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Impact of Monetary Policy Announcements on Euro Area Yields

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Abstract

This paper examines the impact of announcements of unconventional monetary policies on euro area bond markets. In particular, to isolate the role of the ECB during the combined period of global financial crisis and zero lower bound, we examine the EA yield changes inside a one day window surrounding the announcement of selected non-standard measures. Furthermore, for the purpose of determining the channels through which the monetary policy operates, we use the Arbitrage-free Nelson Siegel model adjusted for lower bound to decompose yield changes to a change in monetary policy expectations and to a change in term premium. Focusing on seven particular announcement dates, our analysis shows that the non-standard measures introduced before 2014 did not manage to produce the expected reduction of euro area yields. The detailed yield decomposition reveals that this was mainly due to tighter monetary policy expectations driven by a hesitant communication strategy employed by the ECB and unconventional measures not meeting the anticipated level of magnitude set by other central banks, in particular the FED. The first considerable dampening effects on bond rates were attained in late 2014 and beginning of 2015 with initiated forward guidance and quantitative easing programs.

JEL-Codes: E51, E32, E43, E44, E52, E58

Keywords: European Central Bank, Yield curve, Krippner-AFNSM, Event study, Expected short rate, Term premium, Monetary policy announcements

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[1]The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Bank of Slovenia.

1. Outline and past literature

This paper analyses the impact of non-standard measures on the euro area financial yields. There are several reasons why practitioners should care how financial markets are affected by monetary policy. Namely, asset prices strongly resemble market expectations on future monetary policy and with that essentially condition the effectiveness of non-standard measures. Next, asset prices importantly determine wealth of economic agents, state of banks' balance sheets, costs of raising new funds and servicing of existing debt. Falling asset prices can therefore significantly impair normal functioning of monetary transmission. In addition, most investment and consumption decisions influencing aggregate demand depend on long-term yields. From a central banking point of view it is therefore very significant how monetary measures are translated to an entire yield curve and not just its short-term part. In fact, the ECB introduced several non-standard measures that were directed at providing additional credit and financial easing through Euro-area debt markets. In that respect it is reasonable to expect that the impact of the ECB's unconventional monetary policy would first be resembled in financial yields as opposed to macroeconomic effects that might only be revealed with significant lag and in the mean time be affected by a multitude of external factors. For these reasons the euro area debt markets seem to be an obvious starting point for analysing the effectiveness of unconventional monetary policy.

The financial yields can in a broader sense be affected either by steering the financial market expectations about the future monetary policy - commonly denoted as policy signalling - or by influencing the relative supply of assets held by the private sector - denoted the portfolio allocation effect. In the context of the non-standard measures introduced between 2008 and 2014, the signalling effect could be perceived as the markets' recognition of the central bank's commitment to maintain future short-term interests near zero, whereas the portfolio allocation is associated with a reduced bond term premium due to an increased demand for medium-to-long-term debt securities and their close substitutes. This kind of decomposition follows the pure expectation theory according to which long-term yields reflect expected return that could be earned by investors from rolling the short-term risk-free asset over a given horizon, and a residual return, reflecting the risk associated with the time component and investors' reluctance towards holding an asset with longer duration. Moreover, as the investors care about the future, both effects should take place immediately after central bank's announcement of the large-scale asset purchases at the future date. Namely, by communicating its intention to the public, central banks may provide the forward guidance to financial markets about future commitments and at the same time indicate the future stock of a particular asset.

Disentangling the two channels plays an important role in understanding how monetary measures get transmitted to financial markets and carries potential policy prescriptions for the volume and monetary tools to be used. For example, in case of the muted signalling channel, the central bank might need to reconsider its communication and forward guidance strategy, whereas in the case of non-operational portfolio channel the volume of measures and targeted assets might be an issue. To differentiate between the two channels our analysis decomposes the euro area financial yields into term premium and the expected short rate path using term-structure modelling techniques. We relate changes in term premium to portfolio channel and the expected short path to signalling of future monetary policy. To isolate the impact of the ECB on financial markets from other influences, the decomposed yield changes are analysed within one day surrounding the announcements of the ECB's unconventional policies.

Analysing the impact of monetary policy on financial markets in the manner just describe has a

long lasting tradition in the existing literature. In the pre-crisis period the event-study methodology was used to analyse the effects of the announced policy rate changes on financial markets. For example, Kuttner (2001) examines the impact of target FED rate on bond yields. The analysis uses data from futures market to decouple expected and surprise changes. The results suggest that the anticipated policy changes have effect close to zero on bond yields, in contrast to an unanticipated change, where impact is large and highly significant. Similar results were obtained for stock market prices in analysis by Bernanke and Kuttner (2005). Gürkaynak et al (2005) employ high-frequency event-study analysis to examine the explanatory power of policy rate changes on intra-daily asset price data. They found that a single factor, i.e. FED fund rate, is not sufficient to explain bond yield changes induced by the monetary policy announcement. Instead, accounting for the future policy path is necessary for capturing entire asset price variation. With respect to the latter, they show that statements, captured by a future policy path factor, have much greater impact on longer-term yields than on the short-term interest rates.

Knowing that the long-term interest rates can predominantly be influenced by a future policy path rather than short rate movements becomes especially important in the crisis and the ZLB period with introduction of measures beyond key policy rates. In fact, according to the New Keynesian models, non-standard measures can only be effective to the extent they change expectations regarding the future policy path (Eggertsson and Woodford, 2003). However, these models are derived based on a restrictive assumption of no financial frictions. In reality, assets are imperfect substitutes, meaning that changing relative supply of a particular asset will have material effect on its price, which opens floor for the portfolio balance effect. The basis to model both channels, signalling and portfolio, could be found in Kim and Orphanides (2007) and Kim and Wright (2005), who by fitting a term-structure model to the US Treasury yields, find that large portion of the long-term yield declines in the pre-crisis period could be ascribed to fall in term premium.

Conversely, Christensen and Rudebusch (2012) utilize this approach in the ZLB time and find that following the FED's announcements of eight major QE programmes, yields for the US 10-year Treasury bond reduced by 89 basis points in total, where the majority of the reduction is attributable to downward revised expectations about the future short-term interest rates. In contrast, their results for the UK indicate that QE announcements affected the financial markets through the portfolio allocation channel as the majority of the 10-year gilt decline could be ascribed to the reduction of the corresponding term premium. A similar portfolio rebalancing effect was found by Christensesn and Krogstrup (2014) for the Swiss long-term government bond yields, following the Swiss National Bank announcements of extending the central bank reserves without any long-term asset purchase programmes.

Standard monetary policy application of the term-structure models and yield curve decomposition commonly follows a conventional doctrine according to which monetary policy impacts an economy through risk-free rate and its policy path (Woodford, 2003). However, many, recently employed, non-standard measures at least partly address also the risk premium. In that light, the term structure models could be used to decompose yields to the expected path and risk premium as suggested by Cochrane and Piazzesi (2005) and Cochrane and Piazzesi (2008). Similar approach was used by Kim and Singleton (2012) who find that significant portion of the Japanese long-term yield dynamics during the ZLB is governed by the risk premium.

In addition to term-structure modelling and observed decomposed yield changes on announcement day, the event-study techniques also include regression based methods to analyse the impact on financial yields. For example, Rogers et al (2014), Wright (2012) and Haitsma et al (2015) regress daily yield changes on a selected measure of monetary surprise. In both cases the event-

study analysis is used, the approach already introduced by Gagnon et al (2011), which focuses on examining the long-term government bond yields on a day before and a day after the particular QE announcement. Joyce et al (2011) and Gagnon et al (2011) apply VAR model with the set of exogenous variables controlling for external influence to examine the impact of central bank induced reduction in the debt stock on excess return and term premium.

Our study focuses on the announcements of seven respective programs devised by the ECB in an attempt to provide additional stimulus to the euro area economy. The announcement dates were selected in a way to encompass the unconventional policies with active engagement in the securities markets. At each particular announcement date we examine the impact of the ECB's monetary policy on euro area yields in a one-day window surrounding the announcement of the program. This type of event study analysis offers a convenient way for examining the effects of monetary policy decisions by isolating the role of the ECB from other external influences. Furthermore, by estimating the term structure model that respects the zero lower bound, proposed by Krippner (2011-2015), in real time, we can attribute changes in the Euro-area yields to the change in expected short rate and to the change in the corresponding term premium.

From the perspective of the overall euro area our results are broadly in line with the recent studies (e.g. example Rodriguez and Carrasco (2014), Kang et al (2015) and Rogers et al 2014), according to which the announcements of the ECB's monetary policy decisions did not produce a far reaching effect on financial markets, or at least not the one that could have been observed in case of the FED or to a lesser extent in case of the Bank of England. For the measures introduced before 2014 the euro area bond yields increased. Reasons for this counter-intuitive response can be twofold. First, as argued by Rogers et al (2014), non-standard measures introduced by the ECB have been largely aimed at reducing intra-Euro sovereign spread, which led to vastly heterogeneous effect across the Euro. Second, institutional framework of the EU prevented the ECB to employ unconventional policies in volume and a level of commitment comparable to other central banks, e.g. the FED or Bank of England. In that manner, Kang et al (2015) argue that the hesitant communication strategy, stressing the temporary nature of the non-standard measures potentially led some market segments to interpret announcements as bad news by linking the non-standard measures explicitly to extraordinary economic times. This is supported by the fact that overall reduction of yields in the entire euro area coincide with the first large scale asset purchase programs in 2014 and the ECB's permanent commitment to non-standard measures.

Beyond this introduction, the structure of the paper proceeds as follows: Section 2 presents the preferred modelling strategy to obtain a term premium and expected short rates from the observed euro area yield curve; Section 3 provides the event study analysis of the effects of key monetary policy decisions; Section 4 compares impact on the euro area periphery and core; Section 5 performs sensitivity analysis; Section 6 concludes.

2. Modelling strategy

To fully develop the event study analysis on bond prices surrounding the policy announcement dates, we employ a dynamic term structure modelling framework. Namely, this framework allows to explicitly model the expectations component for instantaneous risk-free rate and residual term premium. In particular, the three-factor Affine Nelson-Siegel model (ANSM) adjusted for the lower bound presents our preferred modelling choice as it provides a meaningful interpretation of the estimated parameters. The choice follows the course of similar event study analyses,

e.g. Christensen and Rudebusch (2012), Ichiue and Ueno (2013) and Christensen and Krogstrup (2014) who also show relative superiority of the ANSM framework compared to the other yield curve models or simple random walk with respect to forecasting performance and general fit to the actual data. Further, our focus is put on the announcement of non-standard programs that were introduced as the alternative or complement to the standard policy rate due to its limited space for further reduction. In a low interest environment standard yield curve models become theoretically and empirically inconsistent as they allow fitted yields to evolve to negative values with material probability greater than zero. Therefore, in order to prevent arbitrage opportunities and improbable yield curve fits we have to account for the lower bound on interest rates. Throughout the paper we utilize the modification of ANSM proposed by Krippner (2011-2015) that enforces the lower bound on interest rates and offers an arbitrage-free approximation of the framework proposed by Black (1995). The latter imposes the mechanism which defines the actual short rate at time t as the shadow rate r_t that would prevail in absence of the zero lower bound, and a call option offered to investors to hold physical currency with zero return, when the shadow rate evolves to negative values:

$$\underline{r}(t) = r(t) + max(-r(t), 0) \tag{1}$$

The mechanism described by Equation (1) recognizes the existence of physical currency by implying an option to investors to be compensated with payoff $-r(t) = |r(t)|$ for investing at a negative rate $r(t)$. That is, whenever a shadow rate ($r(t)$) undertakes a negative value, the actual rates will be zero as $\underline{r}(t) = -r(t) + max(-[-r(t), 0]) = -r(t) + r(t) = 0$. Considering conventional financial wisdom, a corresponding forward rate expression can be obtained as an expected compounding return from investing in $\underline{r}(t)$:

$$\underline{f}(t,\tau) = \underbrace{E[r(t+\tau|x(t)]}_{f(t,\tau)} + \underbrace{E[max{-}r(t+\tau), 0|x(t)]}_{z(t,\tau)} \tag{2}$$

where $f(t,\tau)$ is shadow forward rate of a given maturity τ and $z(t,\tau)$ is the corresponding forward rate option effect. Krippner (2011-2015) provides a closed form analytical solution for the forward rate curve adjusted for the lower bound in continuous time. For the estimation purposes, forward rate curve enters the state space representation as measurement equation and can in its most generic form, that is, a most general case without any structure on the parameter imposed, be represented as:

$$\begin{aligned} \underline{f}(t,\tau) =& r_L + [f(x_t,\tau) - r_L] \cdot f(t,\tau) \cdot \Phi\left[\frac{f(x_t,\tau) - r_L}{\omega(\tau)}\right] + \\ &+ \omega(\tau) \cdot \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}\left[\frac{f(x_t,\tau) - r_L}{\omega(\tau)}\right]^2\right) \end{aligned} \tag{3}$$

where $\Phi[\cdot]$ stands for a unit normal cumulative density function and $\omega(\tau)$ stands for the volatility function. The corresponding state equation is defined as the Ornstein-Uhlenbeck's continuous analogue of the AR(1) process for the state variables:

$$x_t = \theta + \kappa[\theta - x_{t-1}] + \sigma \tag{4}$$

Where x_t is $N \times 1$ vector of state variables, θ is a vector of long-term state constants, κ is a mean reversion matrix, and σ is a volatility matrix. Important to note here is that the above evolution of state variables is defined under the physical P measure process. The P measure refers to the actual expected values adjusted by individual investor's risk perception. In complete and arbitrage-free markets, however, it turns out that there exists a risk-neutral measure Q, which essentially summarizes all investors' risk premia. Under this measure, the resulting expected returns on all assets, therefore, equal the risk-free rate. Hence, the process P first has to be adjusted for the risk in order to be able to explain the forward rate term structure. A bridge to risk-adjusted process for state variables is a linear market price of risk, which is according to Krippner (2015) defined as a time varying function of a constant $N \times 1$ component of risk γ and $N \times N$ component Γ that relates market price of risk to each state variable. Accounting for the market price of risk expressed as $\Pi(t) = \gamma + \Gamma\, x_t$, provides the risk-adjusted parameters $\tilde{\kappa} = \kappa + \Gamma$ and $\tilde{\theta} = \tilde{\kappa}^{-1}(\kappa, \theta - \gamma)$. A closed-form analytical solution for $\underline{f}(x_t, \tau)$ is governed by a closed-form analytical expressions for $f(x_t, \tau)$ and $\omega(\tau)$, which are defined by state variables x_t and parameters $\tilde{\kappa}$, $\tilde{\theta}$, σ, and r_L. Equations (2)-(4) present a non-linear state-space model which is estimated by the Extended-Iterated Kalman filter procedure. A standard term structure relation is used to obtain interest rates $\underline{R}(t, \tau)$ from forward rates [2]:

$$\underline{R}(t, \tau) = \frac{1}{\tau} \int_o^\tau \underline{f}(t, u) du \tag{5}$$

The shadow short rate $r(t)$ from equation (1) is within this framework extracted from the shadow part of the $\underline{\mathrm{R}}$(t,0) and can be defined as a linear function of state variables $x(t)$:

$$r(t) = a_0 + b_0^{'} x(t) \tag{6}$$

The structure described by (1)-(6) represents the most flexible and general form of the lower-bound Gauss Affine Term-Structre Model, commonly denoted as Shadow/GATSM. However, as stated in the beginning of this section, a subclass of GATSM defined as Shadow Arbitrage-free Nelson-Siegel Model (ANSM) has proven to be the most parsimonious representation for our purpose and many other macro-finance related tasks. In particular, since we are interested in the bond market information from the perspective of the event study analysis of the ECB non-standard measure announcements, the model fit will be of particular importance and we therefore proceed our empirical estimation with the three unobserved factors (Shadow/ANSM(3) model). Other applications may prefer lower factor orders at the expense of model fit, Krippner (2015). The Shadow/ANSM specification imposes a structure on general Shadow/GATSM parameters, which enables state variables to obtain a convenient economic interpretation. Intuitively, the three unobserved factors in the ANSM case can from the yield curve fit perspective, be perceived as the Level (L), Slope (S), and Curvature (C) factors, where in relation to macro-finance the Level and Slope have proven to exhibit a considerable causal relation to inflation and output growth, respectively (see Krippner (2008) and Diebold (2015)). In addition, the ANSM representation deals with another limitation of the most general GATSM specification, namely the inability to account for the small-sample bias common to the estimation of the dynamic term structure models. The latter usually tend to produce estimates biased towards a system dis-

