Monetary Policy Surprises Over Time

Marcello Pericoli* and GiovanniVeronese*
Banca d'Italia

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Abstract

We document how the impact of monetary surprises in the euro area and the US on financial markets has changed from 1999 to date. We use a definition of monetary policy surprises, which singles out movements in the long-end of the yield curve– rather than those changing nearby futures on the central bank reference rates. By focusing only on this component of monetary policy our results are more comparable over time. We find a hump-shaped response of the yield curve to monetary policy surprises, both in the pre-crisis period and since 2013. During crisis years Fed path-surprises, largely through their effect on term premia, account for the impact on interest rates, which is found to be increasing in tenor. In the euro area the path-surprises reflect the shifts in sovereign spreads, and have a large impact on the entire constellation of interest rates, exchange rates and equity markets.

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1 Introduction

The global financial crisis has sidelined the traditional tool for expansionary monetary policy and central banks have resorted to unconventional policies, including forward rate guidance, large-scale purchases of private and public securities and the broadening of the pool of assets eligible as collateral. This increased dimensionality over which monetary policy operates complicates the task of finding a concise measure of the stance of monetary policy, and even more in defining private sector expectations over it, potentially invalidating any attempt to rely on simple event-study methods.

Measuring the effect of monetary policy news on asset prices hinges on the possibility to extract the surprise component contained in policy announcements. In periods of conventional monetary policy, when the stance is well summarized by the level of short-term nominal interest rates, identification of the surprise is achieved by computing the difference between the central bank's announcement concerning the official rate or the monetary policy stance and the "ex-ante" expectation of this announcement. With announcements occurring at well defined dates, the *event study approach* introduced by Kuttner (2001) and Bernanke and Kuttner (2003) has been used extensively to assess how financial markets react to monetary policy surprises, as well as to improve the identification of monetary policy shocks in VAR models (Cochrane and Piazzesi, 2002).

Still, if one is willing to consider a *composite* effect of monetary policy surprises on other asset prices, a measure of monetary policy surprise can be recovered by examining the "joint" movement in government bond yields around announcements. Looking at the shifts along the entire term structure, rather than at very short term, allows to detect also movements in long rates induced by announcements on forward guidance as well as on asset purchases, which have been the key policies used by central banks in the recent years. According to this logic, Wright (2012) and Rogers et al. (2014) define a monetary policy surprise using the first principal component score of the 2-year, 5-year and 10-year US Treasury futures to capture the movements in the US term structure induced by announcements. They then abstract from the question of the efficacy of monetary policy in affecting government bond yields, which they take as their input, and attempt to measure the *pass-through* from a given "average" shift in yields onto other asset prices.

We embrace this approach to document the reaction of several asset prices to monetary policy surprises in the euro area and in the United States. Since the analysis spans pre-crisis years as well as the most recent period of unconventional monetary policies by the European Central Bank (ECB) and the US Federal Reserve (Fed) we do not attempt to estimate these reactions over a common sample, but rather split it into more homogenous periods.

We distinguish three different periods to account for the substantial changes in monetary policy frameworks and instruments over these years. Namely, we define a **pre-crisis** period from January 1999 until November 2008, the official start of the first Quantitative Easing program in the US. The second period, which we label **crisis**, runs from November 2008 to Decemeber 2012, a few months before the first "tapering" announcement by the US Fed. The last period, which we label **post-crisis**, runs from January 2013 to September 2016, the end of our sample.

Since our study spans years of both conventional and unconventional monetary policies, we identify a particular dimension of monetary policy surprises, which we deem to be more comparable across these different periods. In particular, we flesh out the component affecting more the longer-end of the yield curve— rather than the one leading to changes in nearby futures on the central bank reference rates. To this end we follow Gürkaynak et al. (2005), the first to propose a decomposition of surprises into a "path-component" and a "target"one. They show how in the US the path component, even in the years before the global financial crisis, represented an important dimension of monetary policy decisions, with instead Fed FOMC decisions regarding the target rarely being a surprise. After the global financial crisis, with official rates falling towards zero and with the adoption of forward guidance and quantitative easing measures, the component relating to the target undoubtedly lost further relevance as a source of monetary surprises, while the path component gained further prominence.

