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Spillover Effects of Forward Guidance Shocks

How ECB Communication Influences Economic Outcomes in Neighboring Economies

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Abstract

With policy rates at the zero lower bound, the ECB is increasingly relying on forward guidance to stimulate the economy. In this thesis paper, I show that the ECB's communication has important effects on economic outcomes both inside and outside of the eurozone. I use high-frequency price changes in financial assets around 197 ECB monetary policy announcements between 2002 and 2019 to construct exogenous communication shocks, which are applied as external instruments in a SVAR-IV. I estimate effects of the ECB's forward guidance on macroeconomic variables in the euro area and in several neighboring economies, with a focus on Sweden, Norway, and Denmark. I find that after an accomodative ECB communication shock, economic activity in Denmark and Sweden clearly increases. In Norway, some effects are of the opposite sign. Moreover, only the Norwegian krone seems to appreciate in response to the shock. My results are suggestive of a fear of floating-situation, in which Sveriges Riksbank eases its monetary policy stance in response to an accomodative ECB communication shock. This prevents the Swedish krona from appreciating and leads to expansionary economic effects.

Keywords: Forward Guidance; Monetary Policy Spillover Effects; Central Bank Communication; Exchange Rates; Fear of Floating

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All errors are my own.

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1 Introduction

In the wake of the European debt crisis, the ECB cut its policy rates to historically low levels. With little room for maneuvering the policy rates, the ECB resorted to other measures to stimulate the economy. In particular, forward guidance — central bank communication which shapes market expectations of future policy rates — has been given an important role. In 2019, ECB President Mario Draghi stated that "the use of forward guidance ... it's been quite effective. Now we've been using it for several years and it's been quite successful in steering market expectations and basically, it's become the major monetary policy tool we have now".[1] As the ECB continues to rely on forward guidance, a deeper understanding of how central bank communication impacts economic outcomes inside and outside of the eurozone is needed.

In this thesis paper, I examine how ECB communication shocks impact macroeconomic variables in Sweden, Norway, and Denmark — three highly similar countries with different exchange rate arrangements. My main research questions include: How does the ECB's communication impact economic outcomes in the euro area? How does the ECB's communication impact economic outcomes in neighboring economies, in particular Sweden, Norway, and Denmark? How do the domestic central banks react to the ECB shocks? Based on the cross-country results, does exchange rate flexibility seem to matter for the spillover effects?

My main contribution is twofold. First, I contribute to the growing literature on high-frequency monetary policy shocks and information effects in central bank announcements. Second, I contribute to the literature on cross-border effects of monetary policy; a contested topic which ties into questions about monetary policy autonomy and exchange rate flexibility. In their seminal paper, Gürkaynak et al. (2005) show that central bank communication influences the yield curve by shaping market expectations of future policy rates. The authors measure intraday price changes in financial instruments around monetary policy announcements, and construct two factors from the shocks: The target factor captures shocks related to current policy rates, while the path factor captures shocks related to expectations of future rates. The path factor has since become well-established in the empirical literature on forward guidance. Campbell et al. (2012) note that path factor shocks often lead to wrong-signed revisions in private market forecasts of inflation. They conclude that the path factor has two different components: Odyssean and Delphic. Odyssean forward guidance refers to the central bank's commitment to a certain policy rate path, while Delphic forward guidance captures information about the economic outlook. Andrade and Ferroni (2021) construct Odyssean and Delphic factors for the eurozone, and show that the effects of an Odyssean shock is in line with conventional wisdom on forward guidance. A number of studies have also used shocks in government bond yields to capture forward guidance (Hanson and Stein, 2015;

[1] Q&A Session at the ECB Press Conference 6 June 2019.

Kerssenfischer, 2019). The shocks can, similarly to the path factor, be decomposed into a pure monetary policy shock and an information effect. ter Ellen et al. (2020), whose study is part of the growing literature on cross-border effects of monetary policy, use the Gürkaynak et al. (2005) target and path factors to examine ECB spillovers on financial variables in Sweden, Norway, and Denmark. They find that the ECB path factor exerts substantial control over the longer end of the yield curve in all three countries, and conclude that path factor shocks have the potential of influencing real economic outcomes.

To examine ECB communication shocks, I use intraday price changes in a range of financial instruments around 197 ECB monetary policy announcements between 2002 and 2019. From overnight index swaps with maturities between one month and two years, I extract and rotate one target and one path factor, following Gürkaynak et al. (2005). From the path factor, I obtain Odyssean forward guidance shocks by imposing sign restrictions with respect to the Euro STOXX50 equity price index. The sign restrictions are based on conventional knowledge about the influence of monetary policy on stock prices. I also use high-frequency changes in German two-year yields and impose the same sign restrictions, which leaves me with an additional series of exogenous ECB monetary policy shocks capturing forward guidance. To estimate effects on macroeconomic outcomes, I employ the Odyssean forward guidance factor and the pure monetary policy shock series as external instruments for the monthly German two-year yield in a SVAR-IV. The SVAR-IV, famously implemented by Gertler and Karadi (2015), is a relatively new and increasingly popular method in which monetary policy shocks are identified by employing an external instrument rather than imposing time restrictions on the variables in the reduced-form VAR. The framework is well-suited for estimating effects of high-frequency forward guidance shocks. Like in a microeconomic instrumental variables approach, the external instrument is valid if it is correlated with the policy shock and uncorrelated with other structural shocks. In addition to the German two-year yield, the SVAR-IV specification includes exchange rates, equity prices, industrial production, unemployment, HICP inflation, and the domestic monetary policy stance. The latter is captured by short-term interest rates in Norway and Denmark. For the eurozone and Sweden, I use shadow rates constructed by De Rezende and Ristiniemi (2018). The shadow rate is designed to proxy for the monetary policy stance when quantitative easing is included in the monetary policy mix. A lesson from the microeconomic IV approach, which carries over to the SVAR-IV, is that weak-first stage relationships can compromise the validity of standard inference. To account for the strength of the first-stage relationship between the external instrument and the policy variable, I construct weak-instrument robust uncertainty bands following Montiel Olea et al. (2020).

My euro area results corroborate some of the findings of Andrade and Ferroni (2021), and show that forward guidance is an effective monetary policy tool for stimulating economic activity. While there is no significant effect on inflation, an expansionary ECB communication shock clearly depreciates the euro against the US dollar, raises equity prices and industrial production, and lowers the unemployment rate. The euro area shadow rate gradually decreases after a negative forward guidance shock, suggesting that the ECB's message of a future monetary expansion is followed through. In Denmark, which maintains a currency peg within narrow horizontal bands, the impact on economic outcomes is similar. In Sweden and Norway, which both have flexible exchange rates, the results differ tremendously. In Norway, the exchange rate appears to appreciate. Furthermore, the effects on economic activity are contractionary — industrial production decreases and unemployment appears to increase. Contrary to expectation, the Swedish krona clearly does not appreciate — the impulse response is more in line with a depreciation. A similar finding is reported by Franz (2020). Moreover, the effects on Swedish industrial production and unemployment are roughly as large as in Denmark, suggesting an economic expansion. The results are robust to different SVAR-IV specifications and alternative forward guidance shocks. There is, however, no clear pattern for inflation, which appears to increase in Norway and Sweden while no significant response is found in Denmark. The different exchange rate responses, and ensuing effects on economic outcomes, could potentially be explained by the reactions of the domestic central banks. Examining the relative monetary policy stances vis-à-vis the eurozone after an expansionary ECB shock, I find a large and significantly positive effect for Norway, consistent with an exchange rate appreciation. In contrast, the Swedish relative monetary policy stance stays close to zero. The results suggest that Sveriges Riksbank eases its monetary policy stance after an expansionary ECB communication shock. Norges Bank does not ease its monetary policy to the same extent.

To see if the findings apply to other neighboring economies, I perform the same SVAR-IV analysis for an extended country sample of two advanced economies and six countries in emerging Europe. In the United Kingdom, the exchange rate appreciates, the relative monetary policy stance is significantly positive, and unemployment may increase somewhat. The estimated impact on industrial production is positive but small. Also in Iceland the unemployment rate appears to increase, but the effects on the exchange rate and the relative monetary policy stance are less clear. In a number of Central and Eastern European economies, the effects on industrial production and unemployment are at least as large as in the euro area. Exchange rates often do not appreciate, and in most countries, there is no significantly positive effect on the relative monetary policy stance. While HICP inflation tends to increase, there is no clear pattern based on exchange rate regimes. I also find that equity prices generally seem to increase roughly as much as in the euro area.

I conclude that the ECB's communication has important effects on economic outcomes inside and outside of the euro area, and that an ECB monetary policy easing through forward guidance generally has an expansionary impact on the neighboring economies. In countries where the relative monetary policy stance is significantly positive and the exchange rate appreciates, the effects on industrial production and unemployment appear to be muted and may even be of the opposite sign, suggesting that exchange rate adjustments do provide some insulation against foreign monetary policy disturbances. However, exchange rates do not uniformly appreciate against the euro in response to an ECB monetary policy accommodation. This finding could potentially be explained by the reactions of the domestic central banks, which may ease their monetary policy after an expansionary ECB communication shock. This is suggestive of a "fear of floating" situation à la Calvo and Reinhart (2002). Future research should further investigate why central banks with monetary policy autonomy under flexible exchange rate regimes may decide to follow the ECB's monetary policy stance.

2 Background

This section first presents a description of the ECB's monetary policy, with a particular focus on forward guidance. Next, I discuss how effects of the ECB's monetary policy may impact neighboring economies. Finally, I present some brief background information on Sweden, Norway, and Denmark, which all have close ties to the euro area.

2.1 The ECB's Monetary Policy Toolbox

2.1.1 Monetary Policy for Current and Expected Interest Rates

The euro, introduced on 1 January 1999, is the common currency of the member states of the euro area. The euro area's monetary policy is governed by the European Central Bank (ECB). Monetary policy announcements by central banks may lead to rapid changes in the prices of financial assets, including government bonds. The yields of government bonds with different maturities together shape the *yield curve*. The concept of the yield curve is closely related to the *expectations hypothesis*, which can be expressed as a no-arbitrage argument: The yield earned by investing in a long-term bond should equal the yield earned by investing in a series of short-term debt contracts. In practice, long-term yields can be decomposed into expected short-term rates and a term premium component,[2] which contains information about perceived macroeconomic risks (De Rezende and Ristiniemi, 2018). The yield curve is an important indicator of domestic economic conditions and can sometimes predict recessions (Estrella and Trubin, 2006; Ng and Wessel, 2018).

The *policy rate*[3] is widely viewed as the central bank's main policy tool. It is the main determinant of short-term yields (Patterson and Lygnerud, 1999; Estrella and Trubin, 2006). When the central bank lowers its policy rate, it becomes less expensive for banks to borrow and deposit

[2]The term premium can be thought of as investors' additional compensation for the risk of future short-term rates deviating from their expected path (Becker and Smith, 2015)

[3]The ECB sets the Main Refinancing Operations rate, the deposit rate, and the lending rate.

funds at the central bank. Then, interest rates on bank loans become lower and banks will increase lending to investors and consumers. This leads to higher economic growth and inflation. The global financial crisis of 2008-2009, quickly followed by the long-lasting European debt crisis, prompted the ECB to cut their policy rates to historically low levels. With less room for policy rate adjustments, the ECB has increasingly relied on *forward guidance*. In an early account of how central bank communication shapes market expectations, Gürkaynak et al. (2005) show that monetary policy statements not only affect financial prices through changes in current policy rates, but also through changes in the expected path of future rates. Central banks can thus use their communication strategically to influence longer term yields. Naturally, forward guidance impacts the expected path of short-term rates, but it may also impact the term premium by reducing the perceived risk of unexpected future policy rate changes (Becker and Smith, 2015). When the central bank communicates that future rates will be low, expected future short-term rates decrease. This lowers long-term yields. Expecting policy rates to be low in the future, banks can lower interest rates on long-term bank loans, resulting in less expensive loans for businesses and mortgagors. This has an expansionary effect on the economy. The ECB first used forward guidance in July 2013, and has since given forward guidance a highly pronounced role in its monetary policy.

2.1.2 Quantitative Easing and Forward Guidance Going Forward

Since March 2015, the ECB has also conducted large-scale asset purchases, often referred to as *quantitative easing*. Quantitative easing may lower term premia through a portfolio balance channel, but it may also reduce bond yields by signaling the central bank's commitment to a monetary expansion. Bauer and Rudebusch (2014) provide evidence of important signaling effects around announcements of quantitative easing, which lower both expected future rates and term premia. Quantitative easing is widely regarded as an unconventional monetary policy tool; a special measure taken when the policy rate is approaching the zero lower bound. While forward guidance can play a key role in providing economic stimulus in challenging times,[4] it is far from certain that it should be viewed as an unconventional policy tool. When the ECB and the Federal Reserve began conducting forward guidance during the financial and European debt crises, other central banks had used forward guidance for years,[5] without policy rates at the zero lower bound. There are also practical arguments for conducting forward guidance in normal times. It promotes transparency and effectiveness of monetary policy, makes market participants more informed about future policy

[4]Svensson (2003), Krugman (1998), and Eggertsson and Woodford (2003) argue central banks can boost the economy in a liquidity trap, a situation in which interest rates approach zero and changes in the money supply have little to no effect on the price level, by committing to a sustained monetary expansion.

[5]The Reserve Bank of New Zealand first published interest rate forecasts in 1997. Norges Bank and Sveriges Riksbank have conducted forward guidance since 2005 and 2007, respectively.

rates, and may both justify the central bank's decisions and promote accountability (Svensson, 2015). The ECB also seems to view forward guidance as a more long-term addition to the monetary policy toolbox. In 2019, ECB President Mario Draghi stated that forward guidance is their "major monetary policy tool".[6] Peter Praet, member of the Executive Board of the ECB, considers forward guidance to be part of the conventional monetary policy toolbox (Praet, 2018). Finally, market expectations of future policy rates were formed by central bank communication before it was used strategically (Gürkaynak et al., 2005). Markets will, regardless of the status of forward guidance, keep deciphering central bank announcements for hints on future policy rates. Knowing this, central bankers are likely to align their communication with the desired outcomes also in the future.

2.2 Channels of Spillover Effects

Small open economies with close ties to large economies like the euro area may be subject to spillover effects of monetary policy. The literature points toward three channels of transmission: the aggregate demand channel, the exchange rate channel, and the financial channel.[7] Expansionary ECB monetary policy increases euro area consumption and investment. A non-euro country thus experiences higher export demand, which increases inflation and GDP via the *aggregate demand channel*. But if the non-euro country has flexible exchange rates, an ECB monetary policy easing makes the domestic currency appreciate against the euro. This decreases the non-euro country's trade balance and GDP growth via the *exchange rate channel*, which may offset expansionary pressures from abroad. Finally, a monetary expansion decreases long-term yields and increase asset prices in the eurozone. With interlinked financial markets, yields and financial prices may be impacted also in the non-euro country. More accomodative financial conditions may increase the non-euro country's GDP, linking the *financial channel* to the real economy. The size and sign of the spillover effects depend on the relative strength of the channels.

2.3 The Scandinavian Neighbors of the Euro Area

Sweden, Norway and Denmark are small, open, and technologically advanced economies. They are characterized by a common model — the Nordic model — which describes a shared set of economic and social institutions, policies, and practices. The countries feature "an emphasis on education, high income equality, high employment, low public debt, and an innovative and competitive business environment" (IMF, 2013). They also have internationally integrated financial markets and a high degree of trade openness. One notable difference is that Norway is highly

[6] See the introduction of this thesis paper for the full quote.

[7] Authors using this or a similar categorization include Ammer et al. (2016), Kearns et al. (2018), and Santos and Garcia (2020). Also Luis de Guindos (2019), Vice President of the ECB, refers to these channels.

oil dependent, with oil and oil-related products accounting for roughly 18% of the country's GDP in 2018 (European Commission, 2020). Importantly, the countries differ crucially in their degree of integration with the eurozone. Sweden, an EU-member, and Norway, a non-EU member, have flexible exchange rate regimes. In both countries, monetary policy has been characterized by episodes of "leaning against the wind".[8] Denmark, an EU member, operates a currency peg within horizontal bands, allowing for deviations within ±2.5% from 746.038 DKK per 100 EUR. ter Ellen et al. (2020) and Corsetti et al. (2018) argue that variation in the Scandinavian countries' sensitivity to foreign disturbances from the euro area can be attributed to the different exchange rate arrangements. Appendix A.1 presents eight additional non-euro countries with different degrees of exchange rate flexibility. As shown in Table A.2, the exchange rate regimes of Sweden, Norway, and Denmark have been stable over time.

3 Related Literature

This thesis paper primarily contributes to two strands of literature. The first concerns high-frequency monetary policy shocks and information effects in central bank announcements. The second strand of related literature focuses on spillover effects of monetary policy; a topic which naturally relates to questions of exchange rate flexibility.

3.1 High-Frequency Forward Guidance Shocks

Following the early work of Kuttner (2001), a growing number of studies identify monetary policy shocks by examining intraday changes in asset prices around central bank announcements. In particular, forward guidance shocks can be identified by measuring high-frequency changes in two-year government bond yields (Hanson and Stein, 2015; Kerssenfischer, 2019).[9] This approach, however, does not separate the effects of current-rate changes from changes in market expectations of future policy rates. In contrast, Gürkaynak et al. (2005) measure price changes in several money market instruments which capture expectations of future policy rates. From the shocks, the authors extract two factors. The *target factor* reflects changes related to current policy rates. The *path factor* is constructed to reflect changes in expected future policy rates, and is shown to have important effects on the longer end of the yield curve. The path factor has since become well-established in

[8] Leaning against the wind implies that the policy rate is set somewhat higher than justified by inflation and unemployment, in concern of financial stability. See Svensson (2017) and Olsen (2015).

[9] Gertler and Karadi (2015) measure effects of Federal Reserve forward guidance by identifying shocks in three-month Fed funds futures.

the empirical literature on forward guidance.[10]

On announcement dates, the central bank may not only present its monetary policy decisions. It may also disclose information about the economic situation (Nakamura and Steinsson, 2018). Building on the work of Gürkaynak et al. (2005), Campbell et al. (2012)[11] document that path factor shocks around monetary policy announcements often lead to wrong-signed revisions in private market forecasts of inflation and unemployment. The authors argue the path factor captures two types of forward guidance — Odyssean and Delphic — with widely different effects. *Odyssean* forward guidance refers to when the central bank publicly commits to a future monetary policy stance — like Odysseus committed to staying on the ship by tying himself to the mast. The Odyssean kind is consistent with classical descriptions of forward guidance. *Delphic* shocks refer to signals about the economic outlook and likely policy actions. While a negative Odyssean forward guidance shock should have an expansionary impact on the economy, a negative Delphic shock may appear to have the opposite effect on certain variables, since it signals that future interest rates may be low due to low inflation. Studies on Delphic and Odyssean forward guidance are part of a growing literature on information effects in monetary policy announcements. A number of authors have begun separating *pure policy* effects from *information* components in high-frequency asset price shocks.[12] In general, the results show that a negative pure monetary policy shock, corresponding to a policy rate decrease or a message of low future interest rates, has expansionary effects on the economy. In contrast, a negative information shock, corresponding to a message of low future inflation, has contractionary effects. The different components of forward guidance are not only a feature of high-frequency identification schemes; they are part of the ECB's practical forward guidance. Peter Praet has explicitly stated that "the ECB's formulation of forward guidance includes a Delphic component clarifying the assessment, and an Odyssean element reasserting the strategy" (Praet, 2013). Andrade and Ferroni (2021) identify Delphic and Odyssean ECB shocks and find widely different effects on financial and macroeconomic variables in the euro area. They also show that the Odyssean element became predominant after the ECB started providing explicit forward guidance messages.

The concept of Delphic information effects presumes that the central bank holds private information about the economic outlook: If market participants were perfectly informed about economic conditions, there would be no information shock in asset prices around central bank announcements. Since central banks employ highly specialized staff and produce their own forecasts, they are likely to have superior information about the economy. Also Odyssean forward guidance can be understood in the context of information asymmetries between the central bank and the market (Bassetto, 2019). This is because the central bank has private information not only about the economy, but

[10] Authors who use the Gürkaynak et al. (2005) factors include, for example, ter Ellen et al. (2020), Kearns et al. (2018), Lakdawala (2019), and Franz (2020)

[11] See also Campbell et al. (2017).

[12] See Jarociński and Karadi (2020), Cieslak and Schrimpf (2019), Kerssenfischer (2019), and Laséen (2020).

also about its own preferences. These preferences are revealed when the central bank communicates its intended policy actions.

3.2 Cross-Border Effects of Monetary Policy

3.2.1 Flexible Exchange Rates and Central Bank Considerations

Floating exchange rates may offset some contractionary or expansionary pressures from abroad. This insulation feature was presented as an argument for flexible exchange rates in the Calmfors report, probably the most comprehensive cost-benefit evaluation of adopting the euro to date (Calmfors et al., 1997, chapter 3). In his famous case for flexible exchange rates, Milton Friedman (1953) notes that a float may limit transmission of inflation across borders. The most important reason for choosing a float is, however, that it allows the central bank to use its monetary policy tools to pursue domestic objectives related to price stability and real stability. This is also known as *monetary policy autonomy.* Friedman states that "... flexible exchange rates ... are a means of permitting each country to seek for monetary stability according to its own lights, without either imposing its mistakes on neighbors or having their mistakes imposed on it" (Friedman, 1953, p. 200). With fixed exchange rates, the domestic central bank must instead follow the monetary policy stance of the foreign base economy.[13]

Also central banks with monetary policy autonomy may sometimes adapt to the monetary policy stance in a foreign country. Calvo and Reinhart (2002) document that central banks in both emerging and advanced economies with flexible exchange rates may actively stabilize exchange rate movements, referring to this phenomenon as a "fear of floating". There may be several reasons behind the reluctance to accept large exchange rate changes. Davis (2016) concisely states that "Mechanically, a central bank with a floating currency has complete monetary policy autonomy and can do whatever they want with their interest rate instrument. But when setting policy, central banks face trade-offs. One of these trade-offs is between the need to stabilize the domestic economy and the need to stabilize capital flows, the exchange rate, and the external accounts" (Davis, 2016, p. 18). Per Jansson, Deputy Governor of Sveriges Riksbank, argued in the Monetary Policy Meeting on 11 February 2015: "... the ECB's measures also create challenges ... The plan is to make very extensive purchases of financial assets, equivalent to at least almost three times Swedish GDP ... In

[13]Monetary policy autonomy is also central in the Mundell-Fleming trilemma, which stipulates that a country cannot have monetary policy independence, free capital flows, and exchange rate stability at the same time. Rey (2013) argues the trilemma is invalidated because of large monetary policy spillovers, transmitted through global financial conditions. Nelson (2020) objects against this view, arguing that Rey (2013) erroneously defines monetary policy autonomy as the complete insulation against foreign influences. Monetary policy autonomy, based on the works of Friedman, should instead be understood as the ability of the central bank to use its monetary policy tools to achieve its domestic objectives. This is consistent with spillover effects.

the event of a more tangible and rapid appreciation of the krona, it will be even more difficult for the Riksbank to attain an inflation rate in line with the target within a reasonable time perspective. This is a factor that needs to be taken into account when designing monetary policy, both now and going forward."[14] While it is unclear to what extent Sveriges Riksbank adapts its monetary policy based on the ECB's actions, the quote highlights that even a central bank with monetary policy autonomy may wish to adjust its policy stance toward that of a foreign central bank, if an exchange rate movement would hinder the achievement of domestic objectives.

3.2.2 Spillovers of the ECB's Monetary Policy

The ECB is gaining attention as an important source of international monetary policy spillovers. Kearns et al. (2018), investigating high-frequency spillovers of several central banks, argue that financial openness makes advanced economies sensitive to disturbances from abroad. In an upcoming paper,[15] Corsetti et al. (nd) investigate spillover effects of various ECB shocks on neighboring non-euro economies, finding substantial spillovers which do not seem to be muted by flexible exchange rates. The authors refer to their findings as an "exchange rate insulation puzzle", and relate it to the fear of floating phenomenon. Bluwstein and Canova (2016), comparing samples of advanced and emerging European non-euro economies, find that flexible exchange rates provide no insulation against spillovers of unconventional ECB policies. They report great cross-country heterogeneity in the responses to ECB shocks. Franz (2020) document that contrary to expectation, the Swedish krona does not depreciate in response to a contractionary ECB monetary policy shock: If anything, the reported impulse response is in line with an appreciation. He also finds that Swedish and Norwegian two-year interest rate differentials relative to the euro area are never significantly different from zero, unlike countries with less close ties to the eurozone. Corsetti et al. (2018) observe that during the financial crisis, which deeply impacted the euro area, Danish output fell dramatically. Swedish output fell almost as much as Danish output, but rebounded quickly, while Norwegian output remained relatively stable. The authors attribute this to flexible exchange rate dynamics. ter Ellen et al. (2020) construct target and path factors to study ECB spillovers on financial variables in Sweden, Norway, and Denmark, and find large effects, albeit stronger in Denmark. Path surprises have persistent effects and may thus affect real economic variables. Furthermore, they find that the ECB's monetary policy largely controls the long end of the domestic yield curve in all countries.

[14]Minutes of the monetary policy meeting held on 11 February 2015, Sveriges Riksbank

[15]Presented by Gernot J. Müller at CEBRA's conference on exchange rates and monetary policy (hosted by the CEPR and Sveriges Riksbank) on 2 October 2020.

4 Methodology

This section presents the methodology of the thesis paper; beginning with the identification of ECB forward guidance shocks, and ending with the SVAR-IV framework, which neatly incorporates the exogenous shock series in a vector-autoregression setting.

4.1 The Identification of Exogenous Monetary Policy Shocks

4.1.1 High-Frequency Identification

Ramey (2016) lists three conditions which must be satisfied by measured macroeconomic shocks for proper inference: (1) They must be exogenous with regard to other current and lagged endogenous variables in the model; (2) They must be uncorrelated with other exogenous shocks; and (3) They must be unanticipated. The identification of exogenous monetary policy shocks is particularly difficult because monetary policy decisions are made in response to economic conditions.

High-frequency identification aims to fulfill the three conditions. The essence of the approach is to capture monetary policy surprises by gauging market responses to monetary policy events, which in practice is done by measuring changes in financial asset prices in a narrow time window around monetary policy announcements. The policy rate is an important determinant of prices in financial markets, and markets shape their expectations of the policy rate change based on their information about the economic situation. The underlying logic is that any policy rate change has one part that is expected, and one part that is unexpected by markets. Furthermore, the expected part is assumed to already be incorporated in prices and yields before the announcement. If market expectations of the policy rate change are correct, prices should remain unchanged when the central bank announces its policy rate decision. However, if markets fail to anticipate any component of the monetary policy decision, such as the sign or size of the policy rate change, asset prices will quickly adjust after the announcement to incorporate the new information. The difference in prices of financial assets before and after policy announcements is thus caused by the unexpected part of the policy rate decision, which can be interpreted as a monetary policy shock. Likewise, a decision to *not* change the policy rate may lead to a shock, if markets expected a policy rate change to take place.

4.1.2 Principal Component Analysis and Factor Rotation

High-frequency changes in German government bond yields capture shocks related to current policy rates and forward guidance. To analyze forward guidance separately, I use data on high-frequency shocks in money market instruments which reflect expectations for the EONIA rate,[16] and extract target and path factors following the methodology of Gürkaynak et al. (2005). The factors are created by performing a principal component analysis of high-frequency shocks in n financial assets around T monetary policy announcements. The extracted factors are then rotated to be given a structural interpretation as related to current versus expected policy rates.

Let X be a $T \times n$ matrix of shocks in overnight index swap (OIS) rates with n different maturities at T policy announcements. X is the product of the factors F and a vector of factor loadings Λ, plus the error term η.

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

Two factors $F = \begin{bmatrix} F_1 & F_2 \end{bmatrix}$ are extracted using a standard principal component analysis. These factors have no structural interpretation. To transform them into target and path factors $\Gamma = \begin{bmatrix} \Gamma_1 & \Gamma_2 \end{bmatrix}$, I perform a suitable factor rotation, which is described in Appendix B.1. The goal is to identify an orthogonal matrix $U_{2\times 2}$, such that:

$$\Gamma = FU \tag{2}$$

The factors Γ explain the same amount of variation in X as the factors F. However, the path factor Γ_2 is orthogonal to shocks in the one-month OIS rate, which is assumed to reflect current policy rates. Instead, it captures shocks in OIS rates of longer maturities. In this framework, a forward guidance shock is thus identified as a shock which (i) moves expected policy rates and (ii) is uncorrelated with changes in the current policy rate.

4.1.3 Sign Restrictions and Information Elements

The most important criticism against high-frequency identification is that the measured shocks may not be truly orthogonal to economic conditions. This is because the central bank may act based on private information about the state of the economy (Ramey, 2016). If the central bank signals some of this information during monetary policy announcements, high-frequency price changes may not only be caused by monetary policy shocks — they may also reflect that markets have updated their information about the economic outlook. The information element can be removed by applying sign restrictions. A number of authors exploit the theoretical high-frequency co-movement of financial market yields and other variables, such as the equity price index, around

[16] EONIA is mainly determined by the ECB's policy rates.

monetary policy announcements.[17]

Assume the observed high-frequency movement in a bond yield in a narrow intraday window around a monetary policy meeting can be expressed as the sum of a pure monetary policy shock and an information effect. Conventional wisdom stipulates that a contractionary monetary policy shock should raise yields and lower stock prices. According to standard stock valuation models like the dividend discount model, the present value of a share is equal to the sum of its expected discounted dividends. A monetary policy tightening raises the discount factor and may also, due to contractionary effects on the economy, cause the expected dividends to decrease. We thus expect a contractionary monetary policy shock to be accompanied by a negative shock in stock prices. If instead stock prices increase on some meeting dates, we have reason to suspect that a strong information effect, which signals low future inflation, is present. We can use sign restrictions to disentangle pure monetary policy shocks from information elements, both of which are contained in the yield shock.

Let Γ be a $T \times 2$ matrix in which the first column is a vector of shocks in the bond yield at T monetary policy announcements. The second column is a vector of shocks in a stock price index. Γ can be described as the product of two matrices such that $\Gamma = Z\Pi$:

$$\begin{pmatrix} \Gamma_y & \Gamma_s \end{pmatrix} = \begin{pmatrix} Z^P & Z^I \end{pmatrix} \begin{pmatrix} \pi_y^P & \pi_s^P \\ \pi_y^I & \pi_s^I \end{pmatrix} \tag{3}$$

Z is a $T \times 2$ matrix in which the first column is a vector of pure policy effects; the second column is a vector of information effects. The two columns are orthogonal to each other. Π is a 2×2 matrix of parameters guiding how pure policy and information shocks impact bond yields and stock price movements. Three assumptions are made: (i) π_y^P and $\pi_y^I > 0$; a positive pure policy shock and a positive information shock both increase yields, (ii) $\pi_s^P < 0$; a positive pure policy shock has a negative effect on stock prices, (iii) $\pi_s^I > 0$; a positive information shock increases stock prices. The task is to find a suitable matrix Π that fulfills these criteria, such that equation 3 holds. While positive co-movement of yields and equity prices around some event dates is indicative of a sizable information component, the approach also ensures the removal of information elements at times when the pure monetary policy component is dominant.

I implement the sign restrictions following Kerssenfischer's (2019) approach, which is similar to that of Jarociński and Karadi (2020) and Cieslak and Schrimpf (2019), but ensures orthogonality of the columns of Z by applying the median target criterion of Fry and Pagan (2011). First, I

[17] See Jarociński and Karadi (2020), Kerssenfischer (2019), Cieslak and Schrimpf (2019), Laséen (2020). Andrade and Ferroni (2021) also use sign restrictions, but they observe inflation-linked swap contracts. Jarociński and Karadi (2020) argue the information revealed by ILS contracts is included in the identification when using stock prices.

draw 2000 2×2 matrices from a standard normal distribution. By applying a QR decomposition to each of these matrices, I obtain the candidate matrices $\hat{\Pi}$. From these, a unique matrix is found by applying the median target criterion, which in practice is done by selecting the matrix which minimizes the sum of squared deviations from the median values of each element across all draws of Π. The same method can be used in order to disentangle Odyssean forward guidance from the Delphic components of the path factor.

4.2 External Instruments in Vector Autoregressive Models

4.2.1 The SVAR-IV Framework

The shocks from high-frequency event studies can be incorporated in a structural VAR-setting, allowing for estimation of effects on macroeconomic variables. This hybrid method, sometimes referred to as SVAR-IV,[18] can be seen as a macroeconomic version of the instrumental variables methods commonly used in microeconomic research. The underlying logic is identical: If we have problems of simultaneity or omitted variable bias, we can obtain consistent estimates by applying an external instrument which is correlated with the variable of interest but uncorrelated with other variables in the error term. The SVAR-IV clearly solves a number of problems which may be encountered in a structural VAR-setting, in particular when financial variables such as market-based interest rates or equity prices are present. Financial variables may react quickly (within minutes and even seconds) to monetary policy decisions. In a standard SVAR with timing restrictions and monthly data, the assumption that other variables react to policy rate changes with a lag may thus be violated. There is also a risk of simultaneity. A forward-looking central bank may react to news before they manifest in inflation or output changes, but at the time of the policy decision, the news may already be incorporated in financial prices. In other words, even if monetary policy does not react to the financial variables *per se*, it may react to the information contained in asset prices. Potential simultaneity cannot be ignored when examining spillovers, as underlying economic shocks may be correlated across countries. The SVAR-IV method was first developed by Stock and Watson (2012) and Mertens and Ravn (2013). Gertler and Karadi (2015) famously employed the SVAR-IV to identify Federal Reserve forward guidance shocks. Also Andrade and Ferroni (2021), Franz (2020), Miranda-Agrippino (2016), and Lakdawala (2019) use the framework to study monetary policy shocks.

The SVAR-IV distinguishes the *policy indicator* from the *policy instrument* (Gertler and Karadi, 2015). In a standard SVAR model, the policy indicator and the policy instrument are the same; it may, for example, be the central bank's policy rate. In the SVAR-IV model, the policy

[18] It is also known as the external instruments SVAR or a proxy SVAR.

indicator may be an interest rate which reflects monetary policy actions, but the policy instrument is external to the reduced-form VAR. The framework is well-suited for estimating effects of forward guidance on macroeconomic variables. The essential idea is to apply pure monetary policy shocks as external instruments for a longer-term rate which reflects expectations of the future interest rate path. We can then investigate how forward guidance affects economic or financial variables.

Following Gertler and Karadi (2015), the starting point is the common structural VAR model:

$$\boldsymbol{A}\boldsymbol{Y}_t = \sum_{j=1}^{p} \boldsymbol{\Theta}_{t-j}\boldsymbol{Y}_{t-j} + \boldsymbol{\varepsilon}_t \tag{4}$$

$\boldsymbol{Y}_t$ is an $n \times 1$ vector of endogenous variables, $\boldsymbol{A}$ and $\boldsymbol{\Theta}_{t-j}$ are $n \times n$ matrices of coefficients. $\boldsymbol{\varepsilon}_t$ is a vector of structural shocks. Pre-multiplication by $\boldsymbol{A}^{-1}$ yields the reduced-form representation:

$$\boldsymbol{Y}_t = \sum_{j=1}^{p} \boldsymbol{\delta}_{t-j}\boldsymbol{Y}_{t-j} + \boldsymbol{u}_t \tag{5}$$

where

$$\boldsymbol{u}_t = \boldsymbol{B}\boldsymbol{\varepsilon}_t \tag{6}$$

and $\boldsymbol{\delta}_{t-j} = \boldsymbol{B}\boldsymbol{\Theta}_{t-j}$, $\boldsymbol{B} = \boldsymbol{A}^{-1}$. The variance-covariance matrix is given by:

$$E[\boldsymbol{u}_t\boldsymbol{u}_t'] = E[\boldsymbol{B}\boldsymbol{B}'] = \boldsymbol{\Sigma} \tag{7}$$

Let ε_t^p denote the structural shock from the policy equation, while $\boldsymbol{\varepsilon}_t^q$ denotes the structural shocks from the other equations. The vector of structural shocks is thus given by $\boldsymbol{\varepsilon}_t = \begin{bmatrix}\varepsilon_t^p & \boldsymbol{\varepsilon}_t^{q\prime}\end{bmatrix}'$. Similarly, for the policy indicator p and the other endogenous variables $q \neq p$, the vector of reduced-form residuals can be partitioned into $\boldsymbol{u}_t = \begin{bmatrix}u_t^p & \boldsymbol{u}_t^{q\prime}\end{bmatrix}'$. Instead of imposing a particular Cholesky ordering, we identify a vector of pure monetary policy shocks Z_t, which is a suitable external instrument if it is correlated with the policy shock and uncorrelated with the other structural shocks:

$$E[Z_t\varepsilon_t^p] = \phi \tag{8}$$

$$E[Z_t\boldsymbol{\varepsilon}_t^q] = 0 \tag{9}$$

Equation 8 and 9 are the SVAR analogue to the instrument relevance and exogeneity conditions in a microeconomic IV approach. With respect to the notation in Equation 3, Z_t in the SVAR-IV setting corresponds to the column Z^P. The exogeneity restriction can be understood in terms of Ramey's (2016) definition of a properly identified macroeconomic shock: It must be exogenous with respect to other variables in the model. While a narrow event window around monetary policy announcements substantially reduces the likelihood of simultaneous changes in other important variables, high-frequency shocks on ECB meeting days may not per se fulfil the exogeneity condition. Since the ECB conveys information about the economic outlook at monetary policy announcements, the shocks may be correlated with variables such as inflation in the SVAR-IV specification. Controlling for the central bank's private information is thus essential for the estimation of causal effects of monetary policy (Ramey, 2016). As explained in section 4.1.3, a growing literature shows that such information effects effectively can be removed by applying sign restrictions. This results in high-frequency forward guidance shocks which credibly can be interpreted as exogenous with respect to economic conditions.

Let $\boldsymbol{b}$ denote the column vector of impact matrix $\boldsymbol{B}$, which describes the effects of the structural policy shocks on each element of the reduced-form residuals $\boldsymbol{u}_t$. Then, b^q is the response of any u_t^q to an impulse in ε_t^p. To compute impulse responses, we thus need to estimate the column $\boldsymbol{b}$ rather than the entire matrix $\boldsymbol{B}$. In other words, we are interested in finding:

$$\boldsymbol{Y}_t = \sum_{j}^{p} \boldsymbol{\delta}_{t-j} \boldsymbol{Y}_{t-j} + \boldsymbol{b}\varepsilon_t^p \tag{10}$$

The external instrument can be used to obtain an estimate of $\boldsymbol{b}$. In practice, this is done in three steps:

(1) Reduced-Form VAR estimation. Use ordinary least squares regressions to estimate the reduced-form VAR, thereby obtaining the reduced-form residuals $\boldsymbol{u}_t$.

(2) Two stage least squares estimation. Regress the reduced-form non-policy VAR residuals $\boldsymbol{u}_t^q$ on the policy residual u_t^p using Z_t as an instrument. The first stage regresses u_t^p on Z_t. The fitted value $\hat{u}_t^p$ isolates the part of the variation in u_t^p which is correlated with the instrument Z_t. Given that Z_t is valid and relevant, $\hat{u}_t^p$ will be uncorrelated with all structural shocks except for ε_t^p. The second-stage regression of $\boldsymbol{u}_t^q$ on the fitted value $\hat{u}_t^p$ then yields a consistent estimate of the coefficient $\boldsymbol{b}^q/b^p$ for all $q \neq p$:

$$\boldsymbol{u}^q = \frac{\boldsymbol{b}^q}{b^p} \hat{u}_t^p + \eta \tag{11}$$

(3) Use equation 11 to identify b^p, $\boldsymbol{b}^q$ by imposing the restrictions of the reduced-form variance-covariance matrix in equation 7. Details on this final step can be found in Appendix B.2. In the end, we can estimate how a structural policy shock, instrumented by the external instrument Z_t, impacts the variables in the reduced-form VAR.

4.2.2 A Note on Weak Instruments

From microeconomic instrumental variables methods, it is evident that weak instruments may lead to large bias in small samples, and that even a minor violation of validity can cause large inconsistencies. Weak instruments can also be problematic for standard inference in the SVAR-IV case. Stock et al. (2002) recommend a threshold value of 10 for the first-stage F-statistic, which has become a well-established benchmark in the SVAR-IV literature. Also the Wald statistic for the covariance between the external instrument and the normalized policy indicator can be used as an indicator of instrument strength[19] (Montiel Olea et al., 2020). When the instrument is strong, the SVAR-IV estimator is asymptotically normally distributed, which serves as a basis for the standard confidence set (obtained by inverting the corresponding Wald test statistic). But if the instrument is weak, the SVAR-IV estimator is not consistent. Furthermore, the Wald test statistic is not reliable, which means that the obtained confidence intervals could understate the true extent of the uncertainty. In response to these common problems, Montiel Olea et al. (2020) construct weak-instrument robust confidence intervals for the SVAR-IV estimator, based on the classical Anderson and Rubin (1949) method. The weak-instrument robust confidence interval will asymptotically coincide with the standard confidence interval when the instrument is strong. For the weak instrument, the Montiel Olea et al. (2020) confidence intervals may indicate a higher degree of uncertainty, especially when the confidence level is high. As long as the Wald statistic for the covariance between the instrument and the normalized policy indicator exceeds the critical χ^2_1-value for the confidence level, the weak-instrument robust confidence sets for the impulse responses are bounded intervals. For example, the critical χ^2_1-values for 68% and 90% weak-instrument robust confidence bands are 0.9889 and 2.7055, respectively.

5 Data

5.1 The Euro Area Monetary Policy Event-Study Database

To construct the external instruments, I use high-frequency data from the Euro Area Monetary Policy Event-Study Database (EA-MPD). The EA-MPD is a novel event-study database made public in 2019, created by Altavilla et al. (2019b).[20] The dataset has since been updated by the authors. The EA-MPD contains intraday price changes around ECB monetary policy decisions for a wide range of assets. Unlike the Federal Reserve, the ECB reveals its monetary policy decisions and statement in two steps. First, the ECB press release, containing the monetary policy decisions, is

[19] While the Wald statistic has the same noncentrality parameter, it tends to be smaller than the robust F-stat in finite samples.

[20] See also Altavilla et al. (2019a).

published at 13:45. This is followed by a press conference beginning at 14:35, in which the President of the ECB reads the introductory statement, explaining the decisions in detail and providing a rationale based on the economic outlook. The presentation is followed by a Q&A session. Altavilla et al. (2019b) measure the pre-event and post-event prices by taking the last quote of each minute within 10-minute time intervals before and after the event. The authors also cleanse the data of misquotes. The change from the pre-event to the post-event quote is a measure of the surprise. For the full monetary event window,[21] the median price of the minutes in the 13:25-13:35 time interval (before the press release) constitute the pre-event window quote. The median price of the minutes in the 15:40-15:50 interval (after the press conference) is the post-event window quote. At each monetary policy announcement date, the difference between the post-event window quote and the pre-event window quote measures the shock for the full monetary policy event. Table 1 summarizes the high-frequency financial market data from the EA-MPD used in this thesis paper. The shocks are measured using the full monetary event window, covering the press release and the press conference.