[2] Note that the integral solving for interest rates does not have a closed-form analytical solution due to a cumulative Gaussian distribution contained in the forward rates. Numerical integration with constant time-to-maturity increments $\delta\tau$ is used instead: $\frac{1}{\tau}(\sum_{j=1}^{J} \underline{f}(t, j\,\Delta\tau)\Delta\tau)$

playing a far less persistence that the interest rates actually exhibit. In our application this would mean that the future short rates would be expected to revert to their mean too quickly. The small-sample bias is commonly treated by providing a longer data span and by imposing a unit-root process on the most persistent factor, which is essentially what the ANSM structure does. In general, the Shadow/ANSM specification incorporates the following set of restrictions:

$$x(t) = \begin{bmatrix} L(t) \\ S(t) \\ C(t) \end{bmatrix}; \qquad a_0 = 0; \qquad b_0 = \begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix};$$
$$\tilde{\kappa} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \phi & -\phi \\ 0 & 0 & \phi \end{bmatrix}; \quad (\tilde{\theta}) = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \quad \sigma = \begin{bmatrix} \sigma_1 & 0 & 0 \\ \sigma_2\rho_{12} & \sigma_2\sqrt{1-\rho_{12}^2} & 0 \\ \sigma_3\rho_{13} & \sigma_3\frac{\rho_{23}-\rho_{13}\rho_{12}}{\sqrt{1-\rho_{12}^2}} & \sigma_3\sqrt{1-\rho_{13}^2-\frac{(\rho_{23}-\rho_{12}\rho_{13})^2}{1-\rho_{12}^2}} \end{bmatrix} \tag{7}$$

whereas the remaining parameter set is free to vary[3]. Once our specified Shadow/ANSM(3) is estimated we can extract the estimate of a term premium for each given time point and for a given maturity as follows:

$$TP_t(\tau) = \tilde{y}_t(\tau) - \frac{1}{\tau}\int_t^{t+\tau} E(r_s)ds \tag{8}$$

where $\tilde{y}_t(\tau)$ represents a fitted bond yield for a given maturity and $\frac{1}{\tau}\int_t^{t+\tau} E(r_s)ds$ is a risk neutral-component of a yield, identical to all bonds, regardless of issuer, and it represents the average expected short rate over a given horizon. The term-premium is therefore defined as the residual risk component of investing in a bond of a given maturity τ as opposed to a roll-over strategy of investing at instantaneous risk-free rate for a period $t+\tau$. Finally, conditioned on the estimated state variables, the expected path of the risk-free short rate over a given time horizon is defined as the zero truncated expected path of the shadow short rate:

$$\begin{aligned} \tilde{E}_t\left[\underline{r}(t+\tau)|x(t)\right] &= max\left\{0, \tilde{E}_t\left[r(t+\tau)|x(t)\right]\right\} = \\ &= max\left\{0, x_1(t) + x_2(t)\cdot\exp(-\phi\tau) + x_3(t)\cdot\phi\tau\exp(-\phi\tau)\right\} \end{aligned} \tag{9}$$

2.1. Shadow/ANSM vs ANSM

Equation 8 shows that a proper decomposition of yields will essentially rely on the accuracy of the estimated expectation component, which is numerically obtained as a conditional forecast of a short rate. In other words, how reliably the channels, through which the monetary policy affect the asset prices, are recognized will depend on forecasting performance and general goodness of fit provided by our model. As already mentioned, the ANSM model, not accounting for the interest rate lower bound, is theoretically inconsistent as it allows arbitrage opportunities. This empirically manifests itself in the low interest environment, when the linear nature of the ANSM model, does not prohibit a positive probability of yields evolving to negative rates.

However, the notion of linearity in terms of the ANSM model carries another important implication, namely the assumed constant volatilities of interest rates throughout the entire period.

[3] $r_L, \kappa_{11}, \kappa_{11}, \kappa_{12}, \kappa_{13}, \kappa_{21}, \kappa_{22}, \kappa_{23}, \kappa_{31}, \kappa_{32}, \kappa_{33}, \theta_1, \theta_2, \theta_3, \sigma_1, \sigma_2, \sigma_3, \rho_{12}, \rho_{13}, \rho_{23}$

This is in contrast to empirical stylized facts related to the stickiness of interest rates, observed for economies with an extended zero lower bound environment, e.g. Japan or the US. In that respect, ignoring the stickiness of short rates would in the ZLB period assume a relatively rapid increase of interest from the ZLB which would in turn lead to a consistent understatement of the term-premium. In fact, the bias just described was empirically confirmed for ANSM models related to the US and Japan data by Ichiue and Ueno (2013).

Conversely, the Shadow/ANSM accounts for the ZLB and properly incorporates the distinctly implied reduced volatility of interest rates in a low interest environment and should therefore provide a valid representation of term structure consistently through the entire period. To put this discussion into perspective of the euro area we fit the euro area yield curve, consisting of Euro triple-A zero-coupon sovereign bonds, by respectively applying Shadow/ANSM(3) and ANSM(3) models to the end-of-month yield data spanning the period from January 1995 to June 2015 and including maturities of 0.25, 0.5, 1, 2, 5, 7, and 10 years. Table A.12 compares Shadow/ANSM to ANSM model and their respective goodness of fit measures, whereas the individual parameter estimates are deferred to the Appendix A.

Table 1: Goodnes of fit for Shadow/ANSM and ANSM

	Shadow/ANSM(3)			ANSM(3)		
Maturity	σ_n	Std.err.	RMSE	σ_n	Std.err.	RMSE
0.25	7.68	0.66	6.43	7.91	0.55	7.84
0.5	6.03	0.66	4.96	0.80	0.50	0.14
1	7.04	0.85	6.38	4.53	0.43	4.26
2	6.56	0.81	5.35	4.11	0.61	2.53
5	4.68	0.49	3.78	6.05	0.54	5.64
7	4.33	0.61	3.03	2.59	0.70	1.08
10	10.79	1.00	9.58	15.14	0.90	14.62

Source: *ECB Statistical Data Warehouse, Author's calculations.*

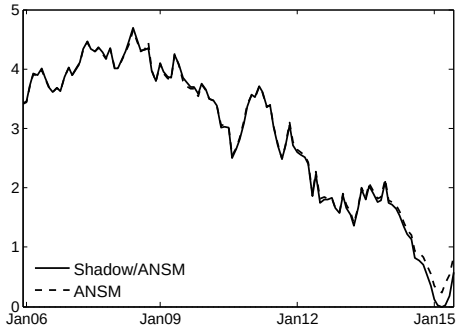
From the perspective of forecasting performance and the accuracy of estimating the expectation component of a bond yield, we can see that the Shadow/ANSM provides a better cross-section fit for 0.25, 5, and 10 year maturities as the difference between yields predicted by the models and actual data, captured by the RMSE statistics, is smaller than in the case of ANSM model. Conversely, the ANSM model provides more accurate predictions of 1, 2, and 7 year yields. Although the forecasting performance for the shortest rate is the most important for the purpose of our analysis, we can hardly say that Shadow/ANSM is any superior to the model not accounting for the ZLB. This result may not be that surprising considering that the two term structure models entirely coincide when interest rates are sufficiently above zero and the fact that the sample is dominated by the period when ZLB was not binding. In fact, the key ECB policy rate (see Section 3) was reduced four times between 2012 and 2014, eventually reaching the binding value of 0.05 %.

Therefore, by solely observing the goodness of fit of estimates, we might not see the actual merits of employing the Shadow/ANSM as opposed to the basic ANSM model. Instead, Figure 1 reveals how the expectation component of the 10-year yield and its corresponding term premium diverge between the two models, once the ZLB becomes binding. As shown by Ichue and Ueno (2013) for the US and Japan, the basic ANSM model tends to consistently underestimate the term premia due to overestimating the projected short rate over the next 10 years. As already outlined, an implication of constant volatility of the short rate in baseline ANSM fails to properly account for the rigidity of short rate movements in the near zero lower bound environment. Consequently,

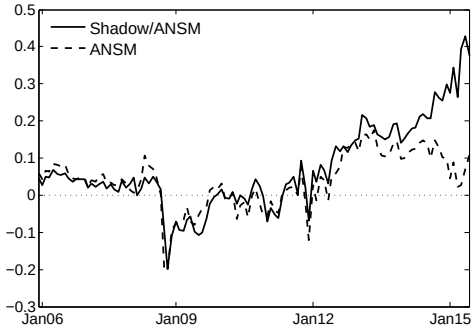
the baseline ANSM projections imply a quick reversion of short rates from the zero lower bound, which in turn makes them empirically inconsistent with the actual observed data. In our case, this bias would be reflected on a rather small portion of the examined sample. However, as it was revealed in Section 3, this period coincides with the introduction of the first non-standard programs that can actually classify as quantitative easing. In that respect, setting up a consistent modelling framework is of particular importance from the perspective of accurately examining the impact of the first large asset purchase program introduced by the ECB and in the context of future research of European monetary policy that is very likely going to involve a prolonged period of binding lower bound.

