Measuring the Signaling Effect of the ECB's Asset Purchase Programme at the Effective Lower Bound

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Abstract

This paper analyses the signaling effect of the European Central Bank's (ECB) statements related to its asset purchase programme (APP) on market expectations for the future path of short-term interest rates in the euro area. Considering a broad set of event days and daily changes in euro area stock indices as surprise reactions to the statements, an event-study analysis is employed to capture the changes in country-specific short-term interest rate expectations, as extracted from an effective lower bound (ELB) consistent shadow-rate term structure model. The empirical results generally support the presence of signaling effects in the euro area, but the estimated effectiveness of the channel has a considerable degree of uncertainty. Regarding country-specific differences, the reaction of interest rate expectations in the periphery countries tends to be stronger for dovish APP statement surprises, and thus these countries may benefit more from the signaling channel. Lastly, the responses of interest rate expectations to APP statement surprises are found to vary considerably depending on the identification strategy of the APP statements, which ultimately shows that these conclusions based on the empirical results are likely to be fragile.

Keywords: Quantitative Easing, Asset Purchase Programme, European Central Bank, Shadow-Rate Term Structure Model, Signaling Channel

1 Introduction

Starting after the global financial crisis, central banks in many advanced economies have been setting policy rates at record low levels. As conventional monetary policy lost its power to lower short-term interest rates and yields of financial assets at the effective lower bound (ELB), central banks began to pursue a policy of purchasing substantial quantities of financial assets, a policy commonly known as quantitative easing (QE), aimed at lowering long-term interest rates to ease financial conditions and stimulate the economy.

On 22 January 2015, the European Central Bank (ECB) joined other central banks in carrying out QE through its Asset Purchase Programme (APP) in order to combat the ongoing economic downturn and historically low inflation in the euro area.[1] While the APP has successfully lowered long-term euro area yields so far, the key question for policymakers and researchers in this regard is how the transmission mechanism of the APP works. The literature emphasizes the role of two key transmission channels which broadly ease financial conditions.

The first channel is known as the portfolio balance channel, through which the APP reduces term premiums of long-term sovereign yields in order to push investors towards riskier assets, thereby reducing a wide range of interest rates and yields and ultimately leading to lower financing costs on capital markets. At the same time, the compression of yields to a bank's securities leads to an increase in the supply of bank loans, resulting in lower borrowing costs for households and companies. While some publications, such as Thornton et al. (2014), find no support for the portfolio balance channel, a large body of literature, mostly event studies of the impact of QE announcements on bond yields and interest rates, support the view that there is a strong portfolio balance channel. Prominent examples include Gagnon et al. (2011), Joyce et al. (2011), and Andrade et al. (2016) for the US, the UK, and the euro area. Therefore, the standard view shared to date by policy makers and many researchers is that QE works primarily through the portfolio balance channel.

The second channel is the signal channel, which is a form of forward guidance used by central banks to influence market participants' expectations about future short-term interest rates. As stressed by Bernanke et al. (2004), one explanation is that announcements of asset purchases directly signal market participants that short-term interest rates will be kept at the effective lower bound for a longer period of time. Another explanation is that announcements of asset purchases signal a more pessimistic economic outlook by the central bank. In any case, announcements of asset purchases eventually lead to expectations of lower interest rates. Consequently, the signaling channel directly stimulates ag-

[1] Since a QE program such as the APP is defined as a broad-based asset purchase program, the impact of other smaller purchase programs such as CBPP1/CBPP2, SMP, LTRO/TLTRO, and other instruments is not considered in this paper.

gregate demand, since investment and consumption decisions depend on the future path of short-term interest rate expectations. On the other hand, the signaling channel pushes down all longer-term interest rates via the expectation hypothesis largely through lower short-term interest rate expectations. In contrast to the portfolio balance channel, the effectiveness of the signaling channel is uncertain to date (Gambetti and Musso, 2017).[2] In fact, researchers are not only in disagreement on the size and persistence of the signaling effect, but also on whether the signal channel is actually operative. Empirical evidence provided by papers such as Krishnamurthy and Vissing-Jorgensen (2011) and Bauer and Rudebusch (2014) find evidence for a strong signaling channel in the US, whereas Gagnon et al. (2011) find virtually no support for it. Regarding the UK's QE program, Christensen and Rudebusch (2012) report a negligible role of the signaling channel. As for the euro area, Deutsche Bundesbank (2016) reports a growing importance of the signaling channel over time, and Andrade et al. (2016) find that the announcement of the introduction of the APP reduced substantially the survey forecasts of short-term interest rates, whereas Urbschat and Watzka (2017) and Altavilla et al. (2015) find a negligible signaling effect measured as the change in Overnight Index Swap (OIS) rates at all maturities.

However, in contrast to the previous literature that focusses on the earlier phase of the APP, which mostly contained dovish statements, it has become necessary to distinguish between statements that are perceived as rather hawkish and those that are perceived as more dovish, given that the ECB has been cautiously adding elements associated with a tighter monetary stance in its APP-related forward guidance to prepare the markets for the exit from the stimulus in the wake of economic recovery and rising inflation in the euro area from the second half of 2016 onwards.[3] As suggested by Glick and Leduc (2012), QE announcements associated with an easier monetary stance tend to reduce long-term interest rates, while QE announcements associated with a tighter monetary stance lead to increases in long-term interest rates. Regarding the transmission mechanism through which QE affects long-term interest rates, these statements are also likely to have different signaling effects on the expected future path of short-term interest rates. More specifically, the signaling channel does not necessarily have an expansionary effect, but may also have an contractionary effect.

[2] Besides the signaling and portfolio balance channels, there are other transmission channels of QE which concentrate on specific market segments or objectives. The credit channel describes increasing willingness on the part of banks to provide credit through increasing banking assets and through increasing the assets of borrowers. The exchange rate channel describes the situation in which QE makes domestic bonds less attractive for foreign investors. Hence, the demand for domestic currency will fall, which will lead to a depreciation of the domestic currency, which in turn will stimulate demand from abroad. The re-anchoring channel is related to the ability of QE to increase inflation expectations via the central bank's commitment to fulfill its inflation target. However, as the credit channel and the exchange rate channel work through decreasing yields triggered by asset purchases, they can be regarded as sub-channels of the portfolio balance channel. The re-anchoring channel can be classified as being within the signaling channel category, since it works through a commitment of the central bank. See Gambetti and Musso (2017).

[3] For example, Mr Draghi said in the opening statement to a press conference on 08.09.2016: 'Meanwhile, the Governing Council tasked the relevant committees to evaluate the options that ensure a smooth implementation of our purchase programme.' which is considered to be a cautiously tapering statement.

The second challenge in estimating the signaling effect is to examine how it affects the individual countries of the euro area. So far, most papers dealing with the APP employ changes in OIS rates to quantify the signaling effect in the euro area.[4] An implication of using these rates is that the same level of short-term interest rate expectations is expected throughout the euro area, which sidelines the role of country-specific fundamentals in shaping market participants' interest rate expectations. As stressed by Andritzky (2012), the structure of government debt has been re-nationalised in the euro area since the financial crisis, resulting in a shift in the ownership of sovereign bonds back towards domestic holders. At the end of 2016, the sovereign debt share held by domestic holders in the major economies of the euro area stood at 40% to 70%, according to Eurostat. As domestic holders in part build their expectations significantly on domestic macroeconomic releases, their country-specific short-term interest rate expectations, embedded in government bond yields, should be taken into account. A number of event studies, such as Connolly and Kohler (2004) and Gürkaynak et al. (2005), investigating the driving forces of short-term interest rate expectations emphasize the role of domestic and foreign macroeconomic news in explaining changes in short-term interest rate expectations over time. Consequently, it is appropriate to explore the impact of the signaling channel on country-specific expected future path of short-term interest rates embedded in the euro area sovereign bond yields.

The aim of this paper is to shed new light on the signaling effects of APP statements on the expected future path of short-term interest rates. First, a novel aspect of this paper is that the dovish or hawkish tone expressed in APP statements is taken into account in order to allow a quantitative assessment of the APP's signaling effect by using reactions of euro area stock indices on identified event dates. Second, an ELB-consistent shadow-rate arbitrage-free dynamic term-structure model is employed to extract country-specific future short-term interest rate expectations embedded in the euro area sovereign zero-coupon bond yields. Finally, an event-study regression analysis is implemented in order to assess the impact of dovish and hawkish APP statement surprise on the estimated country-specific short-term interest rate expectations.

In a nut shell, while the empirical results generally support an operating signaling channel in the euro area, the estimated effectiveness of the channel is associated with a considerable degree of uncertainty. First, the results shows that the APP's signaling channel have effectively affected the future path of short-term interest rate expectations throughout the euro area, which is in direct contradiction with the results of Urbschat and Watzka (2017) and Altavilla et al. (2015). Second, the main result contributing to the literature is that the signaling effect may have different quantitative impacts on the future path of interest rate expectations in core and peripheral countries. The expansion-

[4] OIS are highly liquid instruments that enable financial institutions to exchange the overnight rate for a fixed interest rate for a wide range of maturities without having to change the terms of the corresponding loans. As such, OIS rates reflect the market-based expectations of the future path of short-term interest rates for given maturities. See European Central Bank (2014).

ary side of the signaling effect appears to be stronger in peripheral countries, while the contractionary side is more pronounced in core countries. One possible explanation for this difference in signaling effects might be the economic fragmentation between the core and the periphery, which would influence the the perceptions by market participants of the ECB's economic outlook for the euro area, embedded in the APP statements. A dovish APP statement surprise implies that the outlook is worse than expected by the markets, while a hawkish APP statement surprise indicates a better than expected outlook. Therefore, market participants in stressed peripheral countries are more likely to be more concerned about a dovish statement surprise, and may find a hawkish statement surprise less credible. This finding is consistent with De Santis (2016), which states that the periphery countries benefited more than core countries from APP statements. Third, by decomposing the future path of interest rate expectations, the results show that short-term interest rate expectations in the short- and medium-term up to three years ahead reacted the most to the APP statements. However, a possible omitted variable bias and the partly implausible responses of interest rate expectations in Portugal and Ireland suggest that these empirical results should be interpreted with caution. Lastly, the sensitivity of the empirical results to the identification strategy of the APP statements will be examined. The responses of interest rate expectations to APP statement surprises is found to vary considerably, depending on the choice of the measure of the degree of the surprise, as well as of the event days, ultimately revealing that conclusions based on the empirical results are likely to be fragile.

The rest of this paper is structured as follows. Section 2 explains the identification scheme. Section 3 describes the process of extracting the interest rate expectations, and presents the empirical results. Section 4 tests the robustness of the results. Section 5 concludes.

2 Identification of APP Statement Surprise

2.1 Identifying Event Days

Identifying the impact of QE is a challenging task. As stressed by Swanson (2017), since financial markets are forward looking, only the surprise component of an announcement should affect market prices. Consequently, the lack of an announcement could also surprise markets if a statement was widely expected. Acknowledging this, Swanson (2017) uses a rotated factor model to identify QE and forward guidance shocks in the US. In contrast, most of the literature relies on the narrative approach, which quantifies the impact of QE as changes in certain asset prices observed over a time window

around identified QE-related events.[5] Following this approach, the identification of APP statement surprise consists of two steps. First, APP-related event dates are to be identified. In this regard, prominent works such as Gagnon et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011) only consider official press statements for event identification. While this approach may be appropriate for identifying US and UK QE announcements, owing to their relatively unanticipated nature at their own times, the identification of APP-related event dates is more challenging against the background that the start of APP, in early 2015, had already been communicated to the market in 2014. Therefore, this approach tends to underestimate the number of APP surprises since only considering the ECB's official releases would neglect the presence of market anticipations. If an official statement is widely anticipated by market participants, then it would be already priced in, and asset prices would not react significantly. Other works, such as Altavilla et al. (2015) and De Santis (2016), apply a news search-engine based approach to identify events. That is, they use news search engines such as Factiva and Bloomberg to estimate a news variable, defined as the sum of all news based on a set of APP-related keywords. This approach may be better at capturing market expectations and therefore anticipation effects, but it also tends to overidentify APP-related events. As Urbschat and Watzka (2017) point out, a potential concern with this approach is that the number of news events is highly correlated with any Governing Council meeting, leading to a potential overidentification of events.

To avoid, as much as possible, underestimating or overestimating APP-related events, the identification scheme in this paper is as follows. As for the start of the event timeline, the beginning of the APP statements dates back to 2014 since throughout 2014 Mr Draghi made a series of statements in which the start of QE conditional upon the future path of inflation expectations was hinted at. Overall, the timeline includes all APP-related Governing Council decisions as well as press conferences and releases available in the media section of the ECB's website, and statements made by Mr Draghi including hints of APP-related information extracted from the news search engine Factiva. To reduce the flood of news, the news filters were set as follows: Company was set to 'ECB', the industry was set to 'central banking', and the source was set to 'Reuters'. Due to its length, the APP-related event timeline is found in the Appendix. The advantage of this identification scheme is that only relevant event days are likely to be considered, as it is known that official press statements and statements made by Mr Draghi are reported by the major news agencies, such as Reuters, and closely monitored by the financial markets, whereas statements made by other Governing Council members are not accounted for in the timeline since they are unlikely to be monitored closely by the financial markets.

