somewhat later for debt. The maximum effect on the debt-to-GDP ratio is -1.8 per cent and occurs only after about four years. We also note that the effect on debt is very persistent. This is because the impact on the debt stock is gradual over a longer period, as new lending represents a limited share of total debt.[71]

We then estimate the model for different sample periods to study how the effects have changed over time. We see that the estimated maximum effects on house prices and real debt become larger when data for the later part of the inflation-targeting period are given more weight. For example, if the model is estimated on data after the turn of the millennium, i.e. the years 2000-2022, the maximum effects are approximately -2.5 per cent for the two variables (the midpoint of the sample period shown on the x-axis is then 2011). The Riksbank has previously reported effects on real household debt in the order of -1 per cent based on estimates with a similar model on data up to 2013. Our estimate of the effect for the period 1995-2013 is -0.8 (the midpoint of this sample is 2004) and is thus well in line with the previous estimate, although the model specification differs slightly. The effects on house prices and the debt ratio are also in line with the previous study.[72] The maximum effects on the debt

[68] The monetary policy trade-off with regard to household debt is discussed in Sveriges Riksbank (2013) and the effects of monetary policy on household debt are discussed in Sveriges Riksbank (2014). In this framework, monetary policy affects debt, which in turn affects the likelihood of a crisis and the economic consequences of a crisis.

[69] A simple conceptual model describing the relationship between house prices and household mortgage debt is presented by Svensson (2013).

[70] We choose to estimate the effect on the debt ratio directly instead of deriving it from the effects on GDP and real debt because these two variables are deflated by the GDP deflator and the CPIF, respectively.

[71] See Svensson (2013) for a simple model in which the turnover rate on the housing market determines how quickly monetary policy affects the mortgage stock. This model may provide a partial explanation for the persistent effects of monetary policy on debt.

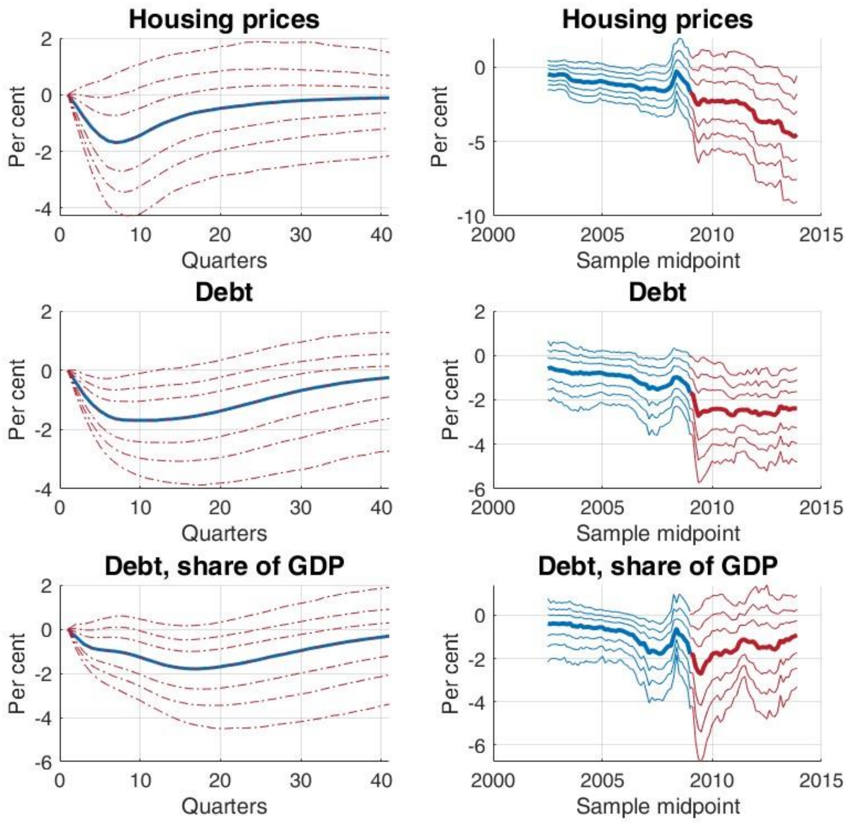
[72] Effects on house prices and debt were estimated with a BVAR model by Laséen and Strid (2013) (and the effect on debt was also reported in Sveriges Riksbank (2014)). The maximum effect on real house prices in this study is -1.1 per cent, which is fully in line with our updated estimate for the sample period 1995-2013. The maximum effect on the debt ratio is -0.5 per cent for this sample period, which is slightly lower than in

ratio appear to have been more stable over time, with maximum effects ranging from around -1 to -2 per cent for samples based on more recent data. The relatively stable effect on the debt ratio over time is in line with the increase in the effects on both real debt and GDP over time.

Figure 10 also shows probability ranges for effects of size 50, 70 and 90 per cent respectively. The probability that an increase in the policy rate will lead to lower real debt is about the same as when the corresponding analysis was conducted 10 years ago, around 95 per cent. The probability that an increase in the policy rate will lead to a lower debt ratio has been around 85 per cent when the model is estimated with more recent data (see the red line), but for the 1995-2022 estimate this probability, too, is around 95 per cent. All in all, the probability that an interest rate increase will lead to lower real indebtedness and a lower debt ratio is thus high.

Laséen and Strid (2013). The main difference between the two models is that we include the real exchange rate in our model. Differences in the estimates could also be due to our use of data from different points in time (different vintages).

Figure 10. Effects of an increase in the policy rate on house prices and debt



Note. The charts in the left-hand column show the effects of a monetary policy shock from SVAR models in which the initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the response and the blue line shows the median response (50th percentile). In the right-hand column, the model is estimated with the same variables as on the left, for different samples, and the charts show how the maximum effects change over time. The model is first estimated with a start period of 1995Q1 and an end period varying from 2010Q1 to 2022Q4 (expanding sample), see blue lines. The model is then estimated with the start period moved forward, 1995Q1 to 2008Q1 and the end period 2022Q4 (shrinking sample), see red lines. The x-axis shows the midpoint of the sample period.

Our estimated effects of monetary policy on real house prices are smaller than those reported in the *Riksbank's commission of inquiry into risks in the Swedish housing market* (RUTH) in 2011. This commission of inquiry reported effects on real house prices with a general equilibrium model and a BVAR model of -2 to -5 per cent when the policy rate is raised by one percentage point. In addition to the sample period being different from our estimates, the assumptions in the BVAR models differ in several respects.[73] However, these effects are more in line with those we obtain when we estimate the model with greater weight on more recent data. Our impression is that there is considerable uncertainty about the effects of monetary policy on house prices in international studies.[74]

As regards the effects of monetary policy on real debt and the debt ratio, Svensson (2013, 2017) has argued that the effects are probably small, and that a rate increase could even have positive effects on both variables. However, this argument is largely based on a model that cannot capture the short-term dynamics of debt, such as housing equity withdrawals.[75] Our results thus show instead that real debt is very likely to decrease when the policy rate is raised. In addition, the effect on real debt is likely to have increased over time. Furthermore, our estimated effects on real debt are well in line with the results of a number of international studies.[76]

5 Concluding discussion

In this staff memo, we have estimated the effects of monetary policy in Sweden during the period 1995-2022 with structural VAR models and recursiveness assumptions. Our estimated effects of an unexpected change in the policy rate on GDP are larger than in previous comparable research studies, which is probably because these effects have become larger over time. The estimated effects on inflation are broadly in line with, or possibly slightly larger than, those in previous studies. The ratio between the effects on the two variables (sacrifice ratio) is also roughly in line with previous studies. Our calculations are relatively insensitive to a range of alternative assumptions regarding the specification of the SVAR model.

Our estimates of how the effects of monetary policy have changed over time fit well into a narrative of increased debt in Sweden and a more interest-rate sensitive economy. Compared with previous studies, which have mainly focused on the increased interest-rate sensitivity of household consumption, we show how the effects on a larger number of variables have changed over time.[77] For example, we show that the effects on housing investment, and hence GDP, as well as house prices and household debt are likely to have increased over time. These changes are broadly in line with the predictions in structural economic models for how the effects of monetary policy change when the level of debt in the economy increases. However, an important difference compared with the predictions in these models is that we do not find support for the fact that the effects on inflation have also become larger over time.[78] This

[73] See Claussen et al. (2011). Their BVAR model differs from ours in several respects, including the variables included, variable transformations and lag length.

[74] See for example the summaries of effects in Claussen et al. (2011) or Robstad (2018).

[75] See Svensson (2013) and the discussion in Laséen and Strid (2013).

[76] See, for example, Robstad (2018), who summarised the effects on real debt in a number of international studies.

[77] See, for example, Stockhammar et al. (2022) for a study focusing on how the effects of monetary policy on household consumption have changed over time.

[78] See Chen et al. (2023), Di Casola and Iversen (2019) and Finocchiaro et al. (2016) for comparisons of the effects of monetary policy with different debt levels in general equilibrium models.

could indicate that companies' pricing has become less sensitive to changes in resource utilisation and costs, i.e. that the Phillips curve has simultaneously become flatter.[79] However, we note that the discussion in the wake of the surge in inflation in 2022 has been more about the fact that companies have raised their prices more than usual relative to how costs have developed.[80] However, this relates to a very short sub-period of the inflation-targeting period and has thus had no discernible impact on our estimates.

The Riksbank has previously drawn the conclusion that higher interest-rate sensitivity means that the policy rate does not need to be raised as much as before to obtain the same tightening effect on the economy.[81] This conclusion is based on the assumption that a more interest rate-sensitive real economy also means that changes in the policy rate have a greater effect on inflation than before. But if it is the case that the effects on resource utilisation have become greater over time while the effects on inflation have been stable, the impact of increased interest-rate sensitivity on monetary policy will depend on the importance a policy maker attaches to stabilising resource utilisation and inflation respectively. If the policy maker focuses only on stabilising inflation (strict inflation targeting), the policy rate changes required to stabilise inflation are roughly the same as before, and one consequence is that the variations in resource utilisation will probably be greater than before. If the policy maker also attaches some importance to stabilising resource utilisation (flexible inflation targeting), the policy rate changes will be smaller than before and one consequence will be that the average deviation of inflation from the target will probably be somewhat larger than before.[82]

Finally, we emphasise that estimates of the effects of monetary policy are uncertain. Our calculations should therefore be compared with the results of research studies that use other methods to identify the effects of monetary policy, in order to provide a broader picture of model uncertainty.