Figure 1: Decomposition of 10-year yield

(a) Expected short rate over next 10 years



(b) 10-year Term Premia



Source: *ECB; author's calculations.*

3. ECB policy responses between 2008-2015

To examine the impact of introduction of different non-standard policies on euro area interest rates we first need to understand what non-standard measures are and in what way they have been used by the ECB to cope with the severities of the global financial crisis. To classify a particular policy response as the non-standard we define these measures according to Borio and Disyatat (2010), as cited by Rodriguez and Carrasco (2014), who describe unconventional policies as the active use of a central banks' balance sheet to directly affect market prices and conditions beyond a short-term interest rate. In contrast, the ECB's monetary policy before 2008 can predominantly be summarized by standard interest rate responses which incorporated open market operations at a variable rate tender. That is, the ECB assessed weekly system's liquidity needs and auctioned the corresponding monetary basis, where commercial banks could bid for additional liquidity at the rate not smaller than minimum decided by the ECB (the Main Refinancing Operations rate or the MRO rate). The intensity of the global financial crisis, however, forced ECB, like many others central banks in developed economies, to complement their standard channel of monetary policy conduct with measures beyond interest rate policies. The non-standard measures introduced by the ECB, as well as the communication surrounding them, have evolved in line with different stages of the crisis (Rodriguez and Carrasco (2014)).

The first stage essentially represents the outburst of financial crisis which was reflected in the intense banking crisis and mounted counter-party risk. To address the consequent liquidity risks and to relax precautionary holdings, the ECB initially changed variable tenders to unlimited

liquidity provisions at the fixed rate tenders. The first policy program detached from the usual altering of main refinancing rates was announced in October 2008. It included an expanded list of assets eligible for collateral in the Eurosystem credit operations and enhanced liquidity provision of longer-term refinancing operations (LTROs). Moreover, in May 2009, the ECB announced its direct and active involvement in the asset markets with introduction of Covered Bond Purchase Programme (CBPP1). The CBPP1 program, however, was only limited to the private debt markets and it eventually materialized in relatively small value of 61 billion EUR. A sense of indecisive commitment towards unconventional policies and engagement in large scale asset purchases could also be noted in the communication strategy employed by the ECB. At the time incumbent president Trichet stressed, on several occasions, the importance of continuous monitoring of newly deployed measures in order to avoid potential adverse effect that might arise from unconventional policies lasting for too long, which implicitly implied a probable phasing out of the measures in the short-term period.

The second stage of the crisis characterizes a sovereign crisis towards which some Euro countries were drawn in 2010 with first stabilizing sign recognized in late 2011. Even though the sovereign crisis evolved extremely rapidly, the ECB introduced only one additional non-standard measure to directly address sovereign debt issues. In contrast to the CBPP1 program, the modalities of the Securities Markets Program (SMP), introduced in May 2010, clearly expressed the ECB's active involvement in private as well as in the public debt markets. The communication strategy, however, did not change significantly as the non-standard measures remained characterized as temporary in nature rather than a new reality. Furthermore, the SMP was eventually entirely sterilized due to newly raised inflation fears. It was not until 2012, when the sovereign and financial crisis re-intensified significantly, that the ECB clearly expressed its commitment to complement its standard monetary policy conduct with unconventional measures of an arbitrary large volume and time span. The latter can most notably be observed in 2012 June's speech of president Draghi, who among others indicated that the ECB would do anything within its mandate to preserve the common euro area. In that light, the third stage of the crisis resembles re-awakening of the Covered Bond Purchase Program (CBPP2) and more importantly the Outright Monetary Transaction program (OMT). Under the OMT program the Eurosystem's central banks obtained an option to buy government issued bond conditioned upon set of structural conditions that a country, which issued the bonds, had to undertake.

The last stage of the crisis is largely connected to deflationary risk and spans the period from 2013 onwards. The period marks the low interest environment with main policy rates essentially hitting their lower bound in 2014 or in case of the deposit rates even dropping to negative values for the first time. As far as the key monetary policy expectations are concerned, Filardo and Hofman (2013) relate a significant drop in the Euro Overnight Index Swap rate (EONIA) in the second half of 2012 to a distinct forward guidance policy, an instrument indicating the future path of key interest rates that had hardly been used by the ECB in the past. As far as the existing non-standard measures are concerned, the period denotes the suspension of the SMP sterilisation and extension of long-term refinancing operations to very long maturities (VLTRO). An important innovation in dealing with the stagnating economy in the third stage, however, is the introduction of quantitative easing (QE) measures that could match the ones observed in policies employed by the FED, the Bank of England, and the Bank of Japan since the beginning of the financial meltdown in 2008. Namely, in September 2014 the ECB announced the extension of Covered Bonds Purchase Program (CBPP3) to all maturities. In January 2015, the large asset purchase intensions were even further stipulated by introducing the Expanded Asset Purchase Programme (EAPP) that among others included the central government bonds of all maturities with announced combined monthly purchases amounting to EUR60 billion. In addition, the

EAPP was announced to be carried out till at least September 2016 or until the sustained inflation path is recognized by the ECB (ECB, 2015). The CBPP3 and EAPP programs differ from the previous non-standard measure and are closer to the actual definition of quantitative easing policy as a clear intention to influence the market prices through issued central bank reserves can be recognized.

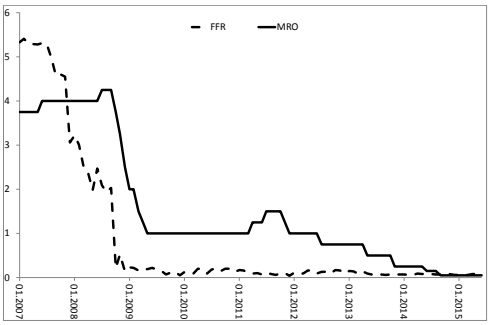
3.1. ECB vs FED

Although the euro area and the US economy experienced almost parallel declines in output and asset prices as a consequence of a global financial shock in 2008, the responses of ECB and FED differed considerably in terms of timeliness and magnitude. Considering first the usual conduct of monetary policy, the FED brought down its key interest rate, the Federal Funds Rate (FFR), to near zero by December 2008 from levels exceeding 5 % in 2007. In contrast, the first response to the crisis by the ECB in 2008 was an interest rate increase, followed by a gradual reduction of the ECB's MRO rate, which was further interrupted by several hikes in 2011 (see Figure 2). The reasons for this deviation in key policy rates dynamics could be sought in the differing mandate of the ECB and FED as well as in the different interpretation of the crisis and its effects. While the ECB has never completely detached from the dual mandate, its primary and formally the only recognized goal during the crisis remained price stability.

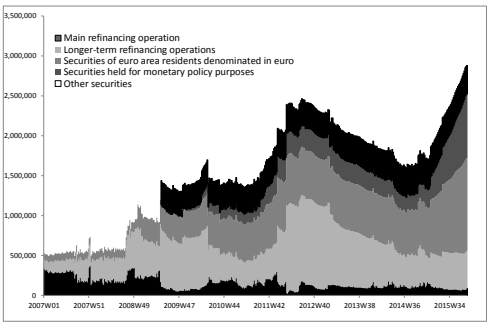
Therefore, the interest rate hikes and the ECB's reluctance to reduce main policy rates can in large part be related to the estimated future inflation risk, whereas in the case of FED the price risk was for the most part downplayed compared to the additional slip in output and financial wealth. In that manner, the comment of the former ECB's president Jean-Claude Trichet upon the increase of key policy rates in April 2011 emphasized the importance of the anchored medium term inflation at 2 % and a need to address the potential influence of the ample liquidity in the system on increasing prices (ECB, 2011). Similarly, the elevated price level mostly driven by commodities was addressed by additional 25 basis point increase in the policy rate amid the peak of the sovereign crisis.

Figure 2: Key policy rates and the ECB's balance sheets

(a) Key policy rates (in %)



(b) ECB balance sheet - selected items



Source: ECB: Statistical Data Warehouse; Federal Reserve Bank of St. Louis.

However, the differing mandates and relative importance given to the anchored inflation expectations are not the only source of differing responses by the ECB and the FED. The non-standard

programs introduced by both central banks also reveal a different interpretation of the crisis in relation to either the bank-based or market-based financing structure of the economy. In the case of the FED, the greatest source of risk to be addressed in the initial stages of the crisis was the huge loss of wealth and confidence as well as the further contraction of economic activity, which could have led to a devastating financial meltdown, Blinder (2013). On the other hand, the primary source of risk interpreted by the ECB was a liquidity shortage originating from the non-transparent and piled-up counter-party risk. The ECB's balance sheet in initial stages, therefore, to the largest part consisted of long-term refinancing operations and extension of corresponding eligible assets (see Figure 2). Conversely, the FED immediately complemented its interest rate cuts with quantitative easing programs and active forward guidance policy. For example, non-standard measures related to securities programs, CBPP1 and SMP, amounted to a maximum of 11 % of the ECB's total assets by 2014, whereas in the case of the FED, securities held for monetary purposes represented nearly 90 % of its balance sheet (Rodriguez and Carrasco, 2014).

As far as the risk related to increased balance sheets and their exit strategy is concerned, the temporary nature of the ECB's initial non-standard programs allowed a shrinkage of its balance sheet by more than 40 % by 2014, mainly due to an early repayment option embedded in the longer-term refinancing programs. In contrast, the large portion of large asset purchase programs by FED was directed to securities between 5 and 10 years duration, meaning that the consolidation of the balance sheet has only been allowed with the selling-off strategy or actual maturity of these assets. However, as described above, the relatively late engagement of the ECB in quantitative easing, with expected tapering not taking place before 2017, is yet to increase ECB's balance sheet by assets related to securities and with the actual risk being absorbed in the latter stage compared to the FED.

From the perspective of setting a structural change as a response to the sources of the financial crisis, the ECB non-standard measures, in particular the OMT, imposed some degree of structural reform on governments making use of it. In contrast, the FED quantitative easing can to a large extent be perceived as a wealth-preserving policy and a continuation of eased monetary standard prevailing in the US since 2002. However, as mentioned earlier, the funding provided by OMT has never actually been utilized by any of the Euro countries up to date.

In the following section we analyse how financial markets perceived the monetary measures outlined above and how did the non-standard programs steer the expectations related to the future development of monetary policy.

4. The impact of non-standard measures on EA interest rates

In this section we perform the event-study analysis to examine changes in the core euro area bond yields upon the announcements of non-standard programs. To isolate the role of the ECB in the period between 2008 and 2015, we estimate the impact of selected policy announcements on the yields over a one-day interval. In line with that, our event study analysis works along three major assumptions: 1) Each announcement is unveiled to the financial markets as a complete surprise; 2) Within a one-day interval, surrounding the announcement, there is no other news that could affect bond yields and interest rates; 3) Markets are efficient in the sense that economic agents update their information set at the announcement of particular measures and not at their actual realization. The first carries a potential threat of understating the actual impact of policy announcement as the economic agents might have anticipated the unveiling of the policy

program beforehand and adjust their portfolios accordingly. Similarly, a potential downward bias is carried with the second assumption. Namely, setting up a one-day window surrounding the announcement poses a trade-off between having a period too short to fully resemble the impact of a newly introduced policy measure on one side, and on the other having the contaminated effect on yields due to other information that might emerge with having a window larger than one day. Nevertheless, even though our analysis might not offer a point precision of estimated impact of MP announcements on the interest rates, it can provide a good insight into how financial markets have perceived the ECB's monetary policy and its credibility in the combined period of the global financial crisis and the zero lower bound period. In addition, the results obtained in this section are directly comparable to the well-known results obtained for the cases of FED (see Gagnon et al (2011), Christensen and Rudebusch (2012)), Bank of England (see Joyce et al (2011)), and Swiss national Bank (see Christensen and Krogstrup (2011)).

Our event study analysis focuses on seven announcement dates related to the unveiling of non-standard programs with a potential to directly or indirectly affect bond markets. In particular, for the purpose of our analysis we assume that bond yields can be affected in two ways, either through the monetary policy signalling channel or through the portfolio rebalancing effect. Namely, in line with the expectation theory (Cochrane, 2001), the yields of a particular maturity can be decomposed into the compounded expected short rate (resembling a roll-over investment into the risk-free short rate), and a term premium indicating additional return investors require for accepting a longer-term yield. Therefore, a policy signalling channel operates when central bank's commitment to easier policy is recognized and investors revise their expectations about the future short rate accordingly. In contrast, the portfolio balance channel comes to effect when central bank's policy actions are resembled in an altered supply related to particular asset market segments. The announced purchases or promised liquid market for certain securities will, according to portfolio balance channel bid up their prices and consequently reduce their yields. Moreover, as Gagnon et al (2011) explain, the altered supply should not only affect the securities it corresponds to, but it is also reasonable to expect to have the effect on the overall yield curve and other closely related assets. The size of the spill over effect will depend on the degree of market segmentation and the extent to which assets of differing maturities are perceived as substitutes.

The first announcement included in the analysis does not include asset purchase interventions per se, but the program involving an expanded list of assets eligible for collateral in Eurosystem credit operations and enhanced liquidity provision of longer-term refinancing announced in October 15th, 2008, represented the first non-standard response to the global financial turmoil and offered a clear indication of easier monetary policy in the future. Conversely, a stronger portfolio rebalancing effect and its spill-over to sovereign yields could potentially be expected in case of the CBPP1 program, announced in May 2009. The next announcement date included in the analysis resembles the ECB's first direct engagement in the government debt markets with an introduction of the SMP program in May 2010. The OMT and CBPP2 programs are included as the measures reflecting the re-intensification of sovereign crisis and a clear shift to a more assertive communication strategy, already discussed in Section 3. The CBPP3 and EAPP programs are the policy measures most comparable to Large Asset Purchase Programs deployed in the US and the UK and are therefore expected to have the clearest dampening effect with respect to both, policy signalling and the portfolio rebalancing channel. All seven non-standard programs and their respective announcement dates are summarized in the table below:

Table 2: Key non-standard program announcements

No.	Date	Event	Announcement
I	October 15, 2008	Liq. prov	GovC decides to o expand the list of assets eligible as collateral and to enhance the provision of longer-term refinancing.
II	May 7, 2009	CBPP1	Decision that the Eurosystem will in principle purchase euro-denominated covered bonds issued in the euro area.
III	May 10, 2010	SMP	GovC decides to conduct interventions in the euro area public and private debt securities markets.
IV	October 6, 2011	CBPP2	GovC decides to launch a new covered bond purchase programme in November 2011.
V	September 6, 2012	OMT	GovC decides on the modalities for undertaking Outright Monetary Transactions (OMTs) in secondary markets for sovereign bonds in the euro area.
VI	September 4, 2014	CBPP3	President Draghi announces CBPP3 program.
VII	January 22, 2015	EAPP	GovC announces an expanded asset purchase programme with combined monthly purchases of corporate and sovereign bonds in amount of EUR60 billion.

Source: ECB Monetary policy decisions, 2016.

To get a glimpse on the impact that each monetary policy decision, described in Table 2, had on the euro area interest rates, we first conduct a model-free inspection of the yield changes on the ECB announcement dates. The yields that we examine correspond to the Euro-area Overnight Index Swap rate (OIS) and the Euro-area yield curve consisting of triple-A zero coupon sovereign bonds[4]. The euro area OIS can be considered as a contract according to which one party pays another the overnight reference rate (EONIA) compounded over a particular horizon in exchange for a fixed interest rate at the end of the period. The Euro OIS rates can in that sense represent a close proxy for monetary policy expectation, subject to its own term premium, and can therefore offer a first glance to what extent can changes in yields be attributable to the policy signalling. Since OIS rates are by their nature primarily driven by market expectations related to short rate path and risk of how it might be changed, we additionally examine government bonds that tend to be more sensitive to asset purchases (which among others included operations on secondary sovereign market) and portfolio effect. To minimize the influence of credit risk and to capture only the movement that conventionally speaking can be related to monetary actions, for time being, only triple-A rated bonds are examined.

The respective yield changes for 2- and 10-year maturities are reported in Table 3. The first thing to note is that the key non-standard measures introduced before 2014 did not manage to provide the expected negative effect on the benchmark OIS and composite EA yields. This supports the discussion developed in Section 3 arguing that the extent and depth of the ECB unconventional policies might have, from the perspective of financial markets, been considered as somewhat disappointing, especially when compared to some other large asset programs unveiled

[4]The euro area yield curve data is calculated by the ECB and is available at: `https://www.ecb.europa.eu/stats/money/yc/html/index.en.html`. The yields for Euro OIS rates, Germany and Spain refer to the respective Bloomberg zero-coupon yield curves

by either FED or BoE in that period. Reasons for a more reserved response could be found in the institutional framework and the single mandate of price stability to which the ECB has to adhere. In that light, the temporary nature of the non-standard measures, which was repeatedly emphasized in the communication strategy surrounding the announcements before 2014, had very likely led markets to perceive a future turn to a tighter monetary policy. In fact, this perception became even more implicit with the two hikes of the main refinancing rate in 2010 and 2011 that is amid the operating and active non-standard policies.

A significant expected downward impact on the overall yields was only achieved with the actual quantitative easing incorporated in the CBPP3 program, and even more so in the EAPP program, with the total diminishing effect amounting to 16 basis points for the 10-year composite EA yield. Examining particular events individually, a little less segmentation and some degree of common component driving the yield changes can be observed from a relatively consistent Euro OIS and composite EA yields spread. An indication that this common component could be the result of a signalling effect, according to Gagnon et al (2011), could be a small difference in change of 2-year yields compared to a 10-years yield change, observed for SMP, OMT, and CBPP2 and CBPP3 programs. Conversely, a relatively stronger effect on yields for longer durations noticed in cases of CBPP1, CBPP2 and EAPP programs might point towards a stronger portfolio balance effect. However, as the yield changes can manifest themselves through two channels operating in the opposing direction, a model decomposition of yields is necessary to offer a more accurate discussion.

Table 3: Basis point change in EA yields on the MP announcement over a one-day window surrounding MP announcements

	Euro OIS		EA govt. debt	
Announcement	2-year	10-year	2-year	10-year
15/10/2008 Liq. Prov.	-23	-5	-7	8
07/05/2009 CBPP1	-4	25	-2	16
10/05/2010 SMP	2	16	9	8
06/10/2011 CBPP2	8	7	9	13
06/09/2012 OMT	3	10	6	5
04/09/2014 CBPP3	-6	-1	-6	-4
22/01/2015 EAPP	-2	-11	-3	-12

Source: *Bloomberg, ECB, author's calculations.*

To decompose yields to a corresponding term-premium part and an average expected path we perform a rolling estimation of the K-ANSM(3) model (Section 2) in real time, that is on the day before and on the day after the announcement. The real time estimation is needed for an alignment with the assumption of each monetary policy announcement being a complete surprise. In that way, the expected path of short rate is always calculated based on the information that markets have up to a particular moment of interest. Table 4 reports the decomposition of Euro OIS rates and composite EA government bond yields with the duration of 10 years.

Table 4: Decomposition of core EA 10-year yield change (basis points)

Euro OIS rate				
Announcement	MP exp. next 10 years	10-year term premium	Residual	Actual 10-year yield change
15/10/2008 Coll. & liq. Prov.	-11	2	4	-5
07/05/2009 CBPP1	24	-1	2	25
10/05/2010 SMP	12	-1	6	16
06/10/2011 CBPP2	8	-2	0	7
06/09/2012 OMT	12	-5	2	10
04/09/2014 CBPP3	-6	5	0	-1
22/01/2015 EAPP	-16	11	-6	-11

EA composite government bond yields				
Announcement	MP exp. next 10 year	10-year term premium	Residual	Actual 10-year yield change
15/10/2008 Coll. & liq. Prov.	-9	3	14	8
07/05/2009 CBPP1	17	0	-1	16
10/05/2010 SMP	8	-1	1	8
06/10/2011 CBPP2	14	-2	0	13
06/09/2012 OMT	2	-3	6	5
04/09/2014 CBPP3	-14	8	3	-4
22/01/2015 EAPP	-80	68	-1	-12

Source: *Bloomberg, ECB Statistical Data Warehouse, author's calculations.*

Yield decomposition shows that, although rather small, the ECB's unconventional policies, announced before 2014, did in fact manage to reduce the term-premium for the EA fixed income securities with the longest durations. However, the dampening term-premium was largely offset by the expected increase in the ECB's main refinancing rate over the next 10 years. This is a natural continuation of the discussion on hesitant ECB policy responses in the initial stages of the crisis, which is resembled in the fact that the monetary policy announcements in that period were not perceived as a credible signal of a policy change, but rather as a reactionary policy with an expected correction in the near future. We can observe the strongest expected policy rate increase in years 2009 and 2011, coinciding with the ECB reports on the upside inflationary risk and consequent decision to increase the MRO rate to 1.5 %. To even further steer the expectations about the tighter monetary policy, the SMP program was terminated in 2011 and not renewed. As reported in Section 3, the record turned in mid-2012 and at the start of the 2013. The price instability was now perceived in light of deflationary risk, consequently changing the communication strategy towards full engagement of the ECB in preserving the currency union and towards a permanent nature of the non-standard measures. The policy shift gradually gravitated towards a full quantitative easing path in line with the large asset purchase programs already taking place in other developed economies since the initial stages of the crisis. The resulting consequence was the average 10 basis point decrease in the expected short rate over the next 10 years for CBPP3 announcement, and further average 48 basis point decrease upon the introduction of EAPP, where the signalling effect is averaged over both types of the fixed income securities reported in Table 4. Regardless of the policy shift, the way in which the asset prices respond to introduction of non-standard measures in the euro area seems to primarily be determined through the policy signalling channel.

5. Country perspective and different monetary policy objectives

The event-study analysis performed in the previous section was based on a rather traditional perception according to which credit and default risks are thought to be matters isolated from the domain of a standard monetary policy conduct (Drechsler et al, 2014). In that matter, using the Euro-area OIS rates or triple-A government bond rates seem to represent a natural way to analyse monetary transmission and is in parallel to studies conducted for the US, UK or Japan (Rogers et al, 2014). And indeed, the correlation between banking sector and sovereign risk was perceived negligible even in the first two years of the global financial crisis. However, as shown by Fratzscher and Rieth (2015) with the single currency crisis that came to effect in 2010 the two-way causality between the sovereign spreads and bank credit risk significantly intensified (concretely, a 100 basis point increase in sovereign spreads should on average be translated in a 40 bps increase in bank risk), where this feedback loop has been in particular exposed for the most distressed countries. In that manner, intra Euro-area sovereign default risks could no longer be ignored by the monetary policy. As already discussed in Section 3, the additional dimension of monetary policy was specifically addressed by some specific non-standard programs, i.e. the SMP and OMT. In particular, president Draghi stressed on several occasions, the importance of narrowing intra-euro sovereign risk spreads for normal functioning of monetary transmission (ECB, 2012).

Specificities of the euro area and non-standard measures that were directly aimed at reducing default and risk premium imply that monetary policy should be measured differently than it is the case for other economies. That is, by solely observing the impact of unconventional monetary policies on risk-free assets we might get a wrong idea about the actual nature of non-standard measures. To get the real impression on tightness or expansion of monetary policy, a cross-country analysis has to be considered instead. Table 5 presents the one-day changes in the Spanish and Italian sovereign yields and respective spreads relative to the German yields.

Table 5: Basis point changes of 10-year sovereign yields and country spreads over a one-day window surrounding MP announcements

	Germany	Spain		Italy		Risk premium	
Announcement	Yield	Yield	Spread	Yield	Spread	Italy	Spain
Liq. Prov.	-2	-7	-3	-5	-1	14	9
CBPP1	21	11	15	5	9	13	12
SMP	15	-47	-44	-31	-28	37	28
CBPP2	16	-92	-25	36	-12	0	9
OMT	9	-77	-77	-50	-50	-21	-22
CBPP3	-1	-22	-17	-19	-14	0	4
EAPP	-15	-20	-21	-20	-22	-0	-0

Source: *Bloomberg, ECB Statistical Data Warehouse, Author's calculations.*

The first thing to note is that the Italian and Spanish yields are, as opposed to the German case, impacted in the expected decreasing direction for all non-standard programs but the CBPP1. The absolute impact was in general much larger for the periphery EA countries which reflects the targeting nature of non-standard measures. Largely diminishing periphery Euro-area spreads relative to the core indicate that the non-standard measures reverted flight-to-quality flows, which could imply reduction in risk premia through the increased confidence and revival of periphery sovereign markets. To formally examine how the term premium of periphery countries was affected by the selected non-standard measures, the technique used for yield decomposition has

to be slightly reconsidered. Namely, for the purpose of the term structure estimation we assumed that short rates were distributed according to the risk-neutral probability measure Q (see Section 2), which in case of the expectation theory coincides with the true measure P. In other words, we assumed that investors did not demand any risk related premium for holding long-term sovereign assets and that the entire excess return could be ascribed to term premium instead. To extract the risk premium associated with sovereigns, issued by periphery countries, we have to therefore extract the true expected short path process (under P dynamics) and subtract it from the risk-neutral one (Q dynamics) (Piazzesi, 2010):

$$Risk\_premium = E_t^Q \left[r(t+\tau)|x(t) \right] - E_t^P \left[r(t+\tau)|x(t) \right] \tag{10}$$

where E_t^Q represents expectations at time t under risk-neutral probability measure, E_t^P represents expectation operator under actual distribution, and $r(t+\tau)|x(t)$ is future development of short rate r over horizon τ, conditional on the current state of latent factors $x(t)$.

By observing risk premium changes on announcement days in Table 5 we can see that the OMT program produced significant stabilization effects on periphery Euro sovereign markets. In case of Spain and Italy, the ECB's announcement to intervene in sovereign markets in case of considerable default treat reduced sovereign credit risk by more than 20 basis points on the announcement date. However, the OMT program seems to be an isolated case as the other non-standard measures did not produce desirable risk premium reduction. This means that the reduction in intra-euro spreads had to come through the signalling channel indicating permanent expected reduction in short-part of the yield curves for the periphery countries. The dominating channel of low future short rates is formally revealed by yield decomposition presented in Table 6 (the decomposition is conducted in the same manner as in the previous section). The CBPP3 and EAPP programs therefore implied monetary expansion for the overall euro area, where long-lasting low interest policy was recognized also by both, the core euro area and periphery sovereign markets. A country-specific analysis therefore reveals varying expectations about the future common monetary policy that are formed in different sovereign markets within the euro area.

