Monetary Policy Transmission and Spillovers in an Open Economy During Normal and Negative Interest Rate Periods*

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June 12, 2018

Abstract

We analyze the recent experience of negative interest rate policy in Sweden to test for changes in the effects of foreign and domestic monetary policies on domestic financial variables, when the policy interest rate is in negative territory. Using non-linear local projection methods, we find that the negative interest rate period has significantly changed the transmission and spillovers of both foreign and domestic monetary policy compared with the positive interest rate period. Our results suggest that spillovers from Euro-area monetary policy are in general stronger than from U.S. monetary policy, and that foreign forward guidance has become more important than foreign target interest rate policy in the negative interest rate period in Sweden. In addition, as Swedish banks can continue funding their operations through lower market rates, bank profitability seems not to be negatively affected as the policy rate is lowered into negative territory, suggesting that the current policy rate in Sweden is still above the reversal rate (Brunnermeier and Koby 2018), from which an even lower policy rate would be contractionary.

Keywords: Negative Interest Rate Policy, Monetary Policy Transmission, Spillovers, Bank profitability, High-Frequency Identification, Local Projections

JEL Classification Numbers: E31, E32, E43, E44, E52, E58

*We are grateful to Ulf Söderström and seminar participants at the Policy Research Meeting on Monetary Policy, Financial Markets and Institutions at Norges Bank for discussions and comments. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of Sveriges Riksbank.

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1. Introduction

At the onset of the 2008-09 global financial crisis, central banks in several advanced economies quickly moved policy rates to zero and initiated large-scale asset purchases. In more recent years, with inflation still below target, several central banks lowered their policy rates below the previous zero lower bound, embarking on so-called negative interest rate policies (NIRPs). In June 2014 the European Central Bank (ECB) e.g. decided to cut the rate on the deposit facility (DFR) by 10 basis points (bps) into negative territory. Further rate cuts of 10 bps each followed in September 2014, December 2015 and March 2016, bringing the DFR to −0.40 percent.

Such a change in the stance of monetary policy in one country can quickly “spillover” to other countries. The 2008-09 global financial crisis and its aftermath has sparked intense interest in such international monetary policy spillovers, in both academic and policy circles. Indeed, when making monetary policy decisions, the Riksbank has recently been clear that it does not solely taken into account the low inflation and falling inflation expectations in Sweden. It has also needed to take into account the fact that many other central banks, not least the ECB, have conducted a very expansionary policy with a negative interest rate and extensive asset purchases (Riksbank 2018a). Global interest rates have been falling for twenty or so years and are currently very low (see Figure 1). If Swedish monetary policy were to deviate too far from that in other countries, it could lead to severe exchange rate fluctuations. This could make it more difficult to attain the inflation target, but also result in a less favourable development in the real economy. The Riksbank has therefore conducted a very expansionary monetary policy in recent years. In 2015 the repo rate was cut below zero for the first time and the Riksbank also decided to purchase government bonds so that monetary policy would become even more expansionary and have a broader impact. This policy was introduced around the same time as the ECB launched its major asset purchase programme. Since then there has been a relatively lively economic policy debate in both Swedish and European media about the expansionary monetary policy in the two economies. It has centred on the effects and risks of the negative repo rate in itself as well as on whether it has been necessary to maintain the very expansionary policy. The possible debilitating impact of negative interest rates on the profitability of the banking sector has furthermore emerged as an important consideration (BIS 2016). Even more directly, such rates can weaken the profitability and/or soundness of institutions with long-duration liabilities. Hence, the impact of equity prices of financial intermediaries is an important aspect of the possibility of a change in the transmission of domestic monetary policy and spillovers of foreign
monetary policy when policy rates are negative. Monetary policy affects banks profitability through a variety of channels and it is not straightforward to determine what the overall effect will be. The open economy aspects and spillovers from the Euro-area and the United States are especially important in the Swedish context since Swedish Banks mainly rely on wholesale funding to finance their activities.¹

The above mentioned negative interest rate policy, the recent debates and the international interconnections motivates the question: does a negative interest rate policy constitute a mere continuation of a conventional positive interest rate policy or does it fundamentally change the transmission and spillovers of domestic and foreign monetary policies to financial variables?

There is, in most standard New Keynesian models, however little reason to believe that the transmission of monetary policy into deposit and lending rates would change when policy rates are negative.² In these models, the economy enters a liquidity trap as policy rates approach zero only because of an exogenously assumed zero lower bound. This assumption has been questioned, especially since a group of central banks have set negative interest rates. Brunnermeier and Koby (2018) however, explicitly analyse the possibility that there may be a threshold level of the policy-controlled interest rate (the reversal rate) below which further interest rate reductions would become counterproductive. The general finding is that in an environment in which banks face a capital constraint which depends on current and expected profitability, a more negative market interest rate may tighten capital constraints and reduce the incentive to lend by negatively affecting interest rate margins and the profitability of banks. These results contrast with the standard literature (e.g. Gertler and Karadi, 2011) in which a lower interest rates release capital constraints by boosting asset values. This may in turn stimulate lending and risk-taking behaviour. In such an environment, the negative returns may incentivise portfolio rebalancing and a search for yield. Hence, both approaches point to bank profitability as a central aspect but which of the effects dominates is an empirical question.³

¹ In 2015 deposits represented 42% of the total liabilities of the Swedish banks. This ratio is much lower than that observed in the largest euro area economies, which averaged slightly over 66% during the same period (Madaschi and Nuevo 2017). Approximately half of the Swedish banks’ funding is in SEK while the rest is split between other currencies (Finansinspektionen 2017). Foreign currency funding introduces diversification and the possibility of lower funding costs but it could introduce a risk that shocks on the international capital markets spread to the major Swedish banks and make it more difficult to secure funding even though confidence in the banks’ economic position remains solid.

² As a more general theoretical matter, macro models with nominal rigidities, information asymmetries, menu costs, or lending constraints typically imply asymmetric responses to monetary policy interventions. A standard menu-cost model imply e.g. that big monetary policy shocks are neutral because firms find it optimal to adjust nominal prices, while small monetary policy shocks would have real effects because keeping nominal prices fixed is associated with only a second-order cost. For example, Cover (1992) and DeLong and Summers (1988) argue that contractionary monetary policy affects real variables more than expansionary policy. Using international data, Karras (1996) finds evidence of asymmetry in the effects of monetary policy on output using European data.

³ Several empirical papers have addressed related questions regarding the changing behaviour and impact of
Our paper contributes to the existing empirical literature in four ways. First, we focus on the cross-border spillover effects of U.S. and Euro Area monetary policy on a small open economy, namely Sweden, that has brought it’s main policy rates deeper into negative territory than most other central banks. Whereas existing literature focuses on how domestic economic and financial variables are influenced by domestic monetary policy, few papers investigate how asset prices of small open economies are affected by foreign monetary policy. Second, we assess the impact of domestic and foreign monetary policies using a local projection model (Jorda 2005) in order to explore the persistence of the responses of financial variables to domestic and foreign monetary policy. Much of the recent work on this topic has been based on event studies, and therefore focuses on the initial impact of domestic and foreign monetary policy. Using our method, we can study their dynamic responses. An additional benefit of studying the spillovers effects of foreign monetary policy using local projection methods is that we are addressing possible concerns of confounding results from possible endogeneity of our monetary policy shocks. Since Sweden is a small open economy, it is unlikely that the Euro-area and the U.S. monetary policy shocks may suffer from problems such as central bank private information, which may introduce bias to our results. Third, we focus on the effect of U.S., Euro-area and domestic monetary policy when the negative interest rate policy was introduced in Sweden in 2015; and formally test for a the possibility of changes in the spillovers and transmission of foreign and domestic monetary policy relative to the positive interest rate policy period. Fourth, we investigate the effects of different dimensions of foreign and domestic monetary policy. Following Gürkaynak, Sack, and Swanson (2005) we identify two factors that can be interpreted as "target rate surprise" and "forward guidance surprise", which can be used to separately identify the effects of the two types of monetary policy instruments on asset prices. Our key results can be summarized as follows:

monetary policy, e.g., by estimating regime switching models of monetary policy. The idea in these models is that monetary policy is driven not just by shocks but also by changes in the policy parameters. Primiceri (2005) and Sims and Zha (2006) investigated the roles of changes in systematic monetary policy versus shocks to policy in the outcomes in the last 40+ years. While they found evidence for changes in systematic monetary policy, they concluded that they are not an important part of the explanation of fluctuations in inflation and output. Regarding time-varying effects of monetary policy Boivin, Kiley, and Mishkin (2010) focus on time variation in the estimated effects of monetary policy and discuss various reasons why the monetary transmission mechanism might have changed, such as changes in the regulatory environment affecting credit and the anchoring of expectations. An empirical literature which is slightly more related to our paper is the one studying whether effects of monetary shocks on the economy are state-dependent or sign-dependent. Cover (1992) presented evidence that negative monetary policy shocks had bigger effects (in absolute value) than positive monetary shocks. Angrist, Jordà, and Kuersteiner (2017) and Tenreyro and Thwaites (2016) find related evidence that monetary policy is more effective in slowing economic activity than it is in stimulating economic activity. Since the fall of 2008, policy rates have been near, or below, the zero lower bound. Thus, a key question that has arisen is how this possibly nonlinear constraint affects the transmission and spillovers of monetary policy.

Exceptions are Falagiagrda, McQuade, and Tirpak (2015), who show that spillovers occur from ECB’s unconventional monetary policy to yields in non-Euro area eastern European countries, and Rogers, Scotti, and Wright (2016), who document spillovers from U.S. monetary policy on foreign variables in a VAR setup.
First, the strength of spillovers differ significantly according to originating countries. We find strong and significant spillovers from Euro-area monetary policy, whereas spillovers from the U.S. are generally weak or insignificant. This result is very intuitive, the Swedish and the Euro-area economies are very much interconnected through trade and financial linkages.

Second, spillovers of foreign forward guidance become stronger during the negative interest rate period compared to the positive interest rate period in Sweden, which is in line with the idea that forward guidance became a more actively used instrument of monetary policy by the Fed and the ECB since 2008, from when target interest rate policy became a less potent instrument of monetary policy in these economies.

Third, spillovers to equity prices, and more importantly to equity prices of banks and financial firms, are significantly different in normal and negative interest rate policy periods. In normal times, contractionary monetary policy surprises by the ECB significantly increase equity prices of Swedish banks and financial firms. Contrariwise, in the negative interest rate period, the impulse responses change signs and become negative. A possible explanation for these results is that, because deposit rates are stuck at zero in a negative interest rate environment, but market rates continue following the repo rate, only part of banks’ funding costs are lowered. This means that, in this environment, contractionary monetary policy surprises tend to lower stock prices, as funding becomes more costly, and banks may not be willing to pass this cost one to one to lending rates. However, in a positive interest rate environment, contractionary monetary surprises have positive effects on stock prices, as banks may be willing to increase lending rates more than policy rates, increasing their profitability. These results suggest that, at least from the perspective of banks, the policy rate in Sweden is not below the reversal rate (Brunnermeier and Koby 2018), from which lower policy rates would be contractionary.

Fourth, we find that the transmission from domestic monetary policy show clear similarities with spillovers from the Euro-area in both normal and negative interest rate periods. In other words, the effects of domestic target interest rate and forward guidance are generally strong and significant. In NIRP periods this pattern changes. The effects of both target interest rate and forward guidance on government bond yields become relatively short lived and less persistent. Impulse responses of equity prices, both overall and for banks and financial firms, also show a similar pattern compared to those of Euro-area monetary policy surprises, but rate surprises yield stronger and more persistent impulse responses during the negative policy rate period.

Overall, results suggest that spillovers from Euro-area monetary policy are in general stronger
than from U.S. monetary policy, and that foreign forward guidance has become more important than foreign target interest rate policy in the negative interest rate policy period in Sweden. In addition, as Swedish banks can continue funding their operations through lower market rates, when the policy rate is below zero, stock prices decrease when monetary policy is contractionary, as banks’ funding becomes more costly.

The remainder of this paper is organized as follows. Section II explains the empirical method and Section III describes the dataset and the method to estimate our monetary policy shock measures. Section IV sets out the main results. We conduct sensitivity analysis in Section V. Section VI concludes with some thoughts for future research.

2. Econometric Method

In this section we provide the details of the econometric model used in the study. We also explain our approach to statistical inference.

Our econometric model builds on Jorda (2005) and Tenreyro and Thwaites (2016) and resembles the smooth transition-local projection model (STLPM) employed in Auerbach and Gorodnichenko (2012) and Ramey and Zubairy (2018) who analyze fiscal policy. More specifically, we estimate the following regression:

\[ y_{t+h} = \tau t + F(z_t)\left(\alpha_h^- + \beta_h^- \varepsilon_t + \gamma^- \mathbf{x}_t\right) + (1 - F(z_t))\left(\alpha_h^+ + \beta_h^+ \varepsilon_t + \gamma^+ \mathbf{x}_t\right) + u_t \]

where \( y_{t+h} \) is the dependent variable of interest, leaded \( h \) periods ahead, \( t \) is a linear time trend, \( \varepsilon_t \) is a shock and \( \mathbf{x}_t \) are controls (in the baseline, lags of the dependent variable and the policy interest rate). \( F(z_t) \) is a function of the state of monetary policy \( z_t \), which allows coefficients \( \alpha_h^j \), \( \beta_h^j \) and \( \gamma^j \) to vary accordingly. In the baseline linear specification we assume that \( F(z_t) = 1 \). We are especially interested in estimating the impulse response of variable \( y_t \) at horizon \( h \in \{0, H\} \) in state \( j \in \{+, -\} \) to a shock \( \varepsilon_t \), which is obtained as the coefficient \( \beta_h^j \). In practice we are interested in obtaining a sequence of estimates for \( \beta_h^j \), by varying the horizon \( h \in \{0, H\} \).

In this paper, we use two measures of shocks \( \varepsilon_t \), namely a "policy rate shock" and a "forward guidance shock". These are computed for Sweden, the U.S. and the Euro area. Hence, when using Swedish shocks we get a direct measure of the transmission of domestic monetary policy to domestic variables. When using the U.S. and the Euro area shocks we are able to assess the spillover effects of foreign monetary policy on domestic variables.

Note that except for horizon \( h = 0 \), the error term \( u_t \) will be serially correlated because it
will be a moving average of the forecast errors from $t$ to $t + h$. Thus, the standard errors need to incorporate corrections for serial correlation, such as a Newey-West (1987) correction. We follow Tenreyro and Thwaites (2016) and employ two different approaches to conducting inference on our estimated impulse response functions. The first approach is to calculate standard errors analytically, allowing for the possibility of serially correlated residuals within equations and across equations by using the Driscoll and Kraay (1998) method to adjust standard errors for the possibility of correlation in the residuals across dates $t$ and horizons $h$. The second approach is to bootstrap the key statistics of interest. See Tenreyro and Thwaites (2016) for further details.

3. Data

3.1. Dependent variables

We analyze daily data on a variety of Swedish economic and financial variables that may be directly affected by foreign and domestic monetary policy, and that may change their responses to monetary policy in a negative interest rate environment. These are measured over the period ranging from 1/1/2000 to 31/12/2017. More specifically, $y_t$ consists of the bilateral exchange rates; $\log(\text{SEK/EUR})$, $\log(\text{SEK/USD})$, the trade-weighted exchange rate; $\log(\text{KIX Index})$, Swedish government zero coupon bond yields at 3 month, 2, 5 and 10 year maturities, mortgage lending rates, SBAB\textsuperscript{6}, 3 Month, 1 and 2 years, $\log$ of Nasdaq OMX, All-Share, Equity Index, the ICB Industry, Financials, the ICB Sector, Banks and the ICB Supersector, Real Estate. Hence, we study the spillovers and domestic monetary policy transmission on three foreign exchange indicies, seven interest rates and four equity indicies. For the sensitivity analysis we use parsimonious measures of macroeconomic surprises, namely the Citi Economic Surprise Index for Sweden, Euro Area and the U.S. The Citi Economic Surprise Index is an index that tries to measure the economic data vs. consensus expectations.\textsuperscript{7} All data is measured on a daily frequency and the source is Macrobond.

\textsuperscript{5} Note that the exchange rates are defined in SEK per US Dollar and SEK per Euro, so that a decrease is an appreciation of the Krona. The same holds for the trade weighted KIX index.

\textsuperscript{6} SBAB Bank AB is a state-owned limited liability company active in the Swedish mortgage market. SBAB started its operations in 1985 with the task of lending funds for state mortgage lending, today the bank provides loans and opportunities for savings for individuals, housing associations and real estate companies in Sweden. Since the early 1990s, the company competes with private actors as banks and offers loans to private customers.

\textsuperscript{7} These Citi index is defined as weighted historical standard deviations of data surprises where the weights of economic indicators are derived from the announcement’s effect on the foreign exchange markets to which a subjective decay function is applied.
3.2. Monetary policy surprise measures

We identify monetary policy surprises using the responses of a number of asset prices measured around monetary policy announcements (see Kuttner 2001; Gürkaynak et al. 2005). In order to separately identify the effects of the "policy rate surprise" and "forward guidance surprise" we closely follow the methodology proposed by Gürkaynak et al. (2005). We first collect the asset price responses for a series of financial instruments in a $T \times n$ matrix $X$ with rows of $X$ corresponding to monetary policy announcements and columns of $X$ corresponding to the responses of $n$ different assets prices. As in Gürkaynak et al. (2005) we can think of these data in terms of a factor model,

$$X = FA + v$$

where $X$ is a $T \times k$ matrix containing $k \leq n$ unobserved factors, $A$ is a $k \times n$ matrix of loadings of the asset price responses on the $k$ factors, and $v$ is a $T \times n$ matrix of idiosyncratic components. If $k = 2$, the data matrix $X$ would be responding to two underlying dimensions of monetary policy announcements, plus an idiosyncratic component. Natural candidates for the columns of $F$ are: (i) the surprise component of the change in the policy rate around each monetary policy announcement, (ii) the surprise component of the change in forward guidance, and (iii) any additional dimensions of news about monetary policy or the economy that are systematically revealed on monetary policy announcements.

For estimating the columns of $F$ we take the columns of $X$ to include the responses of asset prices that are closely related to monetary policy. For Sweden we use interest rate changes for the one-month STINA (Stockholm Tomorrow Next Interbank Average) contract with a window of fifteen minutes before and two hours and forty five minutes after each monetary policy announcement, together with daily interest rate changes for the first, second, fourth and eighth FRA (Forward Rate Agreements) contracts. For the US we use interest rate changes for the first and third federal funds futures contracts, together with the second through fourth Eurodollar future contracts, where both are measured with a window of ten minutes before and twenty minutes after each monetary policy announcement. For the euro-area we use daily interest rate changes for the two-week and one-month eonia swap contract, and for the first, second, fourth, sixth and eighth Euribor futures contracts.\(^8\) The STINA, federal funds futures and the

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\(^8\) Changes in the STINA and the first and third federal funds futures interest rates are scaled by adjustment terms that take into account the timing of the implementation of the policy rate within the validity of the contract.
eonia swap contracts provide good estimates of the market expectations in the very near term, while the FRA, Eurodollar futures and Euribor futures contracts provide information about the expected path of policy rates in the coming one or two years. These data are standardized prior to factor estimation.

Since the factors $F$ are unobserved they must be estimated, which is done via principal component analysis. However, these are just a statistical decomposition of the matrix $X$ and cannot be interpreted as measures of "policy rate surprises" and "forward guidance surprises". In order to give such an interpretation we follow Gürkaynak et al. (2005) and rotate $F$ (and $A$) using a $2 \times 2$ rotation matrix $U$ such that the two columns of $F^* = FU$ assume the structural interpretations of "policy rate surprise" and "forward guidance surprise", and remain orthogonal to each other.\footnote{Rotation matrices are square matrices, with real entries. More specifically, they can be characterized as orthogonal matrices with determinant 1. However, even though a rotation matrix $U$ is necessarily orthogonal, it can lead to non-orthogonal rotated factors. If orthogonalized rotated factors are desirable, this must be imposed.} Furthermore, we rescale the first and second columns of $F^*$ such that they respectively move the first and last columns of $X$ prior to standardization one to one (see Appendix for more details on the construction of $F^*$ for each economy).

### 3.3. Assessing the surprise series

Our surprise series measures are presented in Figure 2. Interestingly, we see some common patterns in the surprise measures for the three economies. First, large expansionary policy rate surprises are commonly seen during periods of recession, such as the great recession of 2008/2009 that affected the three economies, and the early 2000s recession in the U.S. and the Euro-area. Furthermore, there is essentially very small policy rate and forward guidance surprises during most of the zero-lower-bound period in the U.S., a pattern that only start changing in early 2015, when the Fed concluded the tapering of QE3 and started signaling the possibility of future interest rate rises. Similarly, small policy rate and forward guidance surprises in the Euro-area are mostly seen after 2015, when the ECB started conducting NIRP.

The validity of our surprise measures clearly depends on the validity of four underlying assumptions.\footnote{See e.g. Sandström (2018) for a related discussion.} The first assumption is that they are correlated with the current and future "true" stance of monetary policy. The second assumption is that there should be no predictable innovations to the noise component of market participants’ expectations of the monetary policy stance in the short run. The third assumption is that there should be no other news affecting the responses of the asset prices used to construct our shock measures within the announcement...
windows. The fourth assumption is that the policy announcement itself should not reveal information about the central bank’s private information set or its reaction function. Gürkaynak, Sack and Swanson (2007) show that interest rates on federal funds futures have great forecasting power for policy rates in the U.S. Barakchian and Crowe (2013) provide strong support for the first three assumptions in US data, while evidence on the fourth assumption is more mixed. Faust et al. (2004) and Gürkaynak et al. (2005) discuss the third assumption and find that their results are robust to excluding dates with multiple data announcements. De Rezende (2017) suggests that policy rate and forward guidance surprises explain a large portion of variation in model-based policy rate expectations in Sweden, providing support for the first assumption using domestic data.

Following Gürkaynak et al. (2005) we also evaluate the validity of the third assumption. We evaluate the importance of both other monetary policy announcements as well as other news on the monetary policy dates. Figure 3 and 4 show the interaction between the two types of surprises in the different countries. Euro-area and U.S. surprises and monetary policy meetings appear in general on different dates except on three occasions. Swedish shocks occur on the same dates as Euro Area shocks also on a few occasions but results below are robust to the exclusion of these few occasions. One date, and observation, which stands out however, is October 8, 2008 when the Bank of Canada, the Bank of England, the ECB, the Federal Reserve, Sveriges Riksbank and the Swiss National Bank announced reductions in policy interest rates. The ECB, the Federal Reserve and the Riksbank all announced that their policy rates would be reduced by 50 basis points. In the baseline specification we will treat this date as any other surprise in domestic rates but as a robustness check we will exclude all dates when the policy surprises are not unique.

Regarding other new information on monetary policy dates we exclude the observations in which announcements of inflation and GDP in Sweden overlap with those of monetary policy - February 23, 2006, February 15, 2007 and February 16, 2012 - and find that results below are robust to that exclusion. Figure 5 shows monetary policy surprises in the Euro-area and the U.S. on dates where there have been additional news announced on the same day. These news announcements are for the U.S.: Consumer price index, Gross domestic product, Non-farm payrolls, ISM manufacturing. The news announcements for the Euro-area are: unemployment, Gross Domestic Product and inflation for both the Euro-area and Germany. One can note very little overlap during the NIRP period especially for the Euro-area but some dates do overlap

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earlier in the sample. One such date is again on October 8, 2008 when the Eurostat’s second estimate of Euro-area real GDP growth was released. At this date it was confirmed that activity fell by 0.2% quarter on quarter in the second quarter of 2008, following growth of 0.7% in the previous quarter. In the sensitivity analysis we will exclude all of these dates with overlapping information as a robustness check.

Our results also support the validity of the fourth assumption for domestic surprises, since U.S. and Euro-area surprises should not reveal information about the Riksbank’s private information set or it’s reaction function. We also find similar spillover effects when excluding U.S. and Euro-area surprises that overlap between each other.

One possible explanation for a possibly different response of the economy to monetary policy surprises is nonlinear dynamics and spillovers, but not directly as a function of the negative policy interest rates. Rather, it could be possible that policy surprises of different kinds are more common at certain times, and it is this that generates dependence of impulse responses on the state of policy interest rates. If positive surprises were more common during a negative interest rate period than in a positive rate period, the results below might account for the finding that policy might be estimated to be different. No such regime-dependent pattern in the surprises exists however. Figures 6 show probability and cumulative density functions of the surprise measures for each economy for the whole sample, as well as for the negative and positive interest rate periods in Sweden. As can be seen, there is little difference between the central tendencies of the distributions of surprises in the two states, that is, positive surprises do not dominate when policy rates are negative.

3.4. Spillovers from Euro-area and U.S. Policy Rate and Forward Guidance Surprises

In this section we start by documenting the spillovers from Euro-area and U.S. policy rate and forward guidance surprises on domestic variables in normal and NIRP periods. More specifically, we exploit the high-frequency approach to identify exogenous monetary policy surprises and use these in conjunction with local projection methods to trace out the dynamic effects of domestic and foreign monetary policy on domestic financial variables. In addition, we test for the possibility of different responses in the positive and negative interest rate policy periods in Sweden.
3.4.1. Spillovers to Equity Prices of Banks and Financial Services

The responses of banks' and financial firms' profitability are especially important to analyze when policy rates are negative since adverse or positive effects on the profitability of banks would point to either important effects through tightening or loosening capital constraints implying either an important transmission through the reversal rate (Brunnermeier and Koby 2018) or stimulative lending and risk-taking behaviour as was described in Gertler and Karadi (2010). Brunnermeier and Koby (2018) show in their model that when interest rates are below the reversal interest rate banks' equity prices will be negatively affected by lower interest rates. Hence, the impact of equity prices of financial intermediaries is an important aspect of the possibility of a change in the effects that domestic and foreign monetary policies may have on bank’s profitability when policy rates are negative.

Monetary policy affects banks profitability through a variety of channels and it is not straightforward to determine what the overall effect will be. Because of these multiple channels we follow Ampudia and Van den Heuvel (2017) and measure the effects of monetary policy on equity prices considering these as a measure which capture the overall effect. Hence, in this subsection we analyze if the effects of domestic and foreign monetary policies on equity prices of financial intermediaries, such as banks, change when policy rates are negative.

Although a number of studies document significant effects of U.S. monetary policy announcements on U.S. equity prices, only a few previous papers examine how equity prices react to monetary policy surprises and no paper has, to our knowledge, analyzed the spillovers to banks’ equity prices.11

The results are depicted in figures 7 and 8. The first four columns show the impulse responses of domestic stock prices (log of the Nasdaq ICB Industry, Financials, the ICB Sector, Banks and the ICB Supersector, Real Estate and Nasdaq OMX, All-Share, Equity Index) to identified Euro-area, U.S. "policy rate surprises" (panel a) and "forward guidance surprises" (panel b) that generates an initial 1 percentage point rise in the policy interest rate in the respective

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11 Studies of the effect of U.S monetary policy on domestic stock prices include Ehrmann and Fratzscher (2004), Rigobon and Sack (2004), Gürkaynak, et al. (2005), and Bernanke and Kuttner (2005). Ehrmann and Fratzscher (2009), consider the impact on foreign equity indexes and find that that a 100 bp tightening of US monetary policy reduces equity returns on average by 2.7%. They show that there is a substantial degree of heterogeneity in the effect of US monetary policy on country-specific equity returns. A few equity markets change hardly at all while others react substantially to US monetary policy shocks. Regarding state-dependence of the responses, Eifinger at al. (2017) show that the response of equities to central bank talk depends on the business cycle. In bad times, monetary policy communication inducing an upward revision of the path of future policy is good news for stocks. During an expansion, the effect is weaker and on average negative. The finance literature also shows that there may be considerable state dependence in the response to news in the stock market. Boyd, Hu, and Jagannathan (2005) show e.g. that on average an announcement of rising unemployment is good news for stocks during expansions and bad news during economic contractions.
country—i.e., $h$ is on the $x$-axis, and $\beta_h$ is on the $y$-axis. The first column displays the central estimate of the impulse response in NIRP times, i.e. when the Swedish policy interest rate (the repo rate) is negative, (dashed lines), and in normal times (dotted lines) where the policy rate is positive (PIRP), and a linear model (solid lines, where the coefficient are restricted to be constant across regimes). The second to fourth columns display central tendencies and 90 percent confidence intervals for the linear model, NIRP, and PIRP, respectively. The charts in the fifth column represent the two estimates of the t-statistic of the null hypothesis that $(\beta_h^+ - \beta_h^-) = 0$, with the area between ±1.65 shaded. At horizon $h = 0$ the results corresponds to an event study regression which only study the impact effects on variables of interest.

U.S. target rate surprises yield generally insignificant responses of all types of equity prices analyzed here. The effects from Euro-area policy rate surprises are, however, significant and positive during normal times but, as in the U.S. case, also insignificant when domestic policy rates turn negative. The difference between NIRP and PIRP periods is however statistically insignificant since the spillover effects are highly uncertain during the negative interest rate period.

Forward guidance surprises, on the other hand, propagate significantly differently in normal and NIRP periods, and especially so for monetary policy surprises from the Euro-area. Following a contractionary forward guidance surprise, equity prices generally increase during normal times but decrease in the NIRP period. One way to think about these results is that banks may prefer higher interest rates in normal times, as their revenues are likely higher when lending interest rates increase. However, banks must also fund their activities, through deposits as well as by issuing debt securities in the market, or by borrowing from each other in the interbank market. Thus, when market interest rates rise, so do banks’ funding costs. Therefore, the effect of higher interest rates on banks’ net interest margins - the difference between banks’ interest rate income and interest rate expenses - is ambiguous. The results of higher interest rates on equity prices that we show implies that the first effect tends to dominate in normal times and most notably, and intuitively, for forward guidance surprises. However, when the policy rate turns negative, deposit rates get stuck at zero, but market rates continue falling. In this environment, banks’ profits are negatively affected when monetary policy is contractionary, as it implies an increase

\footnote{For the Euro area and Sweden we use the 3-month and the 2-year bond yields as policy rates for policy rate and forward guidance surprises respectively. For the U.S. we follow Gertler and Karadi (2015) and use the 2-year government bond yield.}
in the overall funding costs of banks, which may be willing to pass this interest rate rise one to one to lending rates. The result is a fall in banks’ stock prices.

These results are in line with the findings of Altavilla et al. (2017) who find that accommodative monetary policies tend to increase bank stock returns and reduce credit risk in the Euro-area.13 Ampundia and Van den Heuvel (2017) find similar effects for European banks in normal times. They find that rate cuts in normal times benefit all banks in a similar way irrespective of their funding structure so a change in the policy rate moves stock prices in the opposite direction to the rate change. In the period of low/negative rates, the effects are however reversed. Rate cuts are now detrimental for banks stock market valuation. And the differential effects across bank types are more pronounced that in previous periods. For low deposit banks, a 100 basis points short-term rate cut decreases stock prices by 4.3%, for medium banks by 7.6% and by 12.0% for high deposit banks. It is important to note however that these results are on impact, i.e. the reaction of equity prices on the same day as the policy surprise, i.e. at horizon $h = 0$ in our framework. Moreover, we show that the sign of the impulse responses are not static and differ depending on type of monetary policy shock and country of origin.

To shed light on these different results, figure 9 shows the effect of Euro-area monetary policy surprises on Euro-area (and Swedish) banks’ equity prices (log of Euro-area, Equity Indices, STOXX, Banks, Index, Price Return). Studying the effects on impact, i.e. at $h = 0$, in NIRP periods, the results interestingly confirm the conclusion in Ampundia and Van den Heuvel (2017) namely that a lower interest rate implies lower Bank equity prices. This result only holds on impact however and the responses briefly turn negative. The responses for European banks are, however, generally insignificant whereas Swedish banks are more clearly affected. Hence, it is important not only to consider the impact effects but also study the dynamics and type of shock. Forward guidance shocks [change to surprises] interestingly show the greatest differences during normal and NIRP periods.

To provide more intuition and on these results, we study various aspects related to bank profitability and their net interest margins below. More specifically, we compute the effects of monetary policy shocks on market rates as well as mortgage interest rates.

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13 After a monetary policy easing announcement (including long-term liquidity provision, quantitative easing and negative policy rates), the majority of banks experience an increase in the market based expected profitability – proxied by developments in bank stock prices. This result imply that softer monetary conditions do not hurt banks’ main stakeholders. Overall, the evidence from financial markets supports the conclusions that monetary policy easing does not impair bank profitability.
3.4.2. Spillovers to Government Bond Yields and Mortgage Lending Rates

Figure 10 and 11 show the impulse responses of Swedish government bond yields for maturities ranging from 3 months to 10 years to foreign target rate and forward guidance surprises. The impulse responses display a familiar pattern in normal times. Positive policy rate surprises in the Euro-area affect mainly short-term bond yields, whereas forward guidance surprises affect mainly mid- and long-term bond yields (see Gürkaynak et al. 2005). Results for the U.S. are weaker, suggesting that Swedish government bond yields are little affected by U.S. monetary policy. Interestingly, we also find that effects from Euro-area target interest rate and forward guidance policies are persistently increasing during the PIRP period, suggesting that their spillovers are not only seen on impact, but persist and increase their effects for at least four more months.

Comparing results in NIRP vs PIRP periods, we find that spillovers from both target rate and forward guidance surprises are generally larger on impact in NIRP periods compared with conventional times but less persistent. Spillovers from target rate surprises are, however, significant only in a few cases, whereas forward guidance surprises generally appear to be significant in most cases - even for the U.S. Hence, spillovers from foreign forward guidance to domestic government bond yields seems to be more important than from target interest policy during the NIRP period. This result is very intuitive as forward guidance became a more actively used instrument of monetary policy by the Fed and the ECB since 2008, when target interest rate policy became relatively less potent due to lower bound issues in these economies.

The impulse responses, i.e. spillovers, of mortgage lending rates of different maturities to foreign target interest rate and forward guidance surprises are shown in Figures 12 and 13. Spillovers to mortgage lending rates faced by Swedish households show a similar dynamics as government bond yields. Policy rate surprises from the Euro-area spillover to all maturities, whereas surprises from the U.S. do not significantly spillover to Swedish mortgage bonds. Moreover, Euro-area forward guidance surprises affect mainly longer-term lending rates. Comparing the spillover effects from negative vs positive interest rate policy period, we find that mortgage lending rates are not affected by foreign target interest rate policy or forward guidance in the negative interest rate period, contrasting with results from the positive period. These results confirm the findings in Eggertsson et al. (2017), who document a reduced pass through of domestic policy rates to official lending rates. In this context, it is, however, important to note that these mortgage lending rates are official rates posted by SBAB, which appear stickier than the rates that individuals actually face. The reason is that individuals may negotiate lower rates
than the official rates on an individual basis. The official rate for SBAB on a 3 month fixed maturity was e.g. 1.59% on February 19, 2018 whereas the lowest negotiated rate at this time was 1.22%. These negotiated rates are to our knowledge unfortunately not readily accessible which means that we have to rely on official rates. The upshot is that pass through and spillovers to negotiated rates may be higher than the results on official rates which we report here. Weak competition on the Swedish mortgage market is however according to Riksbank (2018b) among other things reflected in an abnormally high share of borrowers paying listed interest rates (see also SEB 2016).

Madaschi and Nuevo (2017) find contrary to the results presented here that the pass-through into bank lending rates since the introduction of negative policy rates appears to have been similar to that in normal times.

3.4.3. Spillovers to Exchange Rates

The spillovers from target interest rate and forward guidance to foreign exchange rates are shown in Figures 16 and 17. These show the impulse responses of $\log(\text{SEK/EUR})$, $\log(\text{SEK/USD})$, and the trade-weighted exchange rate, $\log(\text{KIX Index})$.

Panel a of Figure 14 shows that the SEK appreciates significantly both against the Euro and the U.S. dollar following a policy rate surprise, both in normal and NIRP times. The NIRP responses are greater in magnitude and there is an initial tendency for the Swedish krona to depreciate initially. The same does however not hold for a forward guidance shock (panel b). Here the responses are generally insignificant. Hence, exchange rate seem to respond to Euro-area monetary policy in a similar way as it would react to domestic monetary policy (as shown below), with the Swedish krona appreciating both against the Euro and the U.S. dollar following a contractionary Euro-area monetary policy surprise. In order to shed some light in this, figure 16 shows impulse responses of bond yields in the Euro-area and in Sweden. Policy rate surprises in the Euro-area imply a larger domestic interest rate response relative to the Euro-area response, implying an increasing interest rate difference. Note that policy rate surprises give rise to larger interest rate differences and they also imply greater exchange rate responses relative to forward guidance surprises. Forward guidance surprises imply significant, but very similar, interest rate movements in Sweden and the Euro area and small interest rate differentials. This is consistent

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14 The best negotiated rates are reported by the price comparison site www.comboloan.se (https://www.comboloan.se/bolanebarometer/html/180201/). www.compricer.se is a similar site who reports a mean 3 month mortgage rate for SBAB of 1.43%.
with the smaller and insignificant exchange rate movements.

Figure 15 shows weak and insignificant spillovers to the exchange rate from the U.S. This is in line with the results in Rey (2016) who uses a complementary approach to the local projection method used in this paper following the methodology of Gertler and Karadi (2015) and Mertens and Ravn (2013) with the target rate and forward guidance surprises as in Gürkaynak et al. (2005). They find weak spillovers from U.S. monetary policy shocks to the Swedish economy and the USD/SEK exchange rate.

3.5. Effects from Domestic target rate and Forward Guidance Surprises

In this section, we contrast and compare the spillover results described in the previous sections with the results from domestic target interest rate policy and forward guidance. We follow the same structure as above, and first study the effects on bank profitability, including the effects of domestic monetary policy on market and lending rates, and finally exchange rates.

Figure 17 shows the impulse responses of domestic equity prices (log of the Nasdaq ICB Industry, Financials, the ICB Sector, Banks and the ICB Supersector, Real Estate and Nasdaq OMX, All-Share, Equity Index) to domestic target rate and forward guidance surprises. In general, results are statistically significant for both policy rate and forward guidance surprises, with different responses during normal and negative interest rate periods. Moreover, responses closely resemble those following the Euro-area monetary policy. In normal times equity prices are generally negatively affected by higher policy rates, with responses of equity prices of banks and financial service firms increasing over an extended period before turning negative. In contract, during the NIRP period, domestic target rate surprises affects equity prices negatively, with stronger results than those from from Euro-area target interest rate policy. Responses to forward guidance surprises are generally not significant in normal periods, but are significantly different in NIRP times, when positive surprises imply lower equity prices. Hence, and similarly to results found for spillovers from the Euro-area, forward guidance surprises propagate significantly differently in normal and NIRP periods. These results strengthen the finding above that, during the negative interest rate period, bank profitability seems to not be necessarily negatively affected when interest rates are lowered, as banks may be able to continue funding themselves in a cheaper way by issuing bonds in the market. At least from the perspective of banks, these results suggest that the policy rate during the negative interest rate period is above the reversal rate (Brunnermeier and Koby 2018), from which an even lower policy rate would be contractionary.
Figure 18 shows the impulse responses of Swedish government bond yields for maturities from 3 months to 10 years, following a domestic policy rate and a forward guidance surprise. Like results from foreign monetary policy surprises, the impulse responses display a familiar pattern in normal times. Positive policy rate surprises affect mainly shorter maturities, whereas forward guidance affects mainly mid- and long-maturity yields. During the negative interest rate period, the responses are generally larger in magnitude, but less persistent. This suggests that market interest rates seem to significantly affected during the NIRP period. This contrasts with mortgage lending rates (Figure 19) which are not as responsive in NIRP times as in normal times. These results resemble the ones from foreign monetary policy, and confirm our previous conclusions that the negative interest rate policy environment seems to significantly change the funding structure of banks compared to the normal monetary policy period. In a negative environment, expansionary monetary policy implies lower funding costs for banks, but not necessarily so for households. As a result, as policy rates are lowered into deeper negative levels, banks’ profitability responds positively, explaining the positive effects on equity prices.

Figure 20 shows impulse responses of \( \log(\text{SEK/EUR}) \), \( \log(\text{SEK/USD}) \), the trade-weighted exchange rate, \( \log(\text{KIX Index}) \) to domestic policy rate and forward guidance surprises. The impulse responses show a clear, significant and persistent appreciation of the Swedish krona against both the Euro and the U.S. Dollar. Impulse responses from forward guidance surprises are similar to target rate surprises. In NIRP times the impact on the SEK/EUR exchange rate from a policy rate surprise is generally bigger, but the dynamics is similar to normal times.

### 3.6. Robustness Analysis

The following section examines the robustness of our findings to news and additional information that may be released on monetary policy announcement days, alternative state variable, i.e. the possibility of changing dynamics at different policy interest rate levels.

Our baseline results employ measures of the monetary policy surprises that on some occasions occur on the same dates as other possibly relevant economic news and monetary policy announcements. Figure 21 shows target and forward guidance surprises in Sweden, the Euro-area and the U.S. on dates where monetary policy surprises are common. These surprises are excluded in the results below. Moreover, the baseline regression equation contains a trend, a constant, and one lag of both the policy and the dependent variable. We examine the robustness of the results by also controlling for a parsimonious measures of macroeconomic surprises,
namely the Citi Economic Surprise Index for Sweden, Euro-area and the U.S. We additionally control for the 2-year government bond yield spread between the Euro-area and Sweden, as well as for oil prices and the CBOE, S&P 500 Volatility Index (VIX). Figures 22-24 shows the impulse response of domestic asset prices to domestic and foreign target rate and forward guidance (the baseline results are shown in figures 7 and 8). Results suggest that our baseline results are robust to these additional control variables and that the overall qualitative picture from the IRFs is unchanged.

One might argue that the changing dynamics that we document when policy rates are negative might come into effect at higher policy interest rates and not even be related to negative policy rates. We provide some insights into this question by allowing the function $F(z_t)$ to be equal to one when policy rates are below or equal to 1 per cent but above, or equal to, zero for both the domestic policy rate and separately for the Euro area policy rate (this state is labeled NIRP in the figures below). Hence, the results show the changes between higher policy rates in normal times and low, but positive, policy rates. We show results only for Euro-area forward guidance which had the most significant changes in our baseline results, but results are very similar with other shocks and dependent variables. Figure 25 shows results to these changes for asset prices. Contrary to our baseline results there are no statistical differences between the different states. Hence, the baseline results are driven by events during the NIRP period and not by low policy rates in general.

Market funding costs for banks and mortgage institutions are generally closely related to government bond yields as can be seen in Figure 26. Figure 26a shows a scatter plot of Swedish mortgage bond yields relative to Swedish government bond yields and figure 26b compares the impulse responses of domestic government bond yields with mortgage bond yields to foreign target interest rate and forward guidance surprises. The dynamics are very similar suggesting that the mortgage institutions financing costs are closely connected to the government bond yields during the period we study.

We have furthermore studied the robustness of our results regarding transformation of the dependent variables (differences instead of levels or log-levels) and the possibility of a regime dependent trend and found our results robust to these changes.$^{15}$

$^{15}$Results are available upon request from the authors.
4. Discussion and Concluding remarks

In summary, we use non-linear local projection methods to analyze the recent experience of negative interest rate policy in Sweden to test for changes in the effects of foreign and domestic monetary policies on domestic financial variables, when the domestic policy interest rate is in negative territory. We find that the negative interest rate period has significantly changed the transmission and spillovers of both foreign and domestic monetary policy compared with the positive interest rate period. Our results suggest that spillovers from Euro area monetary policy are in general stronger than from U.S. monetary policy, and that foreign forward guidance has become more important than foreign target interest rate policy in the negative interest rate period in Sweden. In addition, as Swedish banks can continue funding their operations through lower market rates, bank profitability seems not to be negatively affected as the policy rate is lowered into negative territory, suggesting that the current policy rate in Sweden is still above the reversal rate (Brunnermeier and Koby 2018), from which an even lower policy rate would be contractionary.

With that said, we caution that our findings are based on event studies and subject to the typical caveats (see e.g. the discussion in Stock and Watson 2018). Moreover, central banks used several unconventional measures simultaneously which makes it challenging to disentangle the separate effects. In Sweden the NIRP policy was accompanied with an asset purchase program. This makes it challenging to be fully certain that the changing dynamics that we observe are entirely due to the negative interest rate policy.16 The dramatic shift in the dynamics of lending end deposit rates and the very cautious implementation of the asset purchase program are however an indications that NIRP is an important factor. Moreover, the Riksbank Business Survey and other anecdotal evidence support this indication (see e.g. Riksbank 2016a, and 2016b for a discussion). More research on this topic is however needed.

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16 See e.g. Dell’Ariccia, Haksar, and Mancini-Griffoli, (2017) for a discussion and comparison of the effects of Negative Interest Rate Policies (NIRPs) and Quantitative Easing (QE) on bank profitability.
References


Appendix A. Appendix A

Monetary Policy Surprises: Sweden  The surprise component of the change in the Swedish policy rate, $\Delta r_t^u$, is given by
\[
\Delta r_t^u = \frac{(stina_1^t - stina_{1-\Delta t}^t)(d1 + d2)}{d2} 
\]
where $(stina_1^t - stina_{1-\Delta t}^t)$ is the change in the 1-month STINA interest rate around a window of fifteen minutes before and two hours and forty five minutes after each monetary policy announcement, $d1$ is the number of days between the day the 1-month STINA contract takes effect and the repo rate implementation day, and $d2$ is the number of days within the repo rate implementation day and the day in which the contract ends.

Monetary Policy Surprises: U.S.  As in Kuttner (2001) and Gürkaynak et al. (2005), the surprise component of the change in the US policy rate in the next monetary policy meeting, $\Delta r_t^u$, is given by
\[
\Delta r_t^u = (ff_1^t - ff_{1-\Delta t}^t) \frac{D1}{D1 - d1} 
\]
where $d1$ denotes the day of the announcement of a policy decision, $D1$ is the number of days in the month and $ff_1^t - ff_{1-\Delta t}^t$ is the interest rate change for the first federal funds future contract measured around a window of ten minutes before and twenty minutes after the policy announcement. In addition, we can also obtain the surprise component of the change in the US policy rate in the second monetary policy meeting from $t$,
\[
\Delta r_{t,2}^u = \left[(ff_3^t - ff_{3-\Delta t}^t) - \frac{d2}{D2} \Delta r_t^u \right] \frac{D2}{D2 - d2} 
\]
where $d2$ and $D2$ are the day of that second monetary policy meeting and the number of days within the month containing that meeting, respectively.

Monetary Policy Surprises: Euro Area  The surprise component of the change in the European policy rate, $\Delta r_t^u$, is given by
\[
\Delta r_t^u = es_{t}^{0.5} - es_{t-\Delta t}^{0.5} 
\]
where $es_{t}^{0.5} - es_{t-\Delta t}^{0.5}$ is the interest rate change for the 2-week eonia swap contract.
Estimating Additional Dimensions of Monetary Policy Announcements  With the surprise components of the policy rate change for each economy in hands, we estimate the "policy rate shock" and the "forward guidance shock" for each economy as the following. First, we construct the matrix

\[ X_t = [\Delta r_t^u \Delta i_t] \]

where \( \Delta i_t \) is a row vector containing the interest rate change for the contracts that provide information about the expected path of policy rates in the coming one or two years for each economy. For Sweden, \( \Delta i_t \) contains daily interest rate changes for the first, second, fourth and eighth FRA (Forward Rate Agreements) contracts. For the US, \( \Delta i_t \) contains \( \Delta r_{t,2}^u \) together with the second through fourth Eurodollar future contracts, measured with a window of ten minutes before and twenty minutes after each monetary policy announcement. For the euro-area, \( \Delta i_t \) contains daily interest rate changes for the one-month eonia swap contract, and for the first, second, fourth, sixth and eighth Euribor futures contracts. All these series are standardized prior to the factor estimation. We then assume that each element of \( X_t \) has a factor structure,

\[ X_{lt} = \lambda_l F_t + v_{lt} \]

where \( F_t \) is a \( k \times 1 \) dimensional vector of factors, \( \lambda_l \) is a \( k \times 1 \) vector of factor loadings and \( v_{lt} \) denotes an idiosyncratic component. In matrix notation,

\[ X = FA + v \]

where \( X \) is a \( T \times n \) matrix, \( F \) is a \( T \times k \) matrix of latent factors, \( \Lambda \) is a \( k \times n \) matrix of factor loadings and \( v \) is a \( T \times n \) matrix of idiosyncratic components.

Since \( F \) is not observed, it needs to be replaced by estimates \( \hat{F} \), which are obtained via standard PCA. As in Gürkaynak et al. (2005), we set \( k = 2 \). In order to allow for a more structural interpretation of these unobserved factors, we follow Gürkaynak et al. (2005) and rotate \( F \) so that the first factor corresponds to \( \Delta r_t^u \) and the second factor corresponds to surprise movements in policy rate expectations over the coming one or two years that are not driven by \( \Delta r_t^u \). In other words, we define a matrix \( F^* \) such that

\[ F^* = FU \]
where

\[ U = \begin{bmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{bmatrix} \]

is an orthogonal matrix with determinant equal to one, and that is identified by a number of restrictions. First, the column vectors of \( U \) have unit length. Second, the columns of \( F^* = (f_1^*, f_2^*) \) remain orthogonal to each other. We also need the restriction that \( f_2^* \) does not load into \( \Delta r_i^u \), so that \( \Lambda_{21}\alpha_1 - \Lambda_{11}\alpha_2 = 0 \), where \( \Lambda_{11} \) and \( \Lambda_{21} \) are entries in the \( 2 \times n \) matrix \( \Lambda \).

The rotated factors are computed as

\[
\begin{align*}
    f_1^* &= \alpha_1 f_1 + \alpha_2 f_2 \\
    f_2^* &= \beta_1 f_1 + \beta_2 f_2
\end{align*}
\]

with

\[
\begin{align*}
    \alpha_1 &= \frac{\Lambda_{11}}{\Lambda_{11} + \Lambda_{21}} \\
    \alpha_2 &= \frac{\Lambda_{21}}{\Lambda_{11} + \Lambda_{21}} \\
    \beta_1 &= \frac{-\alpha_2 \text{var}(f_2)}{\alpha_1 \text{var}(f_1) - \alpha_2 \text{var}(f_2)} \\
    \beta_2 &= \frac{\alpha_1 \text{var}(f_1)}{\alpha_1 \text{var}(f_1) - \alpha_2 \text{var}(f_2)}
\end{align*}
\]

Lastly, we rescale \( f_1^* \) and \( f_2^* \) so that they respectively move the first and last columns of \( X \) prior to standardization one to one.
Figure 1. Nominal Policy Rates and Government Bond Yields, Sweden and the Euro Area, Percent.

Note: The zero coupon yields have been estimated with the Nelson Siegel method.

Source: Macrobond.
Figure 2. Target and Path Surprises in Sweden, the Euro Area and United States.

Note. This figure shows a plot of the target surprises (Factor 1) and path surprises (Factor 2).
Figure 3. Interaction between Target and Path Surprises in Sweden, the Euro Area and United States.

Note: The figure shows scatter plots of target rate and path monetary policy surprises in the Euro Area, the U.S. and Sweden.
Figure 4. Interaction between Target and Path Surprises in Sweden, the Euro Area and United States when Domestic Policy Rate is Negative.

Note: The figure shows scatter plots of target rate and path monetary policy surprises in the Euro Area, the U.S. and Sweden on dates when the domestic policy rate is negative.
Figure 5. Target and Path Surprises in Sweden, the Euro Area and United States on dates with other macroeconomic news announcements.

Note: The figure shows monetary policy surprises in the Euro Area and the U.S. on dates where there have been additional news announced on the same day. These news announcements are for the U.S.: Consumer price index, Gross domestic product, Non-farm payrolls, ISM manufacturing. The news announcements for the Euro Area are: Euro Area unemployment, Euro Area Gross domestic product, Euro Area inflation, Germany unemployment, Germany Gross domestic product and Germany inflation.
Figure 6. PDFs and CDFs of the Regime-Specific Surprises.

Panel a. Target/Rate Factor Monetary Policy Surprises.

Note: Column 1 shows the PDF of the target rate surprises in the different regimes. Column 2 shows the CDF. The dashed lines show the distribution during NIRP, the dotted lines in PIRP, and the solid line the average of the two regimes.


Note: See Figure 4a.
Figure 7. Impulse Response of Banks’ and Financial Services’ Equity Prices to a Euro Area monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: The first four columns show the 7-day the smoothed impulse response to a monetary policy surprise (the type is indicated in the title) that increases the repo rate (in case of a domestic surprise) or the foreign policy rate (in case of a Euro Area or U.S. surprise) by 1 percentage point on impact. In the first column, the solid blue line shows the response in a linear, state independent model, the green dashed line shows the response in a negative interest rate period (NIRP), and the red dotted line the response when the policy rate is positive (PIRP). The second column shows a 90 percent confidence interval around the state independent response, the third column the same interval around the response in NIRP, and the fourth column the interval around the response in PIRP. The fifth column shows t-statistics testing the hypothesis that the difference between the coefficients in NIRP and PIRP is zero. The solid line is calculated using the Driscoll-Kraay method, and the dashed line using a bootstrap approach. The shaded area is ±1.65. NIRP is the period with negative domestic policy interest rates and PIRP is the period with positive domestic policy interest rates.
Figure 8. Impulse Response of Banks’ and Financial Services’ Equity Prices to a U.S. Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 9. Impulse Response of European and Domestic Banks’ Equity Prices to a Euro Area Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 10. Impulse Response of Domestic Government Bond Yields to a Euro Area Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 11. Impulse Response of Domestic Government Bond Yields to a U.S. Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 12. Impulse Response of Mortgage Lending Rates to a Euro Area Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 13. Impulse Response of Mortgage Lending Rates to a U.S. Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 14. Impulse Response of Nominal Exchange Rates to a Euro Area Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 15. Impulse Response of Nominal Exchange Rates to a U.S. Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 16. Impulse Response of Nominal Exchange Rates and Government Bond Yields in Sweden and the Euro area to a Euro area Monetary Policy Surprise in Normal Times (left) and in NIRP periods (right). Central estimates.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: The figures show the 7-day the smoothed impulse response to Euro area monetary policy surprises (the type is indicated in the respective panels) that increases the foreign policy rate (3-month bond yield for the target factor monetary policy surprise and the 2-year government bond yield in the case of the path factor) by 1 percentage point on impact. The solid blue line shows the response for Swedish government bond yields and the dashed red shows the responses for Euro area government bond yields. The left side charts in each panel shows responses in normal times and the right side charts show responses in NIRP times.
Figure 17. Impulse Response of Banks’ and Financial Services’ Equity Prices to Domestic Monetary Policy Surprises.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 18. Impulse Response of Domestic Government Bond Yields to Domestic Monetary Policy Surprises.

Panel a. Target Factor Monetary Policy Surprise

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7a.
Figure 19. Impulse Response of Mortgage Lending Rates to Domestic Monetary Policy Surprises.

Panel a. Target Factor Monetary Policy Surprise

Notes: See Figure 7.
Figure 20. Impulse Response of Nominal Exchange Rates and Equity Prices to a Domestic Monetary Policy Surprise.

Panel a. Target Factor Monetary Policy Surprise

Panel a. Path Factor Monetary Policy Surprise.

Notes: See Figure 7.
Figure 21. Target and Path Surprises in Sweden the Euro Area and United States on dates where monetary policy surprises are common.
Figure 22. Impulse Response of Banks’ and Financial Services’ Equity Prices to a Domestic Monetary Policy Surprise – Extra controls (left) and extra controls as well as removal of common monetary policy dates shown in figure 23 (right).

Panel a. Target Factor Monetary Policy Surprise.

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 7. In addition to the standard controls (lags, policy rate, trend and constants) we control for Citi Economic Surprise Indices, (for U.S., E.A. and Sweden), the Euro Area and U.S. monetary policy rate factor and path factor surprises as well as the 2-year zero coupon bond yield differential between EA and Sweden.
Figure 23. Impulse Response of Banks’ and Financial Services’ Equity Prices to a Euro Area Monetary Policy Surprise – Extra controls and Excluding Common Monetary Policy Surprises.

Panel a. Target Factor Monetary Policy Surprise.

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 22.
Figure 24. Impulse Response of Banks’ and Financial Services’ Equity Prices to a U.S. Monetary Policy Surprise – Extra controls and Excluding Common Monetary Policy Surprises.

Panel a. Target Factor Monetary Policy Surprise.

Panel b. Path Factor Monetary Policy Surprise.

Notes: See Figure 22.
Figure 25. Impulse Response of Banks’ and Financial Services’ Equity Prices to a Euro area Path Factor Monetary Policy Surprise.

Panel a. NIRP state determined by Domestic Policy Rates. F(z) equal to one (denoted NIRP state) when the repo rate is below or equal to 1 but above or equal to zero.

Panel b. NIRP state determined by Euro area Policy Rates. F(z) equal to one (denoted NIRP state) when the Euro area Deposit rate is below or equal to 1 but above or equal to zero.

Notes: See Figure 7.
Figure 26a. Two and five year Swedish Mortgage Bond Yields relative to Government Bond Yields

Note: The left panels show scatterplots of Swedish Mortgage Bond Yields (2 and 5 year maturity) relative to Government Bond yields of the same maturities. The right panels show the spread between 2 and 5 year Swedish Mortgage Bond Yields and Government Bond Yields. The blue highlighted markers show yields during the NIRP period.

Figure 26b. Impulse Response of Domestic Government Bond and Mortgage Bond Yields to a Domestic Target Factor Monetary Policy Surprise.

Note: See figure 7.