Staff memo

The effect of repo rate path changes on asset prices

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SVERIGES RIKSBANK

A staff memo provides members of the Riksbank's staff with the opportunity to publish slightly longer qualified analyses of relevant issues. It is a publication for civil servants that is free of policy conclusions and individual standpoints on current policy issues. Staff memos are approved by the appropriate Head of Department.

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Summary

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In this memo, we analyse how changes in the actual repo rate as well as changes in the repo rate path affect different market interest rates, lending rates to households, the stock market and exchange rates. We answer this question using an event study approach. The first step of the analysis is to separate between expected and unexpected changes in the repo rate path. To do so, we apply two different methods, perceived and intended changes. The perceived change is identified using movements in financial prices linked to the repo rate just around the policy announcement. The intended changes is instead identified with a regression approach following Brubakk et al (2017) and Åhl (2017). Even though we apply two different methods, both measures are quite similar.

Using the approach suggested by Gürkanyak et al. (2005) we then distinguish between movements in the actual repo rate and changes in the repo rate path. This is done through a factor analysis to identify two uncorrelated factors which capture movements in the actual policy rate, the target factor, and the repo rate path, the path factor. We then proceed to investigate how changes in the repo rate and repo rate path affect different asset prices using regression techniques.

The results indicate that changes in both the repo rate and the repo rate path can influence market prices. The effect from changes in the repo rate path goes beyond what can be explained by changes in the repo rate path that are correlated with changes to the current repo rate. This is the case for market interest rates, interest rates facing households and firms as well as exchange rates but not for the stock market. The result is robust to using alternative methods to separate unexpected from expected changes in the repo rate path and also holds using alternative methods to estimate the impact of repo rate path changes on different market prices. This indicates that variation in a published policy rate path is an additional tool a central bank can use to influence market prices.

[1] The authors wish particularly to thank Jan Alsterlind and Ulf Söderström. The opinions expressed in this report are those of the author and are not necessarily shared by the Riksbank.

Introduction

The Riksbank influences the economy through its ability to affect current and expected future financial market conditions. An important monetary policy tool for this purpose is the (risk-free) repo rate which directly controls the overnight interest rate on the interbank market. By varying the repo rate, the Riksbank seek to influence various other financial market interest rates and prices such as interest rates on bonds with longer maturities, mortgage interest rates, exchange rates, and the stock market.

Since 2007, the Riksbank has published the repo rate path, its forecast of the repo rate over the coming three years. There are several reasons for doing so. Two major reasons are consistency and transparency. Basing a forecast on the assumption of the policy rate being constant, which the Riksbank did prior to 2007, implies an inconsistency between the policy rate forecast and the forecasts for the remaining macro variables. Transparency is improved if a central bank can explain its view on a likely future path for its policy rate. Another reason for publishing an interest rate forecast is to provide market participants with guidance about future monetary policy thereby affecting expectations of future financial market conditions.

The purpose of this memo is to investigate the effects that changes in the repo rate and the published repo rate path have on various financial market prices. In particular, we are interested in answering the question, what are the effects on financial markets of changing the repo rate or the repo rate path? To answer this question we use an event study approach.

The event study methodology requires us to identify the expected and unexpected part of each monetary policy decision. To do so we build on the work by Kuttner (2001), Gürkaynak et al. (2005), Brubakk et al. (2017) and Åhl (2017). Kuttner (2001) uses changes in prices on fed fund futures around monetary policy decisions to identify unexpected changes in the federal funds rate. The purpose is to be able to identify the impact of the actual federal funds rate on different market rates. Gürkaynak et al. (2005) and Brubakk et al. (2017) use a similar approach, but also include changes in other financial instruments around the policy decision to determine whether forward guidance from the central bank has an impact on other market interest rates. Åhl (2017) instead uses a regression based technique to isolate unexpected changes in the repo rate path from expected changes.

The results indicate that changes in both the repo rate and the repo rate path can influence market prices. The effect from changes in the repo rate path goes beyond what can be explained by changes in the repo rate path that are correlated with changes to the current repo rate. This is the case for market interest rates, interest rates facing households and firms as well as exchange rates but not for the stock market. The result is obtained using alternative methods to separate unexpected from expected changes in the repo rate path and also holds using alternative methods to estimate the impact of repo rate path changes on different market prices. This indicates that variation in a published policy rate path is an additional tool a central bank can use to influence different market prices.

Our work is related to a growing literature that examines the effect of changes in the policy rate as well as forward guidance of future monetary policy on financial market conditions. For the case of Sweden, Fransson and Tysklind (2016) find that changes in the actual repo rate influence interest rates across maturities and different riskiness. We extend their analysis by investigating whether changes in the published repo rate path affect market interest rates and also extend the analysis to include other types of financial prices. Åhl (2017) examines the impact of repo path changes but focuses on the effects on market forward rates. He finds that repo path changes significantly affect market forward rates up to six quarters after the policy decision. Relative to Åhl (2017), we adopt an alternative way of computing repo path changes. Furthermore, we examine the impact on several financial market interest rates and asset prices. Brubakk et al. (2017), using an approach similar to ours, look at the effects of changes in the policy rate path in both Sweden and Norway on

market interest rates with different maturities. They find that changes in the repo rate path seem to have a significant impact on market interest rates with maturities up to 10 years.

Identifying expected and unexpected monetary policy changes

Financial markets are forward-looking by nature. Financial market prices are therefore to a large extent influenced by information about future events. Conventional asset pricing theory suggests that all available information is reflected in the current market price. An implication of this is that market prices should adjust only if new and unexpected information becomes available. Information that is already available, or newly available information that is in line with expectations should not affect market prices. Publication of a monetary policy decision is an example of new information that can affect financial market prices. By definition, a change in the monetary policy stance can be divided into an expected and an unexpected component:

$$\Delta monetary\ policy\ stance_t \equiv \Delta expected_t + \Delta unexpected_t \quad (1)$$

For a central bank that publishes a forecast (path) for its monetary policy instrument, both the decision about the policy rate to be implemented subsequent to the decision, as well as the forecasted path for the policy rate, can potentially provide new and unexpected information to the market. According to the reasoning above, only the unexpected part of the monetary policy decision should affect market prices. A central stage in our analysis will thereby be to distinguish between expected and unexpected changes in both the repo rate and the repo rate path.

Identifying expected and unexpected changes in the actual repo rate

In an important contribution, Kuttner (2001) proposed a method to separate expected from unexpected changes in the policy rate by looking at how prices on short-term derivative contracts linked to the policy rate move around a policy announcement. With this approach, he shows that unexpected changes in the federal funds rate have a significant impact on other market interest rates in the United States. Fransson and Tysklind (2016) have applied this method to Swedish data. They show that changes in the actual repo rate level have a significant impact on market interest rates as well as interest rates to firms and households.

Identifying expected and unexpected changes of the repo rate path

Identifying the expected and unexpected changes in the repo rate path is less straightforward compared to the actual repo rate. There are essentially two reasons for this. First, the Riksbank is quite explicit about the fact that the repo rate path is a forecast. This means that even though the repo rate path changes in an unexpected fashion, financial market participants might not think of the change as credible, implying that asset prices will not change. The possible lack of credibility could arise if financial market participants do not think the economy will evolve as in the Riksbank forecast. Alternatively, they might think that the Riksbank will not implement the forecasted repo rate path, even though the economy evolves as in the Riksbank's forecasts.

A second reason is that on announcement days, the Riksbank releases not only information about the repo rate and the repo rate path, but also a whole set of forecasts, and a press release documenting the motivation for the decision. Furthermore, the Governor of the Riksbank holds a press conference explaining in detail the motivation for the decision. All this information might induce financial market participants to revise their view of the future repo rate, in ways not incorporated into the repo rate path.

The bottom line is that variation in financial market prices around monetary policy announcements can be a noisy measure of the unexpected part of repo rate path changes compared to repo rate changes. Brubakk et al. (2017) approach this issue by distinguishing between the *perceived* and *intended* impact of changes in the forward guidance by the central bank. The unexpected change in perceived monetary policy is defined as the actual change in financial market prices linked to the future policy rate. They show that perceived changes in the repo rate path have a significant impact on market interest rates with longer maturities. This method of measuring the effect of forward guidance of monetary policy was previously used on the United States by Gürkaynak et al. (2005) who found similar results there.

However, it is not clear whether the perceived policy change, as measured by variation in financial market variables, is also the intended change in policy by the central bank. To address this question, Brubakk et al. (2017) construct two measures of the central bank's intended forward guidance based on the published interest path and the path implied by prices on financial markets prior to the announcement of the new monetary policy. They show that these variables help explain the perceived change in the policy rate and hence conclude that the perceived change was at least partly in line with the intended change. Åhl (2017) uses similar measures to try to isolate the impact of the intended change in the monetary policy stance and show that market expectations about the future interest rate on average move in the direction the central bank had intended when changing the repo rate path.

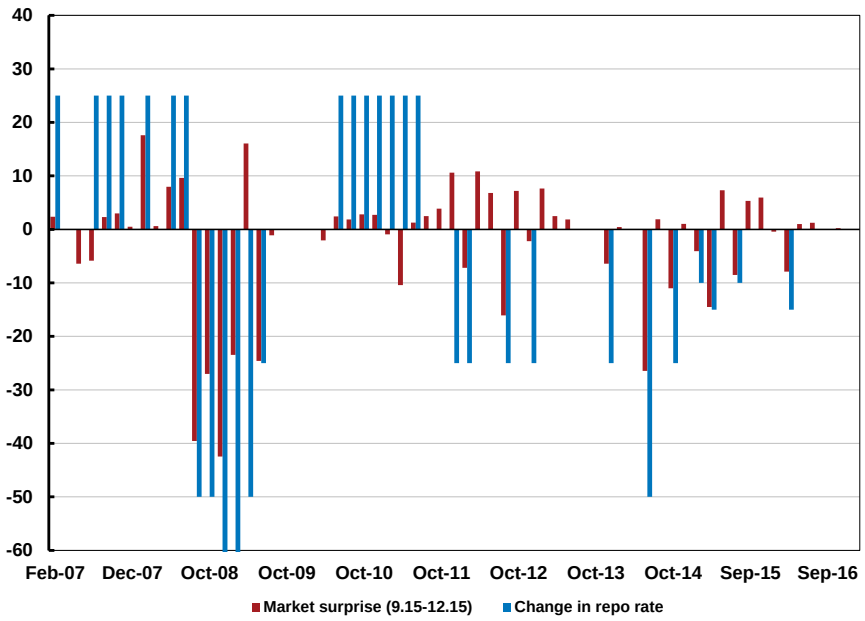
Measuring the expected and unexpected changes in the actual repo rate

We now provide further details about how we implement the approach of Kuttner (2001) on Swedish data. Our procedure has been used previously in the Swedish case by Fransson and Tysklind (2016).

By looking at how the price of a one-month Stina swap changes around a repo rate decision, we can calculate the unexpected part of the repo rate change. The STINA swap contracts has Stibor T/N as the underlying variable and reflects an average of the expected interest rate over the coming month. Hence, with a sufficiently narrow window around the policy decision, and assuming that expected information does not change market prices, all variation in the Stina swap price will reflect unexpected news about the current repo rate decision. In this paper we use changes over a 3 hour window starting 15 minutes before the policy announcement to identify the surprise. The expected repo rate adjustment is calculated as the difference between the repo rate adjustment and the surprise component. For more details about the calculations, see the appendix.

In Figure 1, we see the expected and unexpected components of each Riksbank monetary policy decision from 2007 to 2016. The blue bars show the actual change in the repo rate at each meeting while the red bars show the measure of the unexpected change. For most of the decisions, the unexpected part of the decision is quite small. Also, at some meetings, the actual change and the unexpected change go in different directions. Both observations highlight that it is important to try to isolate the unexpected part of the decision.

Figure 1. Actual and unexpected changes in the repo rate
Basis points



Source: Thomson Reuters and the Riksbank

Measuring the expected and unexpected changes in the repo rate path

The perceived impact

To measure the perceived unexpected part of the announcement of a new policy rate path, we use a similar approach to the one used to identify expected and unexpected changes in the actual repo rate. The approach uses variation in financial contracts closely linked to the future repo rate around policy decisions. This approach is appropriate as we aim to measure the perceived effect of the policy change. This approach closely resembles the method used in Gürkaynak et al. (2005) and Brubakk et al. (2017).

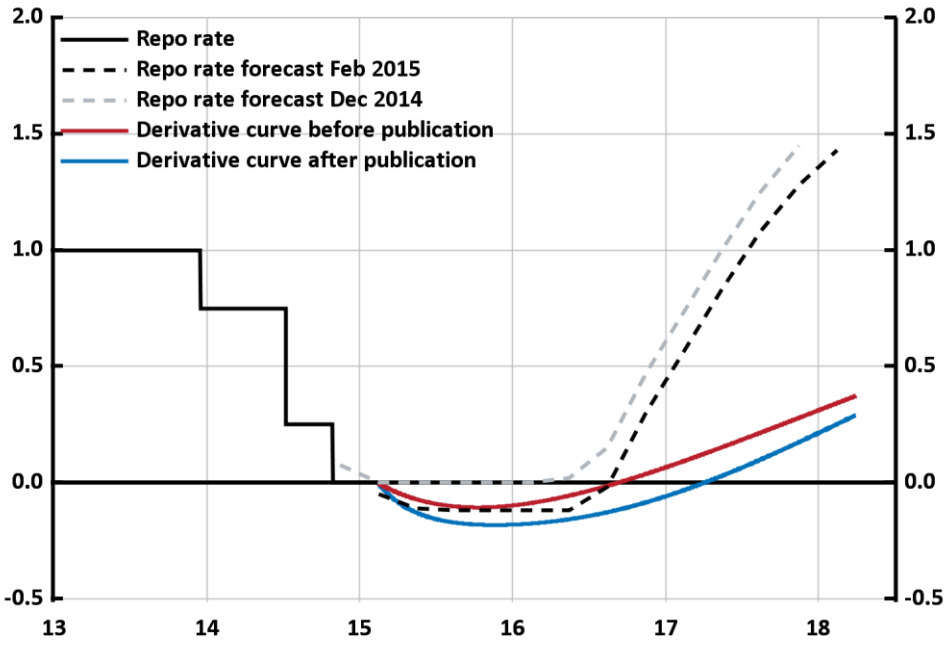
We use two different derivative contracts, RIBA and FRA, which are linked to expectations about the future repo rate to estimate a continuous derivative curve that captures market participants' view of the future repo rate.[2] RIBA contracts are three month swap contracts with the repo rate as the underlying asset and FRA contracts are future contracts with three-month Stibor as the underlying asset. This derivative curve contains not only market expectations about the future repo rate but also various kinds of premiums. However, using only the daily change in the derivative curve, we aim to minimize the influence of movements in premium.[3] We estimate the derivative curve the day prior to a monetary policy announcement, and at the end of the announcement day. Analogous to how we measure the unexpected changes of the repo rate decision, our identifying assumption is that the change in the derivative curve over the announcement day is caused by unexpected changes in future monetary policy. Again, the change in the derivative curve might be a noisy measure of the unexpected part of the repo path, due to the reasons discussed previously. This approach implies that the measure of unexpected change in the repo path is

$$\Delta unexpected_t = \Delta derivative\ curve_t \qquad (2)$$

[2] The curves are estimated using the extended Nelson Siegel method.
[3] This is the case if the various premium in financial market prices are uncorrelated to unexpected movements in monetary policy.

By estimating a continuous curve, we can analyse changes at different horizons. We calculate ninety day averages for the change up to three years on from each policy decision. By doing so instead of using calendar quarters, we make sure that the horizons are the same, no matter where within a quarter a monetary policy decision is announced. Figure 2 shows how this could look. The blue curve is estimated on data from the day prior to the monetary policy announcement in February 2015, the red curve is estimated on data at the end of the announcement day. The difference between the two is assumed to be the unexpected part of the monetary policy announcement.

Figure 2. Changes in derivative curves and the repo rate path
Per cent



Sources: Macrobond and the Riksbank

The expected change in the repo rate path is then computed as the actual change in the repo rate path (the change between the grey and the black dashed lines in the figure) less the unexpected change. Hence,

$$\Delta expected_t = \Delta repo\ path_t - \Delta derivative\ curve_t. \quad (3)$$

The repo rate path is only available as quarterly averages based on calendar quarters. To be able to match the time horizons exactly, we first interpolate the repo rate path to a daily frequency, and then re-calculate new ninety-day averages with the date of the policy announcements as a starting point.

The intended impact

Using the first approach, we measure how the change in the monetary policy stance has been perceived by market participants. The unexpected changes in the repo rate path are calculated by measuring the unexpected component using changes in financial market prices on announcement days. To compute the intended policy, we follow the approach developed by Brubakk et al. (2017) and Åhl (2017). In particular, we explain the expected change in policy with the help of an information set available before the announcement of new policy. Hence,

$$\Delta expected_t = f(available\ information_t). \quad (4)$$

The intended unexpected change in the repo rate path is then the difference between the actual change and the expected part. To implement this procedure, we need a set of covariates that are available before the announcement of a new repo rate path which can explain how expectations about the repo rate path have changed from one meeting to the next. One can then regress the actual change in the repo rate path on these variables and the fitted values from that regression correspond to the expected change in the monetary policy path and the residual corresponds to the intended unexpected change in the policy path. In this memo, we use a set of covariates similar to the ones used in Brubakk et al. (2017) and Åhl (2017) and regress them on the actual change in the policy rate path. More specifically, we estimate the regression

$$\Delta Path_{h,t}^{RB} = \alpha_h + \mu_h^{DC}\left(DC_{h,t-\tau} - DC_{h,t-1}\right) + \mu_h^{D}\left(DC_{h,t-1} - Path_{h,t-1}^{RB}\right) + \epsilon_{h,t} \quad (5)$$
$$\epsilon_{h,t} = \rho_h \epsilon_{h,t-1} + \gamma_{h,t}$$

where $\Delta Path_{h,t}^{RB}$ is the change in the repo rate path in the period *h* quarters after the announcement in period t compared to the previous path during the same period. The term $\left(DC_{h,t-\tau} - DC_{h,t-1}\right)$ is the change in the estimated derivative curve from just after the previous decision up until just before the subsequent decision, during the same period. If prices of derivatives were free from premiums and truly reflected market expectation, this term would capture how the market has revised its expectations about the future policy rate from one meeting to the next.[4] The term $\left(DC_{h,t-1} - Path_{h,t-1}^{RB}\right)$ measures the difference between the market pricing of the repo rate and the repo rate path just after the previous decision. This measure captures the fact that at times market prices deviate substantially from the published repo rate path. For example, if market rates are lower than the previously published repo rate path, this might be an indication that market participants think the repo rate path will be revised down in the future.

Given that we now measure the change in market prices over a longer time frame, this method is more sensitive to movements in premium. For example, a shift in the derivative curve between two meetings will here be interpreted as a shift in market expectations even though in reality the movement could be due to shifts in premiums. To capture more slow moving components of changes in premiums, we allow the residuals in the regression to follow an autoregressive process. The autoregressive term can also be justified by the fact that large differences between the actual repo rate path and market expectations tend to be persistent, implying that it takes some time until they converge. The intended unexpected change in policy corresponds to the residual from the regression, $\gamma_{h,t}$.

How do the perceived and intended measures relate to each other?

There are pros and cons associated with both the perceived and intended measures. The perceived measure is by construction the more precise measure of the actual monetary policy surprise perceived by markets, but it does not say anything about whether the market reaction was in line with the central banks intention. The intended measure could instead potentially answer that question but is on the other hand much harder to measure.

Given that we have two imperfect measures of the unexpected changes in the repo rate path, it could be useful to have a look at how these measures relate to each other. Figure 3a and 3b show the measure of the surprise in quarters 4 and 8 using our measures of the intended and perceived monetary policy surprise. The two measures are highly correlated, with correlations coefficients of 0.69 in quarter 4 and 0.56 in quarter 8. However the measure of intended unexpected changes is much more volatile than the perceived policy change. The reason is most likely that the intended change is much harder to measure and probably contains some elements of measurement error.

[4] The assumption of the term premium being constant over longer periods of time is a strong assumption. Most likely, the term premium is correlated with the same shocks that affect the systematic (expected) policy.

Figure 3a. Unexpected change in repo rate path in the 4th quarter after the announcement
Percentage points

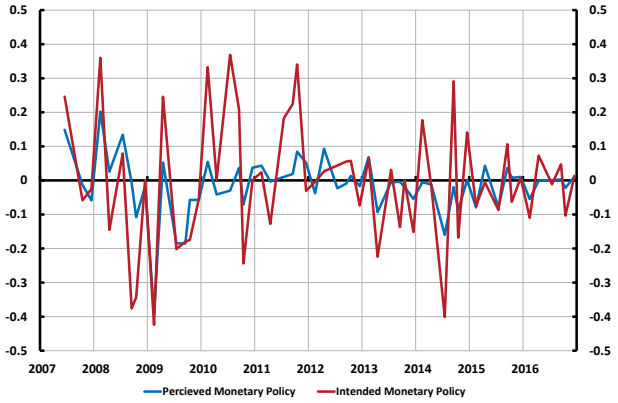
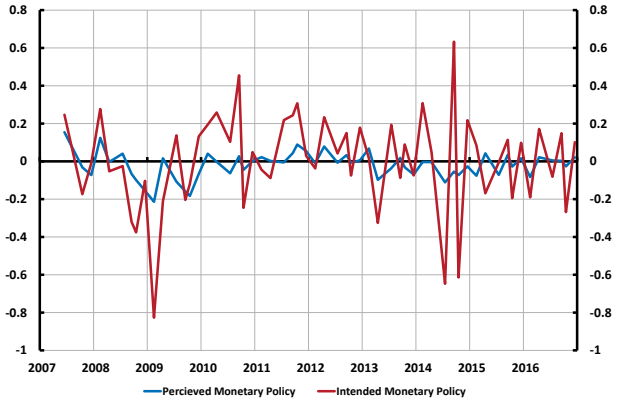


Figure 3b. Unexpected change in repo rate path in the 8th quarter after the announcement
Percentage points



Empirical strategy

Changes, both expected and unexpected, in the repo rate and repo rate path across horizons are naturally strongly correlated with each other. In Figure 4, we show the correlation between unexpected changes in the repo rate and the measure of unexpected changes in the repo rate path at different horizons, computed using the measure of perceived change in the repo rate path. Results are similar if we instead use the measures of the intended change.

Changes over different forecast horizons are highly correlated. The correlation is the highest for horizons closest to each other but also the correlation between the unexpected change in the current repo rate and the measure of unexpected path changes 10 quarters ahead are not negligible.

Figure 4. Correlation between unexpected changes in the repo rate and different parts of the repo path
Correlation coefficients

	Repo	Q2	Q4	Q6	Q8	Q10
Repo	1.00					
Q2	0.76	1.00				
Q4	0.58	0.92	1.00			
Q6	0.55	0.86	0.96	1.00		
Q8	0.53	0.77	0.86	0.96	1.00	
Q10	0.49	0.65	0.73	0.87	0.97	1.00

It is important to deal with this multicollinearity problem, in order to separate effects that depend on changes in the current repo rate from changes in the published repo rate path. To do so, we follow the approach of Gürkaynak et al. (2005), previously used on Swedish data by De Rezende (2016) and Brubakk et al. (2017). This method condenses the changes in the repo rate and the repo rate path into two factors, where the first factor can be interpreted as the change in the current policy rate, referred to as the target factor, and the second factor can be interpreted as a change in the repo rate path orthogonal to the repo rate, referred to as the path factor.

As a test of robustness, we will also use an alternative approach where we make changes in different segments of the repo rate path orthogonal to each other by regression techniques. By using the residuals from a regression on the first segment of the derivative curve on changes in the current repo rate, we will derive a measure of change in this segment of the path that by construction is orthogonal to the actual change in the repo rate. We can then do this step by step on further segments of the curve to study how changes in different parts of the curve influence market prices.

A factor analysis to separate changes in the repo rate from path changes

We now provide further information about our approaches to orthogonalize the repo rate and repo path changes. This method has previously been used on Swedish data by Brubakk et al. (2017).

As we have identified both expected and unexpected changes, we extend the analysis in Gürkaynak et al. (2005) to include both unexpected and expected changes in the repo rate path. We first choose a set of variables to be included in the analysis and collect them in thevectors X^u and X^e, where the vectors collect the unexpected and expected movements in the repo rate and repo rate path respectively:

$$X^u = \left[\Delta repo^u \; \Delta path^u_{Q2} \; \Delta path^u_{Q4} \; \Delta path^u_{Q6} \; \Delta path^u_{Q8} \; \Delta path^u_{Q10}\right]$$
$$X^e = \left[\Delta repo^e \; \Delta path^e_{Q2} \; \Delta path^e_{Q4} \; \Delta path^e_{Q6} \; \Delta path^e_{Q8} \; \Delta path^e_{Q10}\right]$$

For example, the suffix Q2 denotes changes in the repo rate path in the second quarter, measured from the policy announcement, that is 90-180 days after the decision. We then perform a principal component analysis on both vectors and collect the first two principal components in each case. These two factors explain a maximum fraction of the variance of X^u and X^e respectively, but have no structural interpretation. For example, for X^u both factors are correlated with the unexpected change in the current repo rate so we cannot interpret one factor as the change in the repo rate and the other as the change in the repo rate path.

To be able to make that interpretation, we perform the rotation of the principal components suggested by Gürkaynak et al. (2005) (see further details in the appendix). The rotated factors remain orthogonal to each other and explain the same amount of variation in the data as the original factors, but now the second factor is uncorrelated with the change in the actual repo rate. Hence, the first rotated factor can be interpreted as representing changes in the current repo rate and the second factor represents the repo rate path. Finally, we normalize the first factor, which we choose to call target factor, so that a change in the factor corresponds one-for-one with expected and unexpected movements in the current repo rate. We also normalize the second factor, the path factor. For the perceived changes, we make the normalization so that the path factor has the same impact as the target factor on movements in the repo rate path in the ninety-day period two years after the announcement. The path factor for the intended changes is instead normalized to have the same variance as the path factor for the perceived changes. This is to make the interpretation of the estimates easier.

We do this procedure for both ways, perceived and intended, of identifying the expected and unexpected changes that we have described previously. In Figures 5a and 5b, we plot the unexpected target and path factors from the two different approaches. The target factors from the two approaches are close to identical and have a correlation of 0.93. Also the path factors from the two approaches are similar and have a correlation of 0.47.

Figure 5a. The target factor

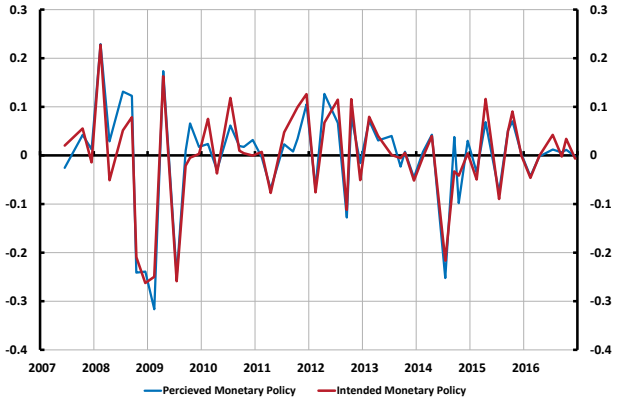
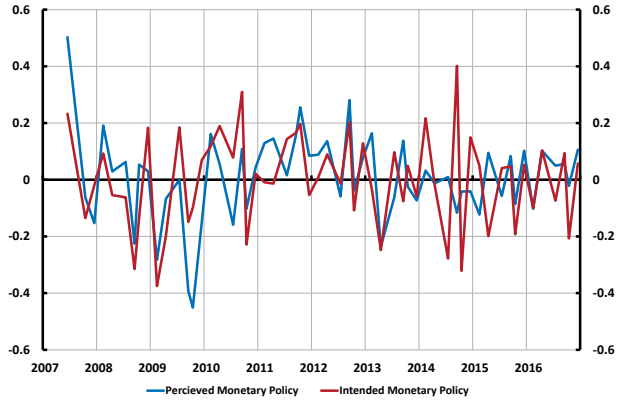


Figure 5b. The path factor



A regression-based technique to separate changes in the repo rate from path changes

Another approach to separate the effects of a change in the repo rate path from changes in the current repo rate is to use regression techniques. Changes in different segments of the repo rate path are regressed on changes in the actual repo rate. The residual from that regression will be orthogonal to changes in the repo rate and give a measure of changes in the path that are uncorrelated with the actual change in the current repo rate. This method is primarily used to test the robustness of the Gürkaynak et al. (2005) method. But the method can also be used to isolate changes in different segments of the repo rate path while retaining uncorrelated changes.

We choose a sequential approach where changes in the repo rate path are divided into three different sections, 1-4 quarters, 5-8 quarters and 9-11 quarters. First, we regress the average change in the path in the first 4 quarters on changes in the repo rate. The residual from the regression is a measure of changes in the short end of the repo rate path which are uncorrelated with changes in the current repo rate. Regressing the changes in the repo rate between 5-8 quarters on changes in the current repo rate and the changes in the first 4 quarters gives a corresponding measure of changes in the middle segment of the repo rate path that are uncorrelated with changes in the current repo rate and with changes in the short end of the curve. We then proceed in an additional step to derive a measure for changes in the very long end of the repo rate path. This procedure gives four uncorrelated measures for changes in the repo rate and different segments of repo rate path which we use to analyse the impact on financial prices. To make interpretation easier, these variables are scaled so that they have the same impact on movements in the repo rate path in the ninety-day period two years after the announcement.

An empirical framework to measure the monetary policy effect on financial prices

To examine the effects of changes in the repo rate and repo path on financial market prices, we use a simple regression-based framework that bears similarities to Kuttner (2001), Gürkaynak et al. (2005), Fransson and Tysklind (2016) and Brubakk et al. (2017). Fransson and Tysklind (2016) regress changes in different market interest rates around monetary policy decisions on expected and unexpected changes in the current repo rate. As Swedish interest rates with longer maturities are highly correlated with their international counterparts, Fransson and Tysklind (2016) control for international movements in interest rates. As a benchmark, we redo their analysis with our data. In particular, we estimate the regression

$$\Delta R_t = \beta_0 + \beta_1 \Delta repo_t^u + \beta_2 \Delta repo_t^e + \varphi \Delta RoW_t + \epsilon_t \quad (6)$$

where ΔR_t is the change on announcement days in the dependent variable of interest, $\Delta repo_t^e$ and $\Delta repo_t^u$ are expected and unexpected movements in the current repo rate, ΔRoW_t is used as a control variable for exogenous movements in international asset markets and ϵ_t is an error term. We expect β_1 to be significantly different from zero. Asset pricing theory suggests that β_2 should not be significantly different from zero.

To examine the effects from changes in the repo rate path, we extend the analysis and estimate the regression

$$\Delta R_t = \beta_0 + \beta_1 \Delta targetf_t^u + \beta_2 \Delta pathf_t^u + \beta_3 \Delta targetf_t^e + \beta_4 \Delta pathf_t^e + \varphi \Delta RoW_t + \epsilon_t \quad (7)$$

where $\Delta targetf_t^X$ and $\Delta pathf_t^X$, for $X = e, u$, are the expected and unexpected target and path factors computed using the principal component analysis described above. As previously described, the target factors will capture the effect from changes in the current repo rate level while the path factors will capture the effect from changes in the repo rate path that are orthogonal to changes in the current repo rate. The same set-up will be used for the two alternative methods used to identify expected and unexpected changes in the repo rate path.

Finally, to study whether orthogonal changes in different segments of the repo rate path have different effects, we estimate a regression on the stepwise orthogonalized parts of the repo rate path:

$$\Delta R_t = \beta_0 + \beta_1 \Delta repo_t^u + \beta_2 \Delta path_{1-4Q,t}^u + \beta_3 \Delta path_{5-8Q,t}^u + \beta_4 \Delta path_{9-11Q,t}^u + \beta_5 \Delta repo_t^e + \beta_6 \Delta path_{1-4Q,t}^e + \beta_7 \Delta path_{5-8Q,t}^e + \beta_8 \Delta path_{9-11Q,t}^e + \varphi \Delta RoW_t + \epsilon_t \quad (8)$$

where $\Delta path_{1-4Q,t}^u$ is the unexpected change in the first part of the repo rate path that is orthogonal to the current level, $\Delta path_{5-8Q,t}^u$ is the change in the middle part of the path orthogonal to the current repo rate and the short end and $\Delta path_{9-11Q,t}^u$ is an orthogonal change in the long end of the repo rate path.

Data

The Riksbank has published its repo rate path since 2007. In this memo, we analyse all monetary policy announcements between 2007 and 2016 which included the publication of a repo rate forecast. There are a few policy decisions during 2007 that did not include a published path. Also, the unscheduled decisions of October 8th 2008 and March 18th 2015 are not included in the analysis. This leaves us with 58 occasions where a policy announcement has been made including a published repo rate path. In this memo, we use daily data and focus on the change between the closing prices the day before the monetary policy announcement and the closing on the day of the announcement.

To identify the surprise in the actual repo rate, we use STINA contracts. STINA contracts are one-month swap contracts with Stibor T/N as the underlying variable. For the estimation of continuous derivative curves, we use both RIBA- and FRA contracts. RIBA contracts are three month swap contracts with the repo rate as the underlying asset and FRA contracts are future contracts with three-month Stibor as the underlying asset. However, we only have data for the RIBA contract from 2009. Hence, for 2007-2008, only FRA contracts are used to estimate the derivative curves.

As outcome variables we use daily changes, from the day before to the close of the announcement day, for a set of different financial variables. The prices include market interest rates, exchange rates and the stock market. We also use listed mortgage rates as outcome variables but here we instead use the change from one day before to four days after

the announcement. This is due to the fact that it usually take a couple of days before these rates are adjusted following a monetary policy decision.

As a robustness check, we have also used a shorter sample that only includes announcements up until 2014. This to avoid the period where the Riksbank has had a negative policy rate and conducted purchases of government bonds. As our conclusion from this analysis is that it does not change the results in any substantial way we have chosen not to report the results here.

Results

This section presents results from our empirical exercises. In each case, we analyse how the repo rate and repo rate path affects:

a) Swedish government bond yields of different maturities,
b) swap rates of different maturities,
c) listed mortgage interest rates of different maturities,
d) the SEK/EUR and SEK/USD exchange rates, and
e) the Swedish stock market index, OMX.

First we show results from the same specification as in Fransson and Tysklind (2016). Then we go on to show the results from perceived changes in the repo rate path using both the specification in equation (7), where we have summarized changes in the actual repo rate and measures of changes in the repo rate path into two different factors and results from the specification where we use the regression-based technique to produce orthogonal segments of the repo rate path. Finally, we show results based on the identified intended changes in the repo rate path.

The impact of changes in the repo rate on financial market prices

Table 1 presents results using the same specification as in Fransson and Tysklind (2016) detailed in equation (6). It reports point estimates and standard deviations of the estimated parameters for the set of different outcome variables.

Table 1. Regression results from equation (6)

	(1) Δgov2yr	(2) Δgov5yr	(3) Δgov10yr	(4) ΔSwap 5y	(5) ΔMrtg 3m*	(6) ΔMrtg 5y*	(7) ΔSEKEUR	(8) ΔSEKUSD	(9) ΔOMX
$repo_u$	0.50***	0.26***	0.14***	0.29***	1.08***	0.31***	-3.89***	-4.20***	1.04
	(0.09)	(0.07)	(0.06)	(0.06)	(0.10)	(0.10)	(1.05)	(1.47)	(0.86)
$repo_e$	-0.05	0.03	0.02	-0.01	0.61***	0.17***	-0.15	-0.15	-0.52
	(0.04)	(0.03)	(0.02)	(0.02)	(0.04)	(0.04)	(0.43)	(0.60)	(0.35)
ΔRoW	0.49***	0.76***	0.82***	0.76***					0.86***
	(0.20)	(0.12)	(0.10)	(0.10)					(0.05)
constant	-0.01	-0.01	0.00	-0.01	-0.02**	-0.01	-0.02	-0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.10)	(0.14)	(0.08)
R^2	0.48	0.58	0.66	0.65	0.92	0.47	0.26	0.17	0.85
obs	56	56	56	56	58	58	58	58	58

***,**,* indicate significant levels of 1, 5 and 10 % respectively. Standard deviation of the regression coefficient in parentheses.

Columns 1-4 show that an unexpected change in the actual repo rate has an effect on government bond rates and swap rates for all maturities, while expected changes have no effect on any of the variables. The estimated coefficient for unexpected changes should be interpreted as the effect on yields in basis-points from a one-basis-point, unexpected change in the repo rate. The estimated coefficient is larger for bonds with shorter maturity, which is natural as they are more directly affected by the current short rate. For example, a one-basis-point change in the repo rate will on average move the two-year government bond rate by

0.50 basis points while the ten-year rate will only move by 0.14 basis points. It is also apparent that the effect of the estimated control variable which captures international movements increases with maturity. This is in line with previous findings that suggest that bonds with longer maturities typically have stronger international co-movements than shorter maturity bonds.

Columns 5 and 6 report the effect on listed mortgage rates. Here we can note that both expected and unexpected changes in the actual repo rate have a significant impact on listed mortgage rate four days after the announcement. Again the estimated effects are larger for rates with shorter maturity.

Columns 7-8 report the impact of a repo rate change on the exchange rate. The effects on the exchange rate against both the euro and the US dollar are similar. The estimated coefficients should be interpreted as a one-basis-point change in the repo rate leads to an appreciation of the exchange rate by about 0.04 percent. A standard 25-basis-point change in the repo rate hence has an impact of roughly 1 percent on the exchange rate. Column 9 shows that repo rate changes seem to have no significant impact on the stock market index. Instead the coefficient on the international control is large and explains most of the variation in Swedish stocks on announcement days.

All of the results reported here are in line with those from Fransson and Tysklind (2016).

The impact of changes in the repo rate and the repo rate path on financial market prices

Perceived changes in the policy path

In this part, we present the results from estimating equation (7), where we regress the different financial variables on the unexpected and expected target and path factors based on the measures of perceived changes in monetary policy. Table 2 reports the results from the regression. In general, both the unexpected target and path factor are significant while the expected factors are not, which is in line with what one would expect, given that only unexpected information should move asset prices. Compared to the results where we only use the actual repo rate, the explanatory power in the regression is in general higher and the estimated coefficient for the foreign movements is in general smaller. Also worth noticing is that the estimated coefficients for the unexpected target factor is very similar to the coefficients for unexpected movements in the actual repo rate in table 1. This is reassuring as the factor is constructed to capture unexpected movements in the actual repo rate.

Table 2. Regression results of equation (7), perceived changes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δgov2yr	**Δgov5yr**	**Δgov10yr**	**ΔSwap 5y**	**ΔMrtg 3m***	**ΔMrtg 5y***	**ΔSEKEUR**	**ΔSEKUSD**	**ΔOMX**
Target factor$_u$	0.59***	0.27***	0.13**	0.30***	0.81***	0.24***	-4.41***	-5.30***	0.51
	(0.06)	(0.06)	(0.06)	(0.05)	(0.12)	(0.09)	(0.90)	(1.34)	(0.93)
Path factor$_u$	0.27***	0.17***	0.10***	0.17***	0.02	0.13***	-2.39***	-3.05***	-0.16
	(0.04)	(0.04)	(0.04)	(0.03)	(0.07)	(0.05)	(0.51)	(0.76)	(0.58)
Target factor$_e$	-0.03	0.03	0.02	0.00	0.76***	0.23***	0.01	0.11	-0.18
	(0.02)	(0.03)	(0.02)	(0.02)	(0.05)	(0.04)	(0.38)	(0.57)	(0.40)
Path factor$_e$	0.03	0.02	0.01	0.02	-0.15***	0.07*	-0.47	0.07	-0.33
	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.03)	(0.33)	(0.49)	(0.34)
ΔRoW	0.15	0.50***	0.69***	0.48***					0.87***
	(0.14)	(0.13)	(0.11)	(0.09)					(0.06)
constant	-0.01**	-0.01	-0.01	-0.01***	-0.06***	-0.02***	0.04	0.05	-0.01
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.08)	(0.12)	(0.08)
R^2	0.82	0.71	0.68	0.81	0.91	0.63	0.53	0.41	0.85
obs	55	55	55	55	57	57	57	57	57

***,**,* indicate significant levels of 1, 5 and 10 % respectively. Standard deviation of the regression coefficient in parentheses.

Focusing on the effect on government bond yields in columns 1-3, it is clear that the estimate of the unexpected path factor increases relative to the estimate of the unexpected target factor when the maturity of the bond increases. This is to be expected as bonds with longer

maturities are more affected by what will happen to the repo rate further ahead in time. The parameters of the expected factors are small and not significantly different from zero. Also, the estimated coefficient of the effect of the change in the international control variable (the KIX-weighted government bond yield) increases with maturity.

In column 4, results for the change in five-year swap rates are presented. The results for the swap rates are similar to the ones for government bond yields which is natural, given the close link between the two. The results for listed mortgage rates, columns 5-6, stand out as expected changes in the repo rate, the target factors, also have an impact on the rates. This is consistent with the findings from Fransson and Tysklind (2016) and suggests that banks change rates only after a repo rate change has occurred even though the change might be expected. Changes in the path factor seem to affect five-year fixed mortgage rates while they do not seem to impact three-month rates. This is to be expected, at the path should not influence the current short mortgage interest rate.

Finally, columns 7-8 present results for the change in the exchange rate of the Swedish krona against the euro and the dollar respectively. Both the unexpected actual change and the path change have a clear impact on the exchange rates. An increase in the actual repo rate or the repo rate path is associated with an appreciation of the krona against both the euro and US dollar. Changes in the current level of the repo rate as well as the repo rate path seem to have no significant impact on daily variation on the Swedish stock market, column 9. However, an increase in the control variable (returns on foreign stock markets) is associated with an increase in the OMX.

Perceived changes in the policy path, a robustness check

Now, as a robustness check we instead use the regression-based technique to obtain different segments of the repo rate path that are orthogonal to each other. The results are presented in Table 3. In general, we can see that unexpected changes to the repo rate and in different segments of the repo rate path seem to influence market prices while expected changes are in general not significant. The exception is listed mortgage rates, where both unexpected and expected changes are significant. The explanatory power of the regressions is in general higher than in the regressions where we use the factors.

Table 3. Regression results of equation (8), perceived changes

	(1) Δgov2yr	(2) Δgov5yr	(3) Δgov10yr	(4) ΔSwap 5y	(5) ΔMrtg 3m*	(6) ΔMrtg 5y*	(7) ΔSEKEUR	(8) ΔSEKUSD	(9) ΔOMX
$repo_u$	0.52***	0.28***	0.19***	0.31***	1.00***	0.24***	-3.93***	-4.00***	0.73
	(0.05)	(0.06)	(0.05)	(0.04)	(0.07)	(0.09)	(0.83)	(1.29)	(0.88)
$path_u$ 1-4Q	0.31***	0.13***	0.06	0.10***	-0.11***	0.20***	-1.06*	-2.16**	0.23
	(0.04)	(0.05)	(0.04)	(0.03)	(0.05)	(0.06)	(0.58)	(0.90)	(0.63)
$path_u$ 5-8Q	0.11***	0.11***	0.08***	0.14***	0.13***	0.02	-2.01***	-1.83***	0.05
	(0.03)	(0.04)	(0.03)	(0.02)	(0.04)	(0.05)	(0.49)	(0.76)	(0.56)
$path_u$ 9-11Q	0.03	0.07*	0.08***	0.04	-0.05	0.05	0.96**	1.22	0.72
	(0.03)	(0.04)	(0.03)	(0.02)	(0.04)	(0.05)	(0.47)	(0.73)	(0.49)
$repo_e$	-0.06***	0.01	0.01	-0.01	0.64***	0.17***	-0.09	-0.09	-0.56
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)	(0.33)	(0.52)	(0.36)
$path_e$ 1-4Q	0.09***	0.04	-0.01	0.03	0.16***	0.23***	0.33	0.41	1.01*
	(0.03)	(0.04)	(0.03)	(0.02)	(0.04)	(0.05)	(0.50)	(0.77)	(0.52)
$path_e$ 5-8Q	-0.01	0.02	0.01	0.04*	-0.11***	-0.02	-1.24***	-0.64	-0.69
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)	(0.41)	(0.63)	(0.43)
$path_e$ 9-11Q	0.02	0.01	0.18**	0.05	-0.12	0.13	1.88	4.61**	0.42
	(0.08)	(0.10)	(0.09)	(0.07)	(0.11)	(0.15)	(1.35)	(2.09)	(1.44)
ΔRoW	0.17	0.45***	0.69***	0.51***					0.85***
	(0.14)	(0.14)	(0.11)	(0.09)					(0.05)
constant	-0.01*	0.00	0.00	-0.01*	-0.02***	-0.01	-0.02	0.00	-0.02
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.08)	(0.12)	(0.08)
R^2	0.86	0.73	0.75	0.85	0.97	0.67	0.62	0.49	0.88
obs	55	55	55	55	57	57	57	57	57

***,**,* indicate significant levels of 1.5 and 10 % respectively. Standard deviation of the regression coefficient in parentheses.

Looking at the effects on government bond yields in columns 1-3, we see that different maturities react differently to changes to different segments of the repo rate path. Shorter maturity bonds yields are affected by changes in the short end of the path while bond yields with longer maturities are relatively more affected by changes in the long segment. This is no surprise as bonds with longer maturities are more affected by market participants' views about the repo rate in the future, while bonds with shorter maturities should move with the current repo rate and the repo rate in the near future. The estimates for the five-year swap rate, in column 4, are again very similar to the ones for the government bond rate with the same maturity.

The estimates for listed mortgage rates follow the same pattern as in the other specifications, where both unexpected and expected changes are significant. The three-month rate seems to be most sensitive to changes in the actual repo rate while the five-year rate seems relatively more sensitive to changes in the path.

In columns 7-8, the estimates for the euro and the US dollar exchange rates against the Swedish krona are reported. The estimates indicate that changes in the repo rate path up to two years ahead have a significant impact on the exchange rate. And finally, the estimates reported in column 9 indicate that the stock market seems not to react in any particular way to changes in the repo rate or the repo rate path.

Overall the results from this approach is very much in line with the approach using factors. Hence the results of changes in the repo rate path on different market prices seems to be robust for different ways of separating changes in the repo rate path from changes in the actual repo rate.

Intended changes in the policy path

We now report on the results based on the measures of intended changes in the repo rate path. In Table 4, we present the results from the regression in equation (7).

Table 4. Regression results of equation (7), intended changes

	(1) Δgov2yr	(2) Δgov5yr	(3) Δgov10yr	(4) ΔSwap 5y	(5) ΔMrtg 3m*	(6) ΔMrtg 5y*	(7) ΔSEKEUR	(8) ΔSEKUSD	(9) ΔOMX
Target factor$_u$	0.67***	0.31***	0.15***	0.31***	0.81***	0.30***	-5.22***	-6.82***	0.82
	(0.07)	(0.07)	(0.06)	(0.06)	(0.10)	(0.09)	(0.97)	(1.36)	(0.92)
Path factor$_u$	0.22***	0.09**	0.03	0.08***	-0.18***	0.16***	-2.10***	-2.35***	-0.67
	(0.04)	(0.04)	(0.04)	(0.03)	(0.06)	(0.06)	(0.58)	(0.82)	(0.57)
Target factor$_e$	-0.05*	0.03	0.02	0.01	0.81***	0.21***	0.16	0.50	-0.24
	(0.03)	(0.03)	(0.02)	(0.02)	(0.04)	(0.04)	(0.40)	(0.56)	(0.38)
Path factor$_e$	0.11***	0.07***	0.05*	0.07***	-0.10***	0.10***	-0.88**	-0.47	0.11
	(0.03)	(0.03)	(0.02)	(0.02)	(0.04)	(0.04)	(0.39)	(0.55)	(0.38)
ΔRoW	0.30*	0.68***	0.83***	0.67***					0.89***
	(0.17)	(0.13)	(0.11)	(0.10)					(0.05)
constant	-0.01	-0.01	-0.01	-0.01*	-0.06***	-0.02***	0.02	0.04	-0.01
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.09)	(0.12)	(0.08)
R^2	0.74	0.65	0.67	0.72	0.94	0.61	0.46	0.40	0.86
obs	55	55	55	55	57	57	57	57	57

***,**,* indicate significant levels of 1, 5 and 10 % respectively. Standard deviation of the regression coefficient in parentheses.

If we compare these estimates with those from the perceived changes in Table 2, it is apparent that the point estimates are quite similar for most variables across the two approaches. Also, the unexpected path factor is still significant for all financial variables except for the 10 year government bond and the stock market. However, we now also have significant estimates for the expected path factor for many of the financial variables. This might indicate that the constructed measure of intended changes suffers from some misspecification. However, the sign of the expected path factor is the same as for the unexpected factor so the effects do not seem to cancel each other out. We also notice that the explanatory power, R^2, is somewhat lower using the measures of intended changes compared to the perceived changes.

If we look in more detail at the results of the estimates for government bond yields in columns 1-3, we see that the estimates for unexpected changes in both the target factor and the path factor are clearly significant and of the same magnitude as the estimates for the perceived changes. The estimates for the swap rate, column 4, are again very similar to the estimates for the government bond with the same maturity. The mortgage rates in columns 5-6 are also similar to previous estimates. The same is true for the estimates for the exchange rate in columns 7-8. Unexpected changes in the path seem to have significant impact on the exchange rate. Finally, in column 9 we see the result for the stock market and also using this method we have no significant effects from changes in the repo rate on the stock market on the day of the announcement.

The fact that the estimates are of the same magnitude for both the measures of perceived and intended changes in the policy path can be interpreted as indicating that market participants perceive changes in the repo rate and the repo rate path in the way intended by the central bank.

Conclusion

In this memo, we analyse how changes in the actual repo rate as well as changes in the repo rate path affect different market interest rates, lending rates to households, the stock market and exchange rates. An important step in the analysis is to separate between expected and unexpected changes in the repo rate path. To do so we apply two different methods, perceived and intended changes. The perceived change is identified using movements in financial prices linked to the repo rate just around the policy announcement. The intended changes is instead identified with a regression approach following Brubakk et al (2017) and Åhl (2017). However, both measures are quite similar. Using the approach suggested by Gürkanyak et al. (2005) we then distinguish between movements in the actual repo rate and changes in the repo rate path. This is done through a factor analysis to identify two uncorrelated factors which capture movements in the actual policy rate, the target factor, and the repo rate path, the path factor.

The results indicate that changes in both the repo rate and the repo rate path can influence market prices. The effect from changes in the repo rate path goes beyond what can be explained by changes in the repo rate path that are correlated with changes to the current repo rate. This is the case for market interest rates, interest rates facing households and firms as well as exchange rates but not for the stock market. The result is robust to using alternative methods to separate unexpected from expected changes in the repo rate path and also holds using alternative methods to estimate the impact of repo rate path changes on different market prices. This indicates that variation in a published policy rate path is an additional tool a central bank can use to influence market prices.

Appendix

Calculating monetary policy expectations using 'Stina' contracts

Equation 1 below shows how the surprise component is calculated, where t represents publication date, τ_1 is the number of days the contract has run before the implementation of the new repo rate[5] and τ_2 is the number of days left of the contract's maturity after the implementation of the new repo rate. The expected repo rate adjustment is then calculated as the difference between the actual adjustment of the repo rate and the surprise component (see equation 2).

(1) $$\Delta repo_t^{unexpected} \approx \frac{[r_t^{Stina} - r_{t-1}^{Stina}](\tau_1+\tau_2) - \Delta repo_t}{\tau_2 - 1}$$

(2) $$\Delta repo_t^{expected} = \Delta repo_t - \Delta repo_t^{unexpected}$$

Calculating the factors

The repo target and path factors are estimated as follows. Given the matrix:

(3) $$M_t = \left(\Delta repo^u\ \Delta path_{Q2}^u\ \Delta path_{Q4}^u\ \Delta path_{Q6}^u\ \Delta path_{Q8}^u\ \Delta path_{Q10}^u\right)$$

where $\Delta path_{QX}^u$ is the change in the estimated derivative curve of x-quarter of maturity, estimated at time t. We assume that the $T \times 6$ matrix M has a factor structure of:

(4) $$M = F\Lambda + \epsilon$$

where matrix F is a $T \times s$ matrix of latent factors, Λ is a matrix $s \times 6$ matrix of factor loadings and ϵ is a $T \times 6$ matrix of idiosyncratic components.

As F is not observed, it needs to be replaced by estimates, $\hat{F}$, which are obtained via standard PCA. As in Gürkaynack, Sack and Swanson (2005), We set the dimension s of $\hat{F}$ as equal to two ($s = 2$) so that $\hat{F}$ can be partitioned into $\hat{F}_1$ and $\hat{F}_2$.

To allow for a more structural interpretation of these unobserved factors, we follow Gürkaynack et al. (2005) and rotate the factors so that the first factor corresponds to surprise changes in the current repo rate and the second factor corresponds to moves in interest rate expectations over the coming two years that are not driven by changes in the repo rate. In other words, we seek an unknown orthogonal matrix U,

(5) $$U = \begin{pmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{pmatrix}$$

where:

(6) $$Z = FU \Rightarrow F = U^{-1}Z$$

As $\hat{F}$ can be partitioned into $\hat{F}_1$ and $\hat{F}_2$, it follows that Z can be partitioned into Z_1 and Z_2. Let γ_1 and γ_2 denote the (known) loadings of $\Delta repo^u$ on $\hat{F}_1$ and $\hat{F}_2$. Since,

(7) $$\hat{F}_1 = \frac{1}{\alpha_1\beta_2 - \alpha_2\beta_1}(\beta_2 Z_1 - \alpha_2 Z_2)$$

(8) $$\hat{F}_2 = \frac{1}{\alpha_1\beta_2 - \alpha_2\beta_1}(\alpha_2 Z_1 - \beta_1 Z_2)$$

It follows that Z_2 (the path factor) is not influencing current policy surprise Z_1 (the target factor) if,

[5] A Stina contract traded on day t corresponds to the expected interest rate on the Stibor T/N rate from day t+2 until the contract matures. Implementation day is the first Wednesday after publication date.

(9) $\gamma_2\alpha_1 - \gamma_1\alpha_2 = 0$

Furthermore, the matrix U is orthogonal, if the restrictions:

(10) $\alpha_1\beta_1 - \alpha_2\beta_2 = 0$

(11) $\alpha_1^2 + \alpha_2^2 = 1$ and $\beta_1^2 + \beta_2^2 = 1$

are satisfied. Finally, Z_1 (the target factor) and Z_2 (the path factor) are rescaled so that Z_1 moves the current policy surprise ($\Delta repo^u$) one-to-one. The resulting factors can then be re-scaled further in various manner to further improve on their interpretations.

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