WORKING PAPER

ECB spillovers and domestic monetary policy effectiveness in small open economies

NORGES BANK RESEARCH

9 | 2018

SASKIA TER ELLEN,
EDVARD JANSEN
AND
NINA LARSSON MIDTHJELL,

NORGES BANK

Working papers fra Norges Bank, fra 1992/1 til 2009/2 kan bestilles over e-post:
FacilityServices@norges-bank.no

Fra 1999 og senere er publikasjonene tilgjengelige på www.norges-bank.no

Working papers inneholder forskningsarbeider og utredninger som vanligvis ikke har fått sin endelige form. Hensikten er blant annet at forfatteren kan motta kommentarer fra kolleger og andre interesserte. Synspunkter og konklusjoner i arbeidene står for forfatternes regning.

Working papers from Norges Bank, from 1992/1 to 2009/2 can be ordered by e-mail
FacilityServices@norges-bank.no

Working papers from 1999 onwards are available on www.norges-bank.no

Norges Bank's working papers present research projects and reports (not usually in their final form) and are intended inter alia to enable the author to benefit from the comments of colleagues and other interested parties. Views and conclusions expressed in working papers are the responsibility of the authors alone.

ISSN 1502-819-0 (online)
ISBN 978-82-8379-052-8 (online)

ECB spillovers and domestic monetary policy effectiveness in small open economies*

Saskia ter Ellen, Edvard Jansen, Nina Larsson Midthjell†

September 25, 2018

Abstract

In this paper we study financial spillovers from the European Central Bank's (ECB) monetary policy and communication, and whether they have consequences for the effectiveness of domestic monetary policy of small open economies. Recent work suggests that the "trilemma" in international economics as we used to know it, is actually a dilemma: small open economies with floating exchange rate regimes can only have independent monetary policies when the capital account is managed. Our findings show that domestic monetary policy is still effective, but that spillover effects, particularly from the ECB's communication, reduce domestic control over the longer end of the yield curve.

Keywords: monetary policy, forward guidance, international spillovers, asset prices, small open economies

JEL classification codes: E43; E44; E52; E58; G12

*This working paper should not be reported as representing the views of Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank. We are grateful to Eric Swanson for sharing his code and for comments in the early stage of the project, and to Leif Brubakk and Hong Xu for sharing data and results from their Brubakk et al. (2017) paper. We would like to thank Hong Xu, Kjetil Stiansen, Arild Skogmo, and Paulina Tedesco for indispensable help with data collection and research assistance. We further thank Stine Louise Daetz, Meredith Beechey Österholm, Valentina Corradi, Elena Stepanova, and an anonymous reviewer for helpful comments and discussions, and participants of Normac 2017, the workshop on Interest Rates After the Financial Crisis, CEF 2018, IAAE 2018, and seminars at Norges Bank for their comments.

†Saskia ter Ellen and Nina L. Midthjell work at Norges Bank, Saskia.ter-Ellen@Norges-Bank.no. and Nina-Larsson.Midthjell@Norges-Bank.no, and Edvard Jansen works at Formuesforvaltning, Edvard.Jansen@gmail.com.

1 Introduction

> For the past few decades, international macroeconomics has postulated the "trilemma": with free capital mobility, independent monetary policies are feasible if and only if exchange rates are floating. The global financial cycle transforms the trilemma into a "dilemma" or an "irreconcilable duo": independent monetary policies are possible if and only if the capital account is managed. - *Helene Rey, Jackson Hole Symposium 2013*

Over the recent years, it has become clear that monetary policy conducted by large central banks can have serious spillover effects on other countries, and that global financial integration can make monetary policy less independent in general. Rey (2015) argues that (lending) conditions of global financial institutions, as well as credit growth and capital flows, are largely driven by the global financial cycle, which in turn is mostly determined by monetary policy of the major central banks. This leads her to argue that rather than the classical *tri*lemma (exchange rate control, free capital mobility, and independent monetary policy) we are dealing with a *di*lemma: independent monetary policy is only possible with some capital controls ("cross-border flows and leverage of global institutions transmit monetary conditions globally, even under floating exchange-rate regimes").

In this paper we argue that, although spillovers are indeed considerable, central banks of small open economies are still able to affect their domestic yield curve, especially short- to medium-term rates.

We first investigate the spillover effects of monetary policy and communication from the European Central Bank (ECB) on asset prices of small open economies. We use high frequency identification (HFI) to identify shocks in monetary policy and communication, and analyse the effects of these shocks on asset prices and yields in three small open economies that are comparable and highly integrated with the European (Monetary) Union: Denmark, Norway and Sweden. These are interesting cases, as they have varying degrees of integration and monetary policy independence: Denmark is a member of the European Union and has an exchange rate peg to the euro (and hence cannot have independent monetary policy), Sweden is a member of the European Union but has its

own floating currency, and Norway is not a member and has a floating currency as well. We further investigate whether finding spillovers implies that domestic monetary policy has become ineffective, as the "dilemma" paradigm would suggest, and find that this is only partially the case.

The U.S. and the euro area account for approximately 40 percent of world GDP. In this respect, policy actions and statements by the Fed and the ECB are likely to cause spillovers to other countries, and may even impair the ability of central banks in small open economies to have an autonomous monetary policy.[1] The literature on how economic and financial variables of small open economies are affected by foreign monetary policy is dominated by studies looking at spillovers from the Fed to emerging market economies (e.g. Takats and Vela (2014), Chen et al. (2014), Tillmann (2016), Gilchrist et al. (2018)) and between advanced economies (e.g. Ehrmann et al. (2011), Rogers et al. (2016), Bauer and Neely (2014), Neely (2015)).[2] Furthermore, Burriel and Galesi (2018), Georgiadis (2015) and Leombroni et al. (2017), find that ECB's monetary policies, conventional and unconventional, have heterogeneous effects on countries within the euro area. The literature on the effect of ECB's monetary policy and communication shocks on non-euro area countries, however, is scarce. Exceptions are Falagiarda et al. (2015) and Potjagailo (2017). The former, closest in methodology to this paper, show that spillovers occur from ECB's unconventional monetary policy to yields in non-euro area countries from Central and Eastern Europe. The latter investigates euro area monetary policy spillovers to 14 European non-euro area countries by means of a factor-augmented VAR, and finds that spillovers are large, with the strongest effects for countries with fixed exchange rates.

In this paper we focus on financial variables. Financial variables respond instantly to surprise changes in monetary policy and are typically seen as a starting point of the transmission mechanism initiated by a monetary policy decision, and as indicators of the effect on economic variables. Earlier studies (e.g. Canova (2005), Kim (2001), Feldkircher and Huber (2016)) have found that for US monetary policy, the financial channel (i.e.

[1]However, it should be noted that Georgiadis and Mehl (2016) find that increased financial globalisation has *amplified*, rather than *muted*, monetary policy effectiveness.

[2]There is also a number of studies that evaluate spillovers from the US to a large number of countries, often focusing on equity markets. See, for example, Ehrmann and Fratzscher (2009), Hausman and Wongswan (2011), Dedola et al. (2017).

through interest rates) is the most important spillover channel. Moreover, we look at both spillovers from conventional measures and from ECB communication.[3] Brand et al. (2010) find that market expectations for the path of monetary policy change considerably during the press conference following a key policy rate decision by the ECB.

We distinguish between a key policy rate surprise and a communication surprise using high frequency identification (HFI) techniques.[4] We adopt the methodology of Gürkaynak et al. (2005), who apply factor analysis on several U.S. money market instruments to identify two factors of the Federal Open Market Committee's (FOMC) monetary policy and their impact on U.S. equity prices and interest rates.[5] Similarly, from a set of interest rate surprises that together explain the actions and statements of the ECB's monetary policy, we extract two factors. At least prior to the ECB's introduction of asset purchases, these two factors can be interpreted as a policy rate ("target") surprise and a communication ("path") surprise. After the ECB started its asset purchasing programmes, however, the second factor represents a combination of communication about future policy intentions (forward guidance) and communication about asset purchases.

After identifying the policy shocks, we study their impact on small open economies in two steps. First, we analyse the spillovers of such policies on interest rates and asset prices in two small open economies that have close ties to, but are not part of, the euro area: Norway and Sweden. Although these countries are economically and financially integrated with the euro area, they have their own independent monetary policy regimes, in the form of inflation targeting. We compare spillover effects in these countries with a comparable country that has an exchange rate peg to the euro: Denmark. Our findings suggest that both factors have strong and significant effects on small open economies that are close to the euro area. Whereas the spillover effects of policy rate surprises die out quickly, the effect of ECB's communication is very persistent, and may therefore also

[3]Two studies should be mentioned that focus specifically on spillovers from ECB's unconventional monetary policy. Fratzscher et al. (2016) use daily data on international equity returns and portfolio flows to shed light on the financial market impact of unconventional policies between 2007 and 2012. Georgiadis and Gräb (2016) employ an event-study methodology to estimate announcement effects of the Asset Purchase Programme (APP).

[4]Several papers have assessed responses to monetary policy shocks in a HFI framework, see e.g. Campbell et al. (2012), Gürkaynak et al. (2005), Hamilton (2008), Hanson and Stein (2015), and Swanson (2017).

[5]Brubakk et al. (2017) apply this methodology to Norwegian and Swedish data.

affect real economic variables in these countries.

Finally, we investigate the impact and persistence of domestic policy shocks. We find that domestic monetary policy and communication surprises are effective in moving market rates, and that their effects are more persistent than their European counterparts. However, effects of domestic communication are less persistent than those of ECB communication, particularly for the medium to long end of the yield curve. Based on this, we conclude that although spillover effects from ECB monetary policy and communication are strong, they do not imply that small open economies need capital controls in order to have autonomous monetary policies. In other words, the "trilemma" is still alive.

The remainder of the paper is organized as follows: Section 2 presents the data. Section 3 provides an overview of the applied identification methods. The empirical analysis and results are presented in Section 4. Section 5 concludes.

2 Data

We analyse intraday data on a variety of Norwegian, Swedish, Danish and European financial variables, over the sample period January 2002 to June 2018.[6] Over the sample period, the ECB had 185 meetings with key policy rate decisions.[7]

During the sample period the ECB initiated several unconventional monetary policy tools. In this paper, we consider three asset purchase programmes: Securities Markets Programme (SMP, May 2010-2012), Outright Monetary Transactions (OMT, announced September 2012), and the Expanded Asset Purchase Programme (APP, since November 2014).[8] In the rest of the paper, we refer to those as "unconventional monetary policy" (UMP).

In the factor analysis in section 3.2, we use European OIS rates for one, three, six, nine, 12, 18, and 24 months.[9] In robustness tests we also include the five- and ten-year

[6]We choose not to start earlier as Rosa and Verga (2008) show that it took market participants until 2001 to learn about the credibility of the ECB. Moreover, the ECB only held press conferences for every second rate decision in 2001.

[7]The decision to keep rates unchanged is also considered a decision.

[8]Of these asset purchase programmes, the first two were targeted mostly at countries for which their financial market malfunctioning was disturbing the transmission of monetary policy.

[9]European OIS contracts are fixed-for-floating interest rate swaps where the Euro Overnight Index Average (EONIA) is the floating leg interbank rate, i.e. the weighted average of the interest rates on

German Treasury bonds.

In order to evaluate spillovers on small open economies, we make use of a wide variety of financial derivatives contracts that reflect short-, medium and long term interest rates, including money market rates up to one year (FRAs), and interest rate swaps with maturities of two, five and ten years. We use swap rates rather than government bond yields due to the low volume and poor liquidity of the Norwegian bond market in particular. The FRA market is regarded as the most liquid part of the Norwegian, Swedish and Danish money markets. The FRA contracts reflect the short to medium end of the yield curve, while the swap contracts reflect the expected average short-term interest rates over the two-, five-, and ten-year horizons.[10] We include the first to fourth quarter FRA contracts. These contracts capture the three-month interest rate in one to four quarters out. We also apply the factor analysis from Section 3.2 in order to analyse the effects of domestic monetary policy shocks. For equity prices, we use data for the OSEBX (Norwegian) and OMX (C-Danish and S-Swedish) equity indices.

Variables are obtained from 5-minute frequency observations from the Thomson Reuters Tick History database. The data are aggregated from tick-by-tick data, which means that the observation at the time of the ECB policy decision press release, at 1:45 p.m., is the latest tick before that exact time (e.g. a tick quote from a dealer at 1:44:58 p.m.).[11]

3 Identification

3.1 High frequency identification

In line with Kuttner (2001) and Gürkaynak et al. (2005), among others, we identify the key policy rate surprise by using an interest rate instrument that covers expectations about the short-term monetary policy stance. Potential instruments consist of overnight

overnight unsecured transactions for the panel banks (http://www.emmi-benchmarks.eu/euribor-eonia-org/about-eonia.html).

[10]Forward rate agreements are over-the-counter (OTC) cash settled agreements to exchange fixed interest rate and reference rate (NIBOR) payments on a notional amount of NOK 1 million. An interest rate swap is an agreement between two parties to swap interest rate payments where the buyer pays a fixed rate (swap rate) and the seller pays the floating for a pre-determined period.

[11]We deal with missing observations by assuming that such NaN observations mean that there is no change from the previous non-NaN observation.

index swaps (OIS) and futures rates with maturities shorter than the time between two ECB monetary policy meetings. As there is no futures market for the ECB key policy rate, we use OIS rates. At the day of the ECB monetary policy meeting, if t is some time after the policy rate announcement and $t-j$ is right before the announcement, $\Delta i_t^{OIS} = i_t^{OIS} - i_{t-j}^{OIS}$ is assumed to be the unexpected part of the ECB policy rate decision.

Since the sample start, the ECB key policy rate decision has been announced at 1:45 p.m., followed by a press conference 45 minutes later, at 2:30 p.m.[12] We define the *full announcement window* as the time window from 1:30 p.m. to 3:45 p.m., containing both the press release and the press conference. Thus, our full data set consists of observations for this event window for all ECB monetary policy meeting dates over the sample period.

3.2 Factor analysis using principal components

Through its monetary policy announcements the ECB provides information about the current rate decision, as well as the economic outlook, including future monetary policy. Therefore, changes in market rates around the time of these announcements may not only contain a policy rate surprise component, but also a component related to the ECB's communication about the future (forward guidance). Since we are interested in all dimensions of the monetary policy shocks, we need to employ methods to separate the two components. Following Gürkaynak et al. (2005) we apply principal component analysis on interest rate changes around the ECB's monetary policy announcements to extract the two components that together explain most of the variation in these rates around policy announcements. In order to extract the factors, we use data on interest rate changes of maturities up to ten years. This can be represented by:

$$X = F\Lambda + \eta \tag{1}$$

where X is a $T \times n$ matrix of $T = 185$ ECB key policy rate announcements and $n = 7$ European financial variables: the one-month, three-month, six-month, nine-month, one-

[12] All times are in CET. The press conference includes an introductory statement with a subsequent session of Q&A.

year, 18-month and two-year European OIS rates.[13] F denotes a $T \times k$ matrix of the unobserved factors with $k < n$, and Λ is a $k \times n$ matrix of factor loadings. η represents white noise error terms. Each element of X is the change in one of the n variables for the full announcement window. Using principal component analysis on X, we extract the unobserved factors F.

The Cragg-Donald test rejects the hypothesis of more than two factors at the 5% level. Hence, the test implies that in addition to the policy rate surprise, one factor is enough to explain variation in European interest rates within the full announcement window.

Furthermore, to provide a more structural interpretation of the factors, we follow Gürkaynak et al. (2005) (GSS) and rotate the two extracted factors F_1 and F_2 into a new set of factors denoted Z_1 and Z_2.[14] The most important identifying restriction is that a communication surprise should move interest rates with maturities beyond the current policy meeting, but should not at all be related to the surprise in the current policy rate. In other words, only the first rotated factor, Z_1, should load onto the interest rate with the shortest maturity (i.e. the one-month OIS rate, which is the first coloumn of X), which is the monetary policy surprise (target factor to use the notation of GSS), whereas the second rotated factor, Z_2, should not have any relation with the one-month European OIS. Consequently, Z_1 may be interpreted as the policy rate surprise of the ECB announcement, and Z_2 may be interpreted as all other information in the ECB announcement that changes financial market expectations about the future path of key policy rates (Swanson (2017)). In short, we denote the factor as the *path factor* (as in GSS), which, for the UMP sample, is likely to be a representation of both communication and UMP effects.

Finally, to facilitate the interpretation of the rotated factors, Z_1 is rescaled such that it moves one-for-one with the surprise component of the key policy rate setting (measured as the change in one-month OIS), and hence can be interpreted as basis points surprise changes in the one-month OIS. In addition, Z_2 is rescaled such that it can be interpreted

[13] The one-month OIS rate provides a good estimate of the market expectation of the ECB's key policy rates for the closest upcoming Governing Council meetings. For robustness tests we expand X with five-year and ten-year German Treasury yields.

[14] The computational details of this factor rotation, can be found in the appendix of Gürkaynak et al. (2005).

as basis points change in the one-year OIS, in line with Leombroni et al. (2017).

Rather than displaying the loadings of the rotated factors, we show the results of regressing the input variables (X) on a constant and the two rotated and rescaled factors. Table 1 reports the results. The coefficients can be interpreted as the loadings of the extracted factors, and the R^2 reflects how important the variable in X is for the factors Z_1 and Z_2. The results imply that the overall effects of a policy rate surprise (target factor) is strongest for the shortest maturities and dies out for longer maturities, consistent with theory (key policy rates affect the short end of the yield curve). Moreover, the path factor, Z_2, has a characteristic hump-shape with strongest effects on European interest rates with maturities of about one-and-a-half to two years.[15] When the X matrix also consists of surprises in five and ten year German Treasury yields, the largest coefficient can be observed for the five year rate.

Figure 1 plots the two rotated factors over the sample period. An interesting aspect is that the factors do not necessarily move in the same direction, which implies that different surprise components of the ECB announcements may influence interest rates in opposite directions.

To evaluate the effectiveness of domestic monetary policy surprises, we use the shocks as computed in Brubakk et al. (2017).

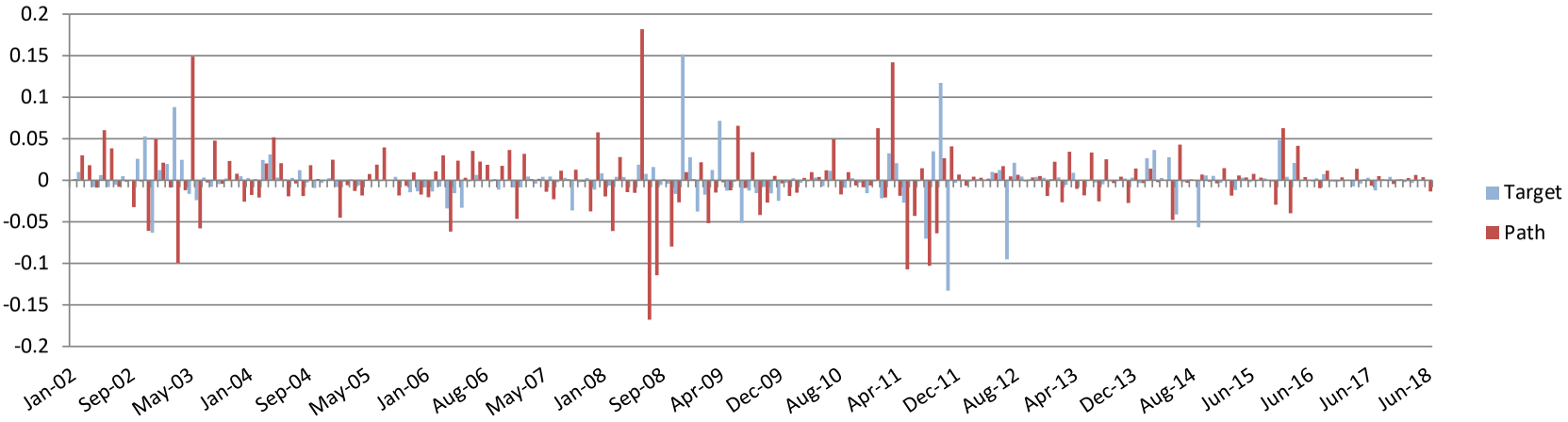
[15]Recall that, by construction, Z_2 has no effect on the one-month OIS.

Table 1: Factor diagnostics: ECB's target and path factors and European rates.

	up to two years				**up to ten years**			
	Target	Path	Adj. R^2	-	Target	Path	Adj. R^2	Obs
1M OIS	1.0000***	0.0000	0.95		1.0000***	0.0000	0.81	185
	(0.0263)	(0.0249)			(0.0657)	(0.0460)		
3M OIS	0.9714***	0.3792***	0.94		1.1149***	0.3543***	0.94	185
	(0.0283)	(0.0294)			(0.0343)	(0.0294)		
6M OIS	0.9354***	0.5762***	0.95		1.1209***	0.5729***	0.95	185
	(0.0364)	(0.0322)			(0.0469)	(0.0235)		
9M OIS	0.8855***	0.8528***	0.97		1.1684***	0.8382***	0.94	185
	(0.0146)	(0.0265)			(0.0446)	(0.0377)		
12M OIS	0.8085***	1.0000***	0.98		1.1241***	1.0000***	0.93	185
	(0.0202)	(0.0254)			(0.0567)	(0.0444)		
18M OIS	0.7017***	1.1824***	0.96		1.0371***	1.2229***	0.91	185
	(0.0399)	(0.0566)			(0.0820)	(0.0649)		
24M OIS	0.6891***	1.0646***	0.92		0.9107***	1.1873***	0.93	185
	(0.0341)	(0.0759)			(0.0453)	(0.0559)		
5Y GTY	0.5016***	0.9730***	0.65		0.4674***	1.3520***	0.88	185
	(0.0874)	(0.0856)			(0.0659)	(0.0438)		
10Y GTY	0.2194***	0.6066***	0.43		0.0674	0.9762***	0.78	185
	(0.0857)	(0.0633)			(0.0790)	(0.0949)		
STOXX	-0.0216	-0.0075	0.00		-0.0360	0.0077	0.01	140
	(0.0222)	(0.0163)			(0.0222)	(0.0221)		
EURUSD	0.0603***	0.0659***	0.31		0.0640***	0.0924***	0.38	161
	(0.0168)	(0.0113)			(0.0141)	(0.0179)		

Note: This table shows the factor loadings and financial market effects for the rotated factor matrix Z. Note that for columns 2–4, OIS rates from one month to two years are used as input variables to obtain the target and path factors. For columns 5–7, input variables also consists of the five and ten year German Treasury bond yield. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). Constant terms are excluded for presentation convenience. ***=1% **=5% *=10% significance level. Sample: from January 2002 to June 2018. Data for the equity indices starts in October 2010, for exchange rates in January 2004. Event window: from 1:30 p.m. to 3:45 p.m.

Figure 1: Two dimensions of ECB shocks - 2002-2018.



This figure shows the realizations of the target and path factors.

4 Empirical analysis and results

Now that we have identified the policy shocks, we study their impact on small open economies. We zoom in on two small open economies that have close ties to, but are not part of, the euro area: Norway and Sweden, and compare the results to a comparable country that has an exchange rate peg to the euro: Denmark.

4.1 Interest rates and asset prices in Norway, Sweden and Denmark

In order to examine the spillovers of ECB's target and path factors on interest rates and asset prices of small open economies, we run the following regression:

$$\Delta R_{t,i} = \alpha + \beta_1 Z_{1,t} + \beta_2 Z_{2,t} + \epsilon_t \tag{2}$$

where $\Delta R_{t,i}$ is the observed change in the Norwegian/Swedish/Danish interest rate or (log) asset price of interest for the time window considered, $Z_{1,t}$ represents the target factor, and $Z_{2,t}$ is the (rescaled and rotated) path factor, representing the forward guidance/UMP surprise.

The results are presented in Table 2. The first column in the table displays the dependent variable. For the monetary policy surprise (i.e. the target factor) the estimated coefficients can be interpreted as the percentage point change in the Norwegain/Swedish/Danish interest rates and the percent change in the stock market index (OSEBX and OMX) from a one-percentage-point ECB policy rate surprise increase.

Norwegian and Swedish financial markets are indeed affected by unexpected changes in the ECB's policy rate setting, and the re-pricing happens very fast after the new information has been received. As expected, the short and medium end of the yield curve respond more strongly to the target factor than the longer-term interest rate instruments. The results further show that the path factor has strongest effects for the medium and longer-term interest rates, while the shortest end of the yield curve is not affected to the same extent. The estimates show a characteristic hump-shape, with a peak around 18-24 months. These findings are in line with what Gürkaynak et al. (2005), Swanson (2017) and Brubakk et al. (2017) find for domestic effects of respectively U.S., and Norwegian

Table 2: Effects of ECB's target and path factors on Norwegian, Swedish, and Danish financial variables.

	Norway				**Sweden**				**Denmark**			
	Target	Path	Adj. R^2	-	Target	Path	Adj. R^2	-	Target	Path	Adj. R^2	Obs
FRA 1	0.3551***	0.3050***	0.20		0.3651***	0.1885***	0.43		0.9130***	0.4170***	0.59	185
	(0.1041)	(0.0643)			(0.0671)	(0.0416)			(0.1411)	(0.0619)		
FRA 2	0.4400***	0.3690***	0.46		0.4565***	0.2902***	0.58		0.7564***	0.9488***	0.77	185
	(0.0665)	(0.0705)			(0.0700)	(0.0545)			(0.0773)	(0.0899)		
FRA 3	0.3166***	0.5201***	0.42		0.5641***	0.4008***	0.61		0.6855***	1.2163***	0.78	185
	(0.1215)	(0.0783)			(0.0774)	(0.0730)			(0.1000)	(0.1063)		
FRA 4	0.5283***	0.6231***	0.52		0.5870***	0.5190***	0.61		0.7387***	1.2648***	0.88	185
	(0.0802)	(0.0735)			(0.1063)	(0.0882)			(0.0733)	(0.1026)		
2Y SWAP	0.3364***	0.4868***	0.48		0.6668***	0.5439***	0.13		0.5877***	0.9038***	0.83	185
	(0.0585)	(0.0434)			(0.1039)	(0.1088)			(0.0635)	(0.0777)		
5Y SWAP	0.2817***	0.4776***	0.40		0.3880***	0.5464***	0.49		0.4138***	0.8331***	0.69	185
	(0.0777)	(0.0672)			(0.1166)	(0.0954)			(0.0698)	(0.0713)		
10Y SWAP	0.2041***	0.4383***	0.36		0.1933**	0.4128***	0.30		0.1643**	0.4952***	0.31	185
	(0.0595)	(0.0458)			(0.0931)	(0.0785)			(0.0708)	(0.0659)		
Equity	-0.0253*	0.0085	0.00		-0.0231	0.0017	0.00		-0.0139	-0.0162	0.00	140
	(0.0152)	(0.0143)			(0.0277)	(0.0206)			(0.0190)	(0.0120)		
FX	0.0143	0.0163**	0.04		0.0219	0.0186***	0.11		0.0007***	0.0002	0.02	161
	(0.0145)	(0.0080)			(0.0134)	(0.0061)			(0.0002)	(0.0002)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's target and path factors on Norwegian, Swedish and Danish financial variables. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). Constant terms are excluded for presentation convenience. ***=1% **=5% *=10% significance level. Sample: from January 2002 to June 2018. Data for the equity indices starts in October 2010, for exchange rates in January 2004. Event window: from 1:30 p.m. to 3:45 p.m.

and Swedish central bank communication.

The size of the spillovers are sizeable For Norwegian and Swedish rates, but not as large as for Denmark. Interestingly, the impact of ECB's monetary policy starts to be similar for Swedish and Danish rates from the two to five year maturity, and the impact of ECB's path factor on the ten year swap rate is virtually the same for Norway, Sweden, and Denmark.

We can also see that Norwegian equity prices are affected by a target surprise, whereas there is no significant effect on Swedish or Danish equity prices. The sign is as expected: interest rates are used to discount future cash flows, higher interest rates implying a higher discounting rate, and hence higher rates lead to lower equity prices. Explicitly, following an unexpected ECB policy rate increase of ten basis points, the Norwegian stock market index is estimated to fall by 0.25%.[16]

Subsequently, we investigate whether international transmission of ECB's monetary policy has changed since the ECB introduced asset purchases as part of their unconventional monetary policy tools on May 10, 2010. The results are presented in Tables 3 to 5 for Norwegian, Swedish and Danish variables, respectively. For Norway and Sweden, the results for the target factor are virtually the same for the pre-UMP and UMP periods. The path factor also provides very similar estimates for the two sample periods for the short end of the yield curve. In fact, we cannot observe any structural differences for the period in which the ECB started unconventional monetary policy. In the case of Denmark, both the target and path factor have a significantly smaller effect on the first forward rate agreement after the ECB starts their unconventional monetary policies.

Furthermore, some sub-sample differences can be seen for the Norwegian stock market. Whereas the full sample results show a small negative impact of monetary policy surprises on the Norwegian stock index, the path factor only has an effect after 2010. This is in line with the ECB's communication during that period. Campbell et al. (2012) define *Delphic* and *Odyssean* forward guidance. Whereas Odyssean forward guidance implies a commitment from the central bank to deviate from its 'normal' conduct of monetary

[16]One could argue that the large share of oil-related companies in the Norwegian equity index makes this index more sensitive to global economic conditions than the Swedish or Danish equity indices, as higher global demand increases oil prices, benefitting such companies.

Table 3: Effects of ECB's target and path factors on Norwegian financial variables.

Norway: 2002-2018

	Constant	Target	Path	Target*UMP	Path*UMP	Adjusted R^2	Obs
FRA 1	0.0025	0.3457*	0.3420***	0.0400	-0.1269	0.20	185
	(0.0021)	(0.1896)	(0.0843)	(0.2123)	(0.1008)		
FRA 2	-0.0013	0.3997***	0.3948***	0.0963	-0.0972	0.46	185
	(0.0015)	(0.0610)	(0.0904)	(0.1175)	(0.1186)		
FRA 3	-0.0032*	0.1729	0.5661***	0.3172*	-0.1926	0.44	185
	(0.0018)	(0.1661)	(0.1059)	(0.1795)	(0.1249)		
FRA 4	-0.0035*	0.5109***	0.6273***	0.0377	-0.0187	0.51	185
	(0.0020)	(0.1424)	(0.0974)	(0.1588)	(0.1325)		
2Y SWAP	-0.0010	0.3488***	0.4859***	-0.0255	0.0064	0.48	185
	(0.0016)	(0.0933)	(0.0566)	(0.1185)	(0.0827)		
5Y SWAP	-0.0012	0.3123***	0.4481***	-0.0787	0.1071	0.39	185
	(0.0018)	(0.1325)	(0.0878)	(0.1500)	(0.138)		
10Y SWAP	-0.0002	0.2449***	0.3880***	-0.1113	0.1798	0.37	185
	(0.0017)	(0.0792)	(0.0456)	(0.1033)	(0.1254)		
OBX	-0.0008	-0.0192	0.0275	-0.0080	-0.0470*	0.01	140
	(0.0005)	(0.0287)	(0.0206)	(0.0327)	(0.0278)		
EURNOK	-0.0003	-0.0249***	-0.0011	0.0654***	0.0447***	0.18	161
	(0.0002)	(0.0105)	(0.0054)	(0.0181)	(0.0173)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's target and path factors on Norwegian financial variables, including a dummy to account for the period of unconventional monetary policy. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). ***=1% **=5% *=10% significance level. Sample: from 2002 to 2018. The UMP period is defined as May 2010 to the end of the sample.

Table 4: Effects of ECB's target and path factors on Swedish financial variables.

Sweden: 2002-2018

	Constant	Target	Path	Target*UMP	Path*UMP	Adjusted R^2	Obs
FRA 1	0.0003	0.3195***	0.2096***	0.1043	-0.0831	0.43	185
	(0.0009)	(0.0912)	(0.0611)	(0.1275)	(0.0754)		
FRA 2	-0.0015	0.4291***	0.3425***	0.0853	-0.1829*	0.60	185
	(0.0010)	(0.1038)	(0.0825)	(0.1255)	(0.0986)		
FRA 3	-0.0024**	0.5386***	0.4417***	0.0749	-0.1441	0.62	185
	(0.0012)	(0.1212)	(0.1097)	(0.1473)	(0.1299)		
FRA 4	-0.0035***	0.6728***	0.5616***	-0.1496	-0.1203	0.61	185
	(0.0014)	(0.1906)	(0.1346)	(0.2012)	(0.1532)		
2Y SWAP	0.0037	0.6002***	0.5182***	0.1204	0.0686	0.12	185
	(0.0049)	(0.1154)	(0.1205)	(0.1996)	(0.2413)		
5Y SWAP	-0.0028*	0.4721***	0.5678***	-0.1581	-0.0498	0.49	185
	(0.0017)	(0.1808)	(0.1381)	(0.2108)	(0.1694)		
10Y SWAP	0.0000	0.2858**	0.4275***	-0.1790	-0.0245	0.30	185
	(0.0018)	(0.1355)	(0.1069)	(0.1611)	(0.1530)		
OMX-S	-0.0007*	-0.0476	-0.0081	0.0396	0.0232	0.00	140
	(0.0004)	(0.0472)	(0.0202)	(0.0534)	(0.0372)		
EURSEK	-0.0001	-0.0015	0.0085	0.0390**	0.0260*	0.17	161
	(0.0002)	(0.0131)	(0.0059)	(0.0197)	(0.0151)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's target and path factors on Swedish financial variables, including a dummy to account for the period of unconventional monetary policy. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). ***=1% **=5% *=10% significance level. Sample: from 2002 to 2018. The UMP period is defined as May 2010 to the end of the sample.

Table 5: Effects of ECB's target and path factors on Danish financial variables.

Denmark: 2002-2018

	Constant	Target	Path	Target*UMP	Path*UMP	Adjusted R^2	Obs
FRA 1	0.0032*	1.2322***	0.5142***	-0.5914***	-0.2416***	0.65	185
	(0.0017)	(0.1396)	(0.0407)	(0.1825)	(0.0935)		
FRA 2	-0.0015	0.8802***	0.9681***	-0.2397	-0.0318	0.77	185
	(0.0014)	(0.1076)	(0.0988)	(0.1830)	(0.2154)		
FRA 3	-0.0027	0.6892***	1.1542***	-0.0429	0.2095	0.78	185
	(0.0017)	(0.0971)	(0.1278)	(0.2344)	(0.2524)		
FRA 4	-0.0019	0.6841***	1.265***	0.1105	-0.0150	0.88	185
	(0.0014)	(0.0694)	(0.1436)	(0.123)	(0.1691)		
1Y SWAP	0.0003	0.2564***	0.5623***	0.2680***	0.0359	0.68	185
	(0.0012)	(0.0569)	(0.0502)	(0.0866)	(0.0687)		
2Y SWAP	-0.0023*	0.6404***	0.9046***	-0.1062	0.0111	0.83	185
	(0.0013)	(0.0994)	(0.1073)	(0.1157)	(0.1292)		
5Y SWAP	-0.0021	0.4607***	0.8137***	-0.1060	0.0777	0.69	185
	(0.0016)	(0.0889)	(0.0827)	(0.1229)	(0.1647)		
10Y SWAP	0.0006	0.2507***	0.4710***	-0.1889	0.1043	0.31	185
	(0.0019)	(0.0911)	(0.0666)	(0.1220)	(0.1623)		
OMX-C	-0.0006	-0.0199	-0.0113	0.0104	-0.0125	-0.01	140
	(0.0005)	(0.0351)	(0.0163)	(0.0408)	(0.0267)		
EURDKK	0.0000	0.0007***	0.0002	-0.0001	0.0000	0.00	161
	(0.0000)	(0.0003)	(0.0003)	(0.0004)	(0.0003)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's target and path factors on Danish financial variables, including a dummy to account for the period of unconventional monetary policy. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). ***=1% **=5% *=10% significance level. Sample: from 2002 to 2018. The UMP period is defined as May 2010 to the end of the sample.

policy, and therefore affects real economic outcomes, Delphic forward guidance mostly informs the public about the central bank's stance on the state of the economy. They argue that these should therefore not affect real economic outcomes. As the ECB's communication can be classified as *Delphic* in the early sample, and rather *Odyssean* in the latter sample, we expect a stronger path effect in the later sample. In the latter sample, asset purchases may have also caused portfolio rebalancing towards Norwegian assets.

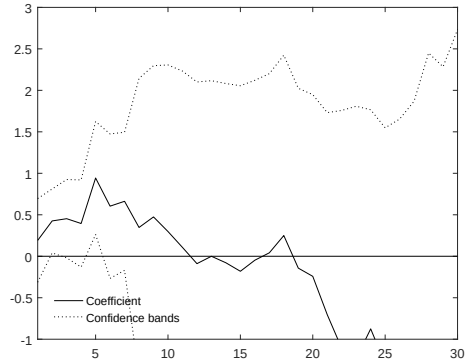
In sum, ECB's current and expected future monetary policy surprises have substantial and statistically significant effects on interest rates and asset prices in two developed small open economies that have close ties to, but are not part of, the euro area. The magnitude of these effects is quite similar for Norway and Sweden, and smaller than for Denmark. Finally, there are only minor sub-sample differences. We will now look at the persistence of interest rate spillovers.

4.1.1 Persistence on interest rates

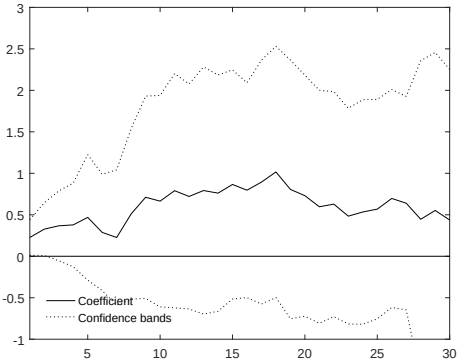
Given the use of relatively small event windows to identify the target and path factors, as well as their effects, it is unclear whether the results we find are persistent. This is important for their transmission mechanism: if the spillover effects die out quickly, it is unlikely that they will have real economic effects. We therefore follow the methodology proposed by Swanson (2017) to gauge the persistence of monetary policy and communication surprises by using a simplified version of Jorda's method of 'local projections' (Jordà (2005)). In particular, this implies running regressions of the form:

$$\Delta R_{t+h} = \alpha + \beta_{1,h} Z_{1,t} + \beta_{2,h} Z_{2,t} + \varepsilon_{t+h} \tag{3}$$

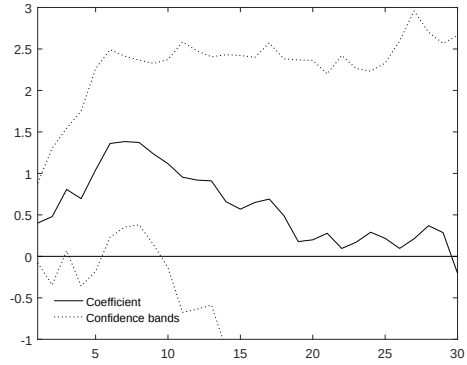
Where R_{t+h} denotes the daily change in variable R from day t to day h, and $Z_{1,t}$ and $Z_{s,t}$ denote the target and path factors, respectively. Effectively, by running this regression for values of h ranging from zero to 29, we obtain the effect these shocks have on asset prices between announcement day and 30 days thereafter. Subsequently, we plot these 30 coefficients together with 95% confidence bands for Norwegian, Swedish and Danish financial variables for both factors.



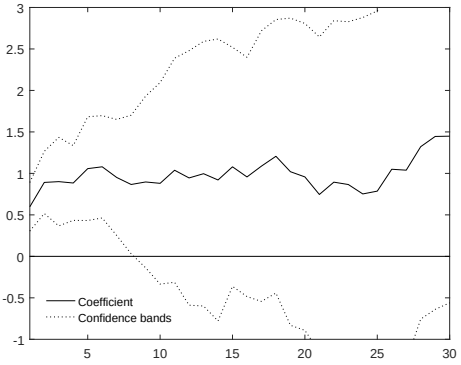
(a) Persistence of target factor on FRA 1



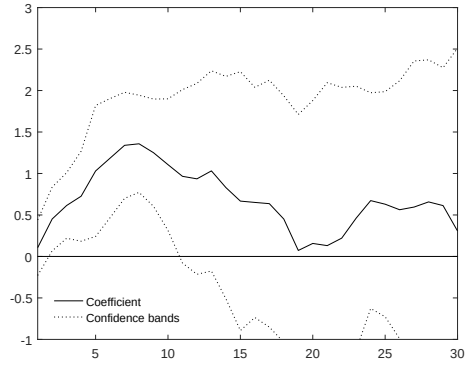
(b) Persistence of path factor on FRA 1



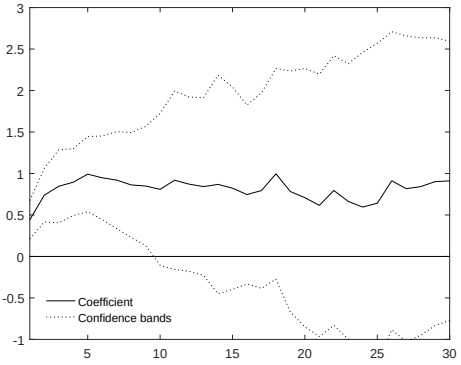
(c) Persistence of target factor on FRA 4



(d) Persistence of path factor on FRA 4



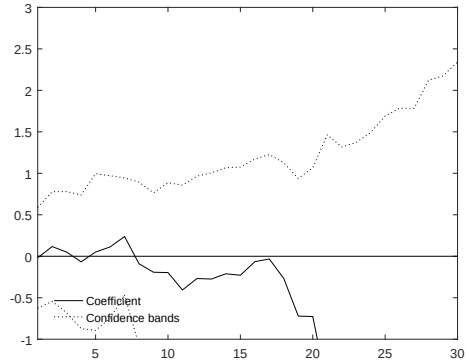
(e) Persistence of target factor on 5Y Swap



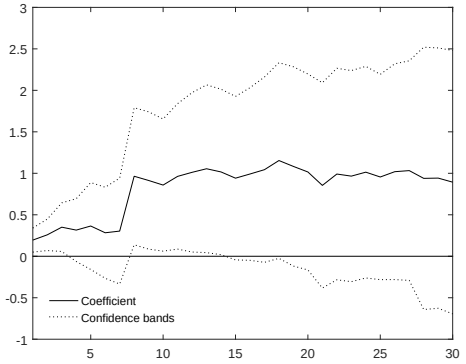
(f) Persistence of path factor on 5Y Swap

Figure 2: Persistence of ECB target and path factor for Norwegian variables

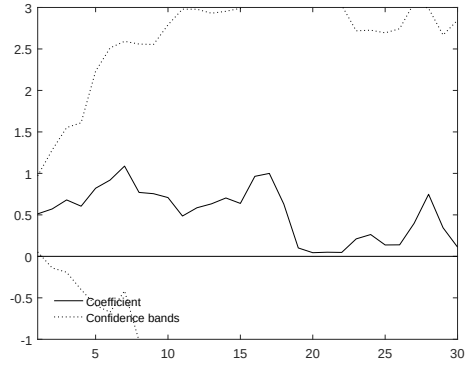
Note: These figures show the persistence of the target and path factor for three selected Norwegian interest rates for up to 30 days. Persistence coefficients are obtained by estimating Equation 3 for $H = 0$ to $H = 29$ with HAC adjusted standard errors. 95% confidence bands are shown around the estimated persistence coefficients.



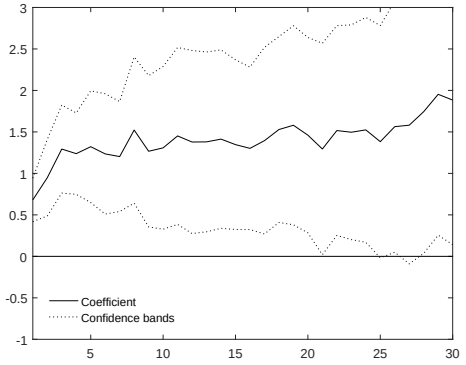
(a) Persistence of target factor on FRA 1



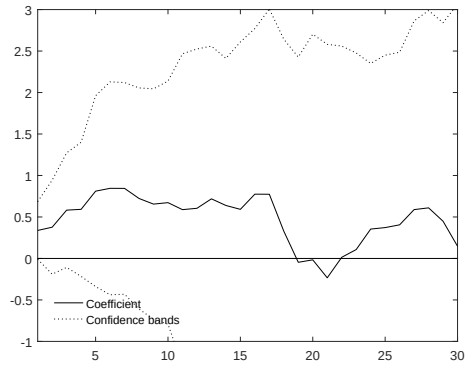
(b) Persistence of path factor on FRA 1



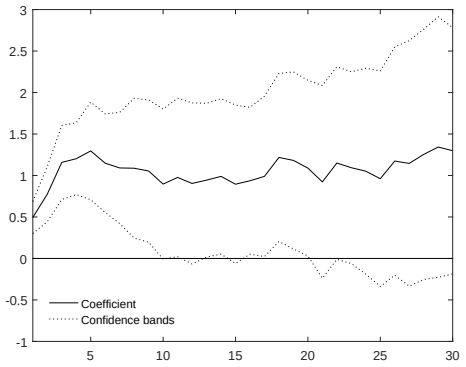
(c) Persistence of target factor on FRA 4



(d) Persistence of path factor on FRA 4



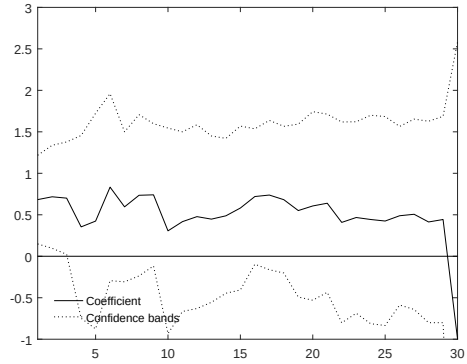
(e) Persistence of target factor on 5Y Swap



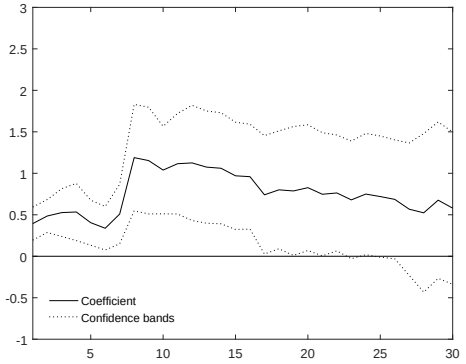
(f) Persistence of path factor on 5Y Swap

Figure 3: Persistence of ECB target and path factor for Swedish variables

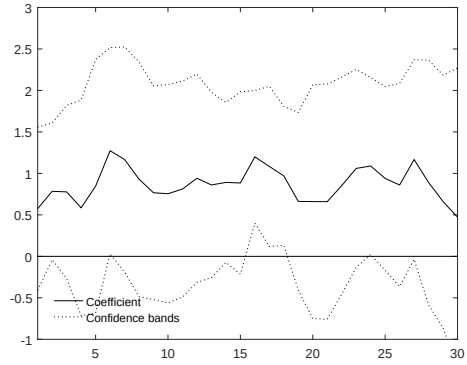
Note: These figures show the persistence of the target and path factor for three selected Swedish interest rates for up to 30 days. Persistence coefficients are obtained by estimating Equation 3 for $H = 0$ to $H = 29$ with HAC adjusted standard errors. 95% confidence bands are shown around the estimated persistence coefficients.



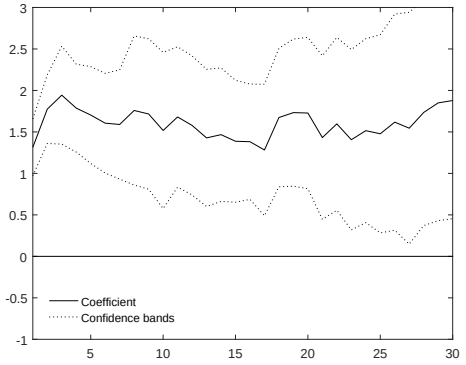
(a) Persistence of target factor on FRA 1



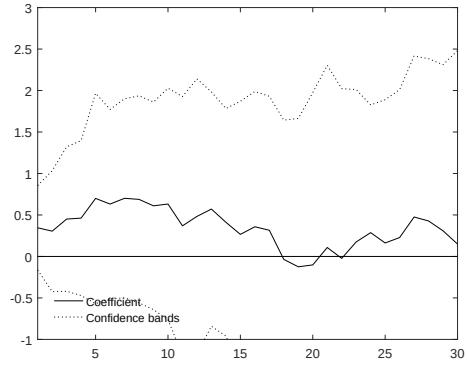
(b) Persistence of path factor on FRA 1



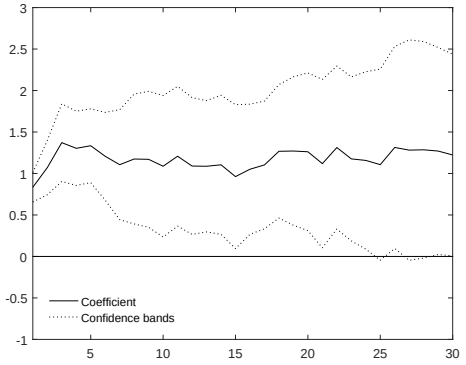
(c) Persistence of target factor on FRA 4



(d) Persistence of path factor on FRA 4



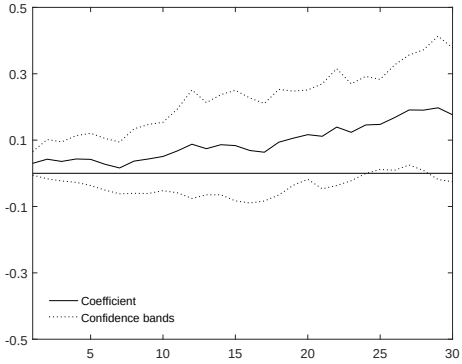
(e) Persistence of target factor on 5Y Swap



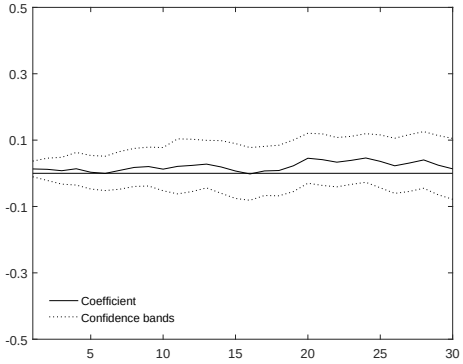
(f) Persistence of path factor on 5Y Swap

Figure 4: Persistence of ECB target and path factor for Danish variables

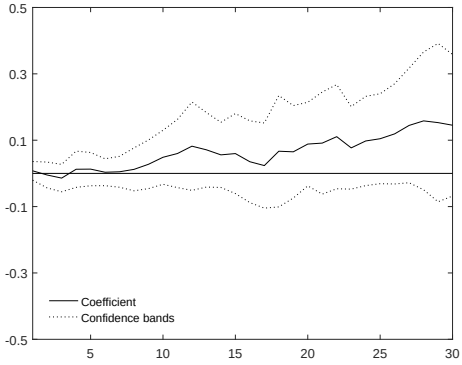
Note: These figures show the persistence of the target and path factor for three selected Danish interest rates for up to 30 days. Persistence coefficients are obtained by estimating Equation 3 for $H = 0$ to $H = 29$ with HAC adjusted standard errors. 95% confidence bands are shown around the estimated persistence coefficients.



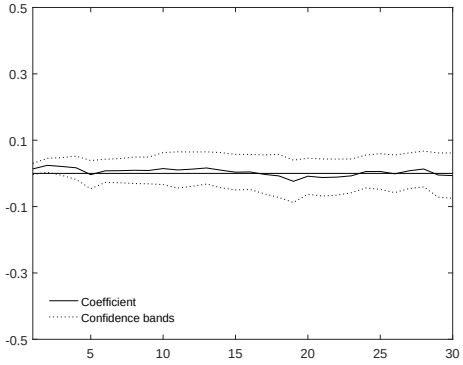
(a) Persistence of target factor on EURNOK



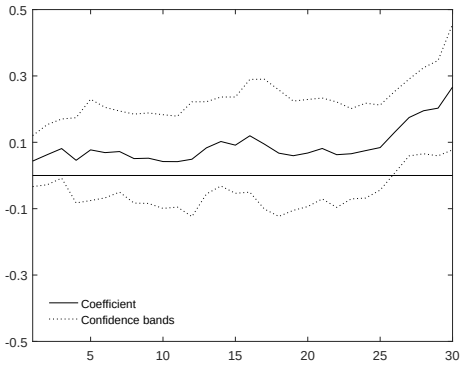
(b) Persistence of path factor on EURNOK



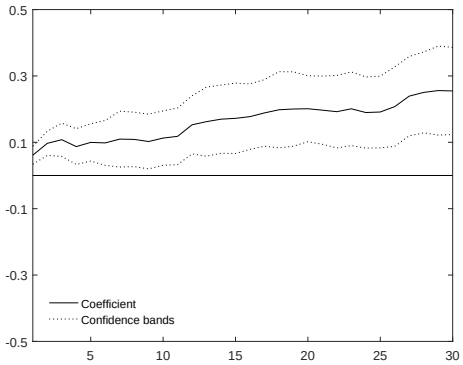
(c) Persistence of target factor on EURSEK



(d) Persistence of path factor on EURSEK



(e) Persistence of target factor on EURUSD



(f) Persistence of path factor on EURUSD

Figure 5: Persistence of ECB target and path factor for currencies

Note: These figures show the persistence of the target and path factor for the euro against the Norwegian krone, Swedish krone, and US dollar for up to 30 days. Persistence coefficients are obtained by estimating Equation 3 for $H = 0$ to $H = 29$ with HAC adjusted standard errors. 95% confidence bands are shown around the estimated persistence coefficients.

From Figures 2 - 5, we can see that the longer the horizon of the interest rate (i.e. the further out on the yield curve), the more important and persistent ECB's path surprises are for Norway and Sweden. Furthermore, whereas we find some (persistence of) spillovers from ECB monetary policy surprises to Norwegian rates, this is barely the case for Sweden. Spillovers from ECB's path factor are stronger for Sweden than for Norway though. ECB's target factor has a stronger and more persistent effect on Danish rates, although they do not survive the somewhat strict test for significance. The effect of the path factor is stronger for Danish rates than for Norwegian rates, but has a very similar effect for Swedish rates.

4.2 Robustness of factor specification

We show that our results are robust to the exact specification of factor input variables. Results are qualitatively the same, and quantitatively very similar. Table 6 shows the correlation between the various ways of extracting the factors. Correlations are very high. We have tested two different variations: expanding the factor input variable set with German Treasuries of five and ten year maturity (Table 7), and extracting the factors for two different subsamples (pre-UMP and UMP; see tables in Appendix for full results).

Table 6: Correlations different factor specifications

X	X up to two years	X up to ten years	full sample X
correlations between:	full & subsample	full & subsample	short & long X
target	0.9990	0.9862	0.9399
path	0.9953	0.9765	0.8985

Note: This table shows correlations between the target (path) factor extracted in three different ways: over the full sample versus over two sub-samples for input variables up to two years (correlation in column 2) or up to ten years (correlation in column 3), and with input variables up to two versus up to ten years for the full sample (column 4).

4.3 Effectiveness of domestic monetary policy in Norway and Sweden

Finally, to be able to further link ECB spillovers with domestic monetary policy effectiveness, we examine the results of Brubakk et al. (2017). In their paper, they extract a target and path factor from Norwegian and Swedish interest rate changes around monetary policy announcements of the Norwegian (Norges Bank) and Swedish (Sveriges

Table 7: Effects of ECB's target and path factors on Norwegian, Swedish, and Danish financial variables.

	Norway				**Sweden**				**Denmark**			
	Target	Path	Adj. R^2	-	Target	Path	Adj. R^2	-	Target	Path	Adj. R^2	Obs
FRA 1	0.4600***	0.2969***	0.20		0.4036***	0.2109***	0.43		1.0240***	0.4388***	0.59	185
	(0.1117)	(0.0591)			(0.0784)	(0.0465)			(0.1416)	(0.0581)		
FRA 2	0.5258***	0.4047***	0.47		0.5300***	0.3088***	0.58		1.0298***	0.9773***	0.74	185
	(0.0763)	(0.0685)			(0.0833)	(0.0541)			(0.0822)	(0.0939)		
FRA 3	0.4276***	0.5802***	0.43		0.6487***	0.4450***	0.62		1.0064***	1.2844***	0.74	185
	(0.1307)	(0.0750)			(0.0979)	(0.0718)			(0.1076)	(0.1092)		
FRA 4	0.6227***	0.7378***	0.56		0.6652***	0.6114***	0.64		1.0402***	1.3694***	0.86	185
	(0.0894)	(0.0686)			(0.1258)	(0.0863)			(0.1112)	(0.1072)		
1Y SWAP	0.3141***	0.3153***	0.18		0.4989***	0.4918***	0.06		0.5528***	0.6113***	0.64	185
	(0.0972)	(0.0641)			(0.0924)	(0.1334)			(0.0772)	(0.0409)		
2Y SWAP	0.4138***	0.5716***	0.52		0.6875***	0.7056***	0.14		0.7393***	1.0486***	0.88	185
	(0.0551)	(0.0504)			(0.1074)	(0.1426)			(0.0553)	(0.0584)		
5Y SWAP	0.2841***	0.6388***	0.50		0.3891***	0.7314***	0.60		0.4520***	1.0766***	0.84	185
	(0.0839)	(0.0540)			(0.1306)	(0.0868)			(0.0722)	(0.0458)		
10Y SWAP	0.1536***	0.6421***	0.54		0.1093	0.6421***	0.50		0.0879	0.7452***	0.50	185
	(0.0543)	(0.0528)			(0.1086)	(0.0978)			(0.0682)	(0.0832)		
Equity	-0.0334**	0.0237	0.02		-0.0154	-0.0072	-0.01		-0.0233	-0.0112	0.00	140
	(0.0158)	(0.0159)			(0.0318)	(0.0238)			(0.0160)	(0.0184)		
FX	0.01450	0.0237**	0.06		0.0235	0.0254***	0.13		0.0007***	0.0002	0.01	161
	(0.0154)	(0.0117)			(0.0146)	(0.0067)			(0.0003)	(0.0002)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's target and path factors on Norwegian, Swedish and Danish financial variables. An extended set of variables is used as factor inputs. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). Constant terms are excluded for presentation convenience. ***=1% **=5% *=10% significance level. Sample: from January 2002 to June 2018. Data for the equity indices starts in October 2010, for exchange rates in January 2004. Event window: from 1:30 p.m. to 3:45 p.m.

Riksbank) central banks. Their sample is slightly different than ours: they use interest rate instruments up to one year (forward rate agreements instead of OIS rates), and their sample period runs from 2001 to 2016. However, in the previous section we have showed that our results are robust to the exact sample specification. The event window is also slightly shorter, but as for our ECB event window, captures exactly the monetary policy announcement and subsequent press conference.[17]

Results are shown in Table 8. Comparing the size of the coefficients, we can see that the effects of domestic target surprises (columns 2 for Norway and 6 for Sweden) are much stronger than of ECB's target surprises (Table 2, columns 2 and 5), especially for the short to medium term (up to two years). They are, however, very similar to the effect of ECB's target surprises on Denmark (Table 2, column 8). Given these results, the monetary policy regime of Norway and Sweden clearly gives the central banks of these countries some control over their yield curve, especially up until two years. The domestic path factor (which captures communication about intended future monetary policy) affects the same maturities as ECB's path factor. It seems that monetary policy communication in the euro area is as important for Norwegian and Swedish rates as is communication about future domestic monetary policy.[18] This is not surprising, given that the euro area is an important trading partner of Norway and Sweden, and thus economic conditions in the euro area are important for these countries.

Domestic target and path surprises have a significant effect on the longer end of the yield curve (five to ten years), but these effects are less strong than the spillover effects from the ECB. Control over the domestic yield curve therefore seems to diminish for the long end of the yield curve. Finally, whereas Norwegian equity prices move in response to ECB target surprises, they do not move in response to domestic monetary policy. The opposite is the case for Sweden: domestic monetary policy affects the Swedish equity market, but ECB's monetary policy does not.

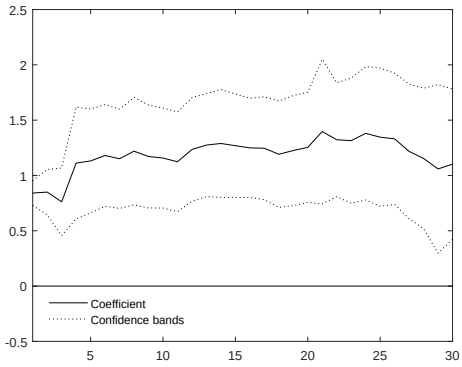
[17]Note that the results are slightly different from those presented in their paper, as they display the results for daily event windows. However, results for event windows of 90 minutes (15 minutes before and 75 minutes after the announcement) are also available. We use these results for better comparability to the ECB spillover results.

[18]Note that we cannot compare the size of the path factor, as the (re)scaling of that factor in Brubakk et al. (2017) is different from our method.

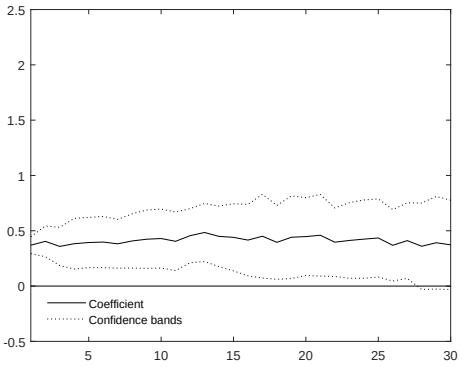
Table 8: Effects of domestic monetary policy on Norwegian and Swedish financial variables. 2001-2016

	Norway				**Sweden**			
	Target	Path	Adj. R^2	Obs	Target	Path	Adj. R^2	Obs
FRA 1	0.8166***	0.3674***	0.94	124	0.7555***	0.2836***	0.74	106
	(0.0354)	(0.0272)			(0.0944)	(0.0338)		
FRA 2	0.8172***	0.5019***	0.96	124	0.5846***	0.3657***	0.98	106
	(0.0197)	(0.0266)			(0.0131)	(0.0110)		
FRA 3	0.6874***	0.6036***	0.98	124	0.4747***	0.3952***	0.97	106
	(0.0216)	(0.0101)			(0.0250)	(0.0100)		
FRA 4	0.6295***	0.6295***	0.97	124	0.4074***	0.4074***	0.95	106
	(0.0210)	(0.0161)			(0.0282)	(0.0120)		
2Y SWAP	0.5280***	0.4585***	0.88	124	0.4396***	0.3571***	0.95	106
	(0.0468)	(0.0320)			(0.0162)	(0.0093)		
5Y SWAP	0.3275***	0.3164***	0.82	124	0.2717***	0.2451***	0.77	106
	(0.0302)	(0.0204)			(0.0327)	(0.0275)		
10Y SWAP	0.2049***	0.2122***	0.64	124	0.1311***	0.1565***	0.52	106
	(0.0322)	(0.0225)			(0.0371)	(0.0195)		
Equity	-0.0029	-0.0002	-0.01	122	-0.0232*	0.0033	0.08	71
	(0.0044)	(0.0040)			(0.0138)	(0.0050)		
FX	-0.0296***	-0.0227***	0.4	124	-0.0263***	-0.0179***	0.44	106
	(0.0099)	(0.0041)			(0.0071)	(0.0031)		

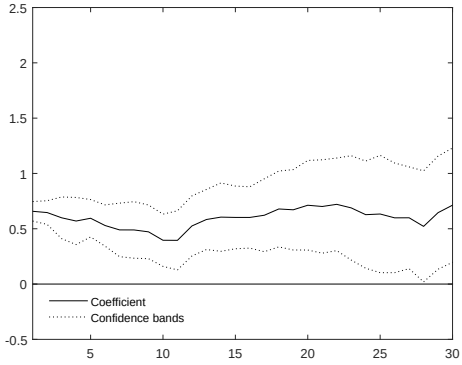
Note: This table displays the results from Brubakk et al. (2017), obtained by estimating Equation 2 for domestic (Norwegian and Swedish) policy shocks, using ordinary least squares with HAC standard errors (in parentheses). ***=1% **=5% *=10% significance level. Sample: from 2001 to 2016. Event window: 90 minutes (15 minutes before announcement until 75 minutes after).



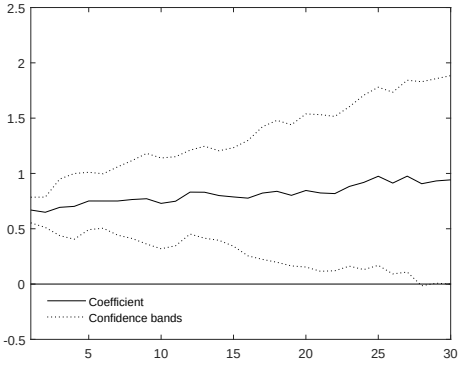
(a) Persistence of domestic target factor on FRA 1



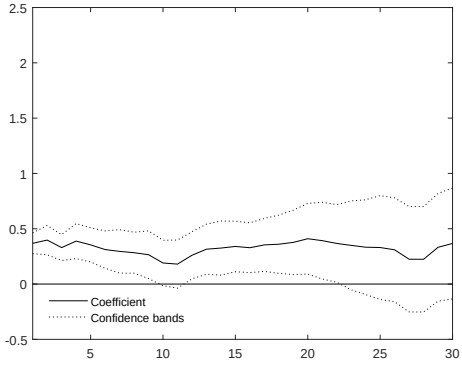
(b) Persistence of domestic path factor on FRA 1



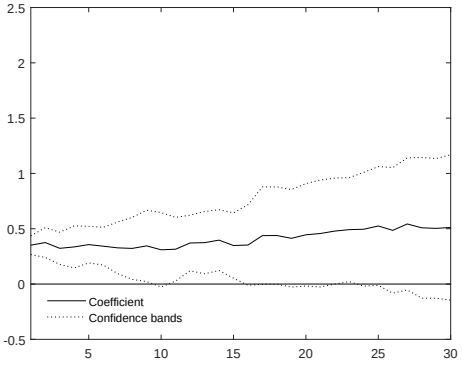
(c) Persistence of domestic target factor on FRA 4



(d) Persistence of domestic path factor on FRA 4



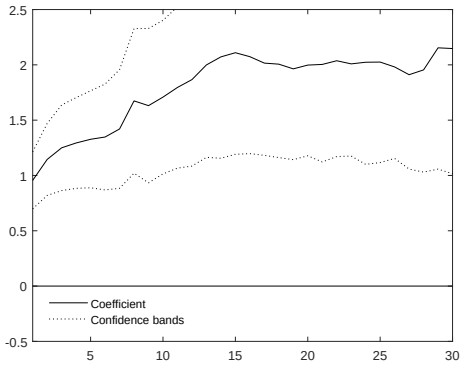
(e) Persistence of domestic target factor on 5Y Swap



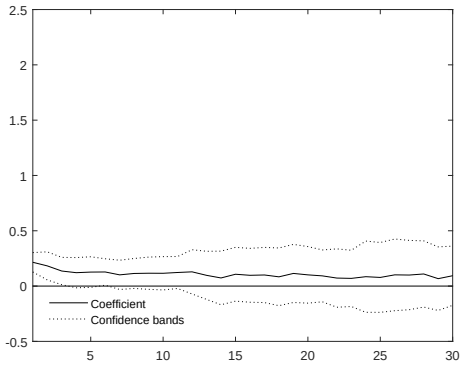
(f) Persistence of domestic path factor on 5Y Swap

Figure 6: Persistence of domestic target and path factor for Norwegian variables

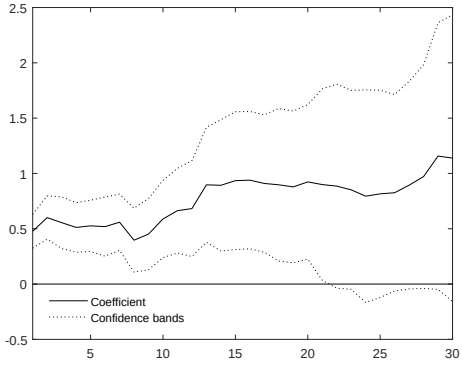
Note: These figures show the persistence of the domestic target and path factor for three selected Norwegian interest rates for up to 30 days. Persistence coefficients are obtained by estimating Equation 3 for $H = 0$ to $H = 29$ with HAC adjusted standard errors. 95% confidence bands are shown around the estimated persistence coefficients.



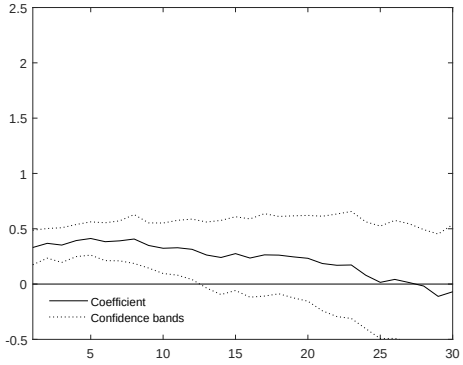
(a) Persistence of domestic target factor on FRA 1



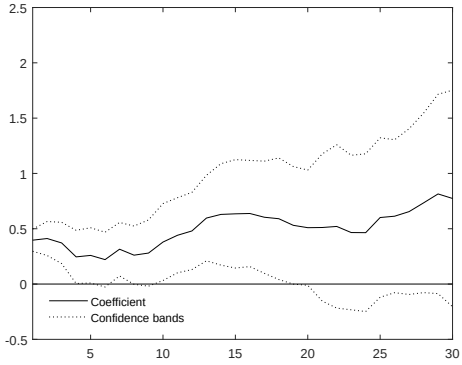
(b) Persistence of domestic path factor on FRA 1



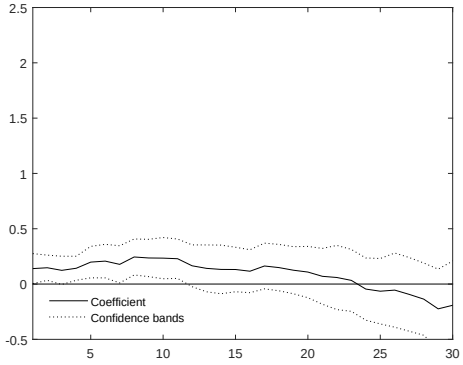
(c) Persistence of domestic target factor on FRA 4



(d) Persistence of domestic path factor on FRA 4



(e) Persistence of domestic target factor on 5Y Swap



(f) Persistence of domestic path factor on 5Y Swap

Figure 7: Persistence of domestic target and path factor for Swedish variables

Note: These figures show the persistence of the domestic monetary policy target and path factor for three selected Swedish interest rates for up to 30 days. Persistence coefficients are obtained by estimating Equation 3 for $H = 0$ to $H = 29$ with HAC adjusted standard errors. 95% confidence bands are shown around the estimated persistence coefficients.

4.3.1 Persistence of domestic monetary policy effects

We also compare the persistence of ECB's spillovers to the persistence of domestic monetary policy. The results are displayed in Figures 6 and 7, and should be compared with Figures 2 to 5. Whereas responses of domestic rates to ECB's monetary policy are virtually absent for Norway and Sweden, especially for the short end of the yield curve, the domestic rates are very responsive to domestic monetary policy, and these responses are also very persistent. The domestic target factor also has a persistently significant effect on domestic rates, especially for Norway, but these effects decrease for the five-year swap yield. We can safely conclude that domestic monetary policy and communication effectively moves the domestic yield curve, despite spillovers from the ECB.

5 Conclusion

This paper investigates the effectiveness of domestic monetary policy in small open economies in the presence of immediate spillovers from the ECB's monetary policy and communication. We employ a high frequency identification approach. We extract two factors from the ECB's policy announcements: a target rate surprise, and a path surprise that contains information provided by the ECB beyond the policy rate decision. We find that small open economies that have close ties to the euro area are also affected by ECB's monetary policy and communication. Although they can still largely effect the short to medium end of the domestic yield curve, the long end of the yield curve is affected by ECB communication the most.

We investigate spillover effects on different parts of the yield curve, as well as on their main equity indices, for Norway, Sweden and Denmark. We find that ECB policy rate surprises have substantial effects on the short end of the yield curves. In addition, policy rate surprises have a strong significant effect on Norwegian equity prices, whereas there is no effect on Swedish and Danish equity prices. The results further suggest that ECB communication has larger effects on medium and longer-term foreign interest rates than the policy rate surprise.

Our results stress the need to consider spillovers from communication. Whereas the

effects of policy rate surprises often fade within a few days, the effects of communication are much more persistent, and as such more likely to influence real economic variables in the affected countries.

Bibliography

Bauer, M. D. and C. J. Neely (2014). International channels of the fed's unconventional monetary policy. *Journal of International Money and Finance 44*, 24–46.

Brand, C., D. Buncic, and J. Turunen (2010). The impact of ECB monetary policy decisions and communication on the yield curve. *Journal of the European Economic Association 8*(6), 1266–1298.

Brubakk, L., S. Ter Ellen, and H. Xu (2017). Forward guidance through interest rate projections: does it work? *Norges Bank Working Paper 6/2017*.

Burriel, P. and A. Galesi (2018). Uncovering the heterogeneous effects of ECB unconventional monetary policies across euro area countries. *European Economic Review 101*, 210–229.

Campbell, J. R., C. L. Evans, J. D. Fisher, and A. Justiniano (2012). Macroeconomic effects of federal reserve forward guidance. *Brookings Papers on Economic Activity 2012*(1), 1–80.

Canova, F. (2005). The transmission of us shocks to latin america. *Journal of Applied Econometrics 20*, 229–251.

Chen, J., T. Mancini-Griffoli, and R. Sahay (2014). Spillovers from united states monetary policy on emerging markets: different this time? *IMF working paper 14/240*.

Dedola, L., G. Rivolta, and L. Stracca (2017). If the fed sneezes, who catches a cold? *Journal of International Economics 10851*, 23–45.

Ehrmann, M. and M. Fratzscher (2009). Global financial transmission of monetary policy shocks. *Oxford Bulletin of Economics and Statistics 71*(6), 739–759.

Ehrmann, M., M. Fratzscher, and R. Rigobon (2011). Stocks, bonds, money markets and exchange rates: measuring international financial transmission. *Journal of Applied Econometrics 26*(6), 948–974.

Falagiarda, M., P. McQuade, and M. Tirpak (2015). Spillovers from the ECB's non-standard monetary policies on non-euro area EU countries: evidence from an event-study analysis. *ECB Working Paper Series 1869*.

Feldkircher, M. and F. Huber (2016). The international transmission of US shocks – evidence from Bayesian global vector autoregressions. *European Economic Review 81*, 167–188.

Fratzscher, M., M. Lo Duca, and R. Straub (2016). ECB unconventional monetary policy: Market impact and international spillovers. *IMF Economic Review 64*(1), 36–74.

Georgiadis, G. (2015). Examining asymmetries in the transmission of monetary policy in the euro area: Evidence from a mixed cross-section global var model. *European Economic Review 75*, 195–215.

Georgiadis, G. and J. Gräb (2016). Global financial market impact of the announcement of the ECB's asset purchase programme. *Journal of Financial Stability 26*, 257–265.

Georgiadis, G. and A. Mehl (2016). Financial globalisation and monetary policy effectiveness. *Journal of International Economics 103*, 200–212.

Gilchrist, S., V. Yue, and E. Zakrajsek (2018). US monetary policy and international bond markets. *FEDS working paper*.

Gürkaynak, R. S., B. Sack, and E. Swanson (2005). Do actions speak louder than words? the response of asset prices to monetary policy actions and statements. *International Journal of Central Banking 1*(1), 55–93.

Hamilton, J. D. (2008). Assessing monetary policy effects using daily federal funds futures contracts. *Federal Reserve Bank of St. Louis Review 90*(4), 377–93.

Hanson, S. and J. C. Stein (2015). Monetary policy and long-term real rates. *Journal of Financial Economics 115*, 429–448.

Hausman, J. and J. Wongswan (2011). Global asset prices and FOMC announcements. *Journal of International Money and Finance 30*, 547–571.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *The American Economic Review 95*(1), 161–182.

Kim, S. (2001). International transmission of u.s. monetary policy shocks: Evidence from var's. *Journal of Monetary Economics 48*, 339–372.

Kuttner, K. N. (2001). Monetary policy surprises and interest rates: Evidence from the fed funds futures markets. *Journal of Monetary Economics 47*(3), 523–44.

Leombroni, M., A. Vedolin, G. Venter, and P. Whelan (2017). Central bank communication and the yield curve. *working paper*.

Neely, C. J. (2015). Unconventional monetary policy had large international effects. *Journal of Banking and Finance 52*, 101–111.

Potjagailo, G. (2017). Spillover effects from euro area monetary policy across Europe: A factor-augmented VAR approach. *Journal of International Money and Finance 72*, 127–147.

Rey, H. (2015). Dilemma not trilemma: the global financial cycle and monetary policy independence. *NBER working paper 21162*.

Rogers, J. H., C. Scotti, and J. H. Wright (2016). Unconventional monetary policy and international risk premia. *International Finance Discussion Papers* (1172).

Rosa, C. and G. Verga (2008). The impact of central bank announcements on asset prices in real time. *International Journal of Central Banking 4*(2), 175–217.

Swanson, E. T. (2017). Measuring the effects of federal reserve forward guidance and asset purchases on financial markets. *Working Paper* (21816).

Takats, E. and A. Vela (2014). International monetary policy transmission. *BIS report*.

Tillmann, P. (2016). Unconventional monetary policy and the spillovers to emerging markets. *Journal of International Money and Finance 66*, 136–156.

Appendix

ECB spillovers - subsample analysis

We investigate whether international transmission of ECB's monetary policy and communication has changed since the ECB introduced asset purchases as part of its unconventional monetary policy tools on May 10, 2010. In this section, we allow for the possibility that a structural change in the conduct of monetary policy in May 2010, by starting asset purchase programs, has affected the factor extraction. To this aim, we extract the factors separately for the two subsamples, i.e. we extract two factor from interest rate changes around monetary policy announcements for the subsample January 2002 up to and including April 2010, and we extract two factors for the subsample May 2010 up to and including June 2018. Results are presented in Tables 9 to 11.

Explanatory power for both countries is substantially higher during the UMP period.[19] Estimated effects on the longest maturities are much larger for the UMP period for both countries. This indicates that a potential interpretation of the communication factor may be a combination of forward guidance and UMP.[20] Note that earlier results showed that these differences are not statistically significant.

[19]It is not obvious whether we should interpret this as a time-effect or as something specific to monetary policy in a time with key policy rates near their effective lower bound and substantial use of unconventional monetary policy. The parameter instability between the sub-samples may come from other factors than UMP.

[20]However, the ECB has in recent years changed its monetary policy communication strategy to include both more forward guidance, but also more transparent guidance.

Table 9: Effects of ECB's monetary policy and communication factors on Norwegian financial variables. Pre UMP & UMP.

Norway	**Pre-UMP: 2002 - April 2010**				**UMP: May 2010 - June 2018**			
	Target	Path	Adjusted R2	Obs	Target	Path	Adjusted R^2	Obs
FRA 1	0.3041	0.3377***	0.15	101	0.4032***	0.2334***	0.50	84
	(0.1875)	(0.0847)			(0.0972)	(0.0593)		
FRA 2	0.3545***	0.3869***	0.41	101	0.5235***	0.3178***	0.56	84
	(0.0634)	(0.0889)			(0.0994)	(0.0752)		
FRA 3	0.0984	0.5598***	0.39	101	0.5258***	0.3967***	0.60	84
	(0.1705)	(0.1055)			(0.0678)	(0.0624)		
FRA 4	0.4356***	0.6159***	0.45	101	0.6126***	0.6377***	0.64	84
	(0.1442)	(0.0967)			(0.0715)	(0.0907)		
2Y SWAP	0.2882***	0.4782***	0.46	101	0.3778***	0.5112***	0.51	84
	(0.0961)	(0.0566)			(0.07)	(0.0615)		
5Y SWAP	0.2563**	0.4415***	0.37	101	0.2951***	0.5776***	0.45	84
	(0.1298)	(0.0881)			(0.0728)	(0.105)		
10Y SWAP	0.1967***	0.3811***	0.33	101	0.2005***	0.5853***	0.42	84
	(0.0804)	(0.0411)			(0.0741)	(0.1218)		
OBX	-0.0227	0.0274	0.00	56	-0.0267*	-0.0206	0.02	84
	(0.03)	(0.0213)			(0.0147)	(0.0193)		
EURNOK	-0.0257**	-0.0007	0.03	77	0.0384***	0.0453***	0.26	84
	(0.0114)	(0.0048)			(0.0142)	(0.017)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's monetary policy and communication on Norwegian financial variables, dividing the sample in two sub-samples. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). Constant terms are excluded for presentation convenience. The two principal components are extracted separately for the two sub-samples. ***=1% **=5% *=10% significance level. Event window: from 1:30 p.m. to 3:45 p.m.

Table 10: Effects of ECB's monetary policy and communication factors on Swedish financial variables. Pre UMP & UMP.

Sweden	**Pre-UMP: 2002 - April 2010**				—	**UMP: May 2010 - June 2018**			
	Target	Path	Adjusted R2	Obs		Target	Path	Adjusted R^2	Obs
FRA 1	0.2971***	0.2042***	0.34	101		0.4298***	0.1434***	0.58	84
	(0.0954)	(0.0603)				(0.09)	(0.0444)		
FRA 2	0.39***	0.3348***	0.57	101		0.5216***	0.181***	0.65	84
	(0.0986)	(0.084)				(0.07)	(0.0536)		
FRA 3	0.4895***	0.4316***	0.57	101		0.6369***	0.3236***	0.70	84
	(0.1123)	(0.11)				(0.0803)	(0.0711)		
FRA 4	0.6104***	0.5485***	0.59	101		0.5666***	0.4666***	0.65	84
	(0.1833)	(0.1346)				(0.0627)	(0.0728)		
1Y SWAP	0.3523***	0.3736***	0.52	101		0.6205***	0.359	0.01	84
	(0.0754)	(0.0576)				(0.1975)	(0.2195)		
2Y SWAP	0.5469***	0.5037***	0.53	101		0.7831***	0.6173***	0.06	84
	(0.1181)	(0.1141)				(0.1851)	(0.2171)		
5Y SWAP	0.4064**	0.5555***	0.53	101		0.3713***	0.5384***	0.41	84
	(0.1792)	(0.1376)				(0.1034)	(0.1024)		
10Y SWAP	0.2345*	0.4193***	0.40	101		0.1532	0.417***	0.18	84
	(0.1298)	(0.1067)				(0.094)	(0.1139)		
OMX-S	-0.0517	-0.0084	0.02	56		-0.0076	0.0136	-0.02	84
	(0.05)	(0.0177)				(0.0274)	(0.0327)		
EURSEK	-0.0012	0.0087	0.00	77		0.0357***	0.0362***	0.29	84
	(0.014)	(0.0059)				(0.0144)	(0.0145)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's monetary policy and communication on Swedish financial variables, dividing the sample in two sub-samples. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). Constant terms are excluded for presentation convenience. The two principal components are extracted separately for the two sub-samples. ***=1% **=5% *=10% significance level. Event window: from 1:30 p.m. to 3:45 p.m.

Table 11: Effects of ECB's monetary policy and communication factors on Danish financial variables. Pre UMP & UMP.

Denmark	**Pre-UMP: 2002 - April 2010**				**UMP: May 2010 - June 2018**			
	Target	Path	Adjusted R2	Obs	Target	Path	Adjusted R^2	Obs
FRA 1	1.1867***	0.4954***	0.66	101	0.6613***	0.2983***	0.62	84
	(0.1431)	(0.04)			(0.1269)	(0.0906)		
FRA 2	0.7622***	0.9508***	0.81	101	0.7434***	0.9725***	0.70	84
	(0.1118)	(0.0989)			(0.1567)	(0.1932)		
FRA 3	0.5412***	1.1376***	0.83	101	0.8002***	1.4099***	0.72	84
	(0.1086)	(0.1334)			(0.2042)	(0.2191)		
FRA 4	0.5246***	1.2451***	0.87	101	0.9353***	1.2951***	0.89	84
	(0.0797)	(0.1424)			(0.1044)	(0.1046)		
1Y SWAP	0.1836***	0.5542***	0.59	101	0.5868***	0.6261***	0.82	84
	(0.071)	(0.0511)			(0.0543)	(0.0494)		
2Y SWAP	0.5308***	0.888***	0.80	101	0.6372***	0.9486***	0.89	84
	(0.1035)	(0.1076)			(0.0624)	(0.0725)		
5Y SWAP	0.3585***	0.8002***	0.74	101	0.4561***	0.9229***	0.63	84
	(0.089)	(0.0823)			(0.0896)	(0.1447)		
10Y SWAP	0.1905**	0.4637***	0.32	101	0.1299	0.5924***	0.31	84
	(0.0894)	(0.0681)			(0.086)	(0.1545)		
OMX-C	-0.0218	-0.0118	-0.02	56	-0.0098	-0.0252	0.00	84
	(0.0376)	(0.0151)			(0.022)	(0.0226)		
EURDKK	0.0007***	0.0002	-0.01	77	0.0006***	0.0003	0.06	84
	(0.0003)	(0.0003)			(0.0002)	(0.0002)		

Note: This table displays the results from estimating Equation 2: analysing the effects of ECB's monetary policy and communication on Danish financial variables, dividing the sample in two sub-samples. Results are obtained using ordinary least squares with HAC standard errors (in parentheses). Constant terms are excluded for presentation convenience. The two principal components are extracted separately for the two sub-samples. ***=1% **=5% *=10% significance level. Event window: from 1:30 p.m. to 3:45 p.m.