[79] An alternative explanation for a flatter Phillips curve is that inflation expectations have become more strongly anchored to the inflation target. However, as long-term inflation expectations have been well anchored for most of the period, this is an explanation that can only apply at the beginning of the period, i.e. in the late 1990s. However, there is no clear empirical support that simple (bivariate) specifications of the Phillips curve in Sweden have become flatter during the inflation-targeting period, see for example Sveriges Riksbank (2018) and Karlsson and Österholm (2019).

[80] See, for example, Sveriges Riksbank (2022b).

[81] See Sveriges Riksbank (2022a).

[82] If the policy maker is only concerned with stabilising inflation (strict inflation targeting), monetary policy is not affected by an increased interest-rate sensitivity to real variables. If the policy maker instead places great emphasis on stabilising the real economy, the increased interest-rate sensitivity means that the policy rate does not need to be adjusted as much as before.

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APPENDIX

A. Data

The variables used in the models and how they have been transformed are shown below in Table 2. CA stands for calendar adjusted, SA stands for seasonally adjusted, ln stands for the natural logarithm and d ln stands for the first difference of the natural logarithm. Figure 11 shows the transformed variables used in the baseline model.

Table 2. Variables and their transformations

Baseline model	Transformation	Source
KIX GDP, fixed prices, index, CA, SA	ln	Sveriges Riksbank
KIX CPI, index, CA, SA	d ln	Sveriges Riksbank
KIX policy rate	level	Sveriges Riksbank
CPIF index, CA, SA	d ln	Statistics Sweden and the Riksbank
Unemployment, 15-74 years, CA, SA	level	Statistics Sweden and the Riksbank
GDP, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank
Policy rate, effective dates	level	Sveriges Riksbank
SEK/KIX index (real exchange rate)	ln	Sveriges Riksbank

Interest rates in more detail	Transformation	Source
Banks' deposit rate, outstanding agreements, all accounts	level	Statistics Sweden
Three-month mortgage rate, new agreements	level	Statistics Sweden
Lending rate non-financial companies	level	Statistics Sweden
Mortgage rate 5 years, average of five banks, list rate	level	Sveriges Riksbank
STIBOR 3-month, fixing	level	Swedish Financial Benchmark Facility
Yield, 10-year Swedish government bond	level	Macrobond Financial AB

GDP and its components in more detail	Transformation	Source
Household consumption, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank
Total investment, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank
housing investment, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank
Private investment excluding housing investment, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank
Exports of goods and services, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank
Imports of goods and services, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank
Net exports of goods and services, constant prices, CA, SA	ln	Statistics Sweden and the Riksbank

Labour market in more detail	Transfor-mation	Source
Hours worked, 15-74 years, CA, SA	ln	Statistics Sweden and the Riksbank
Average hours worked, 15-74 years, CA, SA	ln	Statistics Sweden and the Riksbank
Labour force, 15-74 years, CA, SA	ln	Statistics Sweden and the Riksbank
Labour productivity per hour worked, CA, SA	ln	Statistics Sweden and the Riksbank
Employment, number, 15-74 years, CA, SA	ln	Statistics Sweden and the Riksbank

Prices in more detail	Transfor-mation	Source
CPI, index, CA, SA	d ln	Statistics Sweden and the Riksbank
CPIF excluding energy, index, CA, SA	d ln	Statistics Sweden and the Riksbank
CPI goods (RB definition), index, SA	d ln	Statistics Sweden and the Riksbank
CPI services (RB definition), index, SA	d ln	Statistics Sweden and the Riksbank
CPI food (RB definition), index, SA	d ln	Statistics Sweden and the Riksbank
CPI, mortgage costs (RB definition), index, SA	d ln	Statistics Sweden and the Riksbank
CPI rents (RB definition), SA	d ln	Statistics Sweden and the Riksbank
CPI services excluding rents (RB definition), index, SA	d ln	Statistics Sweden and the Riksbank

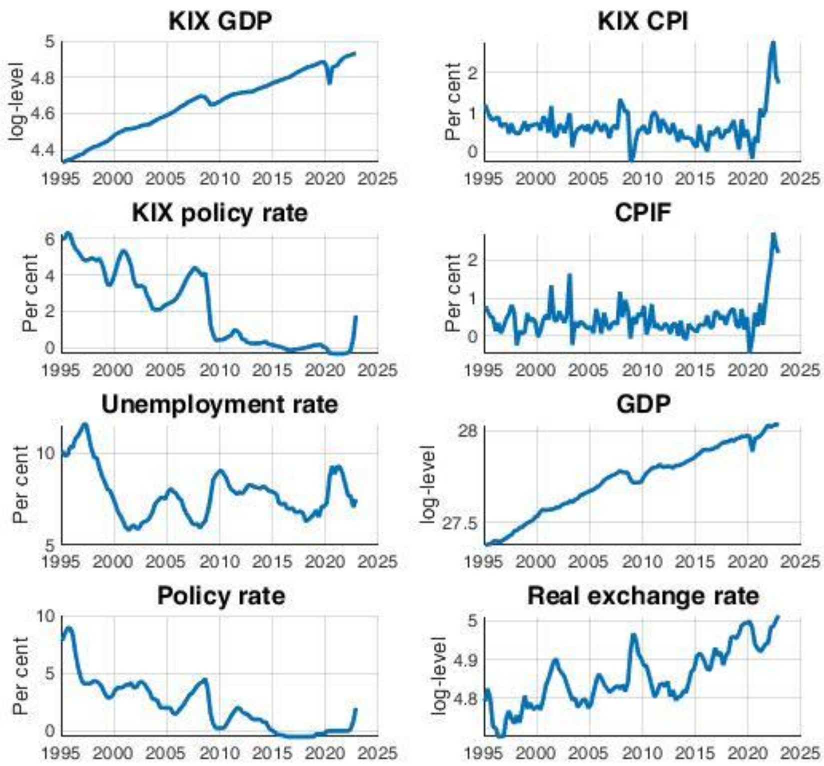
House prices and debt in more detail	Transfor-mation	Source
Real house prices, index*	ln	Statistics Sweden and the Riksbank
Real household debt stock*	ln	Statistics Sweden and the Riksbank
Household debt, share of GDP	ln	Statistics Sweden and the Riksbank

*Deflated with CPIF

Model with monthly data	Transfor-mation	Source
Industrial production euro area, index, CA, SA	ln	Eurostat
Industrial production US, index, CA, SA	ln	Federal Reserve
HICP euro area, index, CA, SA	d ln	Eurostat
CPI US, index, SA	d ln	U.S. Bureau of Labor Statistics (BLS)
Policy rate for the euro area, effective dates*	level	European Central Bank
Federal Funds rate, effective dates	level	Federal Reserve
CPIF, index, SA	d ln	Statistics Sweden and the Riksbank
Unemployment, 15-74 years, CA, SA	level	Statistics Sweden and the Riksbank
GDP indicator, index, SA	ln	Statistics Sweden
Policy rate, effective dates	level	Sveriges Riksbank
SEK per EUR	ln	Sveriges Riksbank
SEK per USD	ln	Sveriges Riksbank

* European Central Bank deposit rate

Figure 11. Variables in the baseline model



Note. KIX-GDP, GDP and real exchange rate are shown in log level. The KIX CPI and CPIF are shown in quarterly change.

B. The model

The VAR model is given by

$$(1) \qquad x_t = \sum_{k=1}^{K} \Pi_k x_{t-k} + \phi d_t + A\varepsilon_t \qquad t = 1, \dots, T,$$

where x_t is a vector (of dimension p) containing the variables of the model, Π_k, $\mathrm{k} = 1, \dots, \mathrm{K}$, are $(p \times p)$ matrices containing the dynamic parameters of the model and d_t is a vector containing deterministic variables (trends and dummy variables). The structural shocks ε_t (dimension p) are assumed to be independent $\varepsilon_t \sim N(0, I_p)$ and $u_t = A\varepsilon_t \sim N(0, \Sigma)$ where the covariance matrix is given by $\Sigma = AA^T$, where A is the lower triangular Cholesky factor. For a parameterisation of the model (a draw from the posterior distribution of Π_k, $\mathrm{k} = 1, \dots, \mathrm{K}$, ϕ and Σ), we compute A and simulate the response to a monetary policy shock. For example, in the baseline model we have $p = 8$ variables, $K = 4$ lags and the deterministic component consists only of an intercept, $d_t = 1$.

We estimate the model with Bayesian methods, which means that we combine a prior distribution for the model's parameters with a likelihood function and simulate draws from the posterior distribution, see for example Karlsson (2012) for a description of these methods for VAR models. We use a so-called normal-diffuse prior distribution for the dynamic parameters Π_k, $\mathrm{k} = 1, \dots, \mathrm{K}$, and ϕ and the covariance matrix Σ. . With this prior, the conditional posterior distributions are available (normal for the dynamic parameters and inverse Wishart for the covariance matrix) and a Gibbs sampler can be used to sample (or draw) from the posterior distribution. . In each model estimation, we draw $R = 5000$ parameter vectors from the posterior distribution and, based on these, construct the probability distribution of the impulse responses to a monetary policy shock. Furthermore, the prior distribution for the dynamic parameters is a so-called Minnesota prior, which means that the coefficients in the matrices Π_k are normally distributed with mean and variance controlled by a number of hyperparameters. We let these hyperparameters assume normal values: $\lambda_1 = 0.2$ (overall tightness), $\lambda_2 = 0.5$ (cross-equation tightness), $\lambda_3 = 1$ (lag length decay) and $\lambda_4 = 0.001$ (exogeneity tightness). We use the hyperparameter λ_4 to impose the restriction that the parameters of the Swedish variables in the equations for the foreign variables are (very close to) zero, so that the foreign variables are effectively exogenous. [83] The prior means of all parameters except for the first eigenlag (i.e. the diagonal elements of the matrix Π_1) are assumed to be zero. For the first eigenlag, we assume mean values of 0.5 and 0.7 for less (e.g. inflation) and more (e.g. GDP) persistent variables, respectively.[84]

The model is implemented in a Matlab programme developed by Mattias Villani - Bayes VAR - and we use a slightly modified version of this programme for all calculations in the article.

C. Are the changes in the effects over time statistically significant?

In Figure 2 in the main text, we show how the maximum (peak) effects on the various variables of a monetary policy shock that raises the policy rate by one percentage point have changed over time. The figure shows the 5th, 12.5th, 25th, 50th (median), 75th, 87.5th and 95th percentiles for the probability distribution of the maximum effect estimated on different samples. In the main text, we conclude that there is a low probability that the effects on inflation and unemployment have changed over time, while there is a high probability that the effects on GDP and the real exchange rate have changed.

We draw these conclusions from approximate probability calculations based on a number of simplifying assumptions. For example, we can compare the estimated effects for the oldest sample, 1995Q1-2009Q4, with the most recent, 2008Q1-2022Q4. For GDP, we can then discern maximum effects that are -0.35 and -1.47 (referring to the median effects). We approximate the distribution of the maximum effect with a

[83] See, for example, Karlsson (2013) for the derivation of the posterior distribution with this prior and for further details on the Minnesota prior.

[84] For the baseline model, we have also tested the value of 1 (i.e. an assumption of a random walk) for the eigenlag for GDP in Sweden and abroad and the real exchange rate and allowed for non-stationary parameter draws. However, this does not affect the estimation results to any great extent.

normal distribution and obtain the distributions N(-0.35,0.22) and N(-1.47,0.64), respectively, where we specify the mean and standard deviation of the distribution. We then calculate the probability that the difference between two independent normally distributed random variables with these parameters is less than zero. We then get a probability that is approximately 95 per cent - the probability that the effect on GDP has become greater over time (in absolute terms) can, on this basis, be said to be high and the difference in the maximum effects estimated with older and newer data can, in this sense, be said to be “significantly different from zero”. A similar calculation shows that the probability that the effect on the real exchange rate has increased over time is also high. For inflation (or unemployment), it is easy to realise (without having to do the calculation) that the corresponding probability is close to 50 per cent because the estimated median effect has not changed much over time.

D. Estimates with alternative assumptions

Here we briefly discuss the results of estimations of different variants of the baseline model. An important part of our study is to shed light on how different assumptions affect the estimated effects, partly to justify the assumptions we made in the baseline model, and partly to know how robust the results are to other assumptions. We start from the baseline model and make one change at a time and study how this affects the estimated effects of monetary policy. Many of these experiments highlight model uncertainty.

Trends and transformations

Difference specification

It is common to estimate VAR models both in log levels (as we do in the baseline model for GDP abroad and in Sweden and the real exchange rate), differences or in log levels and (explicitly) impose assumptions about co-integration between the variables in the model (assumptions about the number of co-integrated relationships and co-integration vectors). The latter option involves estimating a vector error correction model (VECM) and is sometimes called a "pre-testing approach". The pros and cons of the different approaches to estimating impulse responses are not fully understood, but estimating the model in levels, and without adding co-integration relationships, appears to be a more robust option than the other alternatives.[85]

We estimate the model with foreign GDP and in Sweden and/or the real exchange rate in quarterly change (i.e. in first differences) instead of in level as in the baseline model and identify the monetary policy shock in the same way with the recursiveness

[85] Sims, Stock and Watson (1990) show that even if the variables in the model are non-stationary or co-integrated, the log-level specification provides consistent parameter estimates. Gospodinov et al. (2013) show that with short-run restrictions, the differences between the impulse responses of the VAR model with and without co-integration restrictions are small. However, they conclude that the log-level specification without co-integration restrictions is the more robust option and that caution should be exercised in using long-run restrictions for the identification of shocks. See also further discussion of these issues in, for example, Kilian and Lütkepohl (2017).

assumption (see Figure 15). The qualitative effects for both variables remain as expected, but a problem with these estimates is that the effects on the levels of the variables in the longer run are clearly different from zero.[86] These estimates are thus not in line with the usual assumption of monetary policy neutrality, i.e. that monetary policy has no (or at least very limited) long-term effects on real variables. This can be seen as an argument in favour of estimating the model with these variables at the same level as in the baseline model, since the neutrality assumption is then met (see Figure 1). If both variables are included in the model at growth rates, restrictions should instead be applied to ensure that their levels are not affected in the long run (so-called long-run restrictions).[87] But this type of identification assumption is beyond the scope of our paper.

We then estimate the model with the CPIF in level and annual change instead of in quarterly change as in the baseline model (see Figure 17). In previous research with Swedish data, it has been pointed out that there has been a time-varying seasonal pattern in various price indices, which argues in favour of using annual change rather than quarterly change when estimating the model. However, we see that the differences in effects for these two options are relatively small and so this no longer appears to be an important issue.[88] However, we see that the differences are greater when the model is estimated with the CPIF in log level (instead of in growth rate). When we estimate the model with the CPIF at the log level, the long-run effect on the price level is zero. The lack of theoretical support for the need for this (i.e. the effect of a monetary policy shock on the price level in the longer term is, like the effect on the nominal exchange rate in the longer run, indeterminate according to standard theory) argues, in our opinion, in favour of estimating the model on the change in the price index.

Deterministic trends

We estimate the model with linear and quadratic trends for GDP abroad and in Sweden and the real exchange rate (see Figure 17).[89] This has very little impact on the estimated effects. For GDP, the maximum effect is slightly affected but the differences are small in light of the uncertainty surrounding the effects (described by the probability intervals for the effects). We also estimate the model with HP-filtered series for

[86] In , the effects on GDP and the real exchange rate are shown in levels, while both variables are thus included in growth rates in the difference specifications.

[87] See, for example, Björnland and Jacobsen (2010) who include GDP, the real exchange rate and real house prices in growth rates in their VAR model so that these variables are stationary and use long-run assumptions for the first two variables so that the neutrality assumption is met. See also Blanchard and Quah (1989) who introduced this identification method by defining a demand shock in a stationary bivariate VAR model of GDP growth and unemployment as a shock that has no permanent effect on the level of GDP. The VECM model offers a more general framework for studying the long-run effects of structural shocks, see for example Englund et al. (1994) or Kilian and Lütkepohl (2017). However, examining these identifying assumptions is beyond the scope of our paper.

[88] Lindé (2003) estimates the effects of a monetary policy shock with a VAR model estimated on Swedish data for the period 1986-2002 and shows that the results differ when inflation is measured in quarterly and annual changes. The reason for this is that the quarterly change contains time-varying seasonal variation that cannot be handled by regular seasonal adjustment.

[89] For a discussion of the drawbacks of using deterministic trends in VAR models, see Kilian and Lütkepohl (2017).

GDP abroad and in Sweden and the real exchange rate. The effects on GDP and the real exchange rate will then be much smaller than in the baseline model, while unemployment and CPIF inflation will not be affected to any great extent (see Figure 17).[90]

Stationarity

In the baseline model (and in the following insets), several variables are included whose time series are not necessarily stationary - for example, GDP and the real exchange rate. This need not pose problems for the estimation of the VAR model (see discussion above), but one way to deal with it is to allow only parameters that imply that the model is stationary.[91] This is our assumption when estimating the baseline model. We have also tested estimating the model without this restriction, i.e. allowing parameters that make the model non-stationary. Less than 2 per cent of the R=5000 simulated parameter vectors from the posterior distribution made the model non-stationary, and whether or not these are used to estimate the effects of a monetary policy shock has no important impact on our results (the effects without the assumption of stationarity are not shown here). Therefore, throughout the study, we choose to use only parameter vectors that imply that the stationarity condition is fulfilled.

Identification assumptions

An important limitation of this staff memo is that we only identify the effects of monetary policy with the so-called recursiveness assumption. Thus, we do not study other identification assumptions that are commonly used in analyses with SVAR models, such as long-run or sign restrictions.

We estimate the model with alternative assumptions for the short-run restrictions, i.e. assumptions about which of the variables are affected contemporaneously by a monetary policy shock (see Figure 18). Alternatively, we can express this as varying the assumption about which variables the central bank responds to contemporaneously in its reaction function.[92] In the baseline model, we assume that the nominal, and thus also the real, exchange rate is affected contemporaneously by a monetary policy shock while other variables are not affected. Here we study two specifications in which the monetary policy shock affects (i) all variables contemporaneously (the policy rate is ordered first among domestic variables) or (ii) no variables other than the policy rate contemporaneously (the policy rate is ordered last among domestic variables).[93] For example, the former assumption is more in line with the Riksbank's

[90] See Hodrick and Prescott (1997). We use the cyclic component obtained with the HP filter. The sensitivity of the trend to short-run fluctuations in the data is controlled by a parameter lambda which we let equal 1600 (a default value with quarterly data). The lower the value of this parameter, the smaller the estimated effects of monetary policy on the cyclical component of GDP. When the parameter assumes a large value, the HP trend moves towards a linear trend.

[91] This means that we only allow parameter values that imply that the roots of the characteristic equation of the VAR model are outside the complex unit circle (see, for example, equation 2.2.5 in Kilian and Lütkepohl (2017)).

[92] See, for example, Rudebusch (1998) for a description of the recursiveness assumption in terms of the reaction function of the central bank.

[93] These two assumptions are discussed, for example, by Ramey (2016), who also provides examples of studies that use each assumption. Since we have four domestic variables in addition to the policy rate, there are 2^4=16 possible ways of ordering the variables (note that it is only the order with respect to the

macroeconomic model MAJA (and similar dynamic general equilibrium models) where all domestic variables are allowed to react in the same period (i.e. the same quarter) to a monetary policy shock. The latter assumption has the advantage of allowing the central bank to react quickly to exchange rate changes.

In both alternative specifications, the qualitative effects on all domestic variables are as expected. For GDP and unemployment, the effects are very similar regardless of the identification assumption. For the real exchange rate and CPIF inflation, the effects are larger when the real exchange rate is allowed to respond contemporaneously. We conclude that it is important that the nominal, and thus also the real, exchange rate is allowed to respond contemporaneously to the policy rate, while the assumptions for the other variables are less important for our estimated effects. Taken together, these results suggest that our zero restrictions on GDP, unemployment and inflation in the baseline model *do not* imply that we substantially underestimate the effects of monetary policy on these variables.[94]

Foreign variables

A minimal VAR model for studying the effects of monetary policy in Sweden could include the policy rate, some measure of resource utilisation and inflation. However, as Swedish variables have strong correlations with foreign variables in the data, it is reasonable to believe that these may be important for the identification of the monetary policy shock. We estimate variants of the baseline model where different variables are excluded (see Figure 19). Excluding the real exchange rate or foreign GDP has a relatively limited impact on the effects of monetary policy on domestic variables. However, excluding foreign inflation or the foreign policy rate (or all three foreign variables) from the model has a greater impact, and in particular on the response for CPIF inflation, which is then given the "wrong" sign.[95] For example, the foreign policy rate appears to be important in capturing the downward trend in interest rates globally during our sample period, and including this variable will therefore be important for the identification of the monetary policy shock. Our overall conclusion from these model comparisons is that it is important to include the foreign variables in the model, as the variation in these variables explains a large part of the variation in the Swedish variables.

policy rate that matters since we only identify one monetary policy shock). Serwa and Wdowiński (2016) suggest that all possible permutations of short-run restrictions should be weighted together to produce an average response, but we consider the three cases we study to be the most interesting.

[94] A zero contemporaneous restriction is a robust way to ensure that GDP falls when the interest rate is raised, see the discussion in Wolf (2020) in relation to the so-called masquerading problem with sign restrictions. However, the zero restriction also means that the short-run effect is underestimated by definition.

[95] Robstad (2018) estimates the effects of monetary policy in Norway with a recursive BVAR model without foreign variables and finds that inflation rises when the interest rate is raised (the price puzzle). He concludes that it may not be possible to identify the monetary policy shock with the Cholesky assumption. But we show that it could instead be a consequence of foreign variables having been omitted (omitted variable problem). The price puzzle is common in studies on US data and one solution proposed is to include a measure of commodity prices in the model in cases where such a variable has been omitted, see Ramey (2016). We have also estimated our model with the oil price in transformation, but this has no major impact on the estimated responses in the baseline model.

The exogeneity of the foreign economy

In our baseline model, we assume that a Swedish monetary policy shock does not affect the foreign variables (so-called block exogeneity), which is a standard assumption for a small open economy like Sweden. We estimate the model without this restriction and find that the qualitative responses are not affected but that the magnitude of the responses for the domestic variables is affected, in particular for GDP and CPIF inflation (see Figure 20). For GDP we get a slightly larger maximum effect and for CPIF inflation a smaller effect. However, taking into account the uncertainty in the estimates, the differences are limited, i.e. not statistically significant. We nevertheless conclude that it is important that the model is estimated with the exogeneity assumption. Not only is the assumption highly reasonable, but it still has some impact on the estimated effects.

Lags

We estimate the model with different numbers of lags for the variables (see Figure 21). Overall, we find that the estimated effects in the different specifications are similar. The model with lag length 1 deviates the most from the other specifications, which we interpret as meaning that this lag length is too short to capture the dynamics of the data in a satisfactory manner.[96] The specifications with lag length 2 and 4 (baseline) give very similar effects for all variables. The lag length 8 specification produces larger initial effects on the real exchange rate.

Maximum likelihood

We estimate the model with maximum likelihood (ML, or OLS) instead of Bayesian methods as in the baseline estimation (see Figure 22). The qualitative effects of a monetary policy interest rate change on all variables are, as when the model is estimated with Bayesian methods, the expected ones. However, the maximum effects for all variables except unemployment are significantly larger with ML. But we also see that the response of the policy rate is much larger and more persistent when the model is estimated with ML. This highlights the role of normalisation when we compare the effects of monetary policy estimated under alternative assumptions. So far, we have only normalised the initial effect of monetary policy on the policy rate, which typically means that the response of the policy rate path with different assumptions will also be similar. But here we have an example where the policy rate responses are clearly different despite the normalisation of the initial effect.

An alternative way of normalising the effects is to calculate the effects for a common policy rate response (i.e. as a conditional forecast or a so-called monetary policy scenario).[97] Figure 23 in the appendix shows the effects of such a normalisation. We see

[96] Kilian (2001) shows that too few lags (underfitting) in the VAR model can give misleading estimates of the responses, while too many lags (overfitting) mean that the responses are less precisely estimated. Thus, the negative consequences of using too few lags are greater.

[97] For example, for a period the Riksbank presented monetary policy scenarios in which the policy rate was assumed to be 0.25 percentage points higher or lower than in the main scenario. The alternative policy rate path is then conditioned by a sequence of monetary policy shocks. Here, we similarly ensure that the policy rate response in the two cases - Bayesian estimation and ML - is the same.

there that the effects when the model is estimated with Bayesian methods and maximum likelihood are relatively similar. With both approaches, we thus obtain approximately the same estimated effects. One interpretation of this is that the assumptions that follow from the chosen prior distribution for the model's parameters (a so-called normal-diffuse Minnesota prior, see Appendix B) do not have any decisive impact on the estimation of the effects of monetary policy.

Unconventional monetary policy and shadow interest rates

The policy rate is the Riksbank's main monetary policy tool. During the financial crisis of 2008 and the subsequent period, central banks around the world lowered their policy rates to levels close to or below zero and introduced a number of so-called unconventional monetary policy measures to stimulate the economy further.[98] In Sweden, the Riksbank started purchasing government bonds in 2015 to stimulate the economy. One way to control for the Riksbank's asset purchases (QE) is to add a measure of these to the model. We do this by adding a variable showing the Riksbank's holdings of long-term government bonds as a share of the total stock of long-term government bonds and estimate the model for the period 1995Q1-2019Q4.[99]

The effects of an unexpected change in the policy rate when the control variable for QE is added to the baseline model are shown in Figure 24. The effects of the policy rate change in the two models are similar. If asset purchases had had no effect on the macro variables, we would have expected the effects of the model including the QE variable to have been very similar to those of the baseline model. Instead, the model with the QE variable produces slightly smaller effects than the baseline model, which may indicate that the effects with the baseline model overestimate the effects of changes in the policy rate somewhat. Overall, however, the differences in the effects are small and not statistically significant.

An alternative to studying only the effects of changes in the policy rate and asset purchases is to also try to capture the broader effects of unconventional monetary policy with a so-called shadow interest rate, which is a summary measure of the monetary policy stance.[100] A key assumption of this approach is that it is possible to translate unconventional monetary policy, such as the Riksbank's bond purchases, into a policy-rate equivalent. Our focus is mainly on how changes in the policy rate affect the economy, but we examine here how the estimated effects are affected if we use a shadow rate instead of the policy rate.

[98] For example, quantitative easing, forward guidance and other balance sheet measures.

[99] This measure of QE is used, for example, by Kolasa and Wesolowski (2020). During the pandemic, the Riksbank expanded its asset purchases to include other assets such as covered bonds, municipal bonds and corporate bonds, which are not captured by our variable. We choose here to focus on the period before the pandemic when the Riksbank only bought government bonds and estimate the model up to 2019Q4.

[100] For example, Di Casola (2023) and Lyhagen and Shahnazarian (2023) estimate the effects of monetary policy changes in the shadow rate on macroeconomic variables.

However, shadow rates can be constructed in several different ways and we choose to use a shadow rate developed by the Riksbank.[101] Different measures of shadow interest rates can produce large differences in the effects on the macroeconomic variables being studied depending on the shadow interest rate used. Therefore, it is not self-evident that shadow rates always generate a useful and reliable interpretation of the overall monetary policy that one is trying to capture.[102]

We estimate the baseline model where the shadow rate replaces the policy rate for the period 1995Q1-2022Q4. We show two variants where the shadow rate is estimated with two and three factors, respectively, to illustrate how different assumptions about how the shadow rate is constructed can affect the results. The effects of the shadow rates on GDP and unemployment appear to be somewhat smaller than for the policy rate, but the effects are not statistically significantly different from those of the baseline model (Figure 24). In addition, the effect of the shadow rate is somewhat smaller for CPIF inflation (in the two-factor case), but even there the differences are not statistically significant. However, the effect on the exchange rate is somewhat larger in the model with the shadow rate, but again the differences are not statistically significant.

Model with monthly data

We estimate a BVAR model on monthly data and compare the effects of a monetary policy shock with those of the baseline model estimated on quarterly data. In the model, we have monthly data for three foreign variables and five Swedish variables, where our ambition is to make the monthly model very similar to the quarterly model. The foreign variables are industrial production (log-transformed), the quarterly change in the CPI/HICP and the policy rate.[103] The domestic variables are log-transformed GDP, unemployment, the quarterly change in the CPIF, the policy rate and the real exchange rate (log-transformed). We estimate the model for the period 2000m1-2023m12. The monetary policy shock is identified recursively (Cholesky) so that the policy rate is allowed to affect the exchange rate, but no other variables, in the same month (the variables thus have the same order as in the quarterly model).

The effects of monetary policy with the monthly model are shown in Figure 25. Despite some differences in variables and sample period, the estimated effects and the timing of the maximum effects are similar to those of the quarterly (baseline) model. The largest difference is for unemployment, which increases by 0.4 percentage points when the policy rate is raised by one percentage point, a slightly smaller effect than we found with the quarterly model. To summarise, we get roughly the same picture of

[101] The three most common methods have been developed by Wu and Xia (2016), Krippner (2015) and Lombardi and Zhu (2018). We use the shadow rates for the US, the euro area and Sweden constructed by De Rezende and Ristiniemi (2023). Using daily data on shadow rates for the US and the euro area, we create a KIX2-weighted (a weighting between only the euro area and the US) shadow rate at quarterly frequency that replaces the foreign policy rate in the baseline model. In the same way, we create a Swedish shadow rate that replaces the Riksbank's policy rate in the baseline model.

[102] Krippner (2020) shows that small differences in the specification of the shadow interest rate can lead to large variations in the effects on inflation and unemployment with US data.

[103] Unlike the model estimated with quarterly data, the foreign variables are not KIX-weighted and are either euro area only or KIX2-weighted. The real exchange rate is thus either that of the Swedish krona and the euro only or the KIX2-weighted real exchange rate.

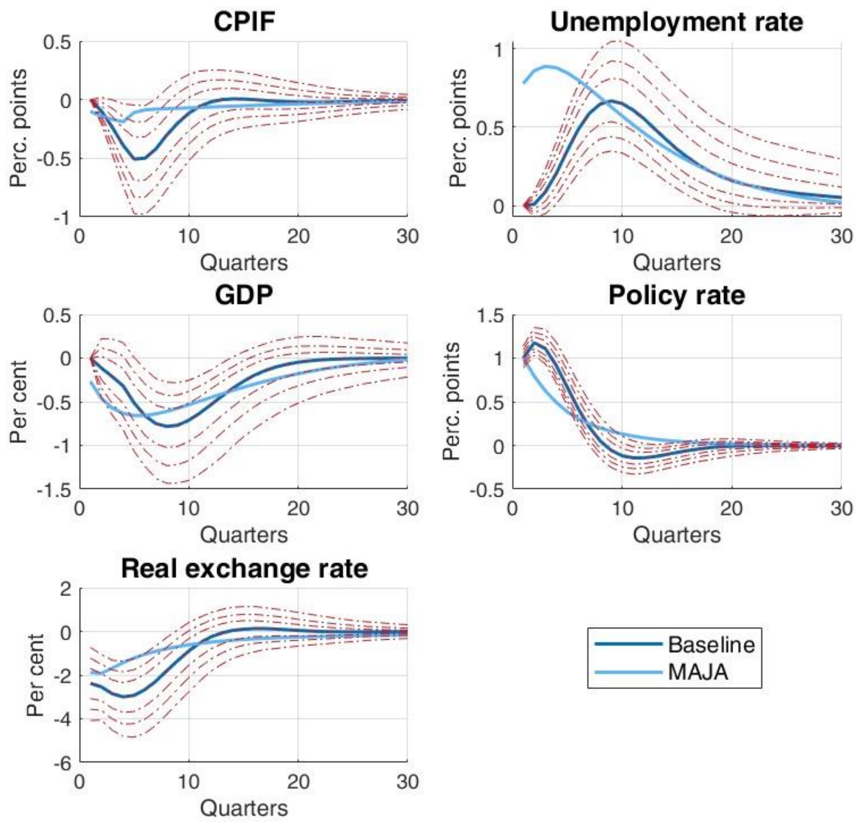
the effects of a monetary policy shock when the model is estimated on quarterly and monthly data.

Figures

The figures below show the effects of an unexpected increase in the policy rate (a monetary policy shock) under different alternative assumptions for the model. Unemployment, GDP, the policy rate and the real exchange rate are shown in levels, and CPIF inflation in annual percentage changes (although it is typically included in quarterly changes in the estimated models). The 5th, 15th, 25th, 75th, 85th and 95th percentiles of the effects in the baseline model are shown in red and the median effect (50th percentile) in the baseline model is shown in blue. The effects for different alternative model specifications are shown in other colours (light blue, yellow, green). The effects are normalised throughout to refer to an initial one percentage point increase in the policy rate.

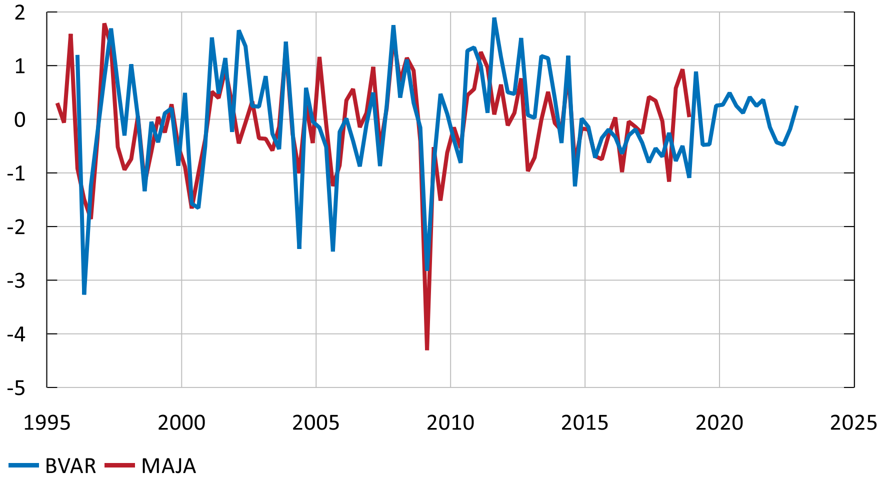
The baseline model

Figure 12. Comparison of the effects of a policy rate increase in the baseline model with those in the Riksbank's general equilibrium model MAJA



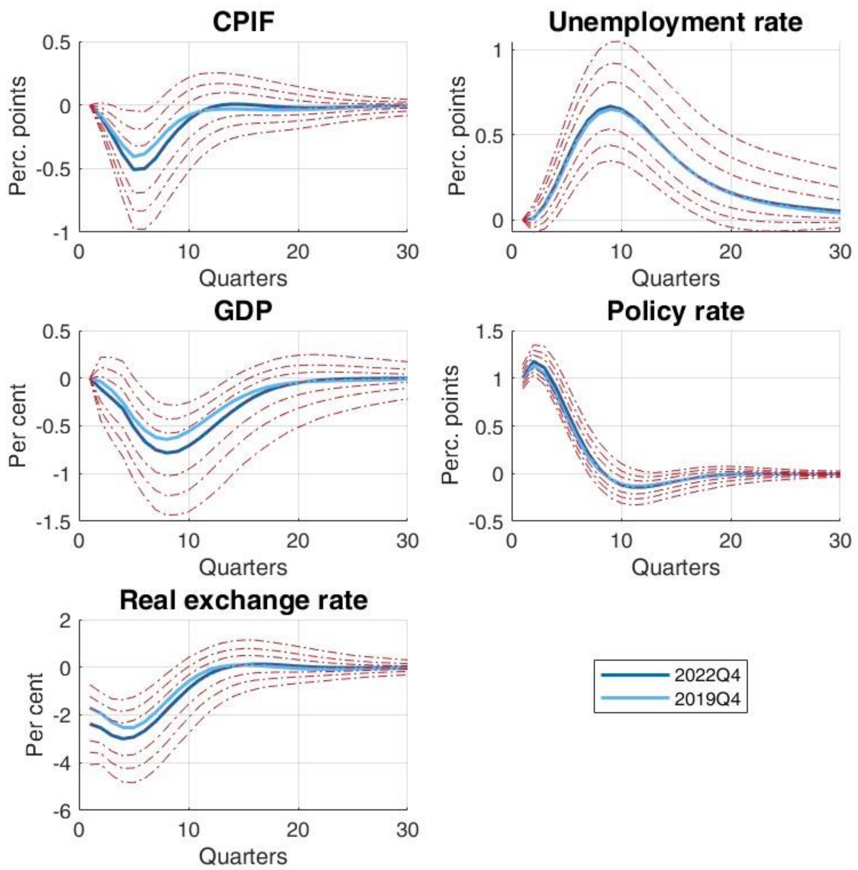
Note. The figure shows the effects of a monetary policy shock in the baseline model and the Riksbank's general equilibrium model MAJA, where the initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the dark blue line shows the median response (50th percentile). The uncertainty bands belong to the baseline model.

Figure 13. Comparison of estimated monetary policy shocks (in standard deviations) in the baseline model and in the Riksbank's general equilibrium model MAJA



Note. The figure shows time series of monetary policy shocks (smoothed estimates) in the baseline model (BVAR) and the general equilibrium model MAJA. The shocks are expressed in standard deviations.

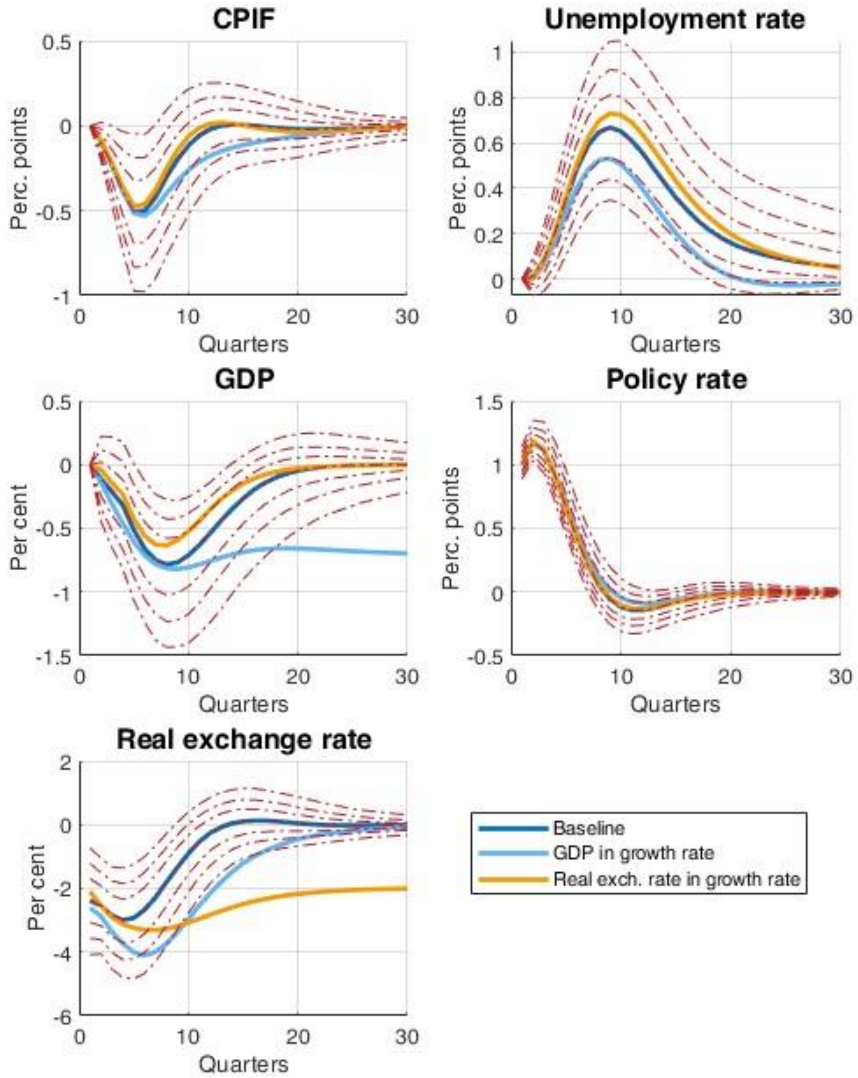
Figure 14. Effects of a policy rate increase in the baseline model estimated for two different samples



Note. The figure shows the effects of a monetary policy shock in the baseline model, where the initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for two different samples: 1995Q1-2022Q4 and 1995Q1-2019Q4. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the blue lines shows the median responses (50th percentile). The uncertainty bands belong to the baseline model with end year 2022Q4.

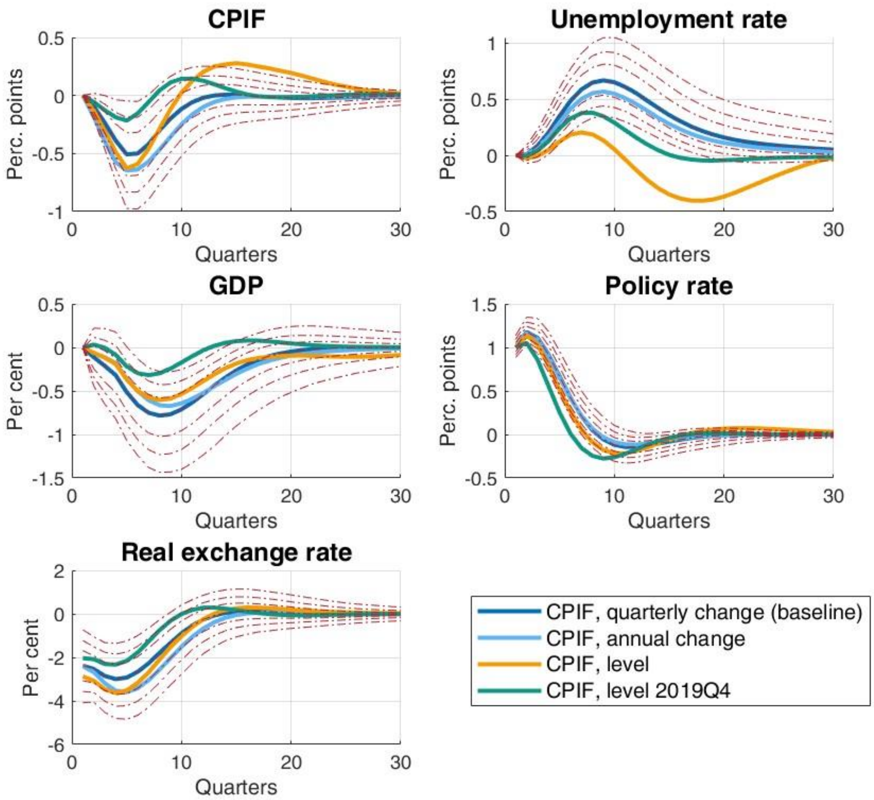
Robustness analysis

Figure 15. Effects of a policy rate increase in variants of the baseline model with GDP or real exchange rate in transformation



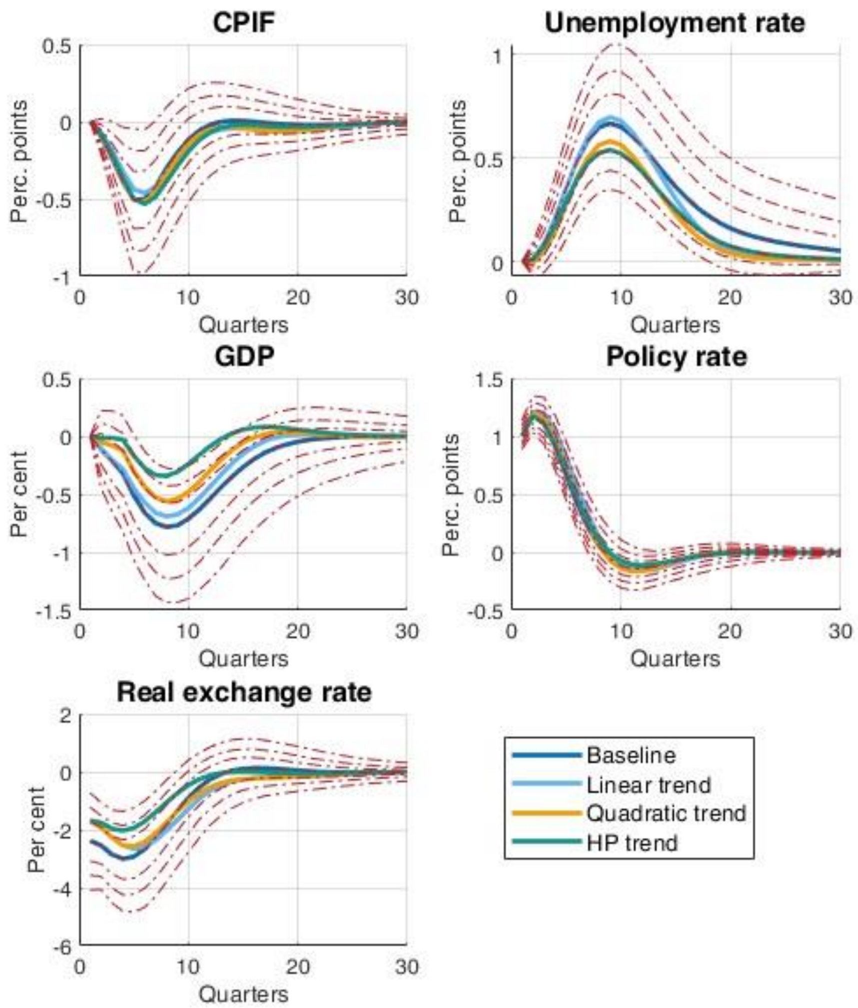
Note. The figure shows the effects of a monetary policy shock in two variants of the baseline model in which GDP and real exchange rate are included in transformation instead of in level. The initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the coloured lines show the median responses (50th percentile). The uncertainty bands belong to the baseline model.

Figure 16. Effects of a policy rate increase in the baseline model with different transformations of the CPIF



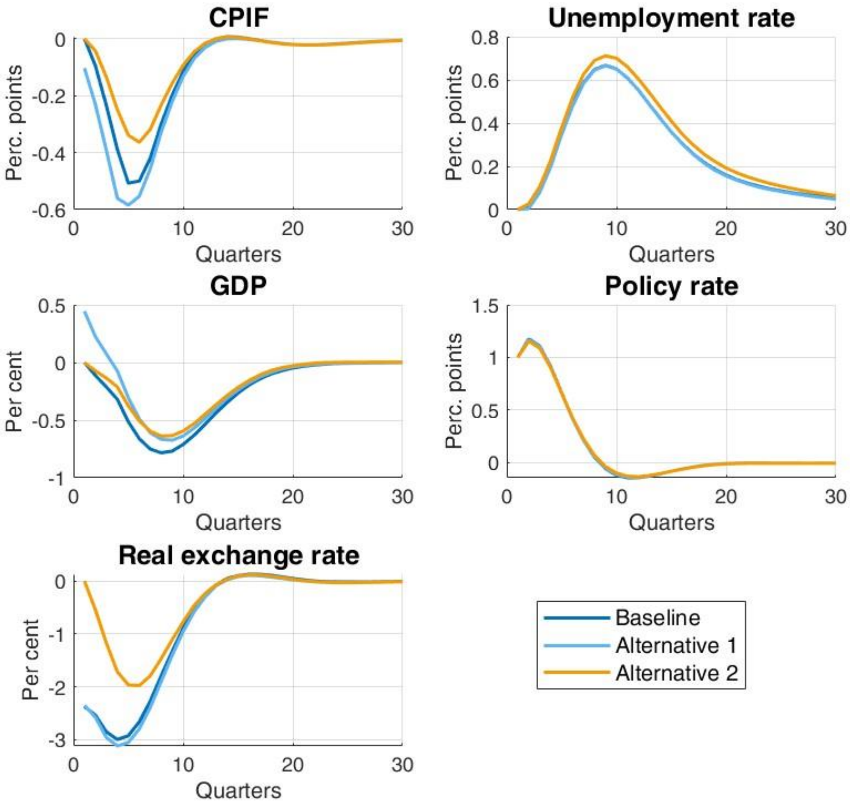
Note. The figure shows the effects of a monetary policy shock in the baseline model with different transformations of the CPIF. The initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4, with the exception of the CPIF, level 2019Q4 (see green line). The CPIF is shown with various transformations and other variables in level. The dashed red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the coloured lines show the median responses (50th percentile). The uncertainty bands belong to the baseline model.

Figure 17. Effects of a policy rate increase with different assumptions about deterministic trends in the baseline model



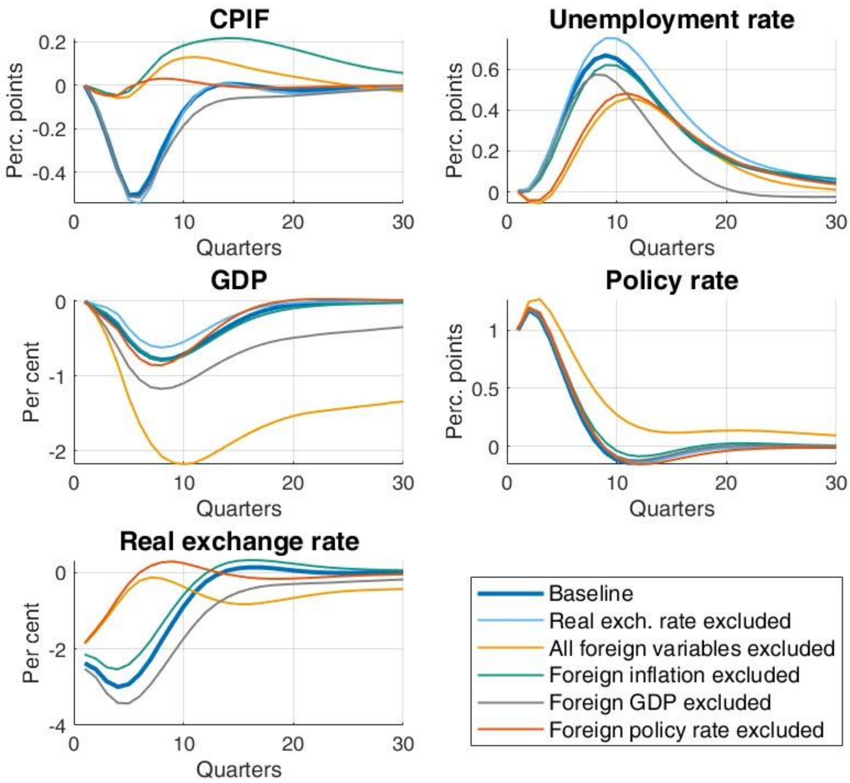
Note. The figure shows the effects of a monetary policy shock in the baseline model, where the initial effect on the policy rate has been normalised to one percentage point. In the baseline model, we have no deterministic trends. In the alternative specifications we include linear and quadratic trends respectively. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The dashed red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the coloured lines show the median responses (50th percentile). The uncertainty bands belong to the baseline model.

Figure 18. Effects of a policy rate increase with different short-run restrictions in the baseline model



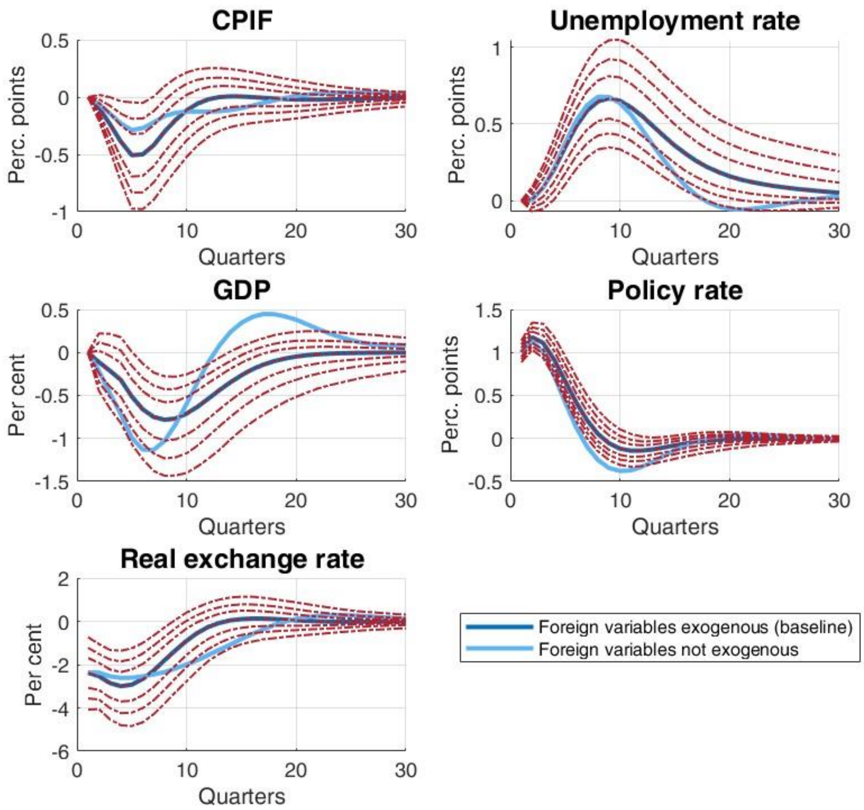
Note. The figure shows the effects of a monetary policy shock in the baseline model with different short-run restrictions. The initial effect on the policy rate has been normalised to one percentage point. In the baseline model, the exchange rate is allowed to react in the same quarter as the policy rate, while the other variables are assumed to react with a lag. Alternative 1 shows the effects when all variables are allowed to react contemporaneously (the policy rate is ordered first among the domestic variables). Alternative 2 shows the effects when all variables are contemporaneously constrained to zero (the policy rate is ordered last among the domestic variables). The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level.

Figure 19. Effects of a policy rate increase in variants of the baseline model where various foreign variables are excluded



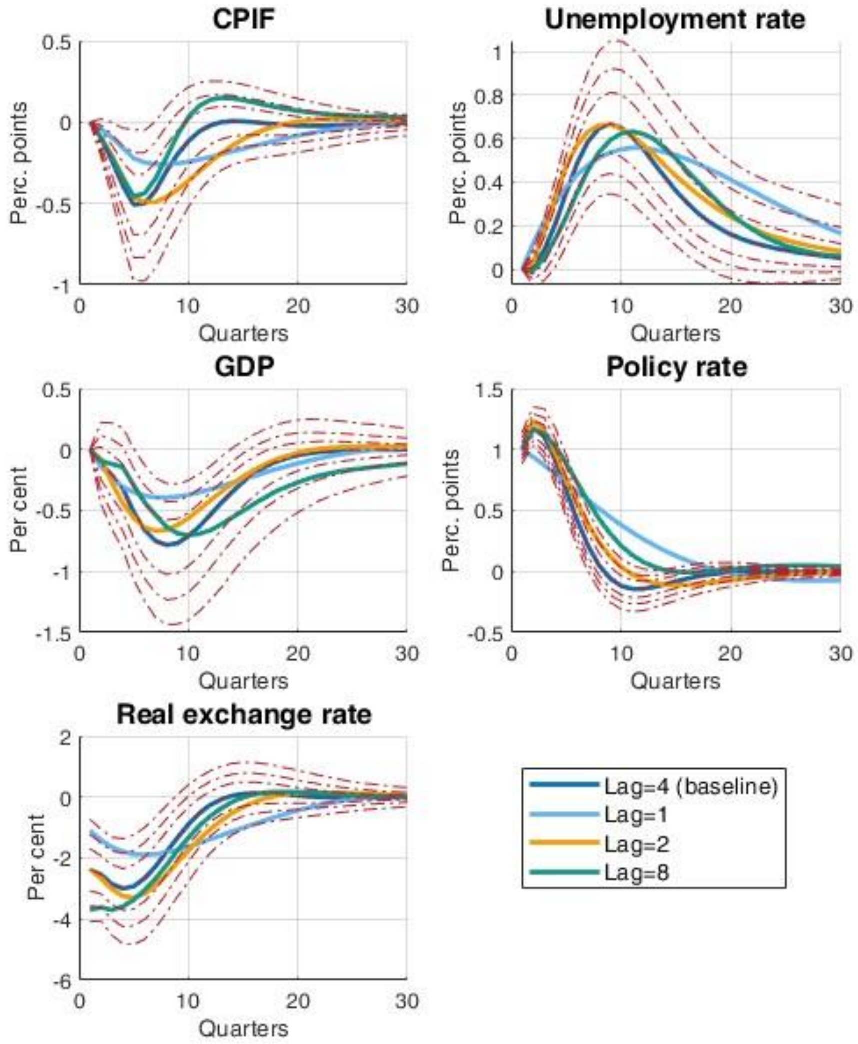
Note. The figure shows the effects of a monetary policy shock in variants of the baseline model in which various foreign variables have been excluded. The initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level.

Figure 20. Effects of a policy rate increase in the baseline model with different assumptions about the exogeneity of foreign variables



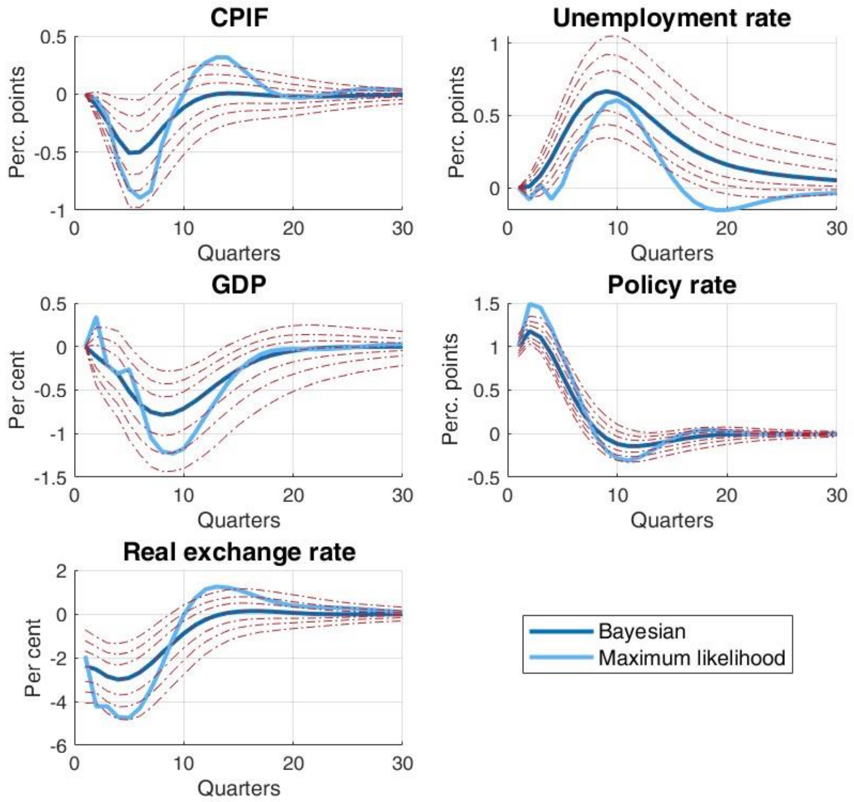
Note. The figure shows the effects of a monetary policy shock in the baseline model with different assumptions about the exogeneity of foreign variables. The initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The dashed red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the blue lines shows the median responses (50th percentile). The uncertainty bands belong to the baseline model.

Figure 21. Effects of a policy rate increase in the baseline model with different numbers of lags



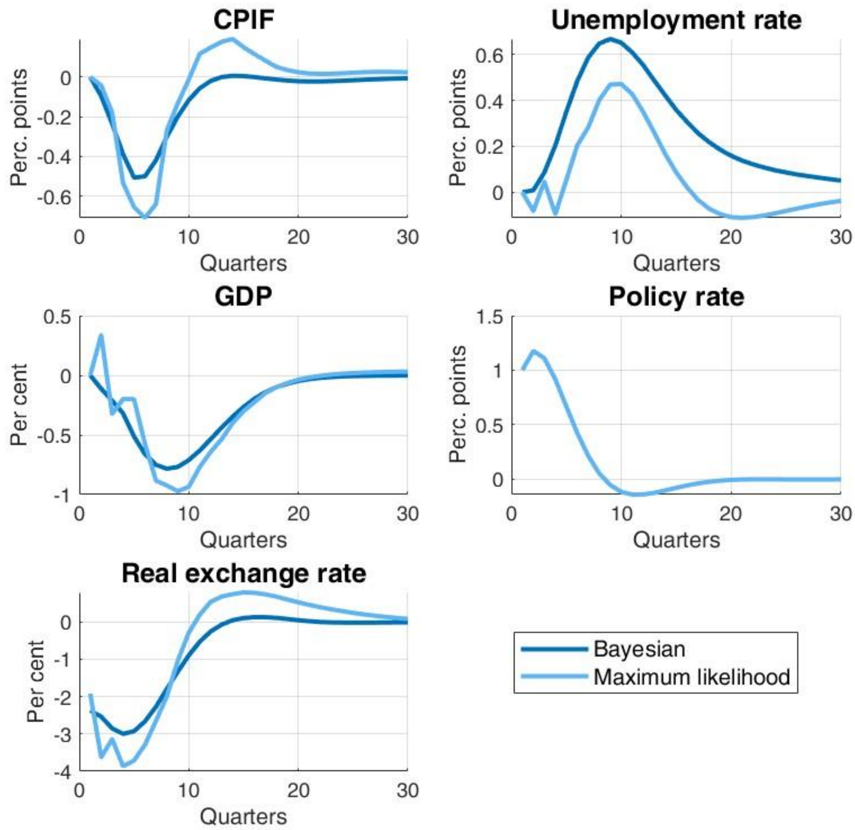
Note. The figure shows the effects of a monetary policy shock in the baseline model with different numbers of lags. The initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the coloured lines show the median responses (50th percentile). The uncertainty bands belong to the baseline model.

Figure 22. Effects of a policy rate increase when the baseline model is estimated with maximum likelihood



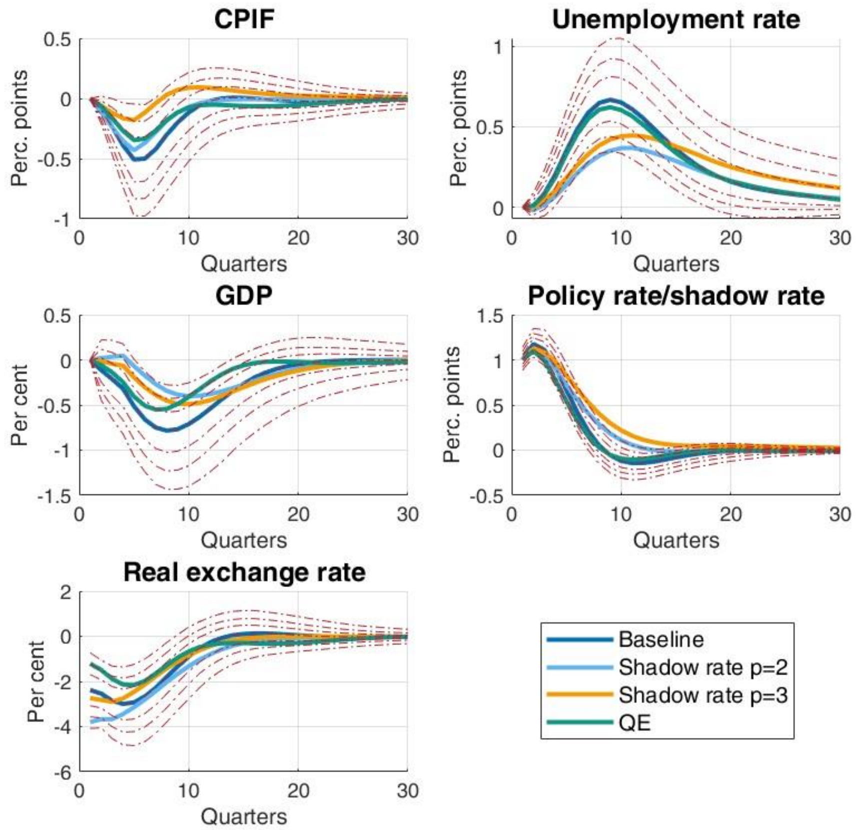
Note. The figure shows the effects of a monetary policy shock in the baseline model when estimated with the Bayesian method (baseline) and with maximum likelihood. The initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the blue lines show the median responses (50th percentile). The uncertainty bands belong to the baseline model.

Figure 23. Effects of a policy rate increase when the baseline model is estimated with maximum likelihood and with the policy rate response from the Bayesian method



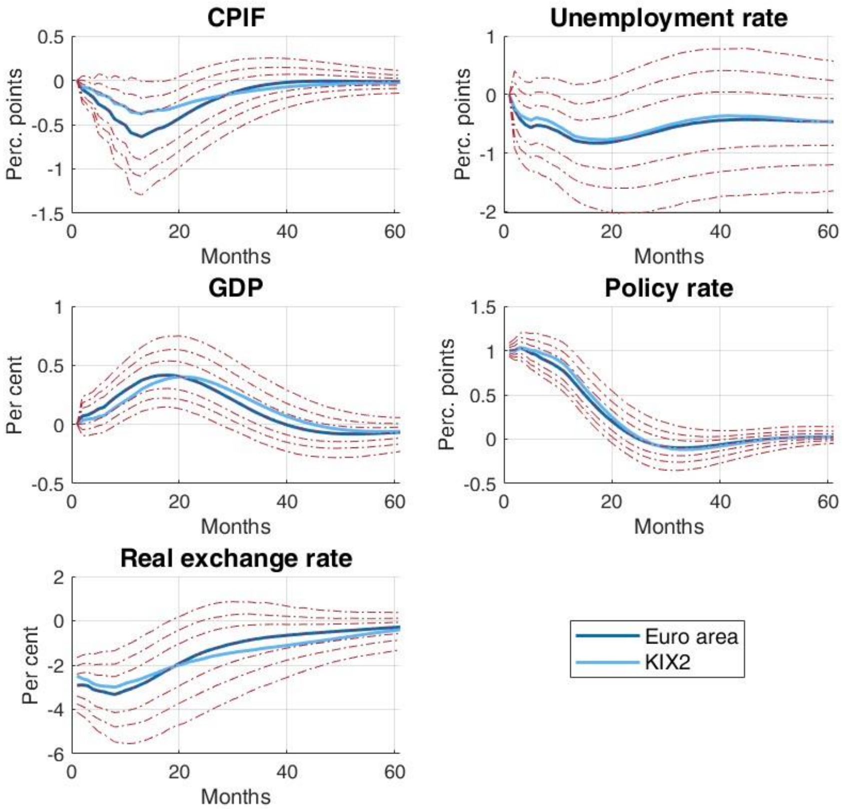
Note. The figure shows the effects of a monetary policy shock in the baseline model when estimated with the Bayesian method (baseline) and with maximum likelihood. The policy rate response is normalised to the response obtained when the model is estimated with Bayesian methods; the initial effect on the policy rate has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level.

Figure 24. Effects of a policy rate increase when the baseline model is estimated with shadow rates and a variable measuring the Riksbank's government bond purchases (QE)



Note. The figure shows the effects of a monetary policy shock in the baseline model when it is estimated with two shadow rates (constructed with either two or three factors, p) instead of the policy rate and when a variable measuring the Riksbank's government bond purchases (QE) is included in the model. The initial effect on the policy rate (or shadow rate) has been normalised to one percentage point. The model is estimated on Swedish data for the period 1995Q1-2022Q4. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the baseline response and the coloured lines show the median responses (50th percentile). The uncertainty bands belong to the baseline model.

Figure 25. Effects of an increase in the policy rate in the baseline model estimated on monthly data



Note. The chart shows the effects of a monetary policy shock in the baseline model estimated on monthly data, where the initial effect on the policy rate has been normalised to one percentage point. The model is estimated for the period 2000m1-2023m12. The CPIF is shown in annual percentage change and other variables in level. The red lines are the 5th, 15th, 25th, 75th, 85th and 95th percentiles of the probability distribution of the response and the blue line show the median response (50th percentile).

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