Nonetheless, some potential issues arising from this identification scheme should

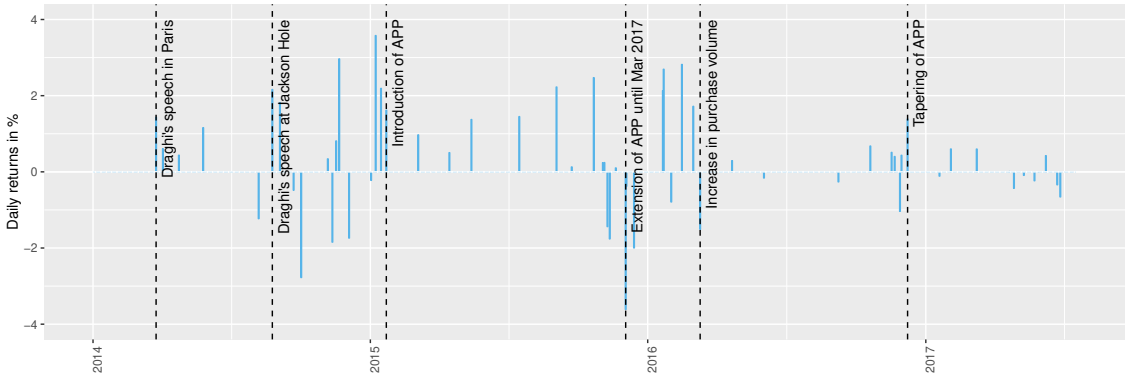
[5] So far there is no canonical surprise measure of QE policy. Aside from studies using asset prices for capturing policy surprises, some studies, such as Altavilla and Giannone (2017), use survey data, while other studies, such as Rosa (2012), rely upon newspaper articles to judge whether QE policy measures were more expansionary or restrictive than expected. However, these measures can be severely affected by judgement bias.

be emphasized. First, as noted by Altavilla et al. (2015), the main problem with such a scheme is that no APP-related events beyond the ECB's communications can be identified, since market participants may adapt their market expectations about the likelihood of an APP measure according to the economic releases. Hence, the overall impact of APP on interest rate expectations could be downward-biased. However, the incorporation of relevant economic releases, such as inflation and growth outlooks, could pollute the timeline with other news, eventually resulting in an upward bias. The second critical point when identifying event dates is the potential bias of the author, which could lead to under- or overestimation of the overall impact of the APP communication on interest rate expectations. As a robustness check, an index of news coverage of the APP in the euro area using related keywords, based on the approach of De Santis (2016), from Factiva could be constructed, and then it could be compared with the APP timeline. The identification of the APP-related event dates would be robust if these dates were in line with the spikes of the news index. However, as each point of this daily news index has to be estimated by hand, such a comparison is left to future research. Finally, it should always be kept in mind that statements arising from APP-related events also include forward guidance elements and in some cases interest rate announcements. Therefore, the impact of the APP statements on interest rate expectations could be overestimated.

2.2 Capturing Monetary Policy Surprises

Having constructed the APP timeline, the second step is to measure the policy surprise on the day of an APP-related event. Most studies use asset price reactions for capturing policy surprises. A crucial issue is which asset prices are appropriate for measuring QE policy surprises. In the related literature, common candidates used in the euro area for measuring such shocks are Euro Overnight Index Swaps (OIS) and Euribor futures, since these instruments reflect short-term interest rate expectations over certain horizons. While using futures and swaps for capturing future short-term interest rate expectations is appropriate for a sovereign state, such as the US or the UK, the shortcoming in using OIS and Euribor futures is that they assume that the short-term interest rate expectations are the same throughout the euro area, and neglect the possibility that specific countries may have different future interest rate expectations, depending on their economic releases. To capture country-specific surprise reactions, the reaction of euro area stock indices to APP statements is employed as a measure of the APP statement surprise. The relation between monetary policy and stock market performance has been widely studied in the literature using different methods, ranging from vector autoregressive models, to event studies, to identification through heteroskedasticity (see, e.g. Cook and Hahn 1989; Bernanke and Kuttner 2005; Rigobon and Sack 2004; Galí and Gambetti 2015). Works such as Bernanke and Kuttner (2005) using an event study find that a 25

Figure 1: APP statement surprises proxied by the daily returns of EuroStoxx 50



Sources: Reuters Datastream; author's calculations

basis point surprise increase or cut in the policy rate leads to about a 1 percent decline or increase in stock market returns. Works using identification through heteroskedasticity such as Rigobon and Sack (2004) and Bohl et al. (2008) find an impact about twice as strong. In contrast to the results based on non-VAR studies, the results from a VAR impulse response analysis of Galí and Gambetti (2015) find evidence that (mostly since 1980) there are long periods of time in which stock prices react positively to a surprise tightening. Based on a general equilibrium model, Galí (2014) finds that increases in interest rates lead to an increase in the bubble component of stock prices. Consequently, stock prices with a high share of bubble component can react positively to surprise increases in the policy rate. However, the majority of the literature notes that a surprising tightening (respectively, loosening) of monetary policy will lead to a decline (respectively, increase) in stock market returns.

The stock index data has been collected from Reuters Datastream, and contains benchmark indices for the following countries: (i) pan-European EuroStoxx 50, (ii) German DAX, (iii) French CAC, (iv) Italian FTSE, (v) Spanish IBEX, (vi) Portuguese PSI, (vii) and Irish ISEQ. Under the assumption of efficient markets, expected policy statements are already priced in and only the surprise component in a statement will affect stock prices.[6] Against this background, an APP statement surprise is defined as the daily (i) EuroStoxx (ii) and national stock index return measured in percentage points on the day of an APP statement. Figure 1 shows the time series of APP statement surprise proxied by the daily return of EuroStoxx 50 using a one-day window size. The most significant APP statements are enlisted. First hints to APP started already in early 2014. On 25 March 2014 the EuroStoxx nearly increased by 1.5%, as Draghi said risks of weakening inflation

[6]There are three variants of the hypothesis. The weak form of the efficient market hypothesis (EMH) states that stock prices already reflect all past publicly available information. The semi-strong form of the EMH additionally assumes a fast pass-through of news information to stock prices. The strong form of the EMH ultimately assumes that stock prices reflect even insider information. There is a vast finance literature dealing with the validity of the EMH. Empirical evidence has been mixed, but generally supporting the weak and semi-weak forms of the EMH in developed economies.

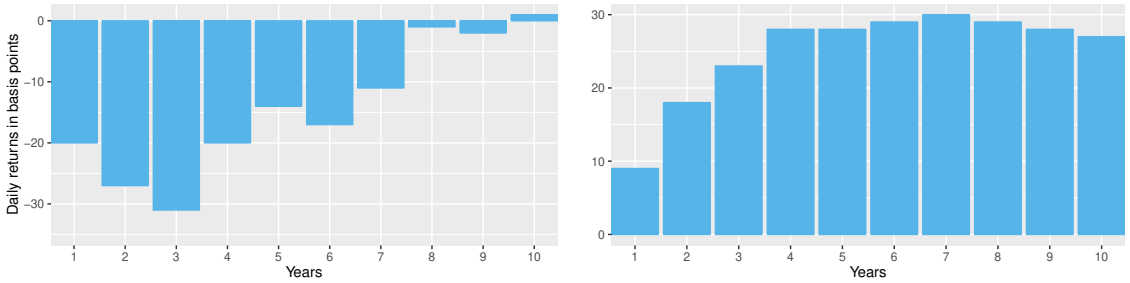
would warrant a broad-based asset purchases. Five months later, in a speech in Jackson Hole on 22 August 2014 Draghi stated that Governing Council would acknowledge the steady decline in medium-term inflation expectations in the euro area and is ready to launch additional measures. At the same day, the EuroStoxx increased by about 2%. On 22 January 2015 the Governing Council officially announced the APP under which €60 billion per month of euro area sovereign bonds and other institutional bonds would be bought. Due to the lack of surprise moment on that day, the index just increased by about 1.5%. On 3 December 2015 the ECB extended the program until at least March 2017 and failed to meet market expectations of an increase in its monthly purchase volume, which led to a sharp decrease of the EuroStoxx by more than 3%. On 10 March 2016 the ECB announced an increase in its monthly bond purchases to €80 billion. In addition, the APP is enhanced by the so-called Corporate Sector Purchase program (CSPP) under which the ECB started to purchase investment-grade cooperate bonds from June 2016. However, regarding that the statement was already expected months ago and Draghi stated that it will not be necessary to further reduce policy rates, the statement seemed to disappointed markets again, as the EuroStoxx decreased by about 2%. On 8 December 2016, as ECB announced tapering APP's monthly purchase volume to €60 billion per month as well as an extension of APP for another year. The extension of APP seemed to have surprised the markets despite of the reduction in the purchase volume, as the EuroStoxx increased by about 1.5%. The APP statement surprises proxied by the daily return of other stock indices are not shown, as they are highly correlated to that proxied by the daily return of EuroStoxx.

To capture the dovish and hawkish side of the APP statement surprises, I follow the approach of Glick and Leduc (2012) and let the stock market reaction speak for itself by dividing the APP statement surprises by their sign. Dovish APP statement surprises are defined as positive movements in the surprise time series, since a more dovish than expected statement would lead to a positive reaction of stock markets. In contrast, hawkish APP statement surprise are defined as negative movements in the surprise time series, since a more hawkish than expected statement would decrease stock prices.

2.3 Response of OIS rates to APP statements

To get a first idea of how the expectations for the future path of short-term interest rates react to the APP's signaling channel, the reaction of OIS rates on dovish and hawkish APP statement days drawn from Reuters Datastream is analyzed in Figure 2. Since OIS are bets on the average value of the overnight rate over a certain horizon (Bauer and Rudebusch, 2014) and the corresponding market is highly liquid for a broad range of maturities, OIS rates are widely used as estimates of average expectations for the path of future short-term interest rates over certain horizons. As for any financial claim, OIS

Figure 2: Changes in OIS rates based on EONIA with maturities up to ten years cumulated over all APP statement days measured in basis points. The left shows cumulative changes on dovish statement days and the right on hawkish statement days.



Sources: Reuters Datastream; author's calculations

rates contain term premiums and are not perfect measures for future short-term interest expectations. Nonetheless, the reaction of OIS rates on these event days allows one to get an impression to what extent changes in interest rate expectations are affected by the signaling channel in the euro area. For example, if the APP's signal channel is responsible for lowering interest rate expectations in the euro area, then a stronger reaction of OIS rates to short and intermediate maturities should be observable on these days.

On dovish APP statement days, it is striking that short and intermediate-term OIS rates reacted the most to the statements, while the response of longer-term OIS rates ranges from weaker to more neutral. This seems to confirm the general expectation that the signaling channel will more effectively reduce interest rate expectations in the short- and intermediate-term, which is plausible insofar as a central bank can only provide credible forward guidance over these horizons in its QE statements.

On hawkish APP statement days, it is observable that the response of the OIS rates stagnates with increasing maturity, which can be explained in two different ways. A straight-forward explanation is that the APP has a stronger signaling effect in increasing intermediate- and longer-term interest rate expectations. On the other hand, a more likely explanation is that the stronger response of longer-term OIS rates merely reflects increases in term premiums due to the limited effective range of the signaling channel. Consequently, this could mean that the signaling effect is also effective in increasing interest rate expectations over the intermediate-term.

Overall, these observations about the OIS rates suggest that the signaling channel plays an important role in guiding interest rate expectations in the euro area over the intermediate-term. To go beyond this model-free evidence, an ELB-consistent empirical dynamic term structure model will be used in the next section, allowsing the extraction of country-specific market-based future short-term interest rate expectations from euro area sovereign zero-coupon bond yields.

3 Model and Empirical Results

To date, two classes of model are most used to make inferences about the evolution of the yield curve: the Nelson–Siegel (NS) and arbitrage-free (AF) models. The first one is the workhorse model in yield curve modeling, and was developed by Diebold and Li (2006). NS models are very popular for the following reasons. First, they provide a parsimonious yet satisfying approximation of the yield curve. Second, the parameters have a clear interpretation as the short, medium and long-run driving forces behind the evolution of the yield curve. More recently, Diebold and Li (2006) have proposed a dynamic NS model (DNS), which has become extremely popular among academics, institutional investors, and central banks due to its remarkably favorable in-sample fit and out-of-sample performance. However, NS and DNS models neglect the crucial theoretical assumption of the absence of arbitrage opportunities regarding the immense depth in the bond trading market (Filipović, 1999).

Beginning with Vasicek (1977) and Cox et al. (1985), the class of AF models has been introduced. It is based on the theoretical restriction of the absence of risk-free arbitrage. The affine versions of these models are particularly popular, owing to the linear structure of the yields (Duffie and Kan, 1996). Despite their rigorous theoretical foundation, the major drawback of affine AF models is a problematic forecasting performance (Duffee, 2002). Consequently, NS and AF models tend to be either empirically successful but theoretically lacking, or theoretically rigorous but empirically lacking.

To overcome this drawback, Christensen et al. (2011) have developed a new class of affine AF models based on the structure of the DNS models. The result is called the arbitrage free Nelson–Siegel (AFNS) model. It inherits the empirically good fit of DNS models, while imposing the desirable assumption of the absence of riskless arbitrage. Recent work using AFNS models has studied the transmission of the QE to the yield curve in the US and the UK (Christensen and Rudebusch, 2012), or has specified long-term inflation expectations using the yield curve dynamics of both nominal and real bonds (Christensen et al., 2010). However, standard AFNS models ignore the existence of a lower bound on nominal interest rates because they allow positive probabilities of yields' moving below the lower bound. Consequently, these AFNS models cannot adequately describe the dynamics of interest rates at the lower bound and, more importantly, lead to biased measures of market expectations for the future path of interest rates when current interest rates become near-zero or negative.

To deal with this issue in a lower bound environment, Christensen and Rudebusch (2014) augment the AFNS model with the shadow short-rate framework introduced by Black (1995) and popularized by Krippner (2012). The outcome is called the shadow-rate AFNS model, and imposes a lower bound on nominal interest rates. Recent examples using shadow-rate AFNS models study the transmission of QE to yields at the zero lower bound (ZLB) in the US (Christensen and Rudebusch, 2016) or specify inflation expecta-

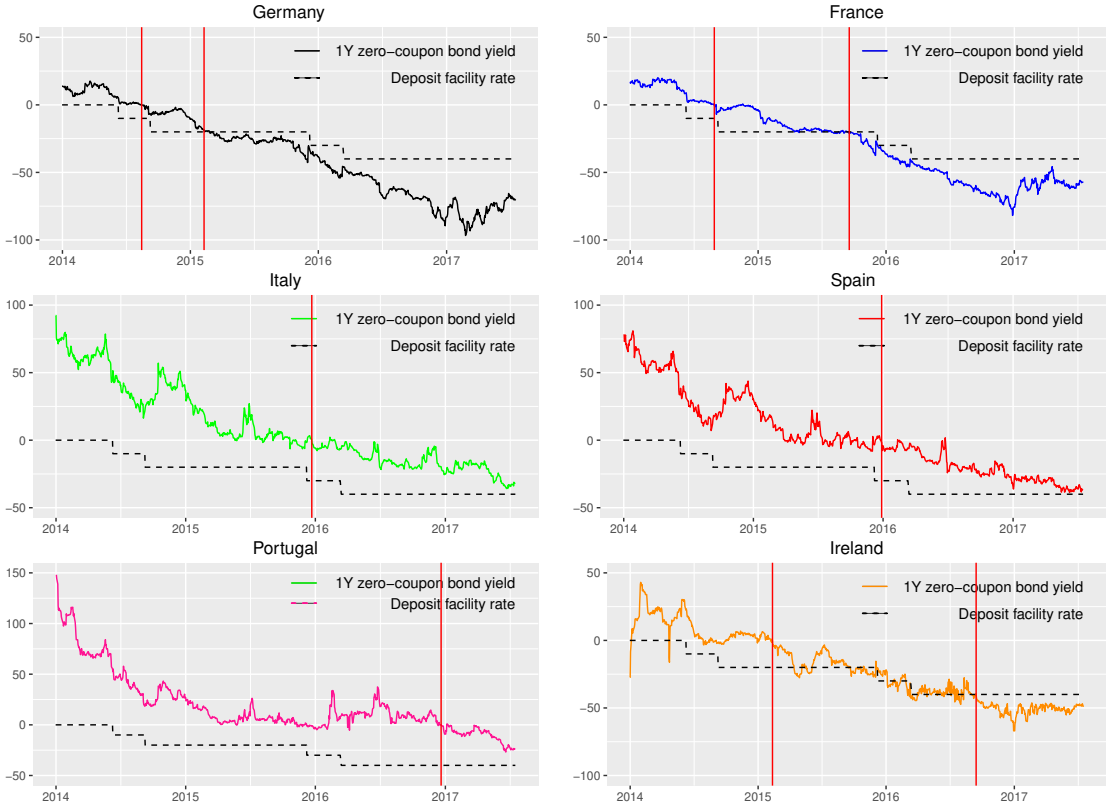
tions using the yield curve dynamics of both nominal and real UK bonds (Carriero et al., 2016). The location of the lower bound is usually considered as being constant and zero or slightly above zero. For the yield data of US and UK bonds, this is an appropriate assumption since the overnight federal funds rate and the Bank Rate have been kept above zero for a prolonged period of time since the financial crisis. Prominent examples incorporating ZLB are Christensen and Rudebusch (2014), Krippner (2013), Wu (2014), and Wu and Xia (2016). For the euro area, however, it may be not appropriate to assume a constant zero lower bound. The reason is that the short-term interest rates tend to anchor to the ECB's deposit facility rate, which has been set below zero since June 2014. In contrast to the US and UK key overnight rates, the deposit facility rate is also not constant, since it has often been changed since the financial crisis. And it is hard to say what could be the lower bound for the deposit facility rate, since the ECB has not set a lower bound for it (Kortela, 2016). Consequently, these aspects point to a time-varying lower bound specification for interest rates in the euro area, as also suggested by Kortela (2016), Lemke and Vladu (2017), and Wu and Xia (2017).

Against this background, the shadow-rate AFNS model has been chosen for the estimation of the dynamics of euro area sovereign bond yields, augmented with an estimation process of a time-varying effective lower bound defined as the lower bound perceived by market participants, which can be different from the deposit facility rate. The daily nominal sovereign zero-coupon yields of Germany, France, Italy, Spain, Portugal, and Ireland are drawn from Reuters DataStream. The time series data start on 2 January 2007 and end on 17 July 2017 and contain six maturities: one, two, three, five, seven, and ten years.[7] A comparison of the deposit facility rate with euro area one-year bond yields, shown in Figure 3, indicates that there are three periods of time when the ELB was binding. First, the yields are positive and bounded by zero or the deposit rate. Second, the yields become negative, but are still bounded by the deposit rate. Third, the yields fall below the deposit rate, as is only the case for German, French, and Irish yields. These three periods are highlighted in red in Figure 3.

For Germany, the first period lasts until 15 August 2014, the second until 9 February 2015, and the third until 17 July 2017, which is the end of the sample period. For France, the corresponding dates are 29 August 2014, 18 September 2015, and 17 July 2017. For Italy, the first period lasts until 22 December 2015, and the second until 17 July 2017. For Spain, the corresponding dates are 28 December 2015 and 17 July 2017. For Portugal, the corresponding dates are 20 December 2016 and 17 July 2017. And for Ireland, the first period lasts until 11 February 2015, the second until 14 September 2016, and the third period until 17 July 2017. The effective lower bound is treated as the sum of the deposit rate and a free estimated parameter for each period, essentially allowing the effective lower

[7] Unlike most term structure papers dealing with QE, three- and six-month sovereign zero-coupon bond yields are not considered in this paper, as these time series are only available from 2010 onwards. A shorter sample period underestimates the persistence of bond yields, ultimately leading to a biased estimate of short-term interest rate expectations.

Figure 3: European one-year sovereign zero-coupon bond yields and the deposit rate



Sources: Reuters Datastream; author's calculations

bound to float around the deposit rate.

3.1 Shadow-rate AFNS framework

The shadow-rate AFNS has three latent state variables, $X_t = (L_t, S_t, C_t)$, which are described by the following system of stochastic differential equations under the risk-neutral Q-measure:

$$\begin{pmatrix} dL_t \\ dS_t \\ dC_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \lambda & -\lambda \\ 0 & 0 & \lambda \end{pmatrix} \left[\begin{pmatrix} \theta_1^Q \\ \theta_2^Q \\ \theta_3^Q \end{pmatrix} - \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} \right] dt + \Sigma \begin{pmatrix} dW_t^{1,Q} \\ dW_t^{2,Q} \\ dW_t^{3,Q} \end{pmatrix}, \tag{1}$$

where the level L_t is an unit-root process under the Q-measure, which is justified by the fact that the level under the real-world P-measure is very close to being a non-stationary process. The slope S_t and curvature C_t are stationary processes, with λ as the mean-reversion rate of both state variables, characterizing the extent to which a deviation of the curvature from its mean influences the mean of the slope. θ^Q denote the means of the state variables under the Q-measure. W_t^Q is a three-dimensional Wiener process with a

lower-triangular diffusion matrix Σ under the Q-measure.

The shadow short-rate (shadow-rate) is defined as the sum of the level L_t and slope S_t, while the short-rate is the maximum of the shadow-rate s_t and a time-varying ELB r_t^{min}:

$$s_t = L_t + S_t, \quad r_t = \max\{s_t, r_t^{min}\}. \tag{2}$$

The time-varying ELB r_t^{min} is given by

$$r_t^{min} = \begin{cases} d_t + \mu_1, & \text{the yield is bounded by zero or the deposit rate} \\ d_t + \mu_2, & \text{the yield becomes negative but is above the deposit rate} \\ d_t + \mu_3, & \text{the yield is below zero and the deposit rate,} \end{cases}$$

where d_t is the deposit facility rate at time t and $\mu_\cdot$ is a free parameter for each of the aforementioned periods.

Christensen and Rudebusch (2016) show that (1) and (2) imply that the yield on the shadow discount bond $y_t(\tau)$ at time t with residual maturity τ is an exponentially affine function of the latent state variables, given by

$$y_t(\tau) = L_t + (\frac{1 - e^{-\lambda\tau}}{\lambda\tau})S_t + (\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau})C_t - \frac{A(\tau)}{\tau},$$

where $A(\tau)$ is the so-called yield-adjustment term, which only depends on the maturity, and captures the convexity effects which characterize the relation between the bond price and the corresponding yield. Its explicit form is to be found in Christensen et al. (2011).

The corresponding instantaneous shadow forward rate is given by

$$f_t(\tau) = -\frac{\partial}{\partial T}\ln P(t,T) = \frac{\partial}{\partial \tau}\tau y_t(\tau) = L_t + e^{-\lambda\tau}S_t + \lambda\tau e^{-\lambda\tau}C_t + A^f(\tau),$$

where the yield-adjustment term in the instantaneous forward rate is given by $A^f(\tau) = -\delta A(\tau)/\delta\tau$. Christensen and Rudebusch (2014) provide a formula for the instantaneous forward rate that respects the ELB r_t^{min}:

$$\underline{f}_t(\tau) = r_t^{min} + (f_t(\tau) - r_t^{min})\Phi\left(\frac{f_t(\tau) - r_t^{min}}{\omega(\tau)}\right) + \omega(\tau)\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left[\frac{f_t(\tau) - r_t^{min}}{\omega(\tau)}\right]^2\right),$$

where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution and $\omega(\tau)$ is a function related to the conditional variance $v(\tau, \tau+\delta)$ of an European call option with a residual maturity of τ, contingent on the zero-coupon bond residual maturity $\tau + \delta$.

$$\begin{aligned}\omega(\tau)^2 &= \frac{1}{2}\lim_{\delta\to 0}\frac{\partial^2 v(\tau, \tau+\delta)}{\partial\delta^2} \\ &= -\frac{1}{2}\sigma_{11}^2\tau - \frac{1}{2}\sigma_{22}^2\frac{1 - e^{-2\lambda\tau}}{2\lambda} - \frac{1}{2}\sigma_{33}^2\left[\frac{1 - e^{-2\lambda\tau}}{4\lambda} - \frac{1}{2}\tau e^{-2\lambda\tau} - \frac{1}{2}\lambda\tau^2 e^{-2\lambda\tau}\right]\end{aligned}$$

The zero-coupon bond yield that respects the ELB is consequently given by

$$\begin{aligned}\underline{y}_t(\tau) &= \frac{1}{\tau}\int_t^{t+\tau} \underline{f}_t(s)ds \\ &= \frac{1}{\tau}\int_t^{t+\tau} \left[r_t^{min} + (f_t(\tau) - r_t^{min})\Phi\left(\frac{f_t(\tau) - r_t^{min}}{\omega(\tau)}\right)\right. \\ &\left. - \omega(\tau)\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left[\frac{f_t(\tau) - r_t^{min}}{\omega(\tau)}\right]^2\right)\right] ds\end{aligned} \tag{3}$$

Under the real-world P-measure, the maximally flexible specification of the shadow-rate AFNS model is

$$\begin{pmatrix} dL_t \\ dS_t \\ dC_t \end{pmatrix} = \begin{pmatrix} \kappa_{11} & \kappa_{12} & \kappa_{13} \\ \kappa_{21} & \kappa_{22} & \kappa_{23} \\ \kappa_{31} & \kappa_{32} & \kappa_{33} \end{pmatrix} \left[\begin{pmatrix} \theta_1^P \\ \theta_2^P \\ \theta_3^P \end{pmatrix} - \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} \right] dt + \begin{pmatrix} \sigma_{11} & 0 & 0 \\ \sigma_{21} & \sigma_{22} & 0 \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{pmatrix} \begin{pmatrix} dW_t^{1,P} \\ dW_t^{2,P} \\ dW_t^{3,P} \end{pmatrix}.$$

As discussed in Bauer and Rudebusch (2014), term structure models suffer from small-sample estimation bias. Since interest rates are highly persistent, model estimates from the above specifications will underestimate the degree of interest rate persistence. As a consequence, the future short-term interest rates will revert to their mean faster than expected, resulting in overly stable expectation estimates. As a consequence, the decomposition process of the yields would be severely corrupted. To reduce the small-sample estimation bias, an unit-root property is imposed on the level factor L_t, which results in a zero restriction of κ_{11} and θ_1.

As a Gaussian term structure model, the conditional mean vector and the conditional covariance matrix are generally given by

$$\begin{aligned} E_t^P[X_{t+\Delta_t}] &= (I - e^{-K^p\Delta_t})\theta^P + e^{-K^p\Delta_t}X_t \\ V_t^P[X_{t+\Delta_t}] &= \int_0^{\Delta_t} e^{-K^P s}\Sigma\Sigma' e^{-(K^P)'s}ds. \end{aligned}$$

The maximum likelihood estimation of the model parameters is based on the extended Kalman filter. To guarantee finding the global maximum, the likelihood with respect to the parameters is maximized using the particle swarm optimization algorithm with 200 particles, followed by the Nelder–Mead simplex algorithm.[8] Translating these continuous-time conditional moments into conditional moments of discrete observations in order to estimate the model parameters, the transition equation describing the dynamics of the state variables under the P-measure is written as

$$X_t = (I - e^{-K^p\Delta t})\theta^P + e^{-K^p\Delta t}X_{t-1} + \eta_t,$$

[8] Among the global optimization algorithms, the particle swarm optimization algorithm has been found to deliver higher likelihoods than other algorithms, such as simulated annealing, genetic algorithms, and pattern search. The Nelder–Mead simplex algorithm is then used to ensure convergence. For technical details, see Eberhart and Kennedy (1995) and Nelder and Mead (1965).

where Δ_t is the time between observations and η_t is the transition error. The measurement equation which describes the dynamics of the zero-coupon bond yields found in Equation (3) is generally non-linear. For the estimation, it has to be linearized by a first-order Taylor approximation:

$$\begin{aligned}\underline{y}_t &= z(X_t;\psi) + \varepsilon_t \\ &\approx z(X_{t|t-1};\psi) + \frac{\partial z(X_t;\psi)}{\partial X_t}\Big|_{X_t=X_{t|t-1}}(X_t - X_{t|t-1}) \\ &= A_t(\psi) + B_t(\psi)X_t + \varepsilon_t,\end{aligned}$$

where $X_{t|t-1}$ is the predicted estimate of X_t at $t-1$ in the extended Kalman filter, ψ contains the model parameters, and ε_t is the measurement error. $A_t(\psi)$ and $B_t(\psi)$ can be written as

$$\begin{aligned}A_t(\psi) &= z(X_{t|t-1};\psi) - \frac{\partial z(X_t;\psi)}{\partial X_t}\Big|_{X_t=X_{t|t-1}} X_{t|t-1} \\ B_t(\psi) &= \frac{\partial z(X_t;\psi)}{\partial X_t}\Big|_{X_t=X_{t|t-1}}.\end{aligned}$$

Lastly, the error structure follows a normal distribution:

$$\begin{pmatrix}\eta_t \\ \varepsilon_t\end{pmatrix} \sim \mathrm{N}\left[\begin{pmatrix}0 \\ 0\end{pmatrix}, \begin{pmatrix}Q & 0 \\ 0 & H\end{pmatrix}\right],$$

where the transition and measurement errors are assumed to be orthogonal to the initial state. The conditional covariance matrix for the transition errors is

$$Q = \int_0^{\Delta_t} e^{-K^P s}\Sigma\Sigma' e^{-(K^P)'s} ds,$$

and the conditional covariance matrix for measurement errors is the diagonal matrix

$$H = \mathrm{diag}(\sigma_\varepsilon^2(\tau_1), \ldots, \sigma_\varepsilon^2(\tau_N)).$$

3.2 Empirical results

The parameter estimates for euro area sovereign bond yields are shown in Table 1. Regarding the interpretation of the parameters, the estimates with respect to German bond yields can be translated into the daily conditional mean-reversion matrix and con-

Table 1: Parameter estimates for euro area sovereign zero-coupon bond yields

	Germany	France	Italy	Spain	Portugal	Ireland
κ_{12}	-0.284	-0.576	-0.277	-0.161***	-0.069***	-0.523***
	(0.252)	(0.219)	(0.425)	(0.015)	(0.001)	(0.001)
κ_{13}	-0.314**	-0.333***	-0.500***	-0.375***	-0.349***	-0.357***
	(0.148)	(0.105)	(0.144)	(0.053)	(0.001)	(0.001)
κ_{21}	0.770***	0.239	0.610	0.647***	2.454***	4.558***
	(0.278)	(0.195)	(0.625)	(0.066)	(0.001)	(0.001)
κ_{22}	1.228***	0.512*	1.221**	1.280***	2.257***	3.669***
	(0.364)	(0.287)	(0.530)	(0.015)	(0.001)	(0.001)
κ_{23}	0.180	0.264*	0.258	0.277***	-0.617***	-1.118***
	(0.188)	(0.156)	(0.284)	(0.024)	(0.001)	(0.001)
κ_{31}	-2.209**	-0.260	0.177	0.768***	-5.129***	-5.951***
	(0.976)	(0.249)	(0.240)	(0.098)	(0.001)	(0.001)
κ_{32}	-2.416***	-0.994	-0.602	-0.447***	-4.509***	-2.464***
	(0.887)	(0.798)	(0.520)	(0.066)	(0.001)	(0.001)
κ_{33}	1.725***	1.537***	2.159***	1.206	2.344***	3.050***
	(0.423)	(0.417)	(0.430)	(0.058)	(0.165)	(0.001)
σ_{11}	0.020***	0.016***	0.040***	0.032***	0.084***	0.062***
	(0.001)	(0.001)	(0.001)	(0.009)	(0.002)	(0.001)
σ_{21}	-0.020***	-0.013***	-0.031***	-0.031***	-0.020***	-0.027***
	(0.001)	(0.001)	(0.001)	(0.006)	(0.002)	(0.001)
σ_{22}	0.014***	0.018***	0.037***	0.033***	0.122***	0.103***
	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)
σ_{31}	-0.033***	-0.036***	-0.123***	-0.067***	-0.2733	-0.222***
	(0.001)	(0.002)	(0.003)	(0.024)	(0.006)	(0.001)
σ_{32}	-0.028***	-0.024***	-0.025***	-0.007***	-0.206***	-0.135***
	(0.001)	(0.001)	(0.003)	(0.013)	(0.005)	(0.001)
σ_{33}	0.046***	0.044***	0.079***	0.060***	0.199***	0.139***
	(0.001)	(0.001)	(0.001)	(0.013)	(0.003)	(0.001)
θ_2	0.006	-0.018	-0.014	-0.010	-0.023	0.009***
	(0.007)	(0.017)	(0.012)	(0.019)	(0.025)	(0.001)
θ_3	-0.073***	-0.063***	-0.051**	-0.063	0.032	0.002***
	(0.018)	(0.015)	(0.022)	(0.032)	(0.067)	(0.001)
λ	0.434***	0.419***	0.457***	0.404***	0.612***	0.630***
	(0.003)	(0.003)	(0.003)	(0.013)	(0.003)	(0.002)
μ_1	-0.003***	-0.001***	0.001***	0.001	0.001***	-0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
μ_2	-0.004***	-0.002***	0.001***	-0.001	0.001***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
μ_3	-0.006***	-0.004***				-0.003***
	(0.001)	(0.001)				(0.001)
$LogL$	111,265.93	112,047.88	104,634.32	105,092.09	91,035.82	95,629.86

Estimated parameters of the shadow-rate AFNS model. Standard errors in parentheses. ***, **, * indicate significance of t-statistics at 1%, 5% and 10%.

ditional covariance matrix:

$$e^{-K^P \frac{1}{260}} = \begin{pmatrix} 1.000 & -0.001 & 0.001 \\ -0.003 & 0.995 & -0.001 \\ -0.009 & 0.002 & 0.993 \end{pmatrix},$$

$$\int_0^{\frac{1}{260}} e^{-K^P s} \Sigma\Sigma' e^{-(K^P)' s} ds = \begin{pmatrix} 1.6 \times 10^{-6} & -1.6 \times 10^{-6} & -2.5 \times 10^{-6} \\ -1.6 \times 10^{-6} & 2.4 \times 10^{-6} & 1.0 \times 10^{-6} \\ -2.5 \times 10^{-6} & 1.0 \times 10^{-6} & 1.5 \times 10^{-5} \end{pmatrix}.$$

As usual, the mean-reversion matrix suggests that the factors are highly persistent on a daily basis and that there is virtually no interaction between them. The conditional covariance matrix suggests that the level factor shock is the least volatile and the curvature factor shock is the most volatile. In terms of covariance, the correlation between the shocks to the level and to the slope, as well as to the level and curvature, is negative, while that between the shocks to the slope and curvature is positive. As for the estimated parameters for the other zero-coupon yields, the results are very similar and therefore they are available upon request. In the next step, the estimated parameters will be used to calculate short-term interest rate expectations. The conditional expectation of the shadow-rate is

$$\begin{aligned} E_t^P[s_{t+\tau}] &= E_t^P[L_{t+\tau} + S_{t+\tau}] = (1 \quad 1 \quad 0) E_t^P[X_{t+\tau}] \\ &= (1 \quad 1 \quad 0)\big[(I - e^{-K^p \tau})\theta^P + e^{-K^p \tau} X_{t-1}\big]. \end{aligned}$$

The conditional covariance matrix of the state variables is

$$V_t^P[X_{t+\tau}] = \int_0^\tau e^{-K^P s} \Sigma\Sigma' e^{-(K^P)' s} ds.$$

Therefore, the conditional covariance of the shadow-rate is

$$V_t^P[s_{t+\tau}] = (1 \quad 1 \quad 0) V_t^P[X_{t+\tau}] (1 \quad 1 \quad 0)'.$$

Following Kim and Singleton (2012), the short-term interest rate expectations τ years ahead is described by

$$\begin{aligned} E_t^P[r_{t+\tau}] &= \int_{-\infty}^{\infty} r_{t+\tau}\Phi(r_{t+\tau}|X_t)dr_{t+\tau} \\ &= r_t^{min} + \int_{r_t^{min}}^{\infty} (s_{t+\tau} - r_t^{min})\Phi(s_{t+\tau}|X_t)ds_{t+\tau} \\ &= r_t^{min} + (E_t^P[s_{t+\tau}] - r_t^{min})\Phi\left(\frac{E_t^P[s_{t+\tau}] - r_t^{min}}{V_t^P[s_{t+\tau}]}\right) \\ &+ \sqrt{V_t^P[s_{t+\tau}]}\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left[\frac{E_t^P[s_{t+\tau}] - r_t^{min}}{V_t^P[s_{t+\tau}]}\right]^2\right), \end{aligned}$$

and the average level of expected future short-term interest rates over the residual maturity τ of the bond is then

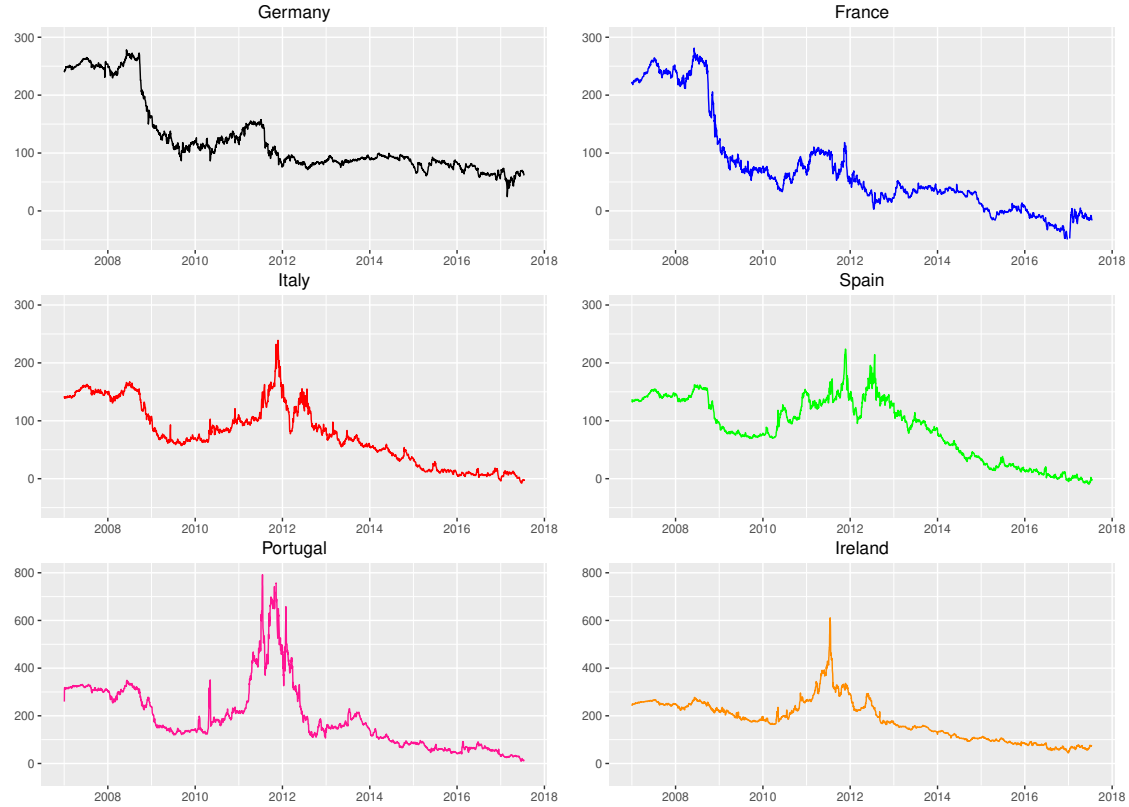
$$\frac{1}{\tau}\int_t^{t+\tau} E_t^P[r_u]du.$$

Figure 4 shows the estimated time series of the country-specific average level of short-term interest rate expectations over the next five years. The movements show that interest rate expectations in the euro area started to decline increasingly from 2014 onwards. As expectations for an European QE program increased significantly during this period, the APP's signal channel seems to have played a significant role in the decline in interest rate expectations. But other domestic and foreign factors, such as worse economic and inflation outlooks or international spillovers, might also have contributed to the decline in interest rate expectations. According to Deutsche Bundesbank (2016), changes in interest rate expectations can also reflect different economic outlooks for the euro area, making an isolation of the contribution of the APP program difficult without considering the relevant event days. Hence, the next step is to quantify the impact of dovish and hawkish APP statement surprises on the short-term interest rate expectations.

There are several well-known approaches to assess the impact of a monetary policy surprise on financial variables. While some studies, such as Wright (2012) and Rogers et al. (2014), rely on a VAR-based impulse-response analysis, the most popular approach is the event-study approach, which was initiated by, e.g. Cook and Hahn (1989), Kuttner (2001), and Cochrane and Piazzesi (2002), and is based on the fact that monetary policy actions and statements can trigger surprise jumps in asset prices within a narrow window. In other words, this approach basically assumes that a surprise reflected by changes in asset prices can be captured within a window of some predetermined size around the given event. Consequently, the choice of an appropriate size for the window is crucial for obtaining an unbiased estimate of the response. While too narrow a window may miss parts of the surprise, too wide a window may pollute the surprise with other news.[9] To address this issue, several papers, such as Rigobon and Sack (2004), Bohl

[9] Given the fast pass-through of changes in financial markets, using a one- or two-day window around an announcement has become common in the literature on high frequency identification of monetary policy.

Figure 4: The country-specific average short-term interest rate expectations over the next five years extracted from euro area sovereign bond yields



Sources: Reuters Datastream; author's calculations

et al. (2008), and Rogers et al. (2014), apply the identification through heteroskedasticity approach proposed by Rigobon (2003). In order to estimate the passthrough of monetary policy shocks, this approach employs the assumption that the variance of monetary policy shocks is higher on days of policy announcements. Additionally, the ITH approach is also robust to endogeneity and omitted variables bias. All in all, this approach is based on much weaker assumptions than the event-study approach. However, one assumption of using this approach here is that the variance of the measure of the surprise, proxied by stock index returns, should be higher on APP statement days. This is very unlikely, since stock markets are influenced by many types of news: economic, business, financial, and political. Monetary policy announcements are only one of these influences. Comparing the event-study and the ITH approaches, Rosa (2011) concludes that the event-study estimates of the response of asset prices to monetary policy shocks indeed contain a significant bias, but it is quite small. He also concludes that the event-study approach outperforms the ITH approach in terms of expected squared error.

Against this background, the event-study approach has been implemented. The event regressions were run in a similar spirit to that in Glick and Leduc (2012). And to control for unobserved market news, I have followed the approach of Urbschat and Watzka (2017) and include the EuroStoxx 50 Volatility (VSTOXX) index and five-year US

bond yields in the regression. Consequently, the change in the country-specific average short-term interest rate expectations over the next five years is regressed against dovish and hawkish APP statement surprises and control variables. The regression equation takes the form

$$\Delta y_t = \alpha + \beta_1 s_t^+ + \beta_2 s_t^- + \gamma_1 vstoxx_t + \gamma_2 \Delta y_t^{US} + \varepsilon_t, \tag{4}$$

where t indexes the business days from January 3, 2007 to July 17, 2017, Δy_t is the daily change in the given average interest rate expectations over the next five years, s_t^+ is the dovish, and s_t^- is the hawkish APP statement surprise. As for the control variables, $vstoxx_t$ is the logarithm of the VSTOXX and Δy_t^{US} is the daily change in five-year US zero-coupon bond yields. Lastly, heteroscedasticity and autocorrelation often arise in high-frequency financial time series, which lead to incorrect standard errors of the APP announcement surprises and control variables. This implies that an inference based on these standard errors will be invalid. Durbin–Watson and Breusch–Pagan test statistics confirm these issues in the models.[10] Therefore, the heteroskedasticity and autocorrelation consistent (HAC) standard errors proposed by Newey and West (1987) will be used to to draw correct inferences on the significance of the above explanatory variables.

Table 2 shows the responses of the average short-term interest rate expectations over the next five years in the euro area to dovish and hawkish APP statement surprises proxied by the daily change in EuroStoxx 50 in Panel A and by the daily change in the corresponding European national stock indexes in Panel B, respectively. As expected, the R^2 values in these regressions are low, overall, reflecting the fact that the dovish and hawkish APP statement surprise variables only account for the variations in interest rate expectations on APP-related event days in the sample period. Nevertheless, it should always be kept in mind that a low R^2 value indicates an omitted variable bias, which means that the estimates may be biased. Overall, the sign, the size, and the significance of the coefficients of the explanatory variables provide insights into changes in the country-specific average interest rate expectations over the next five years in the euro area on APP statement days in comparison to changes on non-statement days over the sample period. Since the estimates of both panels are very similar, the focus will be on the estimates in Panel B, which show that dovish monetary surprises led to highly significant declines in the country-specific average interest rate expectations over the next five years in the euro area, while hawkish monetary surprises raised them with mixed statistical significance.

Regarding dovish APP statements, a one percentage point dovish surprise shock decreases the country-specific average short-term interest rate expectations over the next five years in the euro area by around 0.5 to 0.8 basis points, with interest rate expectations in the periphery countries reacting more sensitively than those from core countries.

Turning to hawkish APP statements, a one percentage point corresponding surprise shock increases the country-specific average short-term interest rate expectations over the

[10] The results are available upon request.

Table 2: The response β of changes in the country-specific average short-term interest rate expectations over the next five years in the euro area to APP statement surprises proxied by the daily change in Eurostoxx 50 and national stock indexes measured in percentage points

	Germany	France	Italy	Spain	Portugal	Ireland
Panel A: EuroStoxx 50						
Dovish APP surprise	-0.548***	-0.498***	-0.712***	-0.631***	-0.730**	-0.699***
	(0.179)	(0.173)	(0.114)	(0.149)	(0.333)	(0.225)
Hawkish APP surprise	0.734	1.056	0.817***	0.871***	0.002	1.849**
	(0.560)	(0.917)	(0.303)	(0.259)	(0.224)	(0.899)
Log VSTOXX	-0.628***	-0.735***	0.026	0.064	-0.405	-0.364
	(0.158)	(0.242)	(0.201)	(0.215)	(0.872)	(0.307)
Δ US 5Y bond yields	0.065***	0.081***	0.012	0.003	-0.067	0.011
	(0.011)	(0.015)	(0.01)	(0.011)	(0.051)	(0.016)
Intercept	1.925***	2.240***	-0.129	-0.250	1.193	1.085
	(0.482)	(0.744)	(0.606)	(0.647)	(2.627)	(0.922)
R^2	0.047	0.045	0.004	0.004	0.002	0.005
Panel B: National stock indexes						
Dovish APP surprise	-0.484***	-0.452***	-0.578***	-0.564***	-0.737*	-0.756**
	(0.177)	(0.174)	(0.083)	(0.183)	(0.402)	(0.299)
Hawkish APP surprise	0.885	1.141	0.418**	0.684**	-0.036	2.463**
	(0.550)	(0.927)	(0.209)	(0.276)	(0.185)	(1.206)
Log VSTOXX	-0.626***	-0.733***	0.023	0.062	-0.404	-0.351
	(0.158)	(0.242)	(0.201)	(0.215)	(0.873)	(0.307)
Δ US 5Y bond yields	0.065***	0.080***	0.012	0.004	-0.067	0.011
	(0.011)	(0.015)	(0.014)	(0.011)	(0.051)	(0.016)
Intercept	1.915***	2.233***	-0.118	-0.242	1.191	1.042
	(0.482)	(0.744)	(0.606)	(0.648)	(2.628)	(0.923)
R^2	0.047	0.045	0.003	0.003	0.002	0.004

HAC standard errors in parentheses. ***, **, * indicate significance at 1%, 5% and 10%.

next five years in the euro area by about 0 to 2.5 basis points, albeit with less certainty than in the dovish case. It is striking that while interest rate expectations in Portugal barely react to hawkish shocks, the response of interest rate expectations in Ireland is remarkably strong. Given their similar underlying economic fundamentals, it is difficult to find a reasonable explanation for such different reactions. A simple explanation would be that double-digit percentage point growth in these countries' zero-coupon bond yields during the sovereign debt crisis led to a substantial underestimation of the persistence of yields over time, resulting in a biased estimation of short-term interest rate expectations. Apart from the reaction of interest rate expectations in Portugal and Ireland, the results suggest that interest rate expectations in the other peripheral countries reacted less strongly than those of core countries to hawkish surprise shocks.

To quantify the cumulative impact of these APP surprises over the entire sample period, the total changes of the country-specific average short-term interest rate expectations over the next five years in the euro area on all dovish and hawkish APP surprises are shown in Table 3, which are calculated by the corresponding response of rate expectations to a one percentage point dovish and hawkish APP statement surprise shock found

Table 3: The total changes in the country-specific average short-term interest rate expectations over the next five years in the euro area due to APP statement surprises measured in percentage points

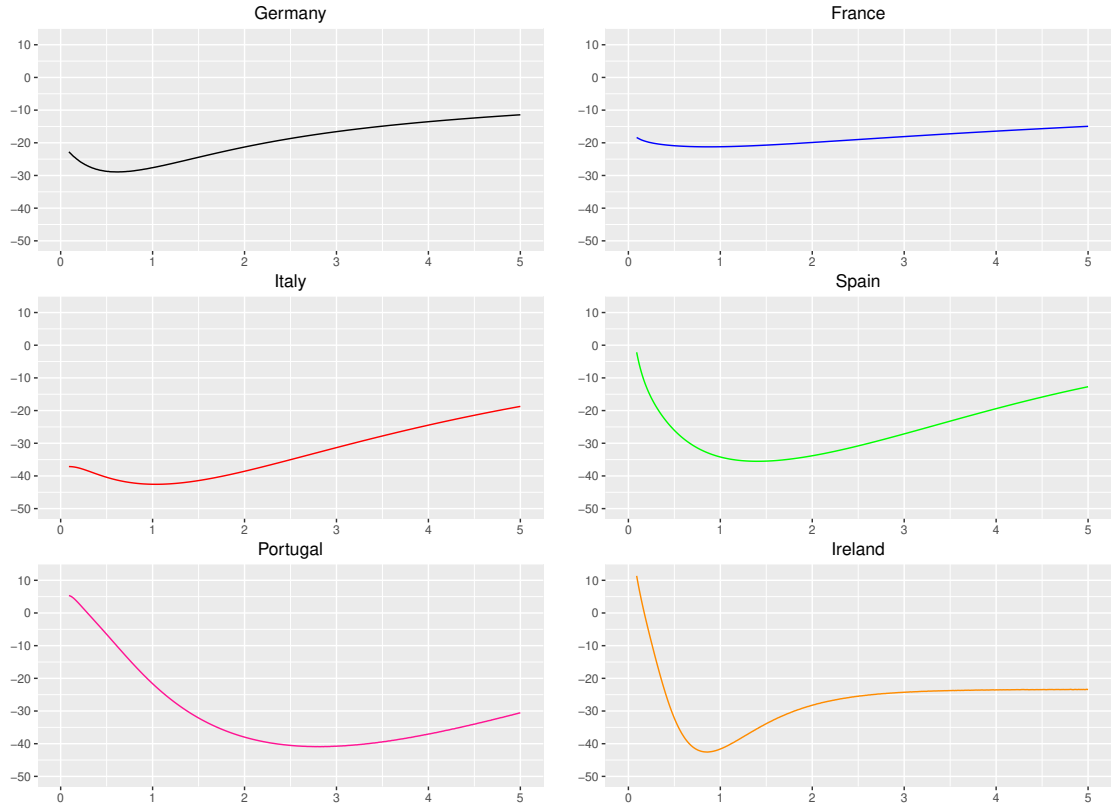
	Germany	France	Italy	Spain	Portugal	Ireland
Panel A: Eurostoxx 50						
Dovish APP surprise	-24	-22	-31	-27	-32	-30
Hawkish APP surprise	17	24	19	20	0	43
Panel B: National stock indexes						
Dovish APP surprise	-20	-19	-33	-25	-30	-26
Hawkish APP surprise	19	27	14	16	-1	43

in Table 2 multiplied by the total sum of dovish and hawkish APP statement surprises over the sample period, respectively. Also here, the figures involving the surprises proxied by national stock indexes found in Panel B are interpretable. These figures indicate that dovish APP statement surprises led to a roughly 19 to 33 basis point significant decline in the country-specific average short-term interest rate expectations over the next five years in the euro area over the sample period, while hawkish surprises increased them largely insignificantly by -1 to 43 basis points in total. As foreshadowed by the point estimates in the previous table, these results suggest that (i) the APP's signaling channel is more effective in reducing future interest rate expectations in peripheral countries, and, with less certainty, that (ii) the signaling effect is stronger in increasing future interest rate expectations in the core countries. However, the response of the German, French, Portuguese, and Irish interest rate expectations to hawkish surprises is highly insignificant in the first three cases and implausible in the latter two cases, reminding us that these point estimates should be interpreted with caution.

One possible explanation for this difference in signaling effect between core and peripheral countries might be how market participants from the respective countries perceive the ECB's assessment of the economic outlook in the euro area, as implied by the APP statements. More specifically, a dovish or hawkish surprise implies a more pessimistic or optimistic assessment of the ECB's future economic outlook than expected by the market. Therefore, it is reasonable to assume that market participants in stressed peripheral countries are more concerned about dovish surprises because it is likely that the more pessimistic assessment embedded in a dovish surprise will be more addressed to their countries. In contrast, market participants in better-situated core countries may be more likely to respond to hawkish surprises, as they find the more optimistic assessment embedded in a hawkish surprise more plausible for their countries. As a result, market participants in peripheral countries would perceive a dovish surprise more strongly, which would eventually lead to a greater decline in their interest rate expectations, whereas market participants in core countries may find a hawkish surprise more credible, which in turn leads to stronger increases in their interest rate expectations. In

other words, interest rate expectations in peripheral countries tend to react more strongly to dovish APP statement surprises, and thus these countries may benefit more from the signaling channel. This finding is in line with De Santis (2016), which states that the periphery countries benefited more from APP statements than core countries.[11]

Figure 5: The total change of the short-term interest rate expectations up to the next five years ahead in the euro area due to dovish APP statement surprises



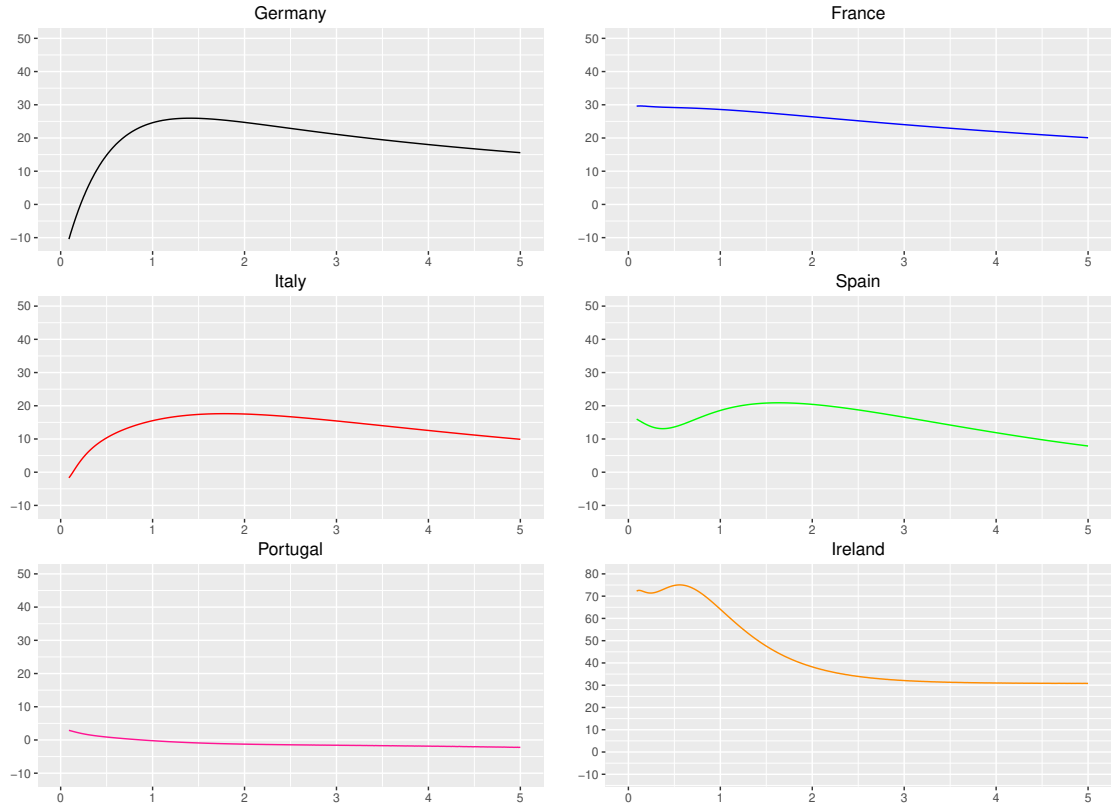
Sources: Reuters Datastream; author's calculations

Lastly, to study the response of interest rate expectations in greater detail, the daily changes in country-specific short-term interest rate expectations up to five years ahead is regressed against APP statement surprises and control variables in the spirit of (4). The total change of country-specific short-term interest rate expectations up to five years ahead on all dovish or hawkish APP statement surprises, which is calculated by the response of the corresponding rate expectations to a one percentage point surprise shock multiplied by the sum of dovish or hawkish surprises, is shown in Figure 5 and Figure 6, respectively. As expected, short-term interest rate expectations in the short- and medium-term up to three years ahead reacted the most to the APP statements. Regarding the total change of interest rate expectations up to the next five years ahead on dovish APP statement surprises, Figure 5 shows a steeper decline of interest rate expectations in

[11] Like most papers dealing with QE programs, De Santis (2016) makes no distinction between dovish and hawkish QE statements and implicitly assume a QE statement is always dovish.

peripheral countries, with peaks around -40 basis points, while the maximal decline of interest rate expectations in Germany and France is around -30 and -20 basis points, respectively. Turning to the total change of interest rate expectations up to the next five years ahead on hawkish APP statement surprises, Figure 6 shows that there is a stronger increase of interest rate expectations in core countries, with peaks around 30 basis points. Regarding the southern periphery countries, the maximum increase of interest rate expectations in Italy and Spain is around 20 basis points, while that for Portugal is about zero. The maximum increase of interest rate expectations in Ireland, however, is around 75 basis points.

Figure 6: The total change of the short-term interest rate expectations up to the next five years ahead in the euro area due to hawkish APP statement surprises



Sources: Reuters Datastream; author's calculations

In a nut shell, the key finding is that the APP's signaling channel may play a crucial role in guiding short-term interest rate expectations over the short- and intermediate-term in the euro area. With regard to country-specific differences in the size of this effect, the signaling effect is found to be more powerful in lowering rate expectations on the part of peripheral countries and in raising rate expectations for core countries, implying the periphery countries may benefit more from the signaling channel. However, a possible omitted variable bias, as indicated by the low R^2 values as well as questionable responses of interest rate expectations in Portugal and Ireland to hawkish APP statement surprise

shocks, suggests that the results may come with a considerable degree of uncertainty. Therefore, these findings must be taken with greater caution.

4 Robustness

Two robustness checks have been used to assess the validity of the specification in the previous section. The first robustness check concerns the choice of APP statement surprise measure in Equation (4), by using another market-based surprise measure, whereas the second also modifies the APP event timeline using a keyword-based surprise measure. In short, while the robustness checks largely support the presence of signaling effects, the magnitude of the effects appears to be uncertain.

First, stock indexes are replaced by a so-called signal-factor derived from a factor analysis incorporating a set of short-, medium-, and long-term financial variable rates. In the spirit of Chen et al. (2014), a factor analysis is applied to identify two factors from a set which contains the daily changes of the 1-year, 2-year, and 3-year ahead 3-month Euribor futures rates, and of 5-year, 7-year, and 10-year OIS rates, on APP statement days. The first factor, known as the signal-factor, is driven by changes in the short- and intermediate-term rates, and therefore should be correlated with the signaling channel. The second factor, called the market-factor, is driven by changes in longer-term rates, and is associated with the portfolio balance channel. These two factors accumulate about 96 percent of the variation of the data set. The common Varimax rotation method is then applied to maximize the sum of the variance of the squared loadings. The signal-factor is then used as the measure of the APP statement surprise, since it corresponds to the surprises of the market regarding information about the future path of interest rates over the intermediate-term, which should be the maximum period over which central banks are able to guide the future path of interest rate expectations. Lastly, the signal-factor is divided into positive and negative reactions, which are then used as measures of the dovish and hawkish APP statement surprises.

Second, the keyword-based Hawkish–Dovish (HD) index proposed by Nardelli et al. (2017) is used as an alternative instrument to gauge the tone of the APP statements. Using a sophisticated Support Vector Machines text classification on a data set of around 9000 monetary policy related media articles published since January 1999, Nardelli et al. (2017) construct an index which measures the degree of dovishness or hawkishness of the media's perception of the ECB's tone at each press conference. To obtain this alternative APP statement surprise shock measure, the so-called one-day communication shock is estimated, which is the difference between the index value on the day of the press conference and that of the previous day. Lastly, the communication shock is divided into negative and positive reactions, which are then used as the measures for the dovish and hawkish APP statement surprises. In contrast to my identified APP-related event

timeline, only the official press conferences from 03 April 2014 to 08 June 2017 are considered here, excluding any APP-related speeches and interviews made by Mr Draghi. Hence, the calculated signaling effects based on these surprises are expected to be rather small.

Table 4: The response β of changes in the country-specific average short-term interest rate expectations over the next five years in the euro area to APP statement surprises proxied by the signal factor and the one-day communication shock of the HD-Index

	Germany	France	Italy	Spain	Portugal	Ireland
Panel A: Signal-factor						
Dovish APP surprise	-1.204***	-1.250***	-1.067***	-1.238***	-1.681**	-1.851***
	(0.303)	(0.282)	(0.201)	(0.318)	(0.674)	(0.405)
Hawkish APP surprise	1.127**	2.097***	0.939***	0.873***	0.032	2.847***
	(0.497)	(0.571)	(0.332)	(0.307)	(0.225)	(0.455)
Log VSTOXX	-0.636***	-0.740***	0.020	0.055	-0.417	-0.375
	(0.158)	(0.243)	(0.201)	(0.215)	(0.873)	(0.306)
Δ US 5Y bond yields	0.065***	0.080***	0.012	0.003	-0.067	0.011
	(0.011)	(0.015)	(0.014)	(0.011)	(0.051)	(0.016)
Intercept	1.947***	2.251***	-0.115	-0.222	1.232	1.116
	(0.484)	(0.744)	(0.605)	(0.647)	(2.629)	(0.921)
R^2	0.049	0.050	0.003	0.003	0.002	0.008
Panel B: HD-Index						
Dovish APP surprise	-9.38*	-11.70	-20.91***	-22.82***	-21.49	-29.74**
	(5.56)	(7.47)	(7.10)	(8.11)	(16.55)	(14.18)
Hawkish APP surprise	-17.43	-14.61	5.27	-4.28	4.37	12.12
	(12.34)	(14.86)	(5.74)	(5.84)	(12.16)	(13.48)
Log VSTOXX	-0.64***	-0.75***	0.03	0.06	-0.40	-0.36
	(0.16)	(0.25)	(0.20)	(0.22)	(0.87)	(0.31)
Δ US 5Y bond yields	0.07***	0.08***	0.01	0.01	-0.07	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)	(0.02)
Intercept	1.97***	2.29***	-0.15	-0.24	1.15	1.08
	(0.49)	(0.77)	(0.61)	(0.65)	(2.63)	(0.92)
R^2	0.044	0.042	0.001	0.001	0.002	0.001

HAC standard errors in parentheses. ***, **, * indicate significance at 1%, 5% and 10%.

Table 4 shows the responses of the average country-specific short-term interest rate expectations over the next five years to dovish and hawkish APP statement surprises, as proxied by the positive and negative reactions of the signal-factor in Panel A and by the negative and positive reactions of the communication shock in Panel B.

In Panel A, the estimates suggest that a one point dovish surprise shock significantly decreases the country-specific average short-term interest rate expectations over the next five years in the euro area by around 1.1 to 1.9 basis points, and that a one point hawkish surprise shock increases these expectations by around 0 to 2.8 basis points with mixed significance. In Panel B, a one point dovish surprise shock decreases the country-specific average short-term interest rate expectations over the next five years in the euro area by around 9.4 to 29.7 basis points with mixed significance, and a one point hawkish surprise

shock insignificantly increases the expectations in Italy, Portugal, and Ireland by around 4.4 to 12.1 basis points, as well as decreases those in Germany, France, and Spain by around 4.3 to 17.4 basis points.

Table 5: The total change of the country-specific average interest rate expectations using different APP statement surprise identification approaches

	Germany	France	Italy	Spain	Portugal	Ireland
			Dovish APP statement surprise			
EuroStoxx 50	-24	-22	-31	-27	-32	-30
National indexes	-20	-19	-33	-25	-30	-26
Signal-factor	-23	-24	-20	-24	-32	-35
HD-shock	-3	-3	-6	-6	-6	-8
			Hawkish APP statement surprise			
EuroStoxx	17	24	19	20	0	43
National indexes	19	27	14	16	-1	43
Signal-factor	22	40	18	17	1	54
HD-shock	-13	-11	4	-3	3	9

The total changes of the average country-specific interest rate expectations over the next five years in the euro area on all dovish and hawkish statement surprises proxied by the EuroStoxx 50, the national stock indexes, the signal-factor, and the HD-index are shown in Table 5.[12]

First, sharing the same identified APP-related event dates, the total changes of rate expectations incorporating the signal-factor are quantitatively similar to the empirical results from the previous section. However, a closer look reveals that the responses of rate expectations in Germany, France, Italy, and Spain to dovish signal-factor shocks do not differ significantly from each other, casting doubt on the finding that the signaling effect is stronger for peripheral countries in terms of lowering rate expectations. Turning to hawkish signal-factor shocks, the responses of rate expectations broadly support the finding that the signaling effect is weaker for the southern periphery countries in terms of increasing rate expectations, albeit the response of rate expectations in France is probably overestimated due to the fact that Germany and France have similar economic fundamentals and therefore should have similar responses of rate expectations.

Second, the total changes of rate expectations incorporating the HD communication shock are quantitatively much less like the empirical results. The total changes of interest rate expectations on all dovish HD communication shocks are quite low. This outcome is not surprising given that the corresponding event timeline only takes into account the

[12]The total change of interest rate expectations over all dovish statement surprises proxied by the signal-factor and the HD-index is estimated similary to those proxied by the EuroStoxx 50 and the national stock indexes in Table 3.

days when press conferences are held, and thus the signaling effect is most probably underestimated in this case. Nevertheless, this shows that the estimated effectiveness of the signaling channel depends heavily on the identification of the event days. The total changes of interest rate expectations on all hawkish HD communication shocks, however, are inconsistent against the background that these results are neither interpretable in a proper way nor statistically significant.

In summary, the empirical results cannot withstand these robustness checks, which show that while APP's signaling effects are found to be present, the magnitude of these effects is questionable, and its estimation strongly depends on the choice of event days as well as on that of the surprise measure.

5 Conclusion

In this paper, the impact of APP's signaling channel on country-specific future short-term rate expectations in the euro area has been examined by using a model-based event study. First, based on an identified event set, euro area stock indexes have been used to extract dovish and hawkish APP statement surprise reactions. Second, country-specific future short-term rate expectations embedded in euro area sovereign zero-coupon bond yields have been extracted by applying an ELB-consistent shadow-rate AFNS model. Lastly, an event-study analysis has been employed to assess the impact of APP dovish and hawkish statement surprises on the estimated short-term interest rate expectations in the euro area.

To conclude, this event-study analysis has been performed during a period of the APP characterized by a transition from a prevalence of dovish statements to an increasing number of hawkish statements. The empirical results suggest that the APP's signaling channel may play a crucial role in guiding the future path of short-term interest expectations in the euro area. The main result is that the signaling channel has the greatest impact on short-term interest rate expectations over the next three years, and may act differently for peripheral countries than for core countries. In terms of lowering rate expectations through dovish statement surprises, the signaling effect tends to be stronger for the periphery countries. In terms of increasing rate expectations through hawkish statement surprises, the signaling effect appears to be stronger for core countries. In other words, the reaction of interest rate expectations in peripheral countries tends to be stronger to dovish APP statement surprises, and thus these countries may benefit more from the signaling channel. One possible explanation for this difference in signaling effects could be that the perception of market participants for the assessment of the ECB's economic outlook implied by the APP statements depends on the development of the domestic economy. However, these implications carry a considerable degree of uncertainty, owing to a possible omitted variable bias and the partly implausible reactions of

the interest rate expectations to the surprises in the empirical results. Finally, while generally confirming the presence of signaling effects, the robustness checks demonstrate the vulnerability of the implications to their dependence on the APP identification scheme. Overall, these results shed light on the significance of the APP's signaling channel in the euro area. Whether these implications will persist in the later phase of the APP, where hawkish statements could predominate, remains a matter for future research.

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Table 6: APP-related statements

Date	Event	Statement related to APP
25.03.2014	Speech in Paris	As such, I expect monetary policy to regain influence over the economic cycle, and our accommodative stance to support a gradual closing of the output gap in the coming years. This is reflected in the current ECB staff projections, which foresee inflation rising to 1.0% in 2014, 1.3% in 2015 and 1.5% in 2016. **If any downside risks to this scenario appear, we stand ready to take additional monetary policy measures that ensure our mandate is fulfilled.** In other words, we will do what is needed to maintain price stability.
03.04.2014	Press Conference (Q&A)	I think you have rightly pointed to the key sentence in the statement: "The Governing Council is unanimous in its commitment to using also unconventional instruments ..." meaning that we havent finished with our conventional measures "...also unconventional instruments within its mandate in order to cope effectively with risks of a too prolonged period of low inflation." **So this statement says that all instruments that fall within the mandate, including QE, are intended to be part of this statement. During the discussion we had today, there was indeed a discussion of QE.**
24.04.2014	Speech in Amsterdam	A third contingency would be a worsening of the medium-term outlook for inflation. One cause for this could be by a broad-based weakening of aggregate demand that derails our baseline scenario of a moderate recovery. Another cause could be a substantial positive supply shock that, given the current low level of inflation, loosens the anchoring of medium-term inflation expectations. **Unlike the other contingencies, the objective here would not be to defend the current stance, but rather to increase meaningfully the degree of monetary accommodation. Hence, the limited margin for manoeuvre that remains over short-term interest rates would not be sufficient. This would be the context for a more broad-based asset purchase programme.**
26.05.2014	Speech in Sintra	At the other end of the spectrum would be a too prolonged downward departure of inflation and/or inflation expectations from our projected baseline scenario, for example due to the interaction between exchange rate developments and medium-term inflation expectations as I explained earlier. **This would call for a more expansionary stance, which would be the context for a broad-based asset purchase programme.**
07.08.2014	Press Conference	Moreover, the Governing Council is unanimous in its commitment to also using unconventional instruments within its mandate, should it become necessary to further address risks of too prolonged a period of low inflation... **Our monetary policy stance remains, and will remain, accommodative, and I can only reaffirm that the Governing Council is unanimous in its commitment to also use unconventional measures, like ABS purchases, like QE, if our medium-term outlook for inflation were to change.**
22.08.2014	Speech in Jackson Hole	Over the month of August financial markets have indicated that inflation expectations exhibited significant declines at all horizons... **The Governing Council will acknowledge these developments and within its mandate will use all the available instruments needed to ensure price stability over the medium term.**
04.09.2014	Press Conference	As our measures work their way through to the economy they will contribute to a return of inflation rates to levels closer to 2%. **Should it become necessary to further address risks of too prolonged a period of low inflation, the Governing Council is unanimous in its commitment to using additional unconventional instruments within its mandate.**
22.09.2014	Speech at the European Parliament	The Governing Council remains fully determined to counter risks to the medium-term outlook for inflation. **Therefore, we stand ready to use additional unconventional instruments within our mandate, and alter the size and / or the composition of our unconventional interventions should it become necessary to further address risks of a too prolonged period of low inflation.**
02.10.2014	Press Conference	As all our measures work their way through to the economy they will contribute to a return of inflation rates to levels closer to our aim. **Should it become necessary to further address risks of too prolonged a period of low inflation, the Governing Council is unanimous in its commitment to using additional unconventional instruments within its mandate.**

Table 7: APP-related statements - Continued

Date	Event	Statement related to APP
06.11.2014	Press Conference	Should it become necessary to further address risks of too prolonged a period of low inflation, the Governing Council is unanimous in its commitment to using additional unconventional instruments within its mandate. **The Governing Council has tasked ECB staff and the relevant Eurosystem committees with ensuring the timely preparation of further measures to be implemented, if needed.**
12.11.2014	Speech in Rome	More recently, it has introduced a further three measures of unconventional monetary policy: the TLTROs, credit lines of up to four years that can be used by banks for loans to households and businesses; two programmes for the purchase of covered bonds and ABS with the aim being to further expand liquidity via operations directed towards the real economy. **All these policy actions, accompanied by the expected maintenance of interest rates at their current level for a long period of time and an ongoing expansion of the ECBs balance sheet, together with the commitment by the Governing Council to take further unconventional policy actions should medium-term inflation expectations worsen or if the measures already decided on prove to be insufficient, has led to an unprecedented degree of monetary accommodation.**
17.11.2014	Speech at the European Parliament	If necessary to further address risks of too prolonged a period of low inflation, the Governing Council is unanimous in its commitment to using additional unconventional instruments within its mandate. **In this context, we have also tasked relevant ECB staff and Eurosystem committees with the timely preparation of further measures to be implemented, if needed. Such measures could include further changes to the size and composition of the Eurosystem balance sheet, if warranted to achieve price stability over the medium term.**
21.11.2014	Speech in Frankfurt	However, once the margin for manoeuvre here becomes exhausted that is, overnight and near-term money market rates are both at the lower bound a third step becomes necessary. If further monetary stimulus is needed, central banks need to by-pass the money market and intervene directly in other asset markets to affect, through prices and quantities, the various transmission channels of monetary policy. **Speaking in Amsterdam earlier this year, I clarified the circumstances under which the ECB would need to resort to asset purchases to increase meaningfully the degree of monetary accommodation. In what I called the "third contingency", I referred to a broad-based weakening of aggregate demand that would threaten our baseline scenario of recovery and/or a loosening in the anchoring of medium-term inflation expectations.**
04.12.2014	Press conference	**In the coming months, our measures will further ease the monetary policy stance more broadly, support our forward guidance on the key ECB interest rates and reinforce the fact that there are significant and increasing differences in the monetary policy cycle between major advanced economies... In this context, early next year the Governing Council will reassess the monetary stimulus achieved, the expansion of the balance sheet and the outlook for price developments...** Should it become necessary to further address risks of too prolonged a period of low inflation, the Governing Council remains unanimous in its commitment to using additional unconventional instruments within its mandate. This would imply altering early next year the size, pace and composition of our measures. In response to the request of the Governing Council, ECB staff and the relevant Eurosystem committees have stepped up the technical preparations for further measures, which could, if needed, be implemented in a timely manner.
02.01.2015	Interview with Handelsblatt	**We are making technical preparations to alter the size, pace and composition of our measures in early 2015, should it become necessary to further address risks of a too prolonged period of low inflation. The Governing Council agrees unanimously on that.**

Table 8: APP-related statements - Continued

Date	Event	Statement related to APP
08.01.2015	Letter to the European Parliament	Early this year, the Governing Council will reassess the monetary stimulus achieved through the set of measures implemented in the second half of 2014, the expansion of the Eurosystem's balance sheet achieved through these measures, and the outlook for price developments. Should it become necessary to further address risks of too prolonged a period of low inflation, the Governing Council is unanimous in its commitment to using additional unconventional instruments within its mandate... **Such measures may entail the purchase of a variety of assets one of which could be sovereign bonds, as mentioned in your letter.**
15.01.2015	Interview with die Zeit	Question: Are you talking about the thousand billion that you want to spend over the next few years, predominantly by purchasing government bonds, and which is to be decided upon at the ECB over the next week. **Answer: I never said "thousand", but as guidance, I mentioned the balance sheet size of the European Central Bank at the beginning of 2012 (No denial) .**
22.01.2015	Governing Council Decisions	**The ECB announces APP:** • **ECB expands purchases to include bonds issued by euro area central governments, agencies and European institutions** • **Combined monthly asset purchases to amount to €60 billion** • **Purchases intended to be carried out until at least September 2016**
05.03.2015	Press conference	**Following up on our decisions of 22 January 2015, we will, on 9 March 2015, start purchasing euro-denominated public sector securities in the secondary market.**
15.04.2015	Press conference	**Purchases are intended to run until the end of September 2016 and, in any case, until we see a sustained adjustment in the path of inflation that is consistent with our aim of achieving inflation rates below, but close to, 2% over the medium term** ...Purchases are intended, intended, to run until the end of September 2016. Some of you, when I first used the word intended, rather than expected, rightly pointed out the difference between the two concepts. This was at the beginning of December last year, in an introductory statement where we changed the word, and that was meant, and was accepted by markets, as being a powerful signal of changing the monetary policy. So, purchases are intended to run until the end of September 2016, and in any case until we see a sustained adjustment in the path of inflation that is consistent with our aim of achieving inflation rates over etc etc, and then there is this new sentence explaining exactly what we mean by sustained and by medium-term. I don't think it's the case now to go beyond this.
14.05.2015	Speech at the IMF	While we have already seen a substantial effect of our measures on asset prices and economic confidence, what ultimately matters is that we see an equivalent effect on investment, consumption and inflation. **To that effect, we will implement in full our purchase programme as announced and, in any case, until we see a sustained adjustment in the path of inflation.**
16.07.2015	Press conference	Looking ahead, we will continue to closely monitor the situation in financial markets, as well as the potential implications for the monetary policy stance and for the outlook for price stability. **If any factors were to lead to an unwarranted tightening of monetary policy, or if the outlook for price stability were to materially change, the Governing Council would respond to such a situation by using all the instruments available within its mandate.**
03.09.2015	Governing Council Decsions	**Draghi announces increase in APP issue share limit from 25% to 33%**
23.09.2015	Speech at the European Parliament	Should some of the downwards risks weaken the inflation outlook over the medium term more fundamentally than we project at present, we would not hesitate to act. **The asset purchase programme has sufficient in-built flexibility. We will adjust its size, composition and duration as appropriate, if more monetary policy impulse should become necessary.**

Table 9: APP-related statements - Continued

Date	Event	Statement related to APP
22.10.2015	Press conference	**Most notably, the strength and persistence of the factors that are currently slowing the return of inflation to levels below, but close to, 2% in the medium term require thorough analysis. In this context, the degree of monetary policy accommodation will need to be re-examined at our December monetary policy meeting, when the new Eurosystem staff macroeconomic projections will be available.** 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. In particular, the Governing Council recalls that the asset purchase programme provides sufficient flexibility in terms of adjusting its size, composition and duration.
03.11.2015	Speech in Frankfurt	**But even though domestic demand remains resilient, concerns over growth prospects in emerging markets and other external factors are creating downside risks to the outlook for growth and inflation. In this context, the degree of monetary policy accommodation will need to be re-examined at the Governing Council's December meeting.** 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.
05.11.2015	Speech in Milan	Today, like before, we are not constrained in our capacity to intervene; we have many instruments at our disposal. We are confronting a situation in which price dynamics are very weak and the macroeconomic picture remains uncertain. **That is why the Governing Council is committed to re-examining the degree of monetary policy accommodation at its next meeting in December.**
09.11.2015	Press release	**Increase in QE issue share limit from 25% to 33%**
12.11.2015	Speech at the European Parliament	From todays perspective, this suggests that a sustained normalisation of inflation could take longer than we anticipated in March when we first appraised the overall impact of our measures. We will closely monitor the risks to price stability and thoroughly assess the strength and persistence of the factors that are slowing the return of inflation to levels below, but close to, 2%. **At our December monetary policy meeting, we will re-examine the degree of monetary policy accommodation.**
20.11.2015	Speech in Frankfurt	At our December Governing Council meeting, we will thoroughly assess the strength and persistence of the factors that are slowing the return of inflation towards 2%... **If we conclude that the balance of risks to our medium-term price stability objective is skewed to the downside, we will act by using all the instruments available within our mandate. In particular, we consider the APP to be a powerful and flexible instrument, as it can be adjusted in terms of size, composition or duration to achieve a more expansionary policy stance.**
03.12.2015	Press conference	**The ECB announces extension of APP until at least March 2017**
04.12.2015	Speech in New York	In the selection of our policy tools, we aim to minimise the extent of such distortions, which is why, for instance, we have so far focused our asset purchases as much as possible in the most liquid and generic asset classes. **But there is no doubt that if we had to intensify the use of our instruments to ensure that we achieve our price stability mandate, we would. There cannot be any limit to how far we are willing to deploy our instruments, within our mandate, and to achieve our mandate.**
14.12.2015	Speech in Bologna	Following the Governing Council's recalibration of our instruments earlier this month, we expect inflation to reach our objective without undue delay. But we continue to closely observe movements in economic and financial conditions. **As I said at the last Council meeting, and again more recently, "there is no doubt that, if we had to intensify the use of our instruments to ensure that we achieve our price stability mandate, we would".**

Table 10: APP-related statements - Continued

Date	Event	Statement related to APP
21.01.2016	Press conference	Yet, as we start the new year, downside risks have increased again amid heightened uncertainty about emerging market economies' growth prospects, volatility in financial and commodity markets, and geopolitical risks. In this environment, euro area inflation dynamics also continue to be weaker than expected. **It will therefore be necessary to review and possibly reconsider our monetary policy stance at our next meeting in early March, when the new staff macroeconomic projections become available which will also cover the year 2018.**
22.01.2016	Speech in Davos	**We have plenty of instruments and especially we have the determination and willingness and capacity of the Governing Council to act and deploy these instruments**
01.02.2016	Speech at the European Parliament	Since our meeting in early December, conditions have once more changed. A moderate recovery of the euro area economy is under way, driven mainly by domestic demand. But downside risks have increased again amid heightened uncertainty about emerging market economies' growth prospects, volatility in financial and commodity markets, and geopolitical risks. Inflation dynamics are also tangibly weaker than we expected in December... **Therefore, at our last meeting in January we judged that it will be necessary to review and possibly reconsider our monetary policy stance at our next monetary policy meeting in early March, when the new staff macroeconomic projections become available.**
15.02.2016	Speech at the European Parliament	In order to make the euro area more resilient, contributions from all policy areas are needed. The ECB is ready to do its part. **As we announced at the end of our last monetary policy meeting in January, the Governing Council will review and possibly reconsider the monetary policy stance in early March.**
01.03.2016	Letter to the European Parliament	**Regarding your questions on possible further monetary policy measures, at its meeting in early March the Governing Council will review and possibly reconsider its monetary policy stance.** There is good evidence that the monetary policy measures taken since June 2014 are working as intended. However, the review has to be seen against the background of increased downside risks to the earlier outlook amid heightened uncertainty about emerging market economies' growth prospects, volatility in the financial and commodity markets, and geopolitical risks. In this environment, euro area inflation dynamics continue to be weaker than expected.
10.03.2016	Governing Council Decisions	**The ECB announces an increase in APP's monthly purchase volume and adds Corporate Sector Purchase Programme to the APP:** • **The monthly purchases under the APP will be expanded to €80 billion starting in April** • **Investment grade euro-denominated bonds issued by non-bank corporations established in the euro area will be included in the list of assets that are eligible for regular purchases**
21.04.2016	Press release	**The ECB reveals details of CSPP**
02.06.2016	Governing Council Decisions	**The ECB announces the start of CSPP on 08 June 2016**
08.09.2016	Press conference	The Governing Council will continue to monitor economic and financial market developments very closely. We will preserve the very substantial amount of monetary support that is embedded in our staff projections and that is necessary to secure a return of inflation to levels below, but close to, 2% over the medium term. If warranted, we will act by using all the instruments available within our mandate. **Meanwhile, the Governing Council tasked the relevant committees to evaluate the options that ensure a smooth implementation of our purchase programme.**

Table 11: APP-related statements - Continued

Date	Event	Statement related to APP
20.10.2016	Press conference	Looking ahead, we remain committed to preserving the very substantial degree of monetary accommodation which is necessary to secure a sustained convergence of inflation towards levels below, but close to, 2% over the medium term. To that end, we will continue to act, if warranted, by using all the instruments available within our mandate. **In December the Governing Council's assessment will benefit from the new staff macroeconomic projections extending through to 2019 and from the work of the Eurosystem committees on the options to ensure the smooth implementation of our purchase programme until March 2017, or beyond, if necessary.**
17.11.2016	Letter to the European Parliament	The ECB does not hold prior meetings with corporations in the context of private placements under the CSPP. **The Eurosystem is not involved in any ex ante discussions about the characteristics of bonds it may be offered under the CSPP in the primary and secondary markets. Rather, all CSPP eligibility criteria are published on the ECB website to allow all potential issuers to take them into account.**
21.11.2016	Speech at the European Parliament	Supported by our monetary policy, the recovery is sustaining its momentum. We also expect headline inflation to continue rising over the coming months. At the same time, we are not seeing a consistent strengthening of underlying price dynamics. Much of the expected increase will be driven by statistical factors related to the stabilisation of oil prices. **Moreover, the return of inflation towards our objective still relies on the continuation of the current, unprecedented level of monetary support, in spite of the gradual closing of the output gap.** It is for this reason that we remain committed to preserving the very substantial degree of monetary accommodation necessary to secure a sustained convergence of inflation towards levels below, but close to, 2% over the medium term.
28.11.2016	Speech at the European Parliament	**At our monetary policy meeting in December we'll assess the various options that would allow the Governing Council to preserve the very substantial degree of monetary accommodation necessary to secure the sustained convergence of inflation towards levels below but close to 2 percent over the medium term**
30.11.2016	Interview with El Pais	Question: In December, will QE be extended beyond March 2017 and the size of monthly purchases reduced? **Answer: This is for the Governing Council to decide and it will do so on December 8. Right now, our latest introductory statement says that we remain committed to preserving the very substantial degree of monetary accommodation which is necessary to secure a sustained convergence of inflation towards levels below, but close to, 2% over the medium term.**
08.12.2016	Governing Council Decisions	**The ECB announces tapering:** • **The Governing Council decided to continue its purchases under the APP at the current monthly pace of €80 billion until the end of March 2017** • **From April 2017, the net asset purchases are intended to continue at a monthly pace of €60 billion until at least December 2017**
19.01.2017	Press Conference	According to Eurostat, euro area annual HICP inflation increased markedly from 0.6% in November 2016 to 1.1% in December. **This reflected mainly a strong increase in annual energy inflation, while there are no signs yet of a convincing upward trend in underlying inflation...** However, measures of underlying inflation are expected to rise more gradually over the medium term, supported by our monetary policy measures, the expected economic recovery and the corresponding gradual absorption of slack.
03.02.2017	Letter to the European Parliament	**The asset purchase programme (APP) addresses the risks of too long a period of low inflation and has not been designed to target yield developments in individual euro area countries.**

Table 12: APP-related statements - Continued

Date	Event	Statement related to APP
09.03.2017	Press Conference	"If warranted, to achieve its objective the Governing Council will act by using all the instruments available within its mandate". You remember from the previous introductory statement. **That's been removed, basically, to signal that there is no longer that sense of urgency in taking further actions while maintaining the accommodative monetary policy stance including the forward guidance. But that urgency that was prompted by the risks of deflation isn't there;** that was the judgement, the assessment of the Governing Council.
21.04.2017	Speech in Washington	While euro area headline inflation has increased markedly over the past year, underlying inflation is expected to continue to remain subdued. **A very substantial degree of monetary accommodation is still needed to secure a sustained return of inflation rates towards levels below, but close to, 2% in line with the ECBs mandate...** The risks of deflation, defined as generalised price declines that trigger a negative spiral of self-fulfilling expectations, have largely disappeared. At the same time, underlying inflation has not shown a convincing upward trend domestic cost pressures remain subdued and recent increases in global price pressures have yet to filter through.
27.04.2017	Press Conference	Our monetary policy measures have continued to preserve the very favourable financing conditions that are necessary to secure a sustained convergence of inflation rates towards levels below, but close to, 2% over the medium term. **Incoming data since our meeting in early March confirm that the cyclical recovery of the euro area economy is becoming increasingly solid and that downside risks have further diminished.** At the same time, underlying inflation pressures continue to remain subdued and have yet to show a convincing upward trend.
10.05.2017	Speech in The Hague	**Incoming data confirm that the cyclical recovery of the euro area economy is becoming increasingly solid and that downside risks have further diminished.Nevertheless, it is too early to declare success. Underlying inflation pressures continue to remain subdued and have yet to show a convincing upward trend...** Maintaining the current very substantial degree of monetary accommodation is still needed for underlying inflation pressures to build up and support headline inflation in the medium term.
24.05.2017	Speech in Madrid	When we introduced unconventional policy instruments in order to secure a return of inflation towards our objective, we were aware that those new instruments could result in somewhat more pronounced side effects than conventional instruments. These side effects have remained contained...**Our current assessment of the side effects suggest therefore that there is no reason to deviate from the indications we have been consistently providing in the introductory statement to our press conferences.**
29.05.2017	Speech in the European Parliament	Despite a firmer recovery, and looking through the volatile readings in HICP inflation over recent months, underlying inflation pressures have remained subdued...**For domestic price pressures to strengthen, we still need very accommodative financing conditions, which are themselves dependent on a fairly substantial amount of monetary accommodation.** At its June monetary policy meeting the Governing Council will receive an update of the staff projections and a more complete information set on which it will be able to formulate its judgement on the distribution of risks around the most likely outlook for growth and inflation.
08.06.2017	Press conference	The information that has become available since our last monetary policy meeting in late April confirms a stronger momentum in the euro area economy, which is projected to expand at a somewhat faster pace than previously expected. **We consider that the risks to the growth outlook are now broadly balanced.At the same time, the economic expansion has yet to translate into stronger inflation dynamics. So far, measures of underlying inflation continue to remain subdued.**

Table 13: APP-related statements - Continued

Date	Event	Statement related to APP
23.06.2017	Speech in Brussels	**In a presentation on the economy at a summit of the EU's 28 leaders on Friday, Draghi said the slow price growth meant that the banks accommodative policy would stay as it is for now, an official with knowledge of Draghi's remarks said.** Underlying inflation, the measure of price growth that excludes volatile unprocessed food and energy costs, edged up to 1.2 percent year-on-year in April from 0.8 percent in March, but then eased again to 1.0 percent in May. But Draghi said he expected wage growth to pick up in coming months.
27.06.2017	Speech in Sinatra	Deflationary forces have been replaced by reflationary ones…However, a considerable degree of monetary accommodation is still needed for inflation dynamics to become durable and self-sustaining. So for us to be assured about the return of inflation to our objective, we need persistence in our monetary policy…**As the economy picks up we will need to be gradual when adjusting our policy parameters, so as to ensure that our stimulus accompanies the recovery amid the lingering uncertainties.**