By describing the effects of monetary policy surprises on a wide range of asset prices we can provide some indication on the underlying channels activated by the ECB and the Fed across these different periods. We find that during the "pre-crisis" period path-surprises, both in the US and the euro area, propagate through the entire domestic term structure of interest rates with a hump-shaped pattern. For the euro area the shifts of the yield curve are also very similar across countries, as sovereign risk was priced uniformly. A contractionary path-surprise by the Fed leads to a USD/EUR exchange rate appreciation and an increase in US stock market, the latter suggesting a positive revision to expected excess equity returns. A similar finding holds for the euro area, with the USD/EUR depreciating and stock market indices in the four largest economies rising.

In the "crisis-period" the impact of US monetary policy path surprises along the term structure is no longer hump-shaped but it is increasing in tenor. This reflects largely the effect of movements in bond term premia, consistent with the functioning of a duration channel of monetary policy. Fed surprises have a modest spillover on other countries' bond and stock markets and their impact operates mainly through the US dollar exchange rate. Conversely, in this period characterized by the sovereign debt crisis and the response by the ECB to contrast the re-denomination risk, ECB surprises are now akin to a shock in the spread between sovereign yields of core and more vulnerable euro area economies. Unsurprisingly, ECB surprises leading to a reduction in soveregin spreads lead to marked increase in euro area stock prices (Krishnamurthy et al., 2015). Also, the impact on the USD/EUR exchange rate is much stronger than in the "pre-crisis" period for the ECB while it is somewhat weaker for the Fed.

In the final "post-crisis" period the transmission of monetary surprises to other asset prices becomes more in line with the "pre-crisis" period. In particular, in the US the yield curve response morphs back to its conventional hump-shape pattern, although the term-premia component still accounts for a sizeable fraction of the shifts. In the euro area, as a result of the fading away of the euro area breakup fears, interest rates across the main economies respond in the same direction to monetary policy surprises, with different magnitude and direction. Furthermore, the path-surprises associated to the ECB forward guidance and Asset Purchase Programme (APP) impact significantly euro-area term premia, while the

response of sovereign risk premia remains muted.

The paper is organized as follows. Section 2 briefly reviews the literature on the impact of surprises on asset prices. Section 3 describes the data. Section 4 introduces our definition of monetary policy surprises, Section 5 presents our methodology to identify their impact, and Section 6 the results. Section 7 concludes.

2 Literature review

A standard problem in empirical macro/monetary economics is separating exogenous changes in monetary policy from endogenous responses of monetary policy to the economy. One approach is to use daily or intra-daily data on days of monetary policy announcements – Kuttner (2001), Bernanke and Kuttner (2003), Gürkaynak et al. (2005), Gürkaynak et al. (2007). This literature assumes that unexpected changes in monetary policy can be proxied by changes in the futures on the federal funds rate, since expected changes should be already priced in the pre-announcement quotes.

Daily data may well not be enough to resolve the issue of endogeneity, as some monetary policy announcements occurred in response to weak macroeconomic reports released earlier in the same day. The potential endogeneity problem is even greater for two-day event windows – Gagnon et al. (2011), Hanson and Stein (2015). The literature addresses this identification problem either by using intra-daily data or by identifying surprises through heteroskedasticity – Rigobon (2003), Rigobon and Sack (2003), Rigobon and Sack (2004). Nevertheless, Gürkaynak et al. (2005) show that results obtained using daily data are not dissimilar from those with intra-daily data, especially for monetary policy surprises events after 1994. Lacking intra-daily data, we tackle the issue of endogeneity between monetary policy and other macroeconomic announcements by controlling for the surprise component in the main US and euro area macroeconomic indicators.

With the introduction of unconventional monetary policies identifying monetary policy surprises is more challenging, because short-term interest rates are close to their lower bound and asset purchases become a new policy tool. Before the global financial crisis Gürkaynak et al. (2005) and Gürkaynak et al. (2007) had already pointed out that only considering changes in the target federal funds rate may not be enough to capture announcements effects on the path of forthcoming federal funds rates. To this end, they extract principal components of yields not only from futures on short-term interest rates, but also from longer tenors. They interpret the resulting first two factors, after a suitable rotation, as a "current federal funds rate target" factor and a "future path of policy" factor.[1]

In line with this approach, some authors propose to measure monetary policy surprises from shifts across the whole term structure. Thus, Rogers et al. (2014) build a monetary policy surprise taken from the entire term structure of US interest rates (or Treasury futures). Swanson (2015) estimates two dimensions of monetary policy during the 2009-2015 zero-lower bound (ZLB) period in the US and shows that, after a suitable rotation, these two

[1]The authors find that both rate changes and statements have important but differing effects on asset prices, with statements having a much greater impact on longer-term Treasury yields.

dimensions can be interpreted as "forward guidance" and Large-Scale Asset Purchase (LSAP) programs. The sizes of the forward guidance and LSAP components of each announcement after meetings of the Federal Open Market Committee (FOMC) between 2009 and 2015 correspond closely to identifiable features of major FOMC announcements over that period. Forward guidance has relatively small effects on the longest-maturity Treasury yields and essentially no effect on corporate bond yields, while LSAPs have large effects on those yields but essentially no effect on short-term Treasuries. Both types of policies have significant effects on medium-term Treasury yields, stock prices, and exchange rates.