Table 6: Basis point changes of 10-year sovereign yields over a one-day window surrounding MP announcements

	Spain		Italy	
Announcement	Exp. short path	Term premium	Exp. short path	Term premium
Liq. Prov.	-13	5	-12	8
CBPP1	8	3	4	0
SMP	-50	2	38	7
CBPP2	-9	0	-3	7
OMT	-63	-13	-44	-5
CBPP3	-20	-1	-17	-1
EAPP	-16	-4	-16	-5

Source: *Bloomberg, ECB Statistical Data Warehouse, Author's calculations.*

6. Sensitivity analysis

Non-standard measures as monetary policy surprise

The strategy used in Section 4 to uncover monetary policy shocks resides on some rather restrictive assumptions. In line with notion that asset prices can only be affected by monetary policy surprises (see e.g. Gürkaynak, 2005) the analysis was based on the short enough window that should in principle enable identification of an unanticipated monetary action and its separation from other influences. But in reality it would not be unreasonable to expect that monetary announcements would have been at least partly anticipated, with news being gradually unveiled to the markets and influenced by policy actions of other central banks and the general macroeconomic environment (Rogers et al, 2014).

For example, in Section 3 we argued that compared to the ECB, the FED responded to the crisis far more aggressively and promptly after the landmark set by the financial breakdown of the Lehman Brothers. In that manner, it can be assumed that the early response of the FED might have led other financial markets around the world to believe that similar measures would be revealed also by other central banks around the world. In other words, prompt and aggressive reaction put FED in a position of leading the markets and setting the norm for the other central banks. Table 8 represents a one day change in decomposition of the composite euro area government yields surrounding the FED's announcements of large asset purchase programs. The detailed description of FED decisions is available in Table 7.

Table 7: FED's LSAP announcements

No.	Date	Event	Announcement
I	November 25, 2008	Initial LASP	FED announces buying of up to $500 billion of mortgage-backed securities (MBS).
II	December 1, 2008	Chairman speech	Chairman Bernanke indicates that the FED could purchase long-term Treasury securities.
III	December 16, 2008	FOMC statement	FOMC indicates possibility to buy long-term Treasury securities.
IV	January 28, 2009	FOMC statement	Announces extended MBS buying and mentions possible long-term Treasury purchases.
V	March 18, 2009	FOMC statement	Fed will purchase an additional $750 billion in agency MBS and announces buying of $350 billion in long teerm Treasuries.
VI	August 12, 2009	FOMC statement	FED announces gradual slowing down of the pace of QE and announces final purchases for October 2009 instead of September.
VII	November 4, 2009	FOMC statement	Amount of agency debt capped at $175 billion instead of the $200 billion previously announced.

Source: *FOMC Monetary policy releases,* 2016.

The EA yield decomposition reveals that the large scale programs, announced by the FED, did in fact produce considerable spill-over effects on the euro area debt markets. The yield change, cumulated over the announcement dates up to March 2009, amounted to little less than 60 basis points. The major part of the yield change can be ascribed to the expected monetary policy easing in the future. The reduction of yields, however, only appears to be in place until the first ECB announcement of asset purchases in May 2009. Following the CBPP1 announcement, the spill-over effects essentially died off, which is not surprising as the euro area financial markets, at that point, had the first actual ECB asset purchasing programs in place, meaning that the FED

announcement did no longer provide the anticipating component or anchor for the monetary policy expectation. What is more significant to observe is that once the FED did no longer provide a direction for the EA markets, the responses of EA yields to ECB's CBPP1 program operated in opposite than the expected direction. Namely the yields increased in EA core as well as in the EA periphery (see Table 5). This could potentially offer an indication that the ECB's non-standard measures were overshadowed by the FED policies and that in the eyes of the financial markets they did not meet the level of intensity and timeliness set by the FED. In other words, we can argue that the expectations about CBPP1 program were formed beforehand and were influenced by external policy conditions[5].

Table 8: Impact of FED QE announcements on EA yields (change in basis points)

EA composite government bond yields				
Announcement	MP exp. next 10 year	10-year term premium	Residual	Actual 10-year yield change
25/11/2008	-13	6	-2	-9
01/12/2008	-23	10	-1	-13
16/12/2008	-18	6	-3	-15
28/01/2009	-9	0	-3	-12
18/03/2009	-9	1	0	-8
12/08/2009	1	0	-1	0
04/11/2009	9	0	0	9

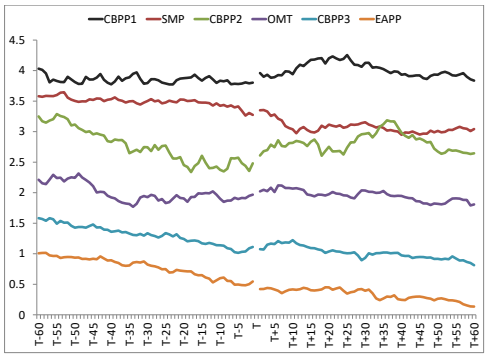
Source: *Bloomberg, ECB Statistical Data Warehouse, Author's calculations.*

An insight in the surprise element of monetary policy can be presumably drawn by observing yield dynamics in extended periods surrounding the announcements. Namely, in line with the previous event-study results of Kuttner (2001), Bernanke and Kuttner (2005), Joyce et al (2011) and others, a considerably persistent effect on asset prices could only be attained through monetary policy surprises. Figure 3 depicts the dynamics of the euro area (composite triple-A bonds) and Spanish yields 60 trading days before and after a particular announcement. The largest and most persistent shift in yield dynamics can be observed in case of the OMT program. As already outlined in previous section, the effect remains limited to the euro area periphery. Conversely, the SMP and CBPP2 produced only a short-lived expected effect on Spanish sovereign yields which was followed by a strong reversion to increasing yield dynamics in the extended period following the announcement. In case of the Euro-area core the largest and most persistent shift could be observed for the first two CBPP programs which could be connected to the reversal in safety flows. In contrast to earlier measures, the EAPP produces consistent effects through the entire euro area with considerable and persistent reduction in sovereign yields being observed for both the Euro-area core and periphery.

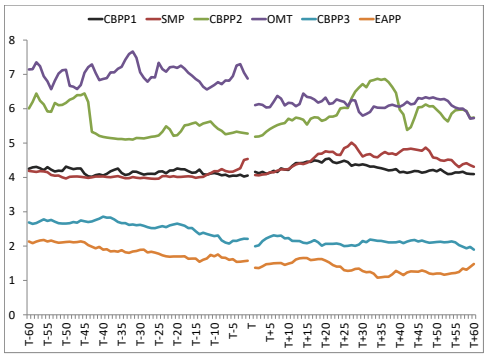
[5]We treat monetary surprises in relation to the central bank's intentions. Namely, one could argue that the disappointment of financial markets reveals an unanticipated tighter than expected monetary policy, but this would be counter-intuitive to the nature of the CBPP1 which was introduced as monetary expansion tool

Figure 3: Sovereign yield dynamics in 60-day window surrounding announcements (in %)

(a) Euro-area core



(b) Spain



Source: *Bloomberg, ECB Statistical Data Warehouse.*

However, concluding on a surprise component based on the extended window surrounding the announcements could potentially lead to a noisy measure contaminated by other influences and general macroeconomic developments. To formally extract a surprise component, the majority of the literature resort to observing parallel change in futures rates as proposed by Kuttner (2001). The idea follows the notion that futures prices reflect the market expectations of future policy rates (Piazzesi and Swanson, 2008). In that manner, changes in futures rates to a monetary policy announcement represent contribution of the surprise component incorporated in change of a key policy rate. With respect to unconventional policies and ZLB period, however, policy rates can no longer be used to estimate the surprise component as a contribution of futures change to the movement of policy rate.

Nonetheless, even though the surprise component cannot be estimated point wise, the size of the change in futures rates can offer an indication on the extent to which the announcements of non-standard measures were unexpected. But since in the ZLB period the short-term interest movement is bounded we focus on one year ahead Euribor futures rates, which should reflect a change in short to medium-term policy path rather than current stance. Having said that, the unchanged futures rates would in principle suggest that the monetary policy announcements were entirely anticipated beforehand. Table 9 shows that futures rates have indeed changed at every announcement for period after 2009 for which the data series is available. However, the mean one day absolute change for period 2009-2015 were surpassed only in case of the CBPP2 program, where rates increased by 10 bps (1.2 standard deviation). For the other measures the change is broadly in line with mean sample indicating that the announcements of monetary policy surprises did not carry an extraordinary surprise element and were at least in part anticipated by markets. In that respect, the monetary policy impact estimated by the event-study analysis should be interpreted with caution as the true effect of non-standard measures is very likely understated.

Table 9: One day changes (in bps) in one year ahead futures rates

	SMP	CBPP2	OMT	CBPP3	EAPP	Mean	St. dev.
One-year ahead futures	4	10	4	-5	-4	4	4

Source: *ECB Statistical Data Warehouse, Author's calculations.*

Event-study and expectation theory

Aside from monetary announcements being unveiled as a complete surprise, the event-study analysis assumptions to the large extent worked along the expectation theory, according to which investors only care about the size of a yield that particular asset is carrying. To the extent that money and bond holdings are imperfect substitutes this allowed us to assume that the anticipated money holdings obtained from future central bank's asset purchases would be invested in other, perhaps riskier assets that are expected to maintain the desired amount of yields. In that manner asset purchases would reduce wider spectre of yields in the economy. In other words, we expected the portfolio effect to be an operating channel for sovereign bonds also in case of CBPP programs, which were primarily aimed at reducing yields of covered bonds. But in reality investors might not be that quick in adjusting their portfolio and size of the earned yield might not be the only driver for investment decisions. A deviation from the pure expectation theory could for example be reflected by the preferred habitat theory according to which investors not only care about the return, but also rank assets according to the preferred maturity (Piazzesi, 2010). In that sense, investors with an explicit preference for particular maturities might not be willing to switch to a longer-part of the yield curve unless term premium is sufficiently high. This could potentially carry important implications for our analysis.

For example, as the CBPP1 program in practice mainly included bond purchases with maturities of three to seven years[6], investors might have sought additional return only in sovereign markets with a comparable maturity, whereas the long-term markets may have stayed unaffected. To verify this, the event-study analysis is replicated on sovereign yields up to 3 years maturity. Table 10 shows that results for the 3-year yield, qualitatively speaking, stays unchanged in comparison to changes in 10-year sovereign bonds. Monetary policy signalling stays the prevailing channel of monetary transmission and sign of changes at each announcement almost entirely agree with the results obtain for the 10-year bonds. Slight changes in the size of the response can be observed in case of Spain. The impact of SMP program induces 30 basis points larger reduction in 3-year yields, whereas in case of the CBPP3 and EAPP the effect gets attenuated.

[6]See ECB, Final Monthly Report on the Eurosystem's Covered Bond Purchase Programme, June 2010.

Table 10: Changes of 3-year sovereign yields over a one-day window surrounding MP announcements (in basis points)

Announcement	ECB 3-A			Spain		
	Exp. short path	Term premium	Actual change	Exp. short path	Term premium	Actual change
Liq. Prov.	-2	-17	-19	-26	-2	-28
CBPP1	4	-1	3	-3	2	-1
SMP	7	3	10	-83	1	-82
CBPP2	12	-2	10	-10	-1	-11
OMT	11	-5	6	-52	-7	-59
CBPP3	-15	9	-6	-24	11	-13
EAPP	-15	10	-5	-18	9	-9

Source: *ECB Statistical Data Warehouse, Bloomberg, Author's calculations.*

Sensitivity to window length

Another aspect of sensitivity of the event-study analysis could be related to the choice of window in which the impact on yields is being examined. For example Christensen and Rudebusch (2012) and Christensen and Krogstrop (2014) explore yield changes in a 2-day window surrounding particular announcements in order to account for the learning process, which might be longer in relation to the measures that were unfamiliar to the markets in the pre-crisis period. Table 11 shows that results are robust to the two-day window.

Table 11: Changes of 10-year sovereign yields on the MP announcement over a two-day window (bps)

Announcement	ECB 3-A			Spain		
	Exp. short path	Term premium	Actual change	Exp. short path	Term premium	Actual change
Liq. Prov.	-17	11	-6	-14	1	-14
CBPP1	12	-2	11	10	0	10
SMP	7	-2	5	-45	0	-45
CBPP2	37	-4	32	-10	0	-10
OMT	7	3	10	-92	1	-92
CBPP3	-10	8	-2	-29	9	-19
EAPP	-71	63	-8	-33	13	-20

Source: ECB; Bloomberg database; author's calculations.

7. Conclusion

With the crucial role that future monetary policy prospects play in the effectiveness of unconventional policies this paper addresses methodological issue of properly estimating monetary policy expectations. This question becomes particularly important in the low interest environment with the short-term yield movement bound by the ZLB. Monetary expectations were modelled using ZLB-adjusted Affine Nelson-Sigel model proposed by Krippner (2015). As the accuracy and fit to the observed yield is crucial for this application the methodology relied on 3 latent factors driving the short rate dynamics and its future path. For the period when the lower

bound became effective in the euro area we show that not accounting for the ZLB can lead to consistent overestimation of expected future short path and consequently to underestimation of term premium. Using the standard Guassian term structure models, therefore, fails to account for the reduced volatility and stickiness of short-term yields in the low interest environment.

The methodology for modelling the monetary expectations was used to examine the role of the ECB in averting financial impairment and the perception of this role by financial markets. The result of the event-study analysis suggests that the non-standard measures affect euro-area financial markets predominantly through the monetary signalling channel, whereas the portfolio balance effect remains rather modest. Based on that result, the desired effects on the euro-area debt markets could be achieved either by introducing the formal forward guidance with explicitly stated future policy commitments or by increasing the span and volume of non-standard measures to attain stronger impact through portfolio balance channel. The event-study analysis shows that the non-standard measures introduced before 2014 did not produce the expected reduction in Euro OIS rates and risk-free sovereign yields. Namely, the re-intensification of the currency and sovereign crisis were followed by the non-standard measures that were specifically targeted at reducing inter-country sovereign yields and country specific risk premia to ensure integrity of the euro area. In that sense, the euro area bond markets exhibited heterogeneous impact on yields, with a tighter stance in the core euro area reverting safety flows and significant reduction in periphery area sovereign yields. In particular, the strongest stabilizing effects could have been observed in the case of the OMT program, where the announcement alone (the OMT has so far not been materialized) reduced risk premia in Spain and Italy by more than 20 basis points. In contrast to measures introduced before 2014, the more explicit forward guidance expressing the permanent nature of unconventional policies and the extended large asset purchase program produced a considerable reduction in expected monetary policy path and yields in general across the entire euro area.

The results of the event-study, however, have to be interpreted with caution and within the limitations of this kind of an analysis. Namely, it is based on rather restrictive assumptions, especially related to the notion that the non-standard measures were unveiled to the financial markets as a complete surprise. The robustness analysis showed that in the majority of the cases the non-standard programs had potentially been at least partly anticipated before their actual announcements. In that manner, the investors potentially already performed some adjustments to their portfolios beforehand, which would lead to underestimation of the portfolio balance effect and yield change on the announcement date. Moreover, the event-study is essentially static analysis of monetary policy impact. It therefore does not offer the insight on the persistence of monetary policy effects and potential learning process that might take place in financial markets.

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Appendix A. Estimated parameters of the term structure models

Table A.12: Parameters of Shadow/ANSM and ANSM

	Shadow/ANSM(3)		ANSM(3)	
Param.	Estim.	Std.err.	Estim.	Std.err
Φ	0.5819	0.0000	0.5547	0.0117
$\kappa_1 1$	0.1259	0.1509	-0.1547	0.1219
$\kappa_1 2$	0.0210	0.2279	-0.3341	0.1942
$\kappa_1 3$	-0.1722	0.1005	-0.0692	0.1329
$\kappa_2 1$	0.2756	0.1953	0.4431	0.1569
$\kappa_2 2$	0.6505	0.2614	1.1310	0.2544
$\kappa_2 3$	-0.3627	0.1369	-0.7123	0.1774
$\kappa_3 1$	-0.1239	0.3073	0.2487	0.3778
$\kappa_3 2$	-0.0094	0.4871	0.0336	0.7053
$\kappa_3 3$	0.3210	0.2814	0.7684	0.4154
θ_1	6.2178	1.5114	3.6951	4.2822
θ_2	-3.3562	0.0339	-1.5626	2.3248
θ_3	-2.3976	1.5041	-1.6067	0.9368
σ_1	0.7566	0.0241	0.7500	0.0530
σ_2	1.0575	0.0055	0.9891	0.0528
σ_3	2.3327	0.1518	2.6092	0.1727
$\rho_1 2$	-0.8098	0.0262	-0.7912	0.0299
$\rho_1 3$	-0.0473	0.0846	-0.2444	0.0868
$\rho_2 3$	0.0002	0.0822	0.0003	0.0830