Table 1: Summary of High-Frequency Data From the EA-MPD

Financial Instrument	Maturity	Name
Overnight Index Swap	One Month	OIS1M
	Three Months	OIS3M
	Six Months	OIS6M
	One Year	OIS1Y
	Two Years	OIS2Y
German Government Bond	One Year	DE1Y
	Two Years	DE2Y
	Five Years	DE5Y
	Ten Years	DE10Y
Euro STOXX50 Index		STOXX50
USDEUR Exchange Rate		USDEUR

The EA-MPD includes ECB events from 7 January 1999, the first monetary policy meeting after the introduction of the single currency. However, the shocks during the first three years of ECB annnouncements are noisy, with disproportionately large positive and negative spikes. Consequently, Altavilla et al. (2019a) and ter Ellen et al. (2020) exclude the pre-2002 shocks from their samples. Rosa and Verga (2008) show that market participants needed about three years, until the end of 2001, to correctly interpret and trust signals from ECB announcements. Furthermore, euro coins and

[21]The EA-MPD contains surprises around three event windows: the press release window, the press conference window, and the full monetary event window.

banknotes started circulating in January 2002; prior to that date, the euro only existed electronically. I thus use data from all monetary policy decisions between 3 January 2002 and 12 December 2019, resulting in a sample of 197 ECB announcements.

5.2 Macroeconomic and Financial Data

In the estimation of the SVAR-IV, I use monthly macroeconomic and financial country-level data. Table C.1 in Appendix C.1 describes the variables and data sources. The data covers the time period from January 2002 until December 2019, unless otherwise stated. Most of the data is from Eurostat and the OECD, other sources are presented in Table C.1. I use data on bilateral *exchange rates*, defined as the price of one euro expressed in the domestic currency. For the euro area, I use the price of one US dollar expressed in euros. For purposes of comparison, the exchange rates are standardized to a value of 100 in January 2015. The core *Harmonized Index of Consumer Prices (HICP)* serves as a measure of inflation. With core instead of headline inflation, the estimations become less sensitive to noise from temporary swings in energy and food prices. The HICP inflation data from Eurostat is not seasonally adjusted; I deseasonalize the data following the procedure described in Appendix C.2. The *industrial production index* is an indicator of economic activity. By excluding the volatile construction sector, the industrial production indices are less likely to reflect unrelated noise. I also include *unemployment rates*. Furthermore, *equity prices* are included; the index names and data sources are listed in Table C.1 and C.2. The inflation, industrial production, and equity price series are transformed into log form and, by convention, multiplied by 100. *German government bond yields* with maturities of one and two years serve as proxies for eurozone yields, and as potential policy indicators. Finally, to capture the domestic monetary policy stance, I use *short-term interest rates* and the *shadow rate* measure by De Rezende and Ristiniemi (2018). The shadow rate is a more accurate proxy for the monetary policy stance when the central bank conducts large-scale asset purchases.

6 Empirical Estimations

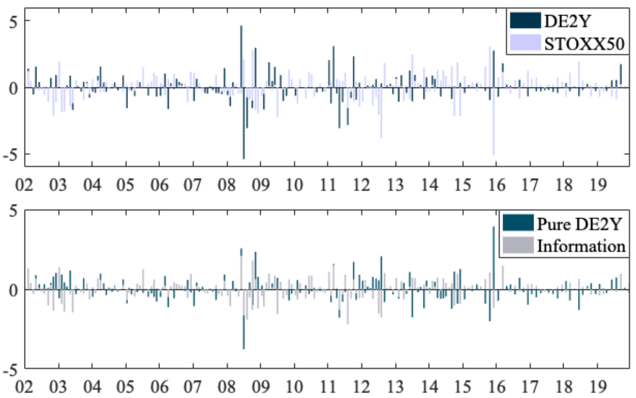
This section outlines the construction of the policy instruments from high-frequency shocks. Two external communication instruments are constructed: pure two-year yield shocks and an Odyssean forward guidance factor. This is followed by a closer examination of important monetary policy dates. The section concludes with a description of the SVAR-IV specification, and an assessment of the first-stage relationships in the SVAR-IV.

6.1 Constructing the External Instruments

6.1.1 The Pure Two-Year Yield Shock Series

Contractionary monetary policy shocks lead to negative reactions in stock prices according to classical present value models such as the dividend discount model. We should thus observe negative co-movement between shocks in the German two-year yield and the Euro STOXX50 index. However, Figure 1 demonstrates that this is not the case: A substantial share of the yield shocks and STOXX50 shocks around ECB monetary policy announcements appear to co-move positively, suggesting the presence of a strong information effect. The information component appears to be dominant at some monetary policy meetings, leading to wrong-signed responses in the German two-year yield. To remove the information component, I follow the sign restrictions procedure outlined in section 4.1.3. The resulting pure monetary policy shocks are plotted along with the information effects, again in Figure 1.

Figure 1: Realization of Pure DE2Y and Information Shocks at ECB Announcements



Note: Financial market shocks at 197 ECB announcements 2002-2019. Factors standardized to mean zero/unit standard deviation for presentation convenience.

6.1.2 The Odyssean Forward Guidance Factor

To measure forward guidance separately, I construct an Odyssean forward guidance factor. Andrade and Ferroni (2021) and ter Ellen et al. (2020) create target and path factors from shocks in OIS rates with maturities between one month and two years. Following their approach, I use surprises in OIS rates with maturities of one, three, six, 12, and 24 months at ECB monetary policy announcements. The path factor is restricted to zero correlation with the one-month OIS rate, which is assumed to capture shocks related to current policy rates. I apply a principal component analysis to the dataset of 197 × 5 shocks in OIS rates at ECB announcements. The first two principal components are extracted and rotated following the procedure outlined in section 4.1.2. To obtain factor loadings on the OIS rates, I regress OIS rate shocks on the target and path factors. Results from the factor diagnostics regressions, without constant terms, are presented in Table 2. To illustrate the effects on the yield curve, I include German government bond yields with maturitis of one, two, five, and ten years. The table also includes estimated effects on the STOXX50 equity price index and the EUR to USD exchange rate.

Table 2: Factor Loadings on Financial Market Rates Around ECB Announcements

	Target	Path	Adj.R^2	Target	Odyssean	Delphic	Adj.R^2
OIS1M	1.0000***	0.0000	0.97	0.9950***	0.0155	-0.0159	0.97
	(0.0259)	(0.0269)		(0.0248)	(0.0316)	(0.0255)	
OIS3M	0.8525***	0.3901***	0.96	0.08589***	0.3702***	0.4106***	0.96
	(0.0264)	(0.0276)		(0.0253)	(0.0324)	(0.0265)	
OIS6M	0.7745***	0.6660***	0.97	0.7760***	0.6616***	0.6706***	0.97
	(0.0296)	(0.0258)		(0.0288)	(0.0315)	(0.0254)	
OIS1Y	0.6851***	1.0000***	0.99	0.6867***	0.9948***	1.005***	0.99
	(0.0199)	(0.0108)		(0.0197)	(0.0130)	(0.0136)	
OIS2Y	0.5634***	1.1592***	0.96	0.5549***	1.1861***	1.132***	0.96
	(0.0389)	(0.0486)		(0.0375)	(0.0567)	(0.0467)	
DE1Y	0.6601***	0.8836***	0.93	0.6408***	0.9479***	0.8123***	0.93
	(0.0344)	(0.0397)		(0.0317)	(0.0433)	(0.0479)	
DE2Y	0.5380***	1.2080***	0.90	0.5110***	1.2928***	1.1208***	0.91
	(0.0465)	(0.0628)		(0.0448)	(0.0817)	(0.0606)	
DE5Y	0.3319***	1.0349***	0.77	0.3058***	1.1171***	0.9506***	0.77
	(0.0649)	(0.0546)		(0.0656)	(0.0938)	(0.0808)	
DE10Y	0.0916	0.6111***	0.46	0.0678	0.6862***	0.5347***	0.47
	(0.0602)	(0.0728)		(0.0569)	(0.1531)	(0.1110)	
STOXX50	-0.0602**	-0.0009	0.05	-0.0000	-0.1904***	0.1937***	1.00
	(0.0233)	(0.0180)		(0.0001)	(0.0001)	(0.0001)	
USDEUR	-0.0329**	-0.0591***	0.22	-0.0178	-0.106***	-0.01055	0.33
	(0.0137)	(0.009)		(0.0155)	(0.0170)	(0.0149)	

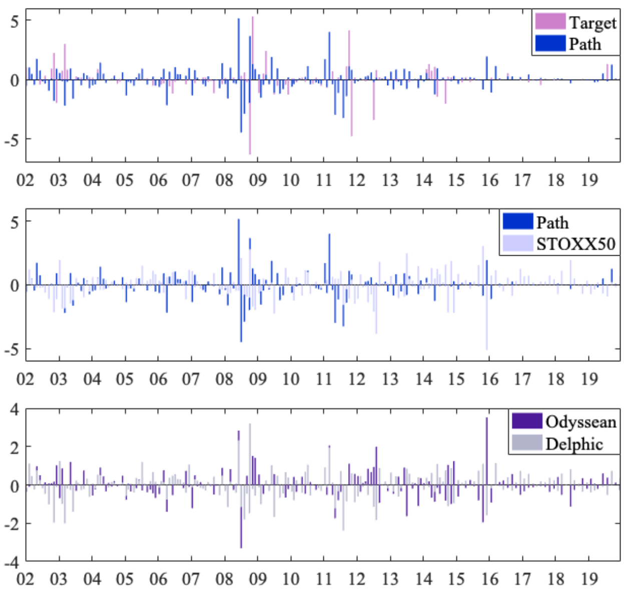
Heteroskedasticity-robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$,$^{***}p < 0.01$. Results of OLS regressions of financial market effects, in narrow time windows around ECB announcements, on factors. The results of two regressions are displayed: first, financial market shocks are regressed on target and path factors; second, the shocks are regressed on target, Odyssean, and Delphic factors. Regression coefficients are presented along with R^2 values. 197 observations are included; in DE1Y regression, 178 observations. Constant terms are omitted for presentation convenience.

By construction, the target factor moves 1:1 with the one-month OIS rate. As expected, the target factor loading decreases in the maturity of the overnight index swaps. The target factor dominates in maturities up to six months; the path factor is clearly more important for longer-term OIS rates. This reflects that prices of longer-maturity OIS rates are mainly determined by expectations of future policy rates, rather than current policy rates. The path factor is constructed to have zero correlation with the one-month OIS rate, and to have unit loading on the one-year OIS rate. For the two-year OIS rate, the path factor loading is higher, with an estimated effect of 1.159. For all OIS rates, the proportion of variation explained by the factors is higher than 95%. The adjusted R^2 value for the one-year rate is 99%. The factor loading coefficients on all OIS rates are statistically significant at 1%. The factor loadings on German yields with maturities of one and two years are similar to those reported for the OIS rates of the same maturities. This indicates that the German yield curve closely follows the ECB's expected policy rates. The factor loadings on five-year and ten-year yields indicate that, as expected, the path factor is more important than the target factor at the long end of the yield curve. The target factor effect on the ten-year yield is small and statistically insignificant; the path factor loading is relatively large at 0.611 and significant at 1%. The adjusted R^2 value in the ten-year government bond yield regression is much smaller than in the OIS rate regressions, reflecting that a substantial share of the information in long-term bond yields is unrelated to monetary policy. Only the target factor has a significant effect on the STOXX50 index; as expected, a monetary tightening decreases stock prices. The exchange rate behaves as expected — a monetary policy tightening appreciates the euro against the US dollar. The path factor coefficient is larger in magnitude and more significant than the estimated target factor effect.

Figure 2 plots the target and path factors. In the same figure, the path factor is plotted together with the Euro STOXX50 equity price index. Again, the path factor and the equity price index appear to co-move positively around a substantial share of the ECB announcements. We thus have reason to suspect that the path factor contains a Delphic element. To remove the Delphic component, I again impose sign restrictions on the path factor with respect to the equity price index. This results in two separate forward guidance components — Odyssean and Delphic, which are presented also in Figure 2. Similar to above, I regress the financial market effects around ECB monetary policy announcements on the target, Odyssean, and Delphic factors. Factor loadings are presented in Table 2.

In the OIS rate and German yield regressions, the factors explain the same proportion of variation as before. The Odyssean and Delphic factor loadings on the one-month OIS rate are small and highly insignificant. The Delphic factor has a somewhat higher factor loading on OIS rates with maturities up to one year; for higher maturities, the Odyssean factor is slightly stronger. Both factors have close to unit loading on the one-year OIS rate. For the German government bond yields, the Odyssean factor appears to be more important than the Delphic factor. All of the estimated Odyssean and Delphic effects on German yields and OIS rates with maturities above one

Figure 2: Realization of Odyssean and Delphic Forward Guidance Shocks at ECB Announcements



Note: Financial market shocks at 197 ECB announcements 2002-2019. Factors standardized to mean zero/unit standard deviation for presentation convenience.

month are highly significant. While the target factor loadings on the OIS rates and German yields follow the same pattern as before, the estimated effects on the STOXX50 index and the exchange rate are now insignificant. In the STOXX50 regression, the Odyssean and Delphic coefficients and the unit R^2 value reflect the sign restrictions which have been imposed with respect to the equity price index around ECB announcements. The path factor effect on the STOXX50 index was close to zero in magnitude and highly insignificant. In contrast, the Odyssean factor has a coefficient of -0.19, negative and statistically significant at 1%. The Delphic factor effect, equally significant, is similar in magnitude but of the opposite sign. The Odyssean forward guidance factor has a negative and statistically significant effect on the exchange rate, indicating that exchange rate immediately appreciates after an ECB monetary policy tightening through forward guidance. The Delphic coefficient is also negative, but insignificant.

6.2 Narrative Study of a Selection of Events

Figure 1 and 2 show that the shocks vary substantially in sign and magnitude across monetary policy announcements. To explore the source of the variation in the factors, I examine a selection of events which were associated with unusually large positive or negative shocks. I restrict the sample of events to those associated with the five largest positive and negative reactions in the pure two-year yield and information effects, meaning 20 large shocks in total. This leaves me with 17 events, as some of the largest shocks in both elements occurred at the same monetary policy announcement. Table 3 summarizes the standardized shocks in question, along with the corresponding monetary policy announcement date.

In practice, I conduct a narrative study by reading transcripts of ECB press conferences, including the ECB President's introductory statement and the following Q&A session at announcement dates. The Q&A sessions may contribute to the formation of market expectations, as they help clarify the ECB's positions on various issues brought up by the audience. This may reveal information about the wider economy as well as the ECB's preferences. Table D.1 in Appendix D.1 summarizes the events, along with the corresponding monetary policy decisions.

Table 3: Summary of Large Market Shocks Around ECB Monetary Policy Announcements

	Pure DE2Y		**Info DE2Y**	
	Shock	Date	Shock	Date
Positive	3.9305	3 Dec.2015	2.0884	6 Jun.2008
	2.5579	5 Jun.2008	1.7978	8 Oct.2008
	2.3417	6 Nov.2008	1.5056	3 Mar.2011
	2.0597	2 Aug.2012	1.4732	10 Mar.2016
	1.7141	6 Oct.2011	1.3732	9 Jan.2003
Negative	-3.7603	3 Jul.2008	-2.2028	4 Aug.2011
	-2.0069	22 Oct.2015	-1.9174	7 Aug.2008
	-1.7887	5 May.2011	-1.7684	2 Aug.2012
	-1.7652	4 Jul.2013	-1.6456	3 Jul.2008
	-1.3038	14 Jun.2018	-1.5391	2 Jul.2009

The table presents 20 large shocks, based on the five largest positive/negative shocks in the pure two-year yield/information effect series. The selection is made from 197 ECB monetary policy meetings between January 2002 and December 2019.

Importantly, conclusions from the narrative study should only be viewed as suggestive, as it is impossible to observe the underlying reasoning of market participants. Many of the largest shocks occurred during times of financial turmoil and great uncertainty, meaning that they may not be fully representative of the shocks in the whole time sample. However, markets clearly build their expectations not only on explicit forward guidance messages, but also on more general information about the economic outlook or hints about the ECB's future monetary policy actions. Direct forward guidance messages can clearly lower market expectations of future policy rates, but the shocks may also capture the signaling channel of quantitative easing announcements. Large-scale asset purchases may demonstrate the central bank's commitment to a monetary policy expansion, which lowers market expectations of future policy rates. In this respect, quantitative easing has a 'forward guidance function', as it may cement market expectations of a sustained monetary policy accommodation.

6.3 The SVAR-IV Specification

The baseline SVAR-IV specification includes seven variables: the German two-year yield, exchange rates, equity prices, industrial production, the unemployment rate, HICP inflation, and the domestic monetary policy stance. The latter is captured by the short-term interest rate or the shadow rate, if quantitative easing has been conducted. In other words, the vector of endogenous variables in the reduced-form VAR is given by:

$$\boldsymbol{Y}_t = \begin{bmatrix} DE2Y_t & FX_t & EqP_t & IP_t & Unemp_t & HICP_t & MP_t \end{bmatrix}'$$

The external instrument, which captures exogenous variation in $DE2Y_t$, is given by the pure two-year yield series and the Odyssean factor. The shocks are aggregated on a monthly basis. If there is no monetary policy meeting during a specific month, the shock value is zero. The forward guidance instrument can thus be described as:

$$Z_t = \{PureDE2Y_t,\, Odyssean_t\}$$

The SVAR-IV estimation is performed using two lags. The lag length is selected based on the Akaike information criterion (AIC). Moreover, Andrade and Ferroni (2021) use two lags in their SVAR-IV. Previous studies have tended to report SVAR-IV responses to a positive, contractionary monetary policy shock. The ECB has, however, aimed to conduct strategic market communication for expansionary purposes. In this thesis paper, it thus makes more sense to report the results of a negative monetary policy shock. The SVAR-IV impulse response functions should be interpreted as effects of an expansionary ECB communication shock which lowers the German two-year yield by 100 basis points. The impulse response functions have a horizon of 48 months.

6.4 First-Stage Relationships

In a standard microeconomic instrumental variables approach, the first step usually involves an assessment of the first-stage relationship between the endogenous explanatory variable and the exogenous instrument. The SVAR-IV analogue is to regress the residuals from the policy equation of the reduced-form VAR model on the external instruments. The reduced-form VAR estimation follows the above specification. Table 4 presents first-stage relationships for the euro area, Denmark, Sweden, and Norway, using the pure two-year yield shock series as external instrument.

Table 4: First-Stage Regressions on Pure DE2Y Shocks

	Euro Area	Denmark	Sweden	Norway
Pure DE2Y	0.0499***	0.0422***	0.0369**	0.0406***
	(0.0149)	(0.0150)	(0.0157)	(0.0134)
Observations	214	214	214	214
Adjusted R^2	0.039	.025	0.021	.024
Robust F-stat	11.240	7.907	5.512	9.143
Wald stat	9.1092	6.3317	5.7312	6.8389

Heteroskedasticity-robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$,$^{***}p < 0.01$. Regression of policy-equation residuals from four reduced-form VARs on external instrument. The reduced-form VARs contain German two-year yields, exchange rates, equity prices, industrial production, unemployment rates, HICP inflation, and the domestic monetary policy stance in the euro area, Sweden, Norway, and Denmark. Constant terms omitted for presentation convenience.

The first-stage relationship for the euro area specification is, unsurprisingly, the strongest. The estimated coefficient is highly significant at 0.1%, moreover, the robust F-statistic is 11.24, above the threshold value of ten. The Wald statistic, which tends to be lower than the F-statistic, is roughly 9.11. For Denmark, Sweden, and Norway, the instrument strength is lower. Out of all Scandinavian countries, the Norwegian reduced-form VAR specification produces the highest F-statistic and Wald statistic, at 9.14 and 6.84, respectively. The corresponding values for Denmark are 5.51 and 7.91, respectively. The Swedish specification has the weakest first-stage relationship, with a robust F-statistic and Wald statistic of 5.51 and 5.73, respectively.

Table 5 presents the corresponding first-stage relationships using the Odyssean forward guidance factor as external instrument. The strength of the first-stage relationship drops for all regressions. The euro area robust F-statistic at 8.22 is no longer above the threshold value for strong instruments. The Wald statistic has also dropped, to 6.27. Among the Scandinavian countries, the Danish regression produces the strongest first-stage relationship, with a robust F-statistic of 5.46 and a Wald statistic of 4.55. The corresponding Norwegian values are 5.41 and 4.42, respectively. The Swedish regression produces a particularly weak first-stage relationship, with a robust F-statistic and a Wald statistic at 3.53 and 3.25 respectively.

Table D.2 in Appendix D.2 presents euro area first-stage relationships using the uncleansed two-year yield shocks, information shocks, path factor, and Delphic factor. The reduced-form VAR specification is the same as above. Interestingly, the information and Delphic shocks produce higher

Table 5: First-Stage Regressions on Odyssean Shocks

	Euro Area	Denmark	Sweden	Norway
Odyssean	0.0455^{***}	0.0391^{**}	0.0320^{*}	0.0347^{**}
	(0.0159)	(0.0167)	(0.0171)	(0.0149)
Observations	214	214	214	214
Adjusted R^2	0.028	.018	0.013	.014
Robust F-stat	8.222	5.461	3.529	5.408
Wald stat	6.2680	4.5457	3.2498	4.4195

Heteroskedasticity-robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$,$^{***}p < 0.01$. Regression of policy-equation residuals from reduced-form VARs on external instrument. The reduced-form VARs contain German two-year yields, exchange rates, equity prices, industrial production, unemployment rates, HICP inflation, and the domestic monetary policy stance in the euro area, Sweden, Norway, and Denmark. Constant terms omitted for presentation convenience.

F-statistics, Wald statistics, and adjusted R^2 values than the pure yield and Odyssean instruments. This shows that a substantial part of the expectations reflected in German two-year yields is related to the economic outlook. The uncleansed two-year yield shocks produce the strongest first-stage relationships. This is expected, given that the shocks contain both pure monetary policy and the information elements. Also the path factor, which reflects the information contained in the Odyssean and Delphic instruments, produces a stronger first-stage relationship.

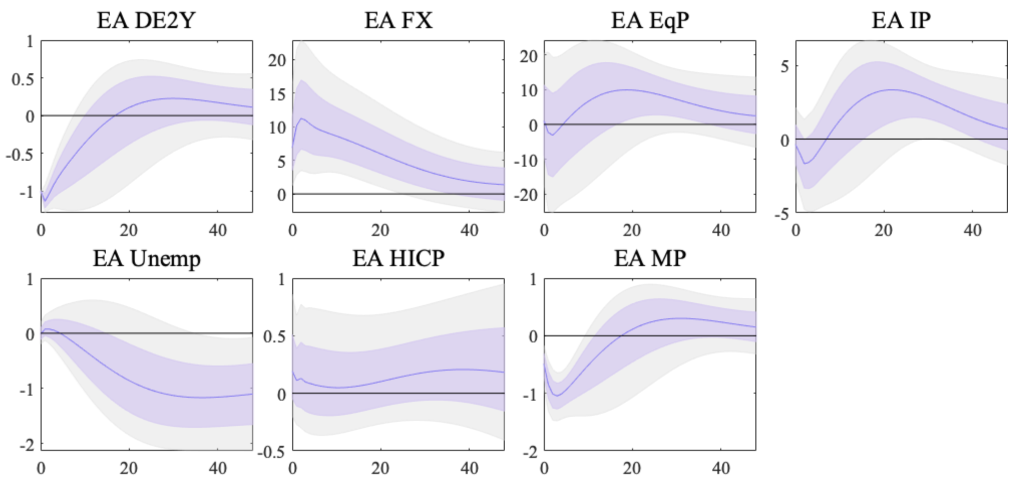
The first-stage assessment of the pure forward guidance instruments clearly indicates a weak-instruments situation in most of the regressions. However, all of the reported Wald statistics are above the critical χ^2_1-value of 2.7055 for 90% weak-instrument robust confidence intervals. To account for the greater extent of uncertainty under weak instruments, I thus present the results of all SVAR-IV estimations along with Montiel Olea et al. (2020) weak-instrument robust confidence bands.

7 Results

7.1 Effects of ECB Forward Guidance Shocks in the Euro Area

This section presents estimated effects of an ECB monetary policy easing through forward guidance on economic outcomes in the euro area. Figure 3 shows impulse responses of the German two-year yield, exchange rates, equity prices, industrial production, unemployment, HICP inflation, and the eurozone shadow rate to a pure ECB two-year yield shock which lowers the German two-year yield by 100 basis points.

Figure 3: Euro Area Effects of a Pure ECB DE2Y Shock



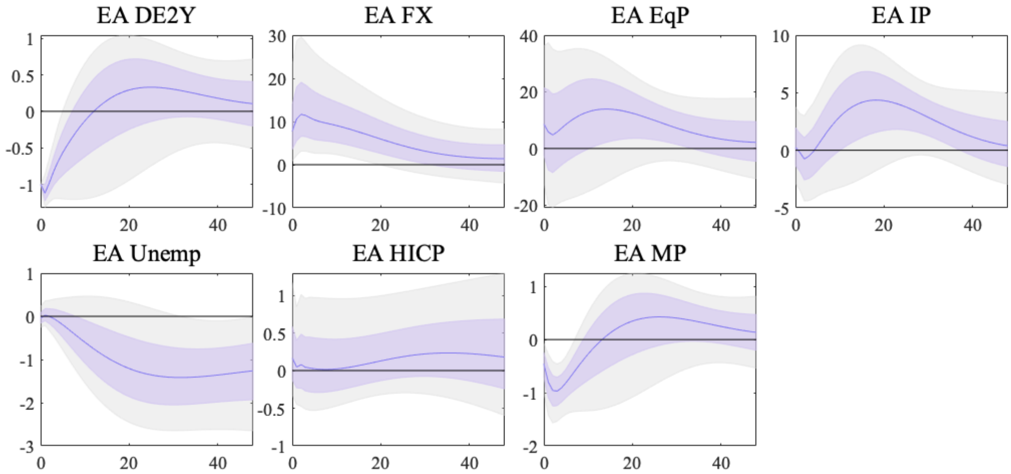
Note: Impulse responses to an expansionary ECB forward guidance shock. External instrument: pure DE2Y shocks. SVAR-IV 2002.01-2019.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$. First-stage relationship: Wald = 9.1092.

After an expansionary forward guidance shock, the price of one US dollar expressed in euros significantly increases. Equity prices seem to increase by 10%; a positive reaction is expected given the sign restrictions, which were imposed with respect to the Euro STOXX50 index. Industrial production significantly goes up by roughly 3%, and the unemployment rate significantly decreases by a little more than one percentage point. The reaction in HICP inflation is positive but insignificant. The euro area shadow rate gradually decreases by 100 basis points in the months following the forward guidance shock, matching the initial shock in the German two-year yield. This indicates that the ECB's promise of a future monetary policy easing is carried through in practice.

Figure E.1a in Appendix E.1 presents impulse responses to an uncleansed two-year yield shock. This results in a price puzzle; inflation goes down after a forward guidance shock. Moreover, the equity price index initially decreases. The puzzling responses can be explained by the presence of an information component, which captures ECB signals about low future policy rates due to low future inflation. The effects of an information shock which reduces the German two-year yield by 100 basis points can be observed in Figure E.1b. The decrease in equity prices is more significant and pronounced, which is expected given the sign restrictions. Furthermore, the decrease in inflation is larger, more significant, and more persistent. Clearly, to obtain results which are consistent with conventional wisdom about forward guidance, the high-frequency shocks must be cleansed of information elements.

Figure 4 presents euro area impulse responses to an Odyssean forward guidance shock. The increase in the equity price index may be somewhat larger, but overall, the results are highly similar to above. An important difference is that the first-stage relationship is weaker, which may explain

Figure 4: Euro Area Effects of an Odyssean ECB Shock



Note: Impulse responses to an expansionary ECB forward guidance shock. External instrument: Odyssean factor. SVAR-IV 2002.01-2019.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$. First-stage relationship: Wald $= 6.2680$.

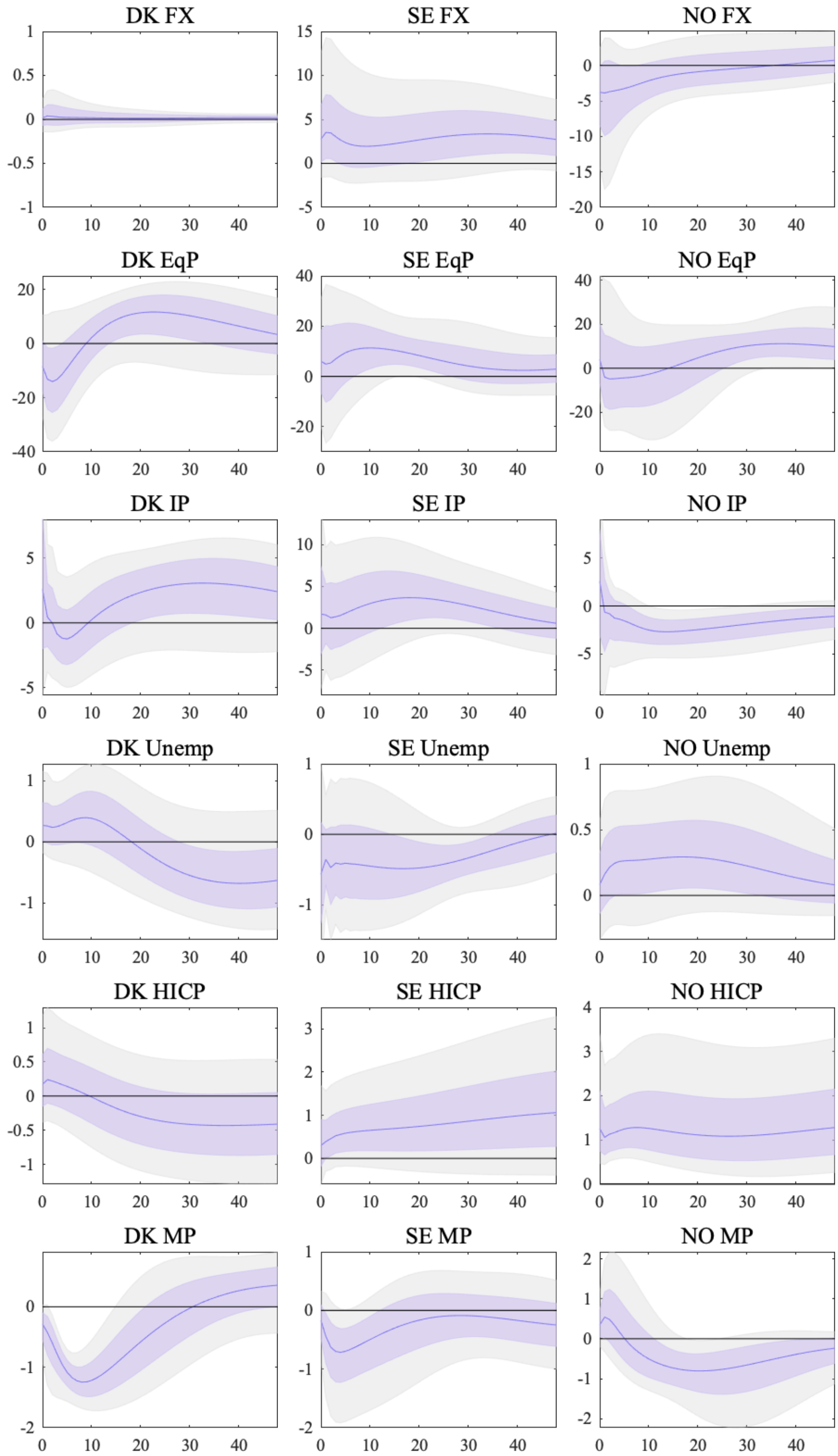
the somewhat wider confidence intervals. The similarity of the impulse responses to the Odyssean factor and the pure two-year yield shocks indicates that the effects of the latter are not primarily caused by current policy rate changes. Instead, expectations of future policy rates seem to drive the effects of the two-year yield. Figure E.1c and E.1d presents impulse responses to path and Delphic factor shocks. The effects are highly similar to above: A path factor shock leads to a price puzzle, and the negative reaction in equity prices and inflation is more pronounced after a Delphic shock. The impulse responses of inflation and industrial production to path, Odyssean, and Delphic shocks confirm the corresponding findings by Andrade and Ferroni (2021).

Taken together, the results suggest that an ECB monetary policy easing through forward guidance has an expansionary effect on economic activity in the euro area: Equity prices and industrial production increase, while the unemployment rate goes down. The effect on inflation is less clear, as the SVAR-IV analysis fails to find any significant effect.

7.2 Spillover Effects of ECB Forward Guidance Shocks

I now investigate how an expansionary ECB forward guidance shock impacts economic outcomes in Denmark, Sweden, and Norway. The baseline SVAR-IV specification is the same as above, but includes domestic variables. The external instrument is given by pure German two-year yield shocks. Figure 5 presents impulse responses of exchange rates, equity prices, industrial production, unemployment, HICP inflation, and the domestic monetary policy stance. The latter is captured by short-term yields in Norway and Denmark, and the shadow rate in Sweden.

Figure 5: Spillovers of Pure ECB DE2Y Shocks



Note: Impulse responses to an expansionary ECB forward guidance shock. External instrument: pure DE2Y shocks. SVAR-IV sample: 2002.01-2019.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$. First-stage Wald statistic: DK 6.3317; SE 5.7312; NO 6.8389.

As expected, the value of the Danish krone remains stable. The impulse responses of equity prices, industrial production, and the unemployment rate are all significant with 68% confidence bands, and suggest an economic expansion. Danish equity prices first have a negative response, but the SVAR-IV estimate turns positive after a little less than ten months. The impulse response suggests an increase in equity prices by roughly 10%. After ten months, Danish industrial production appears to increase by roughly 3%. The impulse response of the unemployment rate suggests a drop by a little more than 0.5 percentage points. The impulse response of HICP inflation is negative but insignificant. After an ECB forward guidance shock, the Danish short-term interest rate gradually decreases by a little more than 100 basis points. The effect is highly significant, and suggests that Danmarks Nationalbank eases its monetary policy roughly on par with the ECB.

Contrary to expectation, the Swedish krona does not appreciate in response to an expansionary ECB monetary policy shock. Instead, the SVAR-IV estimate is positive throughout the horizon, which means that the krona may even depreciate. The effects on the economy are clearly expansionary: Swedish equity prices increase by roughly 10%, industrial production increases by roughly 3%, and the unemployment rate goes down by roughly 0.5 percentage points. Moreover, HICP inflation appears to increase by approximately 1% throughout the horizon. The shadow rate gradually decreases by roughly 80 basis points. The effect on equity prices is significant with 90% confidence bands circa 15-20 months post-shock; all other effects are significant with 68% confidence bands.

The Norwegian krone appears to appreciate; the effect is significant with 68% confidence bands roughly 5 months post-shock. Norwegian equity prices increase by roughly 10% after 15 months; the effect is significant with 90% confidence bands after 35 months. Furthermore, HICP inflation significantly increases by slightly more than 1%. However, in contrast to the Swedish and Danish impulse responses, Norwegian industrial production appears to decrease by roughly 3%. Moreover, the impulse response of the unemployment rate suggests a modest increase by roughly 0.3 percentage points. The effects on industrial production and the unemployment rate are significant with 90% and 68% confidence bands, respectively. The Norwegian short-term yield seems to decrease by roughly 80 basis points throughout the horizon.

Figure E.2 in Appendix E.2 presents spillovers of an Odyssean ECB forward guidance shock. The SVAR-IV estimates largely follow the same pattern as above, but the results are less significant. The weaker first-stage relationships naturally result in lower precision in all estimations. The Swedish Wald statistic is particularly low, resulting in a dramatic increase in the width of the 90% weak-instrument robust confidence intervals.

The results suggest that the Danish and Swedish economies expand after an ECB monetary policy easing through forward guidance; the effects are somewhat smaller in magnitude than in the euro area. The impact on Norway is less clear, as the effects on economic activity are of the opposite sign. Moreover, the impulse response of the Norwegian krone is consistent with an appreciation, but the impact on the Swedish krona is more in line with a depreciation. A similar finding was reported by Franz (2020). Given these different exchange rate responses, we would expect Swedish economic activity to be more affected by expansionary pressures from the euro area.

The exchange rate effects could potentially be explained by the actions of the domestic central banks. If Norges Bank eases its monetary policy stance less than Sveriges Riksbank, we expect the Norwegian krone to appreciate more against the euro. While the SVAR-IV estimates suggest effects of similar magnitude on the Norwegian short-term interest rate and the Swedish shadow rate, the uncertainty bands are wide and leave room for potentially different responses. Moreover, the timing of the responses differ. Swedish shadow rates decrease over the first few months, when the ECB shadow rate also decreases. In contrast, the negative effect on the Norwegian short-term yield is observed later in the horizon.

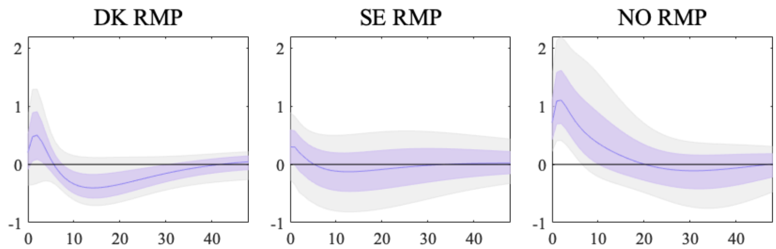
7.3 The Relative Monetary Policy Stance vis-à-vis the Eurozone

To see if the relative domestic monetary policy stances support the observed exchange rate movements, I perform a second set of SVAR-IV analyses. The relative monetary policy stance, which is defined as the difference between the domestic and eurozone monetary policy stance, is included in the SVAR-IV specification in place of the absolute monetary policy stance. In Denmark and Norway, the monetary policy stance is captured by short-term yields; in the euro area and Sweden, shadow rates are used. Figure 6 shows impulse responses of the relative monetary policy stances to a pure ECB forward guidance shock which lowers the German two-year yield by 100 basis points. The external instrument is given by the pure two-year yield shocks. If the domestic central bank does not ease its monetary policy to the same extent as the ECB, we expect the relative monetary policy stance to be positive.

The impulse response of the Danish relative monetary policy stance is positive for the first five months; it later decreases, and reverts back to zero throughout the horizon. The reaction in itself does not speak against the fixed arrangement: Since the Danish krone is pegged between horizontal bands, the relative monetary policy stance may fluctuate somewhat. Moreover, the Danish impulse response is insignificant with 90% confidence bands. Interestingly, the Swedish relative monetary policy stance remains close to zero throughout the horizon. The Norwegian relative monetary policy stance is clearly positive and highly significant; the effect is sizable, indicating a difference of roughly 100 basis points between Norway and the eurozone.

The impulse responses suggest that after an expansionary ECB forward guidance shock,

Figure 6: The Relative Domestic Monetary Policy Stance



Note: Impulse responses to an expansionary ECB forward guidance shock. External instrument: pure DE2Y shocks. SVAR-IV sample: 2002.01-2019.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$. First-stage Wald statistic: DK 6.7084; SE 6.3781; NO 7.6990.

Sveriges Riksbank eases its monetary policy to the same extent as the ECB. This would prevent the exchange rate from appreciating. In contrast, Norges bank does not seem to ease its monetary policy as much, resulting in a significantly positive relative monetary policy stance. This is consistent with an appreciation of the Norwegian krone vis-à-vis the euro. Moreover, the different central bank reactions and exchange rate effects are consistent with the observed outcomes for macroeconomic variables. In Sweden, the magnitude of the effects are about as large as in Denmark, and clearly indicate a monetary policy expansion. In contrast, Norwegian economic activity may even contract.

7.4 Spillovers on an Extended Sample of Neighboring Economies

For further context of the above results, I perform the same SVAR-IV analysis for an extended sample of non-euro countries with different degrees of exchange rate flexibility. Iceland is in many ways similar to Sweden, Norway, and Denmark, sharing the same Nordic model of economic and social policies. The United Kingdom, while distinct from the Nordic countries, is equally economically advanced. Iceland and the United Kingdom have flexible exchange rate regimes. I also include a sample of Central and Eastern European (CEE) economies. The CEE economies share many important characteristics: They are small, emerging market economies with similar economic histories, but have different degrees of exchange rate flexibility. Dabrowski and Wróblewska (2020) argue these circumstances are similar to a "natural experiment". Poland has a floating exchange rate regime. Bulgaria operates a currency board, making the currency completely fixed against the euro. Also Lithuania operated a currency board before adopting the euro in 2015. Throughout the time sample, Croatia and Czechia have had varying intermediate degrees of exchange rate flexibility. The Czech koruna has, however, been permitted to fluctuate more than the Croatian kuna. Hungary should also be interpreted as an intermediate case: The Hungarian forint has been floating since 2008, but before then, it was pegged within horizontal bands. More information about the countries, including an overview of their exchange rate regimes over time, can be found in Appendix A.1.

Table 6 summarizes the country-specific impulse responses, which can be found in Figure E.3 in Appendix E.3. The reduced-form VAR contains the same variables as above. Pure German two-year yield shocks are used as external instrument. A positive impulse response is denoted by $+$, while a negative response is given by $-$. This also means that an exchange rate depreciation (appreciation) is given by $+(-)$. An increase followed by a decrease is given by $+/-$, or vice versa. Only impulse responses which are significantly different from zero with at least 68% confidence bands are included; a bold symbol indicates that the effect is significant with 90% confidence bands. Blank spaces indicate that no significant reaction was found. I also estimate impulse responses of the relative monetary policy stance for the extended country sample, following the same procedure as above. Since the Bank of England has conducted quantitative easing, I use shadow rates for the United Kingdom. For all other countries, short-term yields are used. The impulse responses are shown in Figure E.4 in Appendix E.4.

Table 6: Summary of Impulse Responses for Extended Country Sample

	Exchange Rate	Equity Prices	Ind. Prod.	Unemployment	HICP Inflation
Advanced					
Iceland			+	+	
United Kingdom	−	**+**	+	+	
Emerging					
Bulgaria		−/+	+	−	−
Croatia	−	+	+	−	+
Czechia	+/−	−	**+**	**−**	**+**
Hungary	**+**	+	+		
Lithuania		+	+	−	+
Poland	+		**+**		**+**

Signs of country-specific impulse responses to a pure ECB monetary policy shock. The reduced-form VAR contains the German two-year yield, equity prices, industrial production, unemployment rate, HICP inflation, and domestic short-term yields (shadow rate for the UK).

Clearly, Norway is not the only country in which some effects may be of the opposite sign. In the United Kingdom, exchange rates appreciate and equity prices increase by a little more than 10%. Industrial production increases modestly by roughly 2%. The unemployment rate estimate is initially positive at roughly 0.3 percentage points, and significant with 68% confidence bands. There is no significant effect on inflation. Like in Norway, the relative monetary policy stance is significantly positive and large. In Iceland, there appears to be an increase in unemployment. The SVAR-IV estimate of industrial production is large and positive for the first five months of the horizon, but rapidly moves to zero. The effects on the relative monetary policy stance and the exchange rate are insignificant and have broad confidence bands.

As expected, the exchange rates of Bulgaria and Lithuania remain constant. The relative monetary policy stance also remains relatively close to zero in both countries. In Lithuania, there is a small deviation, similar in magnitude to the effect in Denmark. Moreover, there appears to be an expansionary effect on the economies. Both equity price indices increase by almost 20%; industrial production increases by 3% in Bulgaria, and almost 5% in Lithuania. The Bulgarian unemployment rate decreases by slightly more than one percentage point. In Lithuania, there is a decrease by roughly two percentage points. Only the response in Bulgarian HICP inflation is puzzling, suggesting a decrease. The impulse response is, however, insignificant with 90% confidence bands. In Lithuania, inflation appears to increase by a little more than 1%. The results for Lithuania should be interpreted with care, given the limited time sample.

In Croatia, there is clearly an expansionary effect on the economy. The exchange rate appreciates, but the effect is small. This is expected given the limited degree of exchange rate flexibility, and consistent with the response in the relative monetary policy stance, which never significantly differs from zero. The SVAR-IV estimate of equity prices is positive but insignificant, but industrial production appears to increase by a little more than 3%. Moreover, the unemployment rate significantly decreases by two percentage points, and inflation appears to increase by 1%. The results for Czechia are somewhat puzzling; there appears to be an initial exchange rate depreciation, but there is also a significant positive reaction in the relative monetary policy stance. At the end of the horizon, however, the SVAR-IV estimate of the exchange rate becomes negative and significant with 68% confidence bands. The equity price index appears to initially decrease; the impulse response becomes positive after 10 months for the rest of the horizon, but insignificantly so. Industrial production increases by more than 4%, the unemployment rate significantly decreases by almost one percentage point, and inflation significantly increases by more than 1%. Taken together, the impulse responses suggest an expansionary effect on the economy. In Hungary, the initial exchange rate response is also consistent with a depreciation, but it quickly reverts to zero. The equity price index increases by more than 10%; industrial production goes up by 3%. There is no significant response in unemployment or inflation, but the SVAR-IV estimate of the latter is positive throughout the horizon. The relative monetary policy stance never significantly deviates from zero. In Poland, the initial response of the exchange rate is also in line with a depreciation, but the SVAR-IV estimate has reverted back to zero after 15 months. There is no significant effect on equity prices or unemployment, but industrial production increases by roughly 4%. Moreover, the HICP inflation rate significantly increases by 0.5%. The relative monetary policy stance is initially positive, but the effect is smaller than in Norway and the UK, and it is insignificant with 90% confidence bands.

Taken together, the results suggest that an ECB monetary policy easing through forward guidance generally has expansionary economic effects outside of the eurozone. In some emerging economies, the effects are larger than in the euro area. In most countries, equity prices clearly increase, and in all countries in the extended sample, industrial production increases. In most cases, the response of inflation is positive. There is, however, substantial cross-country heterogeneity in the spillovers. The unemployment rate appears to decrease in emerging Europe, but in the United Kingdom and Iceland, the effects could be positive. Clearly, exchange rates do not always appreciate after an expansionary ECB shock. Moreover; in most countries, the relative monetary policy stance does not substantially deviate from zero.

7.5 Robustness

While recognizing that the two-year yield is "conceptually preferred", Gertler and Karadi (2015) end up using the one-year yield due to first-stage considerations. For the same reason, Lakdawala (2019) also uses the one-year yield. As a robustness check, I thus perform another set of estimations for the euro area and the Scandinavian countries, employing the German one-year yield as policy indicator. Moreover, I construct a second external instrument series, created by shocks in the one-year yield. I perform the same sign restrictions with respect to the STOXX50 index as above. The shocks are available from June 2003. Furthermore, I use the monthly German one-year yield as policy indicator. The impulse responses for the euro area, Denmark, Sweden, and Norway are presented in Figure F.1a, F.2a, F.3a, and F.4a, respectively, in Appendix F.1.

Some impulse responses have changed slightly in magnitude, significance, and timing. The Swedish SVAR-IV estimate of the exchange rate is still positive, but now insignificant. The inflation responses in Denmark and the euro area have changed somewhat; the Danish inflation response is now significant with 68% confidence bands, but it is clearly insignificant with 90% confidence intervals. The euro area inflation response is also negative, but close to zero and insignificant. In the euro area and Denmark, industrial production has a short, negative response before increasing; also the Danish unemployment rate response is temporarily positive. The overall pattern of responses is, however, the same as above.

A potential shortcoming in high-frequency identification relates to the length of the event window. Hanson and Stein (2015) argue that investors may be uncertain about central bank signals, and gradually interpret the information based on trading volumes, price changes, and analyses and articles in financial media. To give markets more time to absorb the ECB's news, I follow Hanson and Stein (2015) and use two-day changes in German two-year yields around monetary policy announcements. For a meeting on date t, I thus compute the yield change from $t-1$ to $t+1$.[22] I follow the same sign restrictions procedure as above, creating a new exogenous external instrument.

[22] For three observations, I use the daily change due to missing values for $t-1$ or $t+1$.

The results are presented in Figure F.1b, F.2b, F.3b, and F.4b. Changes in magnitude are minor, suggesting that most of the information about the ECB's future policy rates is absorbed by markets within the intraday monetary event window. However, using the two-day change as an external instrument results in considerably higher first-stage Wald statistics, making some impulse responses more significant. For example, the Norwegian unemployment rate increase is now significant with 90% confidence bands. Otherwise, the results are largely unchanged.

The baseline policy instrument is constructed from shocks during the full monetary policy event window, including the ECB's press release and press conference. However, a long event window increases the risk of capturing noise from unrelated trading. I thus construct an alternative external instrument which reduces the length of the combined event window. In practice, I take the sum of the changes in the German two-year yield in the *press release window* and the *press conference window*, from the EA-MPD. While the full monetary event window measures the change from the pre-press release median quote to the post-press conference median quote, the individual windows around the press release and press conference are more narrow. The post-press release median quote is calculated as the median of all quotes between 14:10. The pre-press conference median quote is similarly taken from the time interval 14:15-14:25. The combined press release and press conference shocks thus exclude any trading that occurs between 14:10 and 14:15 on announcement days. The impulse responses are presented in Figure F.1c, F.2c, F.3c, and F.4c. Overall, the impulse responses are similar to above. For the euro area, Denmark, and Norway, the first-stage Wald statistics are lower, and some impulse responses are less significant. The lower Wald statistics are not surprising, given that the external instrument captures less information than before. Only the Swedish first-stage Wald statistic is higher than in the baseline specification. Furthermore, the increase in Swedish industrial production is (barely) significant with 90% confidence bands.

The main results for the euro area, Sweden, Denmark, and Norway are robust to increasing the lag length to four and six lags. The impulse responses with four lags can be seen in Figure F.1d, F.2d, F.3d, and F.4d. Impulse responses using six lags are presented in Figure F.1e, F.2e, F.3e, and F.4e. While the Wald statistics become somewhat higher, any changes in magnitude or timing of the effects are minor. For the euro area, Denmark, and Sweden, the results are largely unchanged. For Norway, the exchange rate response becomes less clear, and the industrial production index may indicate an initial increase, but the rise in the unemployment rate is larger and more significant. Overall, the results follow the same pattern as before.

Moreover, the results for the euro area and Sweden are robust to using short-term yields instead of shadow rates: The impulse responses are largely the same as above. Only the impulse responses of the domestic monetary policy stances have changed. The euro area response is somewhat smaller, suggesting a decrease by roughly 80 basis points. When using the shadow rate measure, the decrease amounts to 100 basis points, matching the initial shock in the German two-year yield. The impulse response of the Swedish monetary policy stance becomes smaller and less significant. Given the results, it seems like the shadow rate measure better captures the monetary policy stance when unconventional policy tools are used.

The conclusions also do not change regarding the relative monetary policy stance in Denmark, Sweden, and Norway. The robustness checks, which like above involve using the one-year yield as policy indicator and instrument, longer and shorter event windows, and four and six lags instead of two, are presented in Figure F.5 in Appendix F.2. The Norwegian relative monetary policy stance remains large and highly significant in all estimations. Again, the Danish relative monetary policy stance fluctuates somewhat, but the responses are clearly smaller than in Norway and much less significant. The Swedish relative monetary policy stance remains close to zero, with large confidence bands. In Figure F.5, I also present impulse responses of the relative monetary policy stance using euro area and Swedish short-term yields instead of shadow rates. This part should perhaps not be viewed as a robustness check; rather, it shows interest rate differentials which do not take unconventional monetary policy measures into account. The Danish interest rate differential is positive and of roughly the same magnitude as before. The Norwegian short-term interest rate differential is largely unaffected, which is inconsistent with an exchange rate appreciation, but the confidence bands are relatively wide and leave room for potentially different responses. The Swedish short-term interest rate differential is persistently negative, which is consistent with an exchange rate depreciation and would suggest a monetary policy easing which is even larger than in the eurozone. The response is, however, insignificant with 90% confidence bands.

8 Discussion

This section discusses the main findings of the SVAR-IV analyses, and highlights key lessons for identification. Moreover, the limitations of the study are addressed. Before concluding with policy recommendations, I provide some suggestions for future research.

8.1 Insights on the ECB's Communication Shocks

Since 2013, the ECB has conducted forward guidance to influence economic outcomes in the euro area. This thesis paper shows that an expansionary ECB communication shock leads to a depreciation of the euro against the US dollar, an increase in equity prices, an increase in industrial production, and a decrease in the unemployment rate. The results suggest that forward guidance is an effective monetary policy tool for stimulating economic activity.

ECB communication also impacts economic outcomes in Sweden, Norway, and Denmark. In Denmark, the increases in equity prices and industrial production are roughly as large as in the eurozone, while the unemployment rate decrease is somewhat smaller. In Sweden, the effects are similar. In Norway, equity prices also increase by roughly the same amount, but the industrial production index seems to decrease, and the unemployment rate goes up. While the ECB's communication has expansionary effects on economic activity in Sweden and Denmark, clearly, no such conclusion can be drawn about Norway. Instead, Norwegian economic activity appears to contract. The different results for economic activity are consistent with the observed exchange rate responses. The Norwegian krone seems to appreciate against the euro. In contrast, the positive SVAR-IV estimate of the Swedish exchange rate clearly does not indicate an appreciation of the Swedish krona. The relative monetary policy stances suggest that Sveriges Riksbank eases its monetary policy to roughly the same extent as the ECB, while Norges Bank does not ease its monetary policy as much. The SVAR-IV analyses of the extended country sample supports some of the observed results for the Scandinavian economies:

First, while there is a great cross-country heterogeneity in the magnitude of the spillovers, ECB signals about a future monetary policy easing generally has expansionary effects outside of the eurozone. In most countries, equity prices unambiguously increase. Moreover, economic activity seems to expand: Industrial production goes up and unemployment rates tend to decrease. In some emerging economies, the effects are larger than in the euro area. For example, unemployment in Croatia and Lithuana seems to decrease twice as much. While there is no significant effect on inflation in the euro area, inflation appears to increase in most neighboring economies, including Sweden and Norway. There does not seem to be a clear link between HICP inflation outcomes and the degree of exchange rate flexibility: In Denmark, no significant effect is found, and the SVAR-IV estimate is negative in Bulgaria.

Second, exchange rate movements seem to have some influence over the outcomes for economic activity. In the United Kingdom, the impulse response of the unemployment rate stays close to zero, but may indicate a small initial increase. Moreover, the increase in industrial production is smaller than in any other country in the sample. At the same time, the Pound sterling clearly appreciates against the euro. Taken together with the results for Norway, an exchange rate appreciation after an accomodative ECB forward guidance shock seems to mute some of the expansionary pressures, and may even lead to effects of the opposite sign.

Third, exchange rates do not uniformly appreciate against the euro after an expansionary ECB communication shock. This could potentially be linked to the actions of the domestic central banks. In most countries, there is no meaningful effect on the relative monetary policy stance. The largest and most significantly positive relative monetary policy stances vis-à-vis the eurozone are observed in Norway and the United Kingdom. Out of all countries in the sample, the Norwegian and British currencies most clearly appreciate.

Given the results, there is reason to suspect a fear of floating-behavior among domestic central banks. Importantly, large spillover effects and a high degree of interest rate co-movement do not per se say anything about the state of central bank monetary policy autonomy. Nelson (2020) shows that the concept of monetary policy autonomy under flexible exchange rate regimes, namely the ability of the domestic central bank to use its policy tools in pursuit of domestic objectives, is compatible with foreign spillover effects. Optimal monetary policy may also involve some degree of adaptation to foreign monetary policy actions, depending on whether inflation is below or above target and whether the foreign central bank eases or tightens its monetary policy stance. If inflation is running below target and there is a negative output gap, an exchange rate appreciation would only cause the economy to move further away from the desired state. In contrast, an exchange rate appreciation may be welcomed if inflation is high. The results thus do not imply that the central banks have any lesser degree of monetary policy autonomy, nor do they suggest that monetary policy is sub-optimal in the neighboring economies.

8.2 Implications for Identification

To quantify the content of the ECB's communication, I use high-frequency shocks in various financial instruments around 197 ECB monetary policy announcements between January 2002 and December 2016. While this thesis paper primarily contributes to the growing literature on high-frequency forward guidance shocks and cross-border effects of monetary policy, another contribution is to the applied literature on the innovative SVAR-IV approach. Since the SVAR-IV solves a number of common issues encountered in a structural VAR setting and is well-suited for estimating effects of forward guidance and other expectation-shifting central bank policies, it is likely to keep gaining in popularity going forward. This thesis paper emphasizes the importance of evaluating the first-stage relationships and accounting for potential instrument weakness in SVAR-IV estimations. In particular, confidence intervals can be constructed to reflect the higher uncertainty level under weak instruments. As shown by Montiel Olea et al. (2020), weak-instrument robust confidence intervals can be wide, especially when the first-stage Wald statistic is low and the confidence level is high. If the Wald statistic is very low, like in the Odyssean SVAR-IV analysis for Sweden, the uncertainty bands become exceedingly wide. In such cases, one may consider relying on a different policy instrument and indicator combination which produces a higher first-stage Wald statistic.

The identification of pure monetary policy shocks is a central matter of concern. Previous authors have documented the importance of distinguishing between the pure policy and information components of high-frequency monetary policy shocks (Jarociński and Karadi, 2020; Kerssenfischer, 2019). In particular, Andrade and Ferroni (2021) report widely different effects of Odyssean and Delphic forward guidance in the eurozone. My results corroborate some of their findings. Using the path factor or uncleansed yield shocks leads to a price puzzle, because the instrument is not exogenous with respect to the economic outlook. To obtain sensible results, the external instrument must be cleansed of information elements. This finding calls the results of some previous studies into question. ter Ellen et al. (2020) do not distinguish between the different components of the path factor, which means that some of their estimated results could reflect shared economic conditions in the euro area and Scandinavia, rather than spillovers of the ECB's monetary policy.

The results also show that pure two-year yield shocks largely have the same effects on macroeconomic variables as Odyssean forward guidance. The former, however, has a stronger first-stage relationship with the German two-year yield. In a SVAR-IV setting with government bond yields as policy indicator, pure high-frequency yield shocks thus seem to be a more suitable external instrument for capturing forward guidance. Furthermore, to capture the monetary policy stance of central banks which have conducted quantitative easing, I have conducted the SVAR-IV analyses using shadow rates instead of short-term yields. The estimated easing of the ECB's monetary policy becomes more pronounced with shadow rates, matching the initial shock in the German two-year yield, and the response of the Swedish domestic monetary policy stance becomes more significant. However, one should remember that the shadow rate measure is a *proxy* for the actual shadow rate which is unobservable, implying that there may be some degree of measurement error.

8.3 Limitations

Of course, the analyses conducted in this thesis paper are not free from shortcomings. The study is limited to ECB communication shocks which impact expectations of future policy rates, captured by the German two-year yield and OIS rates. The results cannot necessarily be generalized to other types of disturbances from the euro area. Moreover, while I present impulse responses to a shock which lowers the German two-year yield, the SVAR-IV does not differentiate between the spillover effects of a foreign monetary policy expansion versus contraction. It is possible that domestic central banks react differently depending on whether the ECB eases or tightens its monetary policy stance, as this has different implications for the exchange rate. Furthermore, a central bank's preferences for exchange rate stabilization are likely to depend heavily on the domestic economic situation. Consequently, the results do not necessarily predict how central banks will react to ECB communication shocks in the future, as economic conditions change. Furthermore, the analysis only captures forward guidance shocks on monetary policy announcement dates. Central bankers' communication on other days, in the form of speeches or interviews with media, may also impact market expectations.

Probably the most important potential shortcoming relates to the comparability of the countries in the sample. The number of neighboring economies is limited, and while Sweden, Norway, and Denmark are highly similar in many respects, they also have important differences. For example, Norway is a large oil exporter. Also the countries in the extended country sample differ along more or less important dimensions. The results should be interpreted with this in mind. Furthermore, there is a varying degree of instrument weakness in most of the estimations. Differences in the strength of the first-stage relationships, which are closely tied to the width of the uncertainty bands, may impact the cross-country comparability of the results. Another shortcoming relates to potentially important variables outside of the reduced-form VAR. To my knowledge, there is no readily available measure of for example credit risk in all of the included countries. Another potential limitation concerns the classification of exchange rate regimes, which is central when comparing outcomes in countries with different degrees of exchange rate flexibility. This thesis paper utilizes the classical IMF classification (see Table A.2). There are, however, alternative classification schemes available. For example, Corsetti et al. (nd) use the Ilzetzki et al. (2019) classification of exchange rate regimes over time. The stated degree of exchange rate flexibility in a certain country may vary depending on the method of classification.

The study is also limited in that the SVAR-IV analyses only capture bilateral spillovers, from the euro area to neighboring economies. Any indirect ECB spillovers, which transmit through other economies, are unaccounted for. Moreover, the scope of the analysis is limited to the ECB's monetary policy only. While the euro area generally is considered the most important source of spillovers to European economies, shocks originating outside of the euro area may also matter for economic outcomes. As indicated by the narrative study in section 6.2, actions of other central banks can have some influence over market expectations in the euro area. For example, an ECB policy rate decrease may be perceived as small if other central banks recently cut their interest rates more. This may especially matter when central banks respond to global economic conditions.

8.4 Recommendations for Future Research

My results highlight that the fear of floating-behavior first documented by Calvo and Reinhart (2002) remains a relevant research topic. The reasons for such actions are, however, outside of the scope of this thesis paper. Domestic central banks may have several incentives to limit exchange rate shifts vis-à-vis the euro, and it is not certain that all central banks in the sample have the same priorities and considerations. Future research should look into whether and why this behavior is part of the domestic central banks' optimal monetary policy.

This thesis paper primarily builds on the studies by Andrade and Ferroni (2021) and ter Ellen et al. (2020). ter Ellen et al. (2020) investigate spillovers of ECB target and path shocks on

Sweden, Norway, and Denmark, but do not separate the path factor into its Odyssean and Delphic components. Moreover, they only estimate effects on financial variables. Andrade and Ferroni (2021) disentangle the elements of the path factor and apply them as external instruments in a SVAR-IV, but their analysis is limited to the euro area only. While the communication shocks are generally considered to capture forward guidance, the path factor and German two-year yield may also contain signaling effects of announcements of quantitative easing, which stimulate the economy through market expectations of the future policy rate path. In this sense, quantitative easing can be said to have a forward guidance function. However, Swanson (2017) and Altavilla et al. (2019b) impose additional assumptions on their high-frequency shocks to separate the effects of quantitative easing and forward guidance. Future research should consider investigating spillovers in the context of the Swanson (2017) or Altavilla et al. (2019b) frameworks. I have focused on effects of ECB communication which shifts market expectations of future policy rates, but further separation of the shocks might allow for more specific conclusions about the effects of the different policy tools. Further disentanglement might, however, lead to weaker first-stage relationships in a SVAR-IV setting.

As mentioned above, this study is limited in that indirect spillovers between neighboring economies of the eurozone are unaccounted for. Intraregional monetary policy spillovers in general are likely to matter for economic outcomes in Sweden, Norway, and Denmark, given the Nordic region's high degree of financial integration and intraregional trade. A suggestion for future research is thus to examine spatial monetary policy spillovers between the Scandinavian economies. Another interesting aspect of such an analysis is that Sveriges Riksbank and Norges Bank have conducted forward guidance for a relatively long time — since 2007 and 2005, respectively. Odyssean forward guidance shocks became predominant when the ECB started providing explicit forward guidance messages (Andrade and Ferroni, 2021). Consequently, the findings in this thesis paper are likely to mainly be driven by ECB shocks from July 2013 and on. An analysis centered on the Scandinavian countries, allowing for a longer time period of explicit forward guidance, may shed additional light on how strategic central bank communication influences economic outcomes.

9 Conclusion

Small open economies have always been affected by monetary policy spillovers from large central banks. In recent years, central bank communication has increasingly been used by the ECB in order to steer market expectations and impact longer-term yields. This has important implications for economic outcomes in the euro area and in its neighboring economies. This thesis paper studies how ECB communication shocks, based on 197 monetary policy announcements between 2002 and 2019, impact economic outcomes inside and outside of the eurozone. My main focus is on Sweden, Norway, and Denmark; three highly similar countries with different exchange rate regimes. To conduct the analysis, I constructed exogenous shock series from high-frequency changes in German two-year yields, applying sign restrictions with respect to the Euro STOXX50 index within the same narrow event window. The sign restrictions are justified by conventional wisdom on stock valuation. I also conducted a principal component analysis of high-frequency shocks in OIS rates with maturities between one month and two years. The factors were rotated based on orthogonality assumptions with respect to the shortest-maturity OIS rate, and restricted based on the sign of the co-movement with the same equity price index. This resulted in an Odyssean forward guidance factor. The two ECB communication shock series were applied as external instruments in the innovative SVAR-IV approach, which is a relatively novel and increasingly popular method in monetary economics. The SVAR-IV solves a number of issues encountered in a standard VAR setting, and it is well-suited for examining the impact of forward guidance on macroeconomic variables.

My results show that the ECB's communication impacts economic variables in the euro area and in European non-euro countries. In Denmark and Sweden, economic activity expands after an ECB monetary policy easing through forward guidance. In Norway, economic activity contracts. The different effects could be linked to the exchange rate responses and actions of the domestic central banks. While the Norwegian krone is allowed to appreciate, Sveriges Riksbank seems to ease its monetary policy after an expansionary ECB shock, preventing the Swedish krona from appreciating.

Clearly, a small open economy cannot operate as if economic outcomes are isolated from events in the global economy, especially with a large neighbor like the euro area. The results for an extended sample of eight non-euro economies suggest that an ECB monetary policy easing through forward guidance generally has expansionary effects outside of the eurozone. Central banks in non-euro countries should keep this in mind when designing their own monetary policies, as ECB spillovers may either facilitate or challenge the achievement of domestic objectives depending on the state of the economy. The results also suggest that an exchange rate appreciation may offset some of these spillovers, and that the net effect may even be of the opposite sign. In particular, unemployment could potentially increase if exchange rates appreciate following an expansionary ECB communication shock. When making their monetary policy decisions, central banks should consider whether such effects are in line with the achievement of domestic goals.

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A First Appendix

A.1 Sample of Countries: Exchange Rate Regimes and Further Information

Table A.1 presents eleven neighboring economies of the eurozone: their currencies, central banks, and level of economic development. They all have close ties to the eurozone and arguably, they can all be considered small open economies. Except for Norway and Iceland, they are all members of the EU.[23]

Table A.1: List of Included Non-Euro Economies

Country	Currency	Central Bank	Economy
Bulgaria	Bulgarian Lev	Bulgarian National Bank	Emerging
Croatia	Croatian Kuna	Croatian National Bank	Emerging
Czechia	Czech Koruna	Czech National Bank	Emerging
Denmark	Danish Krone	Danmarks Nationalbank	Advanced
Hungary	Hungarian Forint	Hungarian National Bank	Emerging
Iceland	Icelandic Króna	Central Bank of Iceland	Advanced
Lithuania*	Lithuanian Litas	Bank of Lithuania	Emerging
Norway	Norwegian Krone	Norges Bank	Advanced
Poland	Polish Zloty	National Bank of Poland	Emerging
Sweden	Swedish Krona	Sveriges Riksbank	Advanced
United Kingdom	Pound Sterling	Bank of England	Advanced

*Lithuania adopted the euro in January 2015.

Table A.2 provides an overview of their exchange rate regimes. The degree of exchange rate flexibility goes from 0 (adoption of the euro) to 5 (independently floating). The classification is based on the IMF's annual reports, which document de facto (as opposed to de jure) exchange rate regimes. There is substantial cross-country variation in the degree of exchange rate flexibility vis-à-vis the euro. Some countries maintain a fixed exchange rate regime; the most restrictive of which is the currency board, involving a set value of the domestic currency expressed in euros. The currency peg is somewhat less restrictive, permitting the exchange rate to fluctuate within narrow bands around a set value. Other neighboring economies let their currencies float freely against the euro, which allows their central banks to conduct their own monetary policies independently in order to achieve domestic objectives. Finally, there are a number of intermediate arrangements; for example the crawling peg which allows for adjustments of the par value. There are also managed float regimes,

[23]The UK left the EU in 2020, after the sample period.

in which the central bank may intervene in foreign exchange markets to influence the value of the currency.

Table A.2: De Facto Exchange Rate Regimes 2002-2018

	Bulgaria	Croatia	Czechia	Denmark	Hungary	Iceland	Lithuania	Norway	Poland	Sweden	United Kingdom
2002	1	4	4	2	2	5	1	5	5	5	5
2003	1	4	4	2	2	5	1	5	5	5	5
2004	1	4	4	2	2	5	1	5	5	5	5
2005	1	4	4	2	2	5	1	5	5	5	5
2006	1	4	4	2	2	5	1	5	5	5	5
2007	1	3	5	2	2	5	1	5	5	5	5
2008	1	3	5	2	5	5	1	5	5	5	5
2009	1	4	5	2	5	5	1	5	5	5	5
2010	1	3	5	2	5	5	1	5	5	5	5
2011	1	3	5	2	5	5	1	5	5	5	5
2012	1	3	5	2	5	5	1	5	5	5	5
2013	1	3	4	2	5	5	1	5	5	5	5
2014	1	3	3	2	5	5	1	5	5	5	5
2015	1	3	3	2	5	5	0	5	5	5	5
2016	1	3	3	2	5	5	0	5	5	5	5
2017	1	3	5	2	5	5	0	5	5	5	5
2018	1	3	5	2	5	5	0	5	5	5	5

Classification based on annual country reports by the IMF. 0 = Adopted the euro; 1 = Currency board arrangement; 2 = Conventional peg, peg within horizontal bands; 3 = Crawling peg, crawl-like arrangement, stabilized arrangement; 4 = Managed float; 5 = Floating, free floating.

Source: IMF AREAER Database.

The sample can broadly be divided into two clusters of countries: advanced and emerging market economies. The sample of advanced economies, in addition to Sweden, Norway, and Denmark, consists of Iceland and the United Kingdom. Iceland shares the Nordic model with the Scandinavian economies, and has the same degree of economic and technological development. While highly similar to the other Nordic countries in many respects, Iceland has been uniquely shaped by policy responses to the collapse of the Icelandic banking system in 2008. Iceland experienced a deep financial crisis, prompting the introduction of capital controls to prevent further deterioration of the Icelandic kròna. Some of the restrictions are in place yet today. The effects of the financial crisis in Sweden, Norway, and Denmark were not nearly as severe. The United Kingdom is a larger economy. While distinct from the Nordic economies in terms of economic history and institutions, it also combines social policies with a high degree of market orientation. The emerging economies consist of Poland, Lithuania, Croatia, Czechia, Bulgaria, and Hungary. They are all Central and Eastern European (CEE) economies and share similar economic histories and economic institutions, shaped by their common transition experience from central planning to market economies.

B Second Appendix

B.1 Target and Path Factor Rotation

The factors $F = \begin{bmatrix} F_1 & F_2 \end{bmatrix}$, which were extracted using a standard principal component analysis, have no structural interpretation. To interpret them as target and path factors, we perform a suitable factor rotation following the methodology of Gürkaynak et al. (2005). Let $\Gamma = \begin{bmatrix} \Gamma_1 & \Gamma_2 \end{bmatrix}$ describe the target and path factors. To obtain Γ, we identify an orthogonal matrix $U_{2\times 2}$, such that:

$$\Gamma = FU \tag{12}$$

In particular, U is defined as:

$$U = \begin{bmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{bmatrix} \tag{13}$$

To identify U, we impose certain restrictions. First, we normalize the columns of U to unit length; this results in unit variance of Γ_1 and Γ_2. Second, Γ_1 and Γ_2 are orthogonal to each other, such that:

$$E[\Gamma_1 \Gamma_2] = \alpha_1 \beta_1 + \alpha_2 \beta_2 = 0 \tag{14}$$

Finally, Γ_2 is restricted to zero correlation with the one-month OIS rate. Let the shortest-maturity rate loadings be γ_1 and γ_2 on F_1 and F_2, respectively. From equation 12, it follows that:

$$F_1 = \frac{1}{\alpha_1 \beta_2 - \alpha_2 \beta_1} [\beta_2 \Gamma_1 - \alpha_2 \Gamma_2] \tag{15}$$

$$F_2 = \frac{1}{\alpha_1 \beta_2 - \alpha_2 \beta_1} [\alpha_1 \Gamma_1 - \beta_1 \Gamma_2] \tag{16}$$

For Γ_2 not to influence the shortest-maturity rate, the following must hold:

$$\gamma_2 \alpha_1 - \gamma_1 \alpha_2 = 0 \tag{17}$$

The procedure results in two factors $\Gamma = \begin{bmatrix} \Gamma_1 & \Gamma_2 \end{bmatrix}$, where the factor Γ_2 is orthogonal to shocks in the one-month OIS rate.

B.2 Identifying the Policy Shock Vector of the SVAR-IV

In the final step of the SVAR-IV estimation procedure outlined in section 4.2.1, we obtain the column vector $\boldsymbol{b}$, which describes how a structural policy shock affects each element of the reduced-form residuals.

Following the methodology of Gertler and Karadi (2015), the last step involves taking the partitioned vector of reduced-form residuals $\boldsymbol{u}_t = \begin{bmatrix} u_t^p & \boldsymbol{u}_t^{q\prime} \end{bmatrix}' = \begin{bmatrix} u_{1,t} & \boldsymbol{u}_{2,t}{}' \end{bmatrix}'$. Also partition the impact matrix and the reduced-form variance-covariance matrix:

$$\boldsymbol{B} = \begin{bmatrix} \boldsymbol{b} & \boldsymbol{B}_q \end{bmatrix} = \begin{bmatrix} \boldsymbol{B}_1 & \boldsymbol{B}_2 \end{bmatrix} = \begin{bmatrix} b_{11} & \boldsymbol{b}_{12} \\ \boldsymbol{b}_{21} & \boldsymbol{b}_{22} \end{bmatrix} \tag{18}$$

$$E[\boldsymbol{B}\boldsymbol{B}'] = \boldsymbol{\Sigma} = \begin{bmatrix} \Sigma_{11} & \boldsymbol{\Sigma}_{12} \\ \boldsymbol{\Sigma}_{21} & \boldsymbol{\Sigma}_{22} \end{bmatrix} \tag{19}$$

We can then obtain b^p from:

$$(b^p)^2 = (b_{11})^2 = \Sigma_{11} - \boldsymbol{b}_{12}\boldsymbol{b}_{12}' \tag{20}$$

where

$$\left(\boldsymbol{\Sigma}_{21} - \tfrac{\boldsymbol{b}_{21}}{b_{11}}\Sigma_{11}\right)' \left(\boldsymbol{\Sigma}_{21} - \tfrac{\boldsymbol{b}_{21}}{b_{11}}\Sigma_{11}\right) = \boldsymbol{b}_{12}\boldsymbol{Q}\boldsymbol{b}_{12}' \tag{21}$$

such that

$$\boldsymbol{b}_{12}\boldsymbol{b}_{12}' = \left(\boldsymbol{\Sigma}_{21} - \tfrac{\boldsymbol{b}_{21}}{b_{11}}\Sigma_{11}\right)' \boldsymbol{Q}^{-1} \left(\boldsymbol{\Sigma}_{21} - \tfrac{\boldsymbol{b}_{21}}{b_{11}}\Sigma_{11}\right) \tag{22}$$

where

$$\boldsymbol{Q} = \frac{\boldsymbol{b}_{21}}{b_{11}}\Sigma_{11}\frac{\boldsymbol{b}_{21}'}{b_{11}} - \left(\boldsymbol{\Sigma}_{21}\tfrac{\boldsymbol{b}_{21}'}{b_{11}} + \tfrac{\boldsymbol{b}_{21}}{b_{11}}\boldsymbol{\Sigma}_{\boldsymbol{21}}'\right) + \boldsymbol{\Sigma}_{22} \tag{23}$$

After obtaining b^p, we can identify b^q from equation 11. We then proceed by estimating equation 10, which allows us to see how a structural policy shock, instrumented by Z_t, impacts other variables in the reduced-form VAR.

C Third Appendix

C.1 Sources and Descriptions of Macroeconomic and Financial Data

Table C.1 presents a complete summary of the macroeconomic and financial country-level data used in this thesis paper, including data sources and variable descriptions. While most of the data is from Eurostat, it occasionally lacks data for some countries and time periods. Then, other databases are consulted. In particular, the OECD's iLibrary (Main Economic Indicators) is utilized. Other data sources can be found in table C.1. Country-level equity price indices are summarized in table C.2. The data covers the time period 2002-2019, unless otherwise stated. I standardize the HICP inflation, industrial production, and equity price indices to a base value of 100 in January 2010. Also the exchange rates are standardized to 100 in January 2010, for greater comparability between countries. Any missing values in the time series have been replaced by averages of adjacent values. The Hungarian short-term interest rate series contains 29 such replacements. Iceland's equity price index has seven missing values from December 2007 to June 2008, coinciding with the eruption of the 2008 Icelandic financial crisis. This may imply that potentially important variation is unaccounted for, which is a possible source of error.

C.2 Seasonal Adjustment of Time Series Data

To deseasonalize the core HICP inflation index (Eurostat) and the Icelandic industrial production index (OECD) I apply $S_{n\times m}$ seasonal filters to the time series data, using a multiplicative decomposition.[24] Assume the time series contains one trend component, one seasonal component, and one irregular (residual) component. In essence, the seasonal adjustment procedure can be described as follows: (1) Estimate the trend component using a 13-term symmetric moving average. Detrend the original series by dividing it by the estimated trend component. (2) Estimate the seasonal component by creating seasonal indices for all 12 months of the year and apply a 5-term $S_{3\times 3}$ seasonal filter. Center the seasonal component around one by estimating and dividing it by a 13-term moving average of the filtered series. Deseasonalize the series. (3) Estimate the trend component again by applying a 13-term Henderson filter. Detrend the series by dividing it by the new trend component. (4) Estimate the seasonal component again by applying a 7-term $S_{3\times 5}$ seasonal filter. Again, estimate and divide by a 13-term moving average of the filtered series to center the seasonal component around one. Divide the original series by the seasonal component. The end result is a seasonally adjusted version of the original time series.

[24]See MathWorks (a) and MathWorks (b) for details. The steps largely follow the procedure used in the X-12-Arima Program of the US Census Bureau, see Findley et al. (1998).

Table C.1: Summary of Macroeconomic and Financial Time Series Data

Variable	Source	Description
German Treasury Yields	Deutsche Bundesbank	Yields derived from the term structure of interest rates on listed German government bonds with annual coupon payments, residual maturity of one and two years.
Exchange Rate	Eurostat, ECB	Bilateral exchange rate; for non-euro countries, the price of one euro expressed in the domestic currency; for the eurozone, the price of one US dollar expressed in euros, from ECB statistics.
HICP Inflation	Eurostat	Index, 2010.01 = 100. Transformed into natural logarithmic form. Core inflation excluding energy, food, alcohol, and tobacco. Deseasonalized using S(n,m) filters.
Industrial Production	Eurostat, OECD	Index, 2010.01 = 100. Transformed into natural logarithmic form. Mining, quarrying; manufacturing; electricity, gas, steam and air-conditioning; excluding construction; from Eurostat. Seasonally and calendar adjusted. For Iceland, total index from OECD excl. construction is used, available until 2018.02, and deseasonalized using S(n,m) filters.
Unemployment Rate	Eurostat	Percentage of active population; seasonally adjusted. For Iceland, data available from 2003.01.
Equity Prices	OECD, see Table C.2	Index, 2010.01 = 100. Transformed into natural logarithmic form. Share prices based on main stock exchange index, determined using monthly averages of daily closing prices. For UK, Poland, data from the OECD; for other countries, see Table C.2. For Iceland, 7 missing values (2007.12-2008.06) replaced by average of adjacent values (2007.11,2008.07).
Short-Term Interest Rate	OECD, Eurostat, Bulgarian National Bank	Three-month money market rate; for Bulgaria, deposit rate (BGN) from BNB is used. For Hungary, Croatia, and Lithuania, data from Eurostat; for remaining countries, data from the OECD. For the eurozone, German yields are used. Missing values are replaced by the average of two adjacent values; for Hungary, 29 replacements, for Croatia, 1 replacement.
Shadow Rate	De Rezende and Ristiniemi (2018)	Estimated shadow rates without a lower bound constraint for the Euro Area, Sweden, and the United Kingdom, from De Rezende and Ristiniemi (2018). Daily values transformed into monthly averages.

Table C.2: Summary of Country-Level Equity Price Indices

Economy	Source	Index Name
Euro Area	ECB	Euro STOXX50
Bulgaria	Bulgarian Stock Exchange	SOFIX
Croatia	Zagreb Stock Exchange	CROBEX
Czechia	Prague Stock Exchange	PX
Denmark	Nasdaq OMX Nordic	OMX C20
Hungary	Budapest Stock Exchange	BUX
Iceland	Nasdaq OMX Nordic	OMXIPI
Lithuania	Nasdaq Baltic	OMX Vilnius
Norway	Oslo Børs	OBX
Sweden	Nasdaq OMX Nordic	OMX S30

D Fourth Appendix

D.1 Narrative Study of ECB Monetary Policy Announcements

Table D.1 presents quotes and decisions from 17 events which led to large reactions (either positive or negative) in the pure monetary policy or information elements of the high-frequency two-year yield shocks. The shocks can also be seen in Figure 1. The purpose of the narrative study is to shed light on the information content of ECB monetary policy announcements. The information in Table D.1 is taken from transcribed ECB press conferences. The selection of events is small and may not be representative of all 197 monetary policy announcements between 2002 and 2019, as the included dates were associated with unusually large shocks. Importantly, conclusions from this narrative study should only be viewed as suggestive — the aim is not to provide a comprehensive account of how ECB communication affects market expectations. Rather, it is to explore the content of monetary policy events which were associated with large shocks, and to see if I can find examples of statements which *may* have contributed to the measured reactions.

The content of some statements clearly justify the market reactions, like when the ECB conducts forward guidance for the first time in July 2013. The large and negative pure two-year yield shock suggests that markets revised their expectations toward lower future policy rates. Some events highlight that an interest rate increase (decrease) may, somewhat counterintuitively, be perceived as a negative (positive) shock, if markets expected the interest rate change to be larger. Shocks may also be small in magnitude if markets correctly priced in the monetary policy measure before announcement. Several of the greatest surprises took place in 2008, in the midst of the financial turmoil. During this time, markets seem to frequently revise their expectations, leading to large positive and negative spikes in the shock series. However, shocks at the height of the financial crisis in 2008, which was a situation characterized by great uncertainty, may be unrepresentative of the full sample of policy surprises.

In 2011, at the height of the European debt crisis, ECB President Trichet considers inflation risks to be on the upside. In response to questions about the worsening situation for the periphery countries, he asserts that his focus is to maintain price stability. From the market's perspective, the statements may have revealed ECB preferences for more restrictive monetary policy. In March 2011, there are positive reactions in both of the pure policy and information elements, suggesting that markets adjusted their expectations toward higher policy rates and higher inflation. In May 2011, there were negative shocks in both of the elements. The Q&A session reveals that there may have been expectations of a policy rate increase. Regarding the economic situation, Trichet asserts his focus on price stability. Potentially, this could explain the negative reaction in the information element, as less accomodative monetary policy would worsen the situation in the periphery countries. In August 2011, there is a clear risk of a worsening economic situation. Again, the information element has a negative reaction. In October, there is a positive pure policy shock. While the ECB kept its policy rates unchanged, markets seemed to expect a monetary easing.

In August 2012, there is a positive pure policy shock and a negative information shock. ECB President Draghi speaks of economic risks, which may contribute to the negative reaction in the information element. While the ECB kept its policy rates unchanged, the Q&A session reveals that markets may have expected rate cuts, especially in light of the famous "Whatever it takes" speech delivered by Draghi about a week earlier. Furthermore, the lack of action may have been perceived as a signal of ECB preferences for less accommodative policy than previously thought. The announcement in October 2015 led to a negative pure policy shock and a positive information shock. The former could potentially be explained by Draghi's confirmation that lowering the deposit rate below zero had been discussed. This could signal the possibility of more accomodative monetary policy in the future. At the same press conference, Draghi also states that the economy is in recovery and that this process is expected to continue. This may have contributed to the positive reaction in the information element. In December 2015, President Draghi presents a rate cut and an extension of the asset purchase programme, but markets seem to have expected even more accommodative monetary policy, leading to a large positive pure policy shock. In March 2016, Draghi explains that the economy is in recovery and that this is expected to proceed. There is a positive reaction in the information element. Lastly, in June 2018, there was a negative shock in the pure element of the German two-year yield. In the introductory statement, Draghi provides a clear forward guidance message, stating that interest rates are expected to remain at low levels for at least a year going forward.

Table D.1: Narrative Study of a Selection of ECB Monetary Policy Announcements

Date	Pure	Info	Note	Quote
9 January 2003	-0.5695	1.3732	No policy rate change. Duisenberg states that the "main scenario" is that real GDP growth gradually rises to levels close to potential and that he considers the current interest rates appropriate to maintain price stability.	"We judge the current monetary policy stance appropriate to maintain a favourable outlook for price stability in the medium term." Willem F. Duisenberg
5 June 2008	2.5579	2.0884	No policy rate change. Trichet argues "risks to the outlook for prices remain on the upside and have increased further". In response to a question, he states that interest rates may be increased at the next meeting.	"We will examine the situation very carefully and we will, in our next meeting, not exclude the possibility of increasing rates by a small amount. That is the situation which we are in: it is not certain, it is possible." Jean-Claude Trichet
3 July 2008	-3.7603	-1.6456	The key ECB rates were raised by 25 basis points. President Trichet cites upside risks to inflation as the main reason for this decision. Judging by the first question at the Q&A session, markets had already priced in the interest rate hike. The second question asks whether larger interest rate increases were discussed.	"Mr Trichet, last time you all but announced the rate hike for today and surprised the markets ... They then promptly priced in a series of rate hikes and we had comments from the ECB signalling: 'Don't expect a series of rate hikes now, if we deliver a rate hike, that doesn't mean that. . . '. The market clearly does not believe it." First Questioner, Q&A session.
7 August 2008	-1.1626	-1.9174	No policy rate change. Trichet argues inflation risks are on the upside. Several questioners ask about the risk of a recession and low growth; Trichet affirms that his priority is to maintain price stability.	"...we have only one needle in our compass. That needle is price stability, our definition of price stability ... We do not compare two needles, one of which being price stability and the other business activity or cyclical development ..." Jean-Claude Trichet

Continued on next page

Table D.1 – *Continued from previous page*

Date	Pure	Info	Note	Quote
8 October 2008	-0.9941	1.7978	The three key policy rates were cut by 0.50.	No press conference was held.
6 November 2008	2.3419	0.6238	The key policy rates were cut by 50 basis points. Given recent interest rate cuts by other central banks, the interest rate decrease may have been smaller than expected.	"... when the Bank of England has just cut interest rates by 150 basis points, one might almost be disappointed by a rate cut of only 50 basis points" First Questioner, Q&A session
2 July 2009	0.7032	-1.5391	No policy rate change. Questions at the Q&A session indicate that markets expect interest rates to remain unchanged. Inflation has become negative but Trichet expects this to be temporary. There are concerns of financial turmoil which may impact the real economy.	"[...] the latest data confirm a continued deceleration in monetary dynamics ... [This] supports the assessment of a slower underlying pace of monetary expansion and low inflationary pressures ... " Jean-Claude Trichet
3 March 2011	1.5831	1.5056	No policy rate change. Trichet discusses inflation risks and states that an interest rate increase at the next meeting is possible. In response to a question about whether a future interest rate increase would worsen the situation for the peripheral countries, Trichet asserts that price stability is the primary mandate.	"We mentioned that we are being very vigilant and and my understanding of the position of the Governing Council – fully in line with assessments made in the past - is that an increase in interest rates at the next meeting is possible." Jean-Claude Trichet

Continued on next page

Table D.1 – *Continued from previous page*

Date	Pure	Info	Note	Quote
5 May 2011	-1.7887	-1.2913	No policy rate change. A number of questioners ask whether there were any calls to raise interest rates, in light of higher inflation and high inflation expectations. Others ask about the situation in the periphery countries. Trichet asserts that price stability is the main objective.	"With interest rates across the entire maturity spectrum remaining low and the monetary policy stance accommodative, we will continue to monitor very closely all developments with respect to upside risks to price stability." Jean-Claude Trichet
4 August 2011	-0.6414	-1.2028	No policy rate change. While President Trichet considers inflation risk to be on the upside, there is a situation of rising global uncertainty. He also emphasizes the need for structural reform to improve longer-term growth potential across member countries.	"On the real economy ... we were expecting a progressive slowing-down. In my understanding, we will observe this slowing down in the second quarter ... we are going through a period of a high level of uncertainty" Jean Claude Trichet
6 October 2011	1.7141	0.6164	No policy rate change. Trichet states that inflation is likely to be higher than target, but economic growth is likely to be dampened. Several questioners ask whether a policy rate cut was discussed.	" Mr. Trichet, there were great expectations for a rate cut ... " Questioner, Q&A session
2 August 2012	2.0597	-1.7684	No policy rate change. Draghi argues the euro area risks are on the downside, with growth lower than expected. In response to the first question, Draghi states that the Governing Council discussed lowering interest rates, but decided this was not the time.	"The markets don't seem to be very impressed. [...] So, when you said last week you would do whatever it takes to save the euro, what exactly did you have in mind?" Questioner, Q&A session

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Table D.1 – *Continued from previous page*

Date	Pure	Info	Note	Quote
4 July 2013	-1.7652	0.7142	No policy rate change. The ECB conducts forward guidance for the first time.	"... our monetary policy stance will remain accommodative for as long as necessary. The Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time" Mario Draghi
22 October 2015	-2.0069	1.0481	No policy rate change. Draghi argues the economy is in recovery. He highlights downside risks to inflation. In response to a question, he states that lowering the deposit facility rate below zero has been discussed.	"The Governing Council is willing and able to act by using all the instruments available within its mandate if warranted in order to maintain an appropriate degree of monetary accommodation" Mario Draghi
3 December 2015	3.9305	-1.1697	The asset purchase programme is extended and the deposit rate is cut by 10 bp to -0.30%. Draghi states that inflation has been lower than expected. The first questioner states that markets expected a greater stimulus package.	"Why didn't you do more, given how much you've warned about the risks of low inflation? Why didn't you raise the monthly purchase amount? Why didn't you cut the deposit rate more?" First Questioner, Q&A session
10 March 2016	0.3244	1.4732	All policy rates were cut by at least 5 bp. Large-scale asset purchases were expanded. Draghi states that the recovery is expected to proceed at a moderate pace. While risks are tilted to the downside, the policy measures and past structural reforms are expected to support domestic demand.	"... rates will stay low, very low, for a long period of time ... From today's perspective, and taking into account the support of our measures to growth and inflation, we don't anticipate that it will be necessary to reduce rates further." Mario Draghi

Continued on next page

Table D.1 – *Continued from previous page*

Date	Pure	Info	Note	Quote
14 June 2018	-1.3038	0.6422	No policy rate change. Quantitative easing will continue throughout the next months. Draghi states that the ECB expects inflation to keep converging toward the aim, and will keep the monetary policy accomodative	"... we decided to keep the key ECB interest rates unchanged and we expect them to remain at their present levels at least through the summer of 2019 and in any case for as long as necessary." Mario Draghi

D.2 First-Stage Relationships for Information Elements

Table D.2 presents first-stage relationships for the German two-year yield residuals and four types of ECB shocks: uncleansed shocks in the German two-year yield, the information element of the German two-year yield shocks, the path factor, and the Delphic factor. The euro area reduced-form VAR contains the German two-year yield, exchange rates, equity prices, industrial production, unemployment, HICP inflation, and the shadow rate. The table shows coefficients from an OLS regression of the policy equation-residuals of the reduced-form VAR on the external instrument.

Table D.2: First-Stage Regressions —
ECB Signals About the Inflation Outlook

	Euro Area DE2Y Residual			
DE2Y	0.0609***			
	(0.0128)			
Info DE2Y		0.0873***		
		(0.0214)		
Path			0.0517***	
			(0.0118)	
Delphic				0.0668***
				(0.0222)
Observations	214	214	214	214
Adjusted R^2	0.120	0.088	0.085	0.054
Robust F-stat	22.640	16.560	8.960	9.079
Wald stat	15.9458	13.1303	9.5696	7.4148

Heteroskedasticity-robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Regression of policy-equation residuals from euro area reduced-form VAR on four types of external instruments. The reduced-form VAR contain German two-year yields, exchange rates, equity prices, industrial production, unemployment rates, HICP inflation, and the domestic monetary policy stance. Constant terms omitted for presentation convenience.

E Fifth Appendix

E.1 Effects of Information Shocks and Delphic Forward Guidance

Figure E.1 presents euro area impulse responses to four ECB shocks which lower the German two-year yield by 100 basis points. In panel a), uncleansed shocks in the German two-year yield around ECB announcements is used as an external instrument. In panel b), the information element of the two-year yield shocks is used as an external instrument. In panel c), the Gürkaynak et al. (2005) path factor is used as an external instrument. Finally, in panel d), the Delphic forward guidance component of the path factor is used as an external instrument. First-stage Wald statistics are presented below the figure.

E.2 Spillovers of Odyssean ECB Forward Guidance

Figure E.2 presents Danish, Swedish, and Norwegian impulse responses of exchange rates, equity prices, industrial production, unemployment, HICP inflation, and the domestic monetary policy stance to an Odyssean ECB forward guidance shock which lowers the German two-year yield by 100 bais points. The impulse response of the German two-year yield is omitted for presentation convenience. First-stage Wald statistics are presented below the figure.

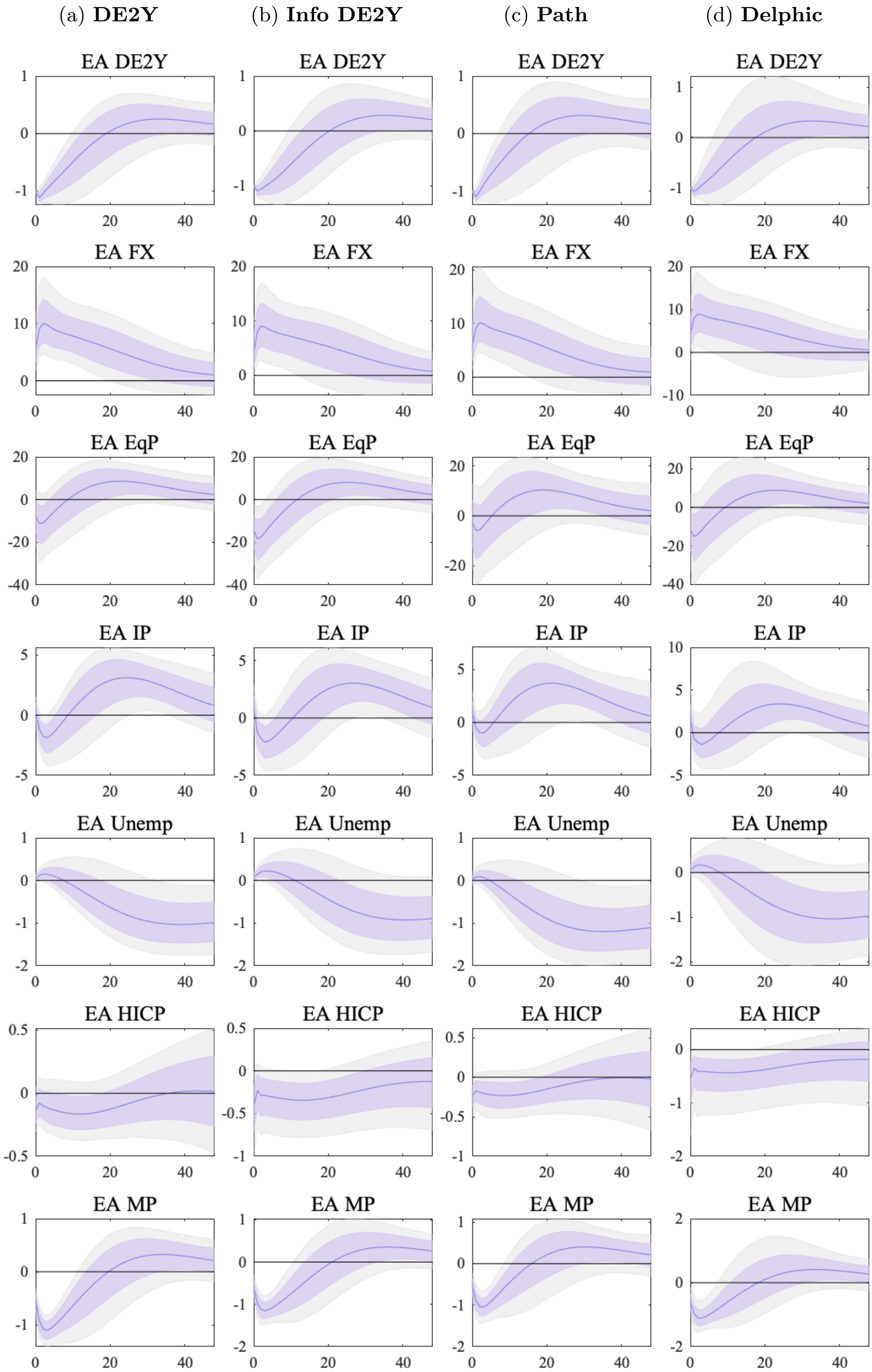
E.3 Extended Country Sample — Macroeconomic Outcomes

Figure E.3 presents impulse responses of exchange rates, equity prices, industrial production, unemployment, HICP inflation, and the domestic monetary policy stance for the extended country sample. The countries are, in order of presentation: Iceland; United Kingdom; Bulgaria; Croatia; Czechia; Hungary; Lithuania; and Poland. The pure two-year yield shock series is used as external instrument. The impulse response of the German two-year yield is omitted for presentation convenience. First-stage Wald statistics are presented below the figure.

E.4 Extended Country Sample — The Relative Monetary Policy Stance

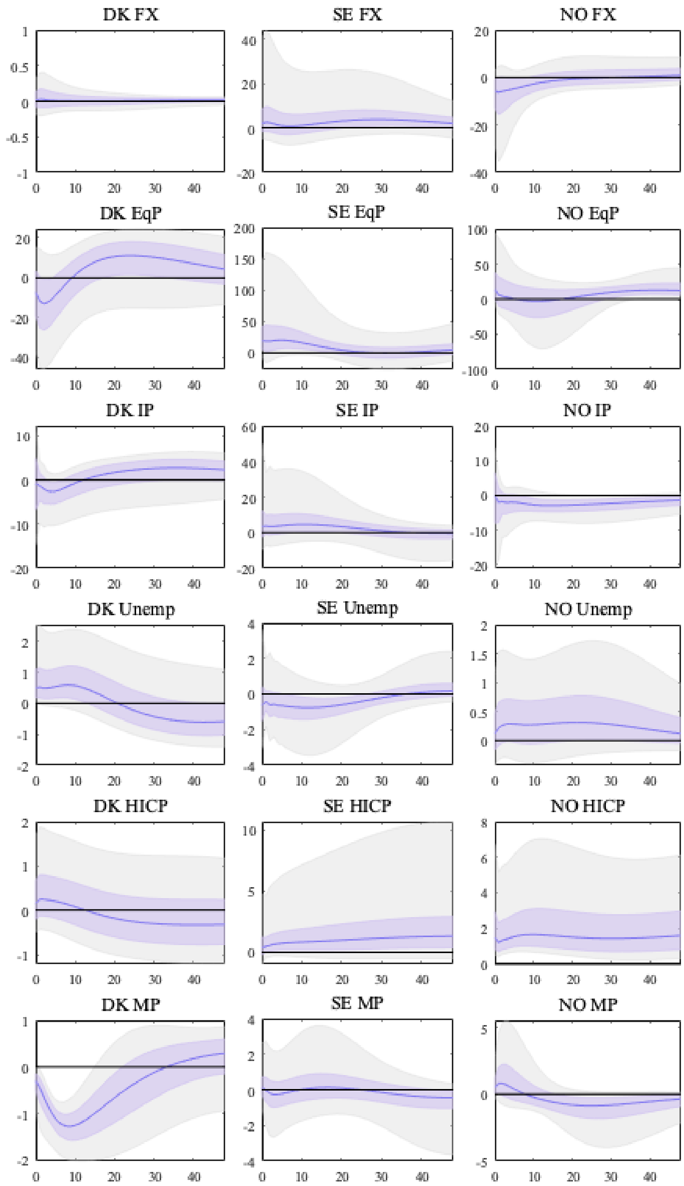
Figure E.4 presents impulse responses of the relative monetary policy stance for the extended country sample. The shadow rate is used for the euro area and the United Kingdom; for all other countries, short-term yields are used. The reduced-form VAR also contains the German two-year yield, exchange rates, equity prices, industrial production, unemployment, and HICP inflation. The pure two-year yield series is used as external instrument. First-stage Wald statistics are presented below the figure.

Figure E.1: Impulse Responses to ECB Signals About the Inflation Outlook



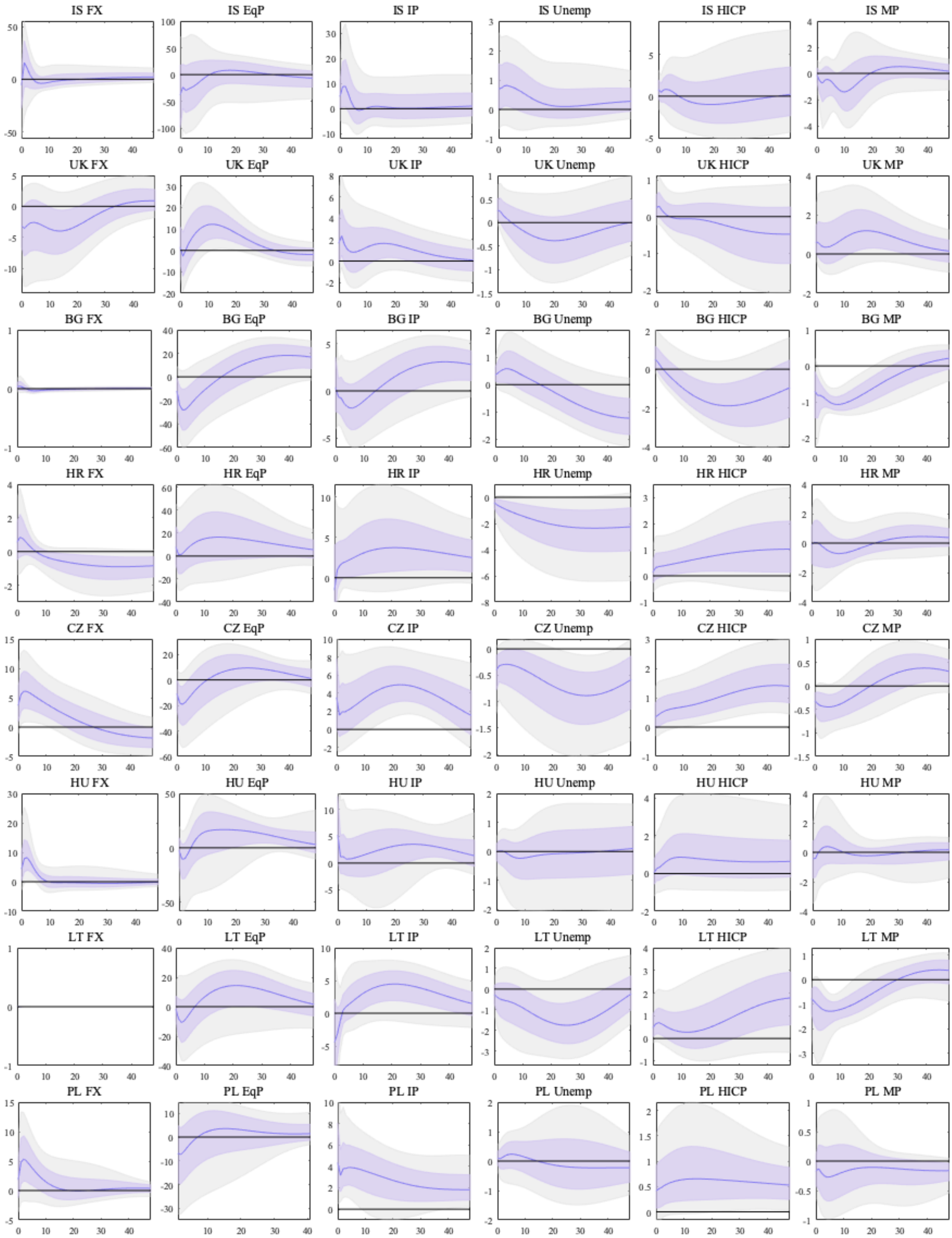
Note: Impulse responses to an expansionary ECB forward guidance shock. SVAR-IV sample: 2002.01-2019.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi^2_1 = 0.9889; 2.7055$. First-stage Wald statistic: For DE2Y, 15.9458; for Info DE2Y, 13.1303; for Path, 9.5696; for Delphic, 7.4148.

Figure E.2: Spillovers of Odyssean ECB Shocks



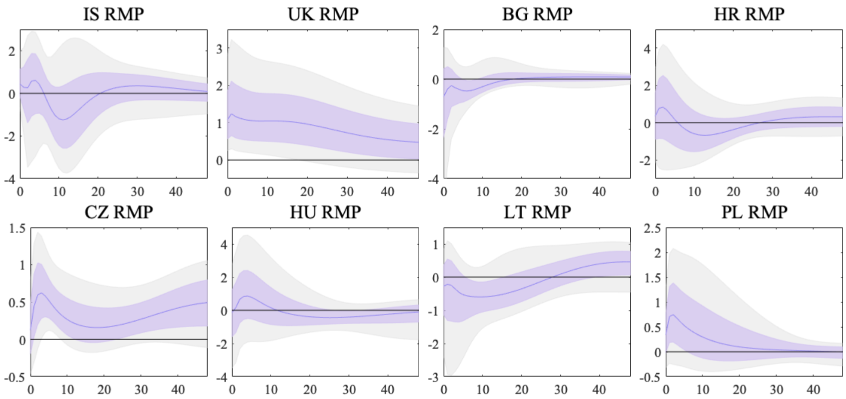
Note: Impulse responses to an expansionary ECB forward guidance shock. External instrument: Odyssean factor. SVAR-IV sample: 2002.01-2019.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$. First-stage Wald statistic: DK 4.5457; SE 3.2498; NO 4.4195.

Figure E.3: Spillovers on Extended Country Sample



Note: Impulse responses to an expansionary ECB forward guidance shock. External instrument: pure DE2Y shocks. SVAR-IV sample: 2002.01-2019.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$. First-stage Wald statistics: IS 5.9209; CH 4.4761; UK 7.4168; BG 6.7084; HR 6.4431; CZ 7.9353; HU 4.8662; LT 6.4907; PL 7.0477.

Figure E.4: Relative Monetary Policy Stance in Extended Sample



Note: Difference between domestic monetary policy stance and eurozone shadow rate. SVAR-IV 2002.01-2019.12; for Iceland, 2003.01-2018.12; for Lithuania, 2002.01-2014.12. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$. First-stage Wald statistics: IS 6.0458; UK 7.8877; BG 5.0474; HR 6.6230; CZ 8.3582; HU 4.8946; LT 5.7406; PL 7.1592.

F Sixth Appendix

F.1 Robustness Checks for Economic Outcomes

Robustness checks for the euro area, Denmark, Sweden, and Norway are presented in Figure F.1, F.2, F.3, and F.4, respectively. The effect on the policy indicator is included in the results for the euro area; for Sweden, Norway, and Denmark, the two-year yield's impulse response is excluded for presentation convenience. The German two-year yield is employed as policy indicator in all estimations, except for panel a).

In panel a) of each figure, the SVAR-IV estimation is performed with the German one-year yield as policy indicator, and an exogenous one-year yield shock series as external instrument. The sample time period goes from June 2003 to December 2019.

In panel b) of each figure, exogenous two-day shocks in the German two-year yield are used as external instrument.

In panel c) of each figure, the external instrument is constructed as exogenous sums of shocks in the German two-year yield, from the press release and press conference windows of the ECB's announcements.

In panel d) of each figure, four lags are used instead of two. Otherwise, the estimation follows the baseline specification.

In panel e) of each figure, six lags are used instead of two. Otherwise, the estimation follows the baseline specification.

In panel f) of Figure F.1 and F.3, the euro area and Swedish short-term yields are as proxies for the domestic monetary policy stance, instead of the shadow rate measures by De Rezende and Ristiniemi (2018).

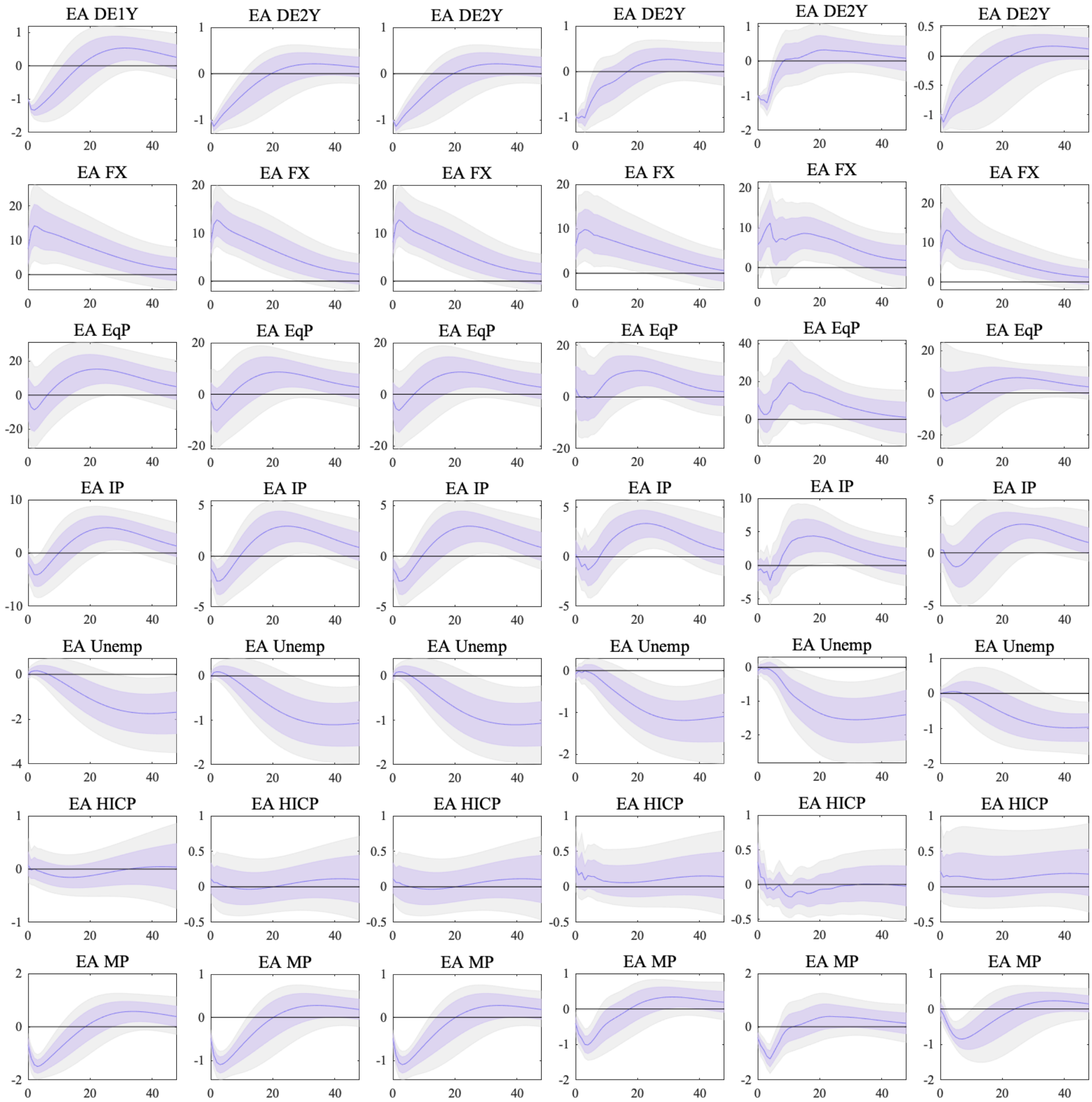
First-stage Wald statistics are presented below each figure.

F.2 Robustness Checks for the Relative Monetary Policy Stance

Panel a) to f) of Figure F.5 present the same robustness checks as above for Denmark, Sweden, and Norway; the only difference is that the relative as opposed to the absolute monetary policy stance is used. Only the impulse response of the relative monetary policy stance is shown. In panel f), short-term yields are used for all countries. First-stage Wald statistics are presented below the figure.

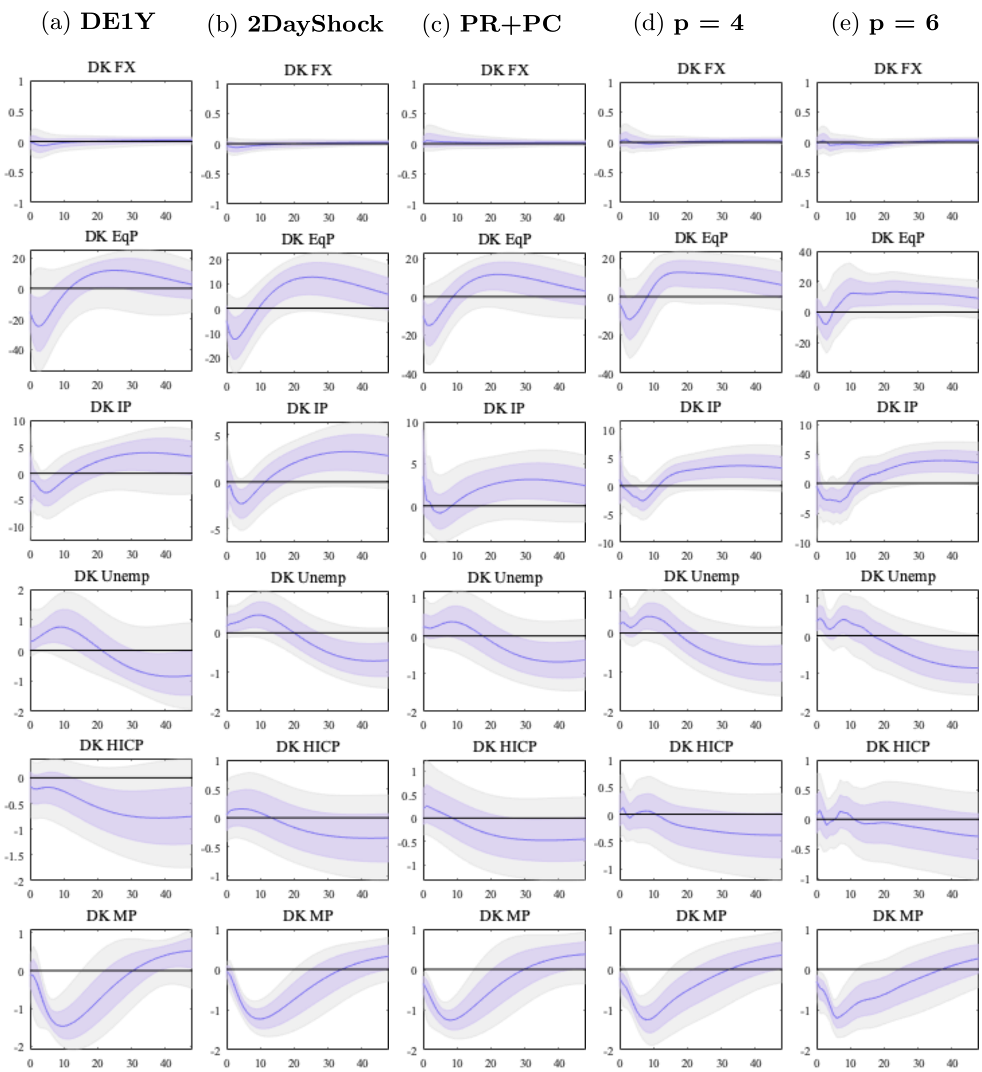
Figure F.1: Robustness of Results for the Euro Area

(a) **DE1Y** (b) **2DayShock** (c) **PR+PC** (d) $\mathbf{p = 4}$ (e) $\mathbf{p = 6}$ (f) **STR**



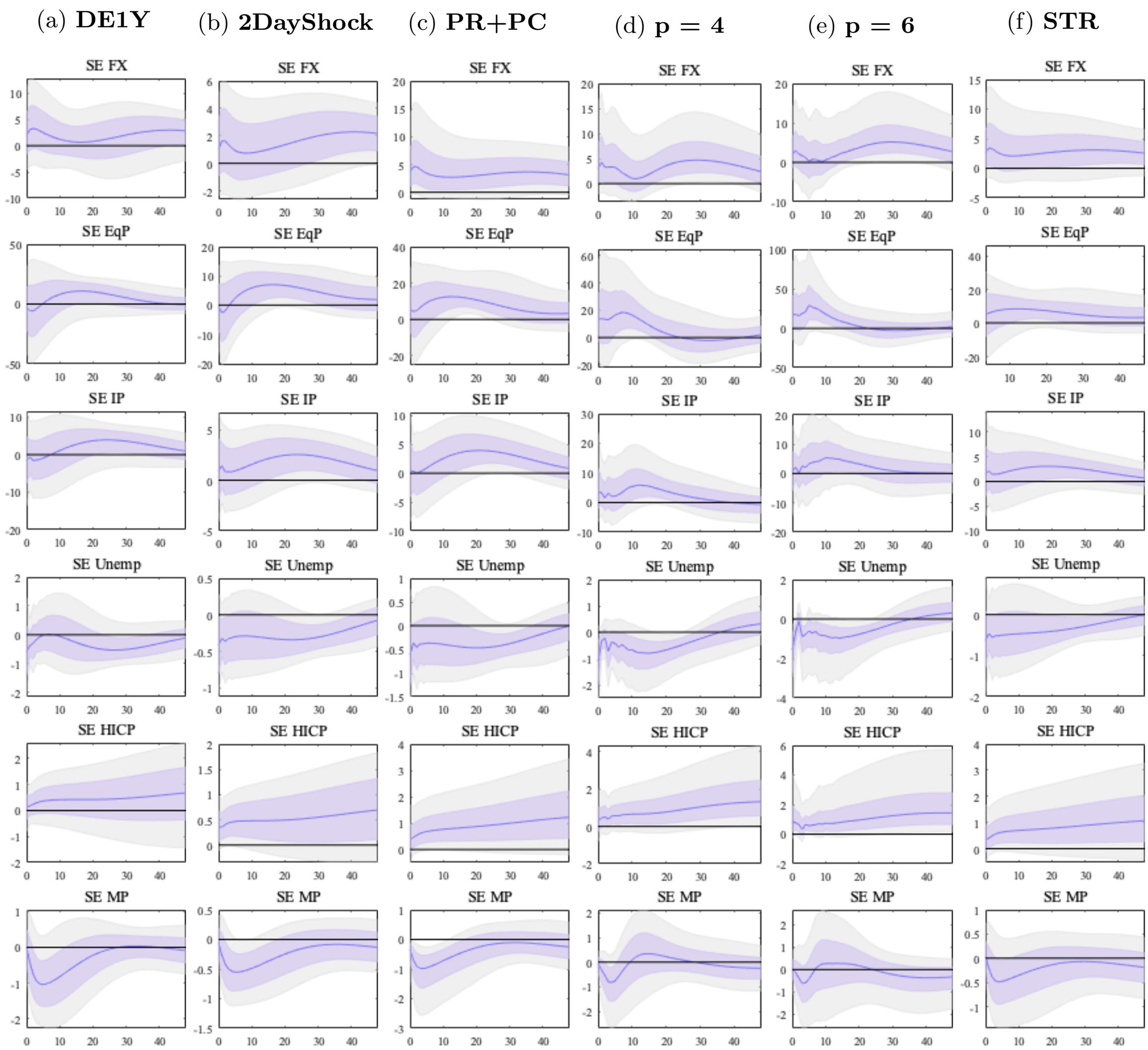
Note: Robustness checks for euro area results. SVAR-IV sample: 2002.01-2019.12, unless otherwise stated. a) One-Year Yield; SVAR-IV sample 2003.06-2019.12. Wald = 9.6703. b) Two-day shock in Pure DE2Y. Wald = c) Pure DE2Y press release window + press conference window shocks. Wald = d) Four lags. Wald = 11.8517 e) Six lags. Wald = 10.5716 f) Short-term yield as measure of domestic MP stance. Wald = 8.3769. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$.

Figure F.2: Robustness of Results for Denmark



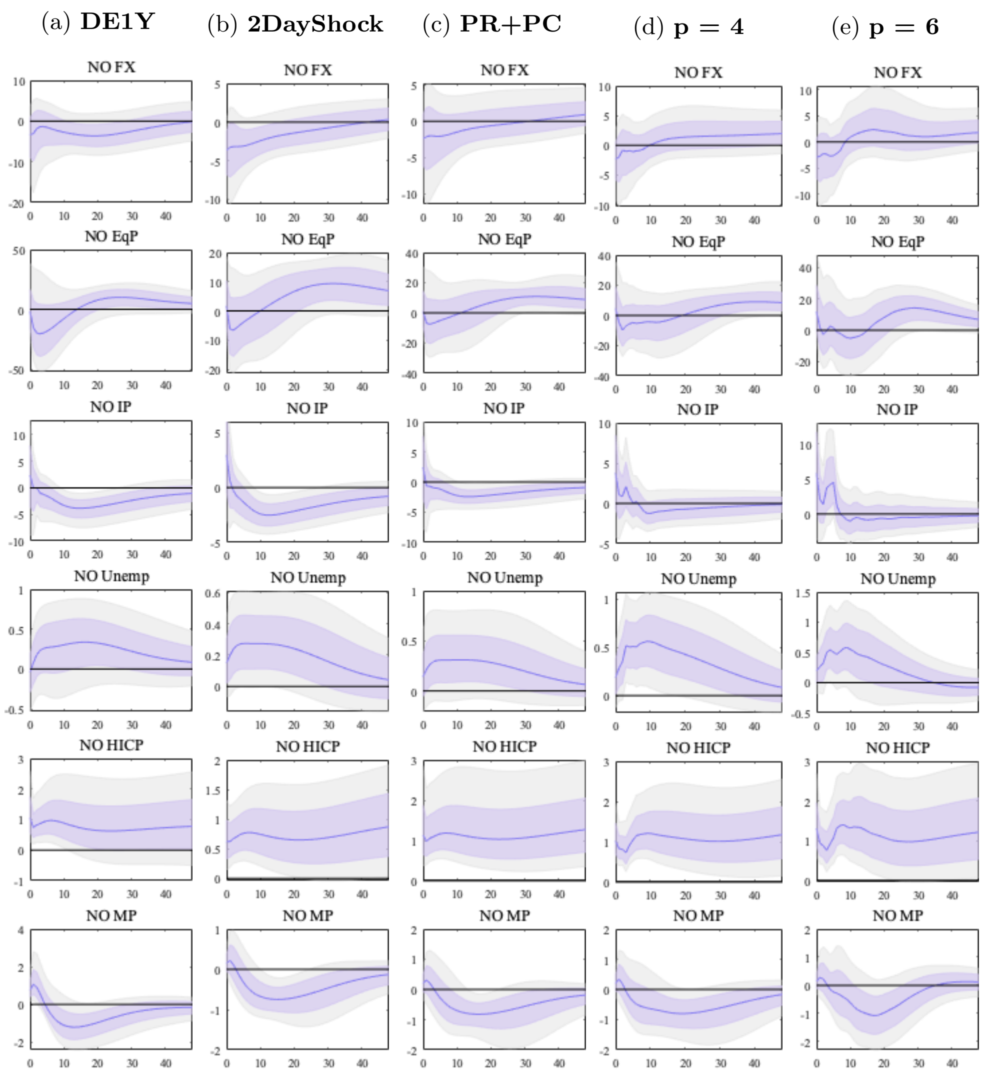
Note: Robustness checks for Danish results. SVAR-IV sample: 2002.01-2019.12, unless otherwise stated. a) One-Year Yield; SVAR-IV sample 2003.06-2019.12. Wald = 7.6348. b) Two-day shock in Pure DE2Y. Wald = 13.0345 c) Pure DE2Y press release window + press conference window shocks. Wald = 7.4944 d) Four lags. Wald = 7.2025 e) Six lags. Wald = 7.3536 Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi^2_1 = 0.9889; 2.7055$.

Figure F.3: Robustness of Results for Sweden



Note: Robustness checks for Swedish results. SVAR-IV sample: 2002.01-2019.12, unless otherwise stated. a) One-Year Yield; SVAR-IV sample 2003.06-2019.12. Wald = 6.4387. b) Two-day shock in Pure DE2Y. Wald = 12.6106. c) Pure DE2Y press release window + press conference window shocks. Wald = 6.4436 d) Four lags. Wald = 5.4161. e) Six lags. Wald = 4.6488. f) Short-term yield as measure of domestic MP stance. Wald = 5.7466. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi^2_1 = 0.9889; 2.7055$.

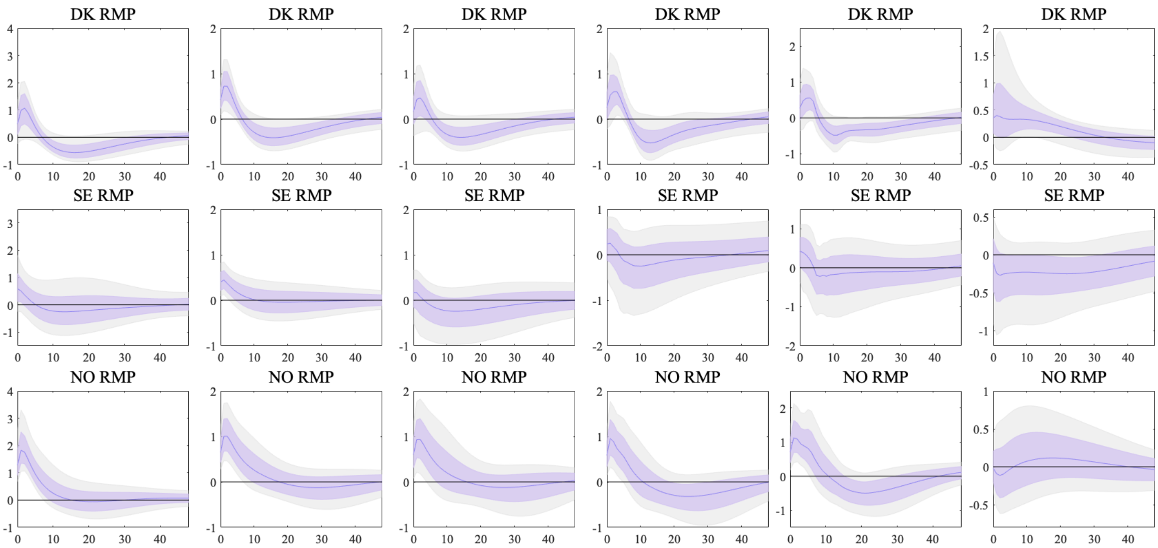
Figure F.4: Robustness of Results for Norway



Note: Robustness checks for Norwegian results. SVAR-IV sample: 2002.01-2019.12, unless otherwise stated. a) One-Year Yield; SVAR-IV sample 2003.06-2019.12. Wald = 8.9369. b) Two-day shock in Pure DE2Y. Wald = 13.8159. c) Pure DE2Y press release window + press conference window shocks. Wald = 7.9124. d) Four lags. Wald = 9.6320 e) Six lags. Wald = 9.4752. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi^2_1 = 0.9889; 2.7055$.

Figure F.5: Robustness of the Relative Monetary Policy Stance

(a) **DE1Y** (b) **2DayShock** (c) **PR+PC** (d) **p = 4** (e) **p = 6** (f) **STR**



Note: Robustness checks for relative monetary policy stances. SVAR-IV sample: 2002.01-2019.12, unless otherwise stated. a) One-Year Yield; SVAR-IV sample 2003.06-2019.12. Wald: DK 7.9353; SE 6.3610; NO 8.3675. b) Two-day shock in Pure DE2Y. Wald: DK 13.2490; SE 13.3360; NO 14.3216. c) Pure DE2Y press release window + press conference window shocks. Wald: DK 7.8487; SE 6.9977; NO 8.7875. d) Four lags. Wald: DK 6.7917; SE 6.3853; NO 9.9815. e) Six lags. Wald: DK 6.6584; SE 6.3259; NO 10.4835. f) Short-term yield as measure of domestic MP stance. Wald: DK ; SE 6.0857; NO 9.7878. Shaded areas correspond to 68% and 90% weak-instrument robust confidence intervals, critical $\chi_1^2 = 0.9889; 2.7055$.