An alternative strategy is to assume that the entire announcement is unexpected and thereby attribute to it the entire jump in asset prices, both government bond yields and other assets. This is the approach followed by several authors (Gagnon et al., 2011; Krishnamurthy and Vissing-Jorgensen, 2011) who provide an assessment of the effects of the LSAP in the US, by adding up the jumps in asset prices recorded in short windows around the key LSAP Fed announcements. This method was used more recently to investigate the effects of the ECB APP on various asset prices, by considering the 22 January 2015 announcement in isolation (Georgiadis and Grab (2015)) or by cumulating the effects recorded on several carefully selected APP announcement dates, spanning from the first hint of such a policy in Septempber 2014 as in Altavilla et al. (2015).[2]

The literature has spotted two main channels at work during unconventional monetary policies. The first is the "signaling channel", activated by the central bank communication or guidance, which can influence expectations about its policy decisions and restore confidence in the financial system. The second is the "portfolio-balance channel", activated by central bank asset purchases, that in turn may be distinct in the "duration channel" in tranquil times, and the "scarcity channel" at times of financial distress (Krishnamurthy and Vissing-Jorgensen, 2011; Altavilla et al., 2015; Swanson, 2015). In this paper we do not attempt to disentangle these two channels. In fact, "forward guidance" may impact both short- and long-term interest rates by means of a reduction of monetary policy uncertainty that tightens long-term premia; similarly, asset purchases may impact targeted assets as well as the several other assets returns – even at the short-end of the maturity spectrum – through portfolio reallocation by investors.

A specific strand of literature has analyzed the channels of transmission of unconventional monetary policy. For the US, Gilchrist and Zakrajšek (2013) show that estimating the effect of Fed announcements of LSAP on corporate credit risk is complicated by the simultaneity of policy decisions and movements in prices of risky financial assets, as well as by the fact that both interest rates of assets targeted by the programs and indicators of credit risk reacted to other common surprises during the recent financial crisis. The authors employ a heteroskedasticity-based approach to estimate the structural coefficient measuring the sensitivity of market-based indicators of corporate credit risk to declines in the benchmark market interest rates prompted by the LSAP announcements. The results indicate that the LSAP

[2]Another approach attempts to estimate the surprise component of asset purchases relying on survey data among investors, regarding the size and the timeline of these programs. However, information on these is quite limited in terms of data availability and the representativity of the investors' beliefs from these surveys is rather incomplete.

announcements led to a significant reduction in the cost of insuring against default risk – as measured by the CDX indexes – for both investment-grade and high-yield corporate credits.

For the euro area Altavilla et al. (2015) evaluate the effects on asset prices of the ECB APP and assess its transmission channels in light of a term structure model with bond supply effects to account for assets with multiple types of risk premia. The model-based predictions for cross-asset price movements are associated with different transmission channels. By means of an event-study around the APP events, they document its sizable impact on asset prices and how the low financial distress prevailing at the time of the program did not undermine its efficacy. While weakening certain transmission channels (scarcity channel) the APP has reinforced other channels, namely the duration and the credit channels, and facilitated the spill-overs to non-targeted assets.

3 Data

3.1 Asset prices

The use of several assets and the analysis of their responses allows to identify the underlying channels of transmission, as advocated by Krishnamurthy and Vissing-Jorgensen (2011) and Jarrow and Li (2015). In general, we expect that announcement effects of unconventional monetary policy measures tend to significantly lower yields for a broad set of market segments, with effects that generally rise with maturity and riskiness of assets. We investigate whether low financial distress, while indeed weakening certain transmission channels, may reinforce other channels because of its interplay with the asset composition of the unconventional measures. Targeting assets at long maturity and spanning the investment-grade space may support the duration and the credit channels. At the same time, the low degree of financial stress prevailing at announcement of the unconventional measures, while weakening the local supply channel, may facilitate spill-overs to non-targeted assets. Table 1 present a description of the data included in our analysis.

Besides bond yields in some euro-area countries and the US, we consider the three main cross-exchange rates (USD/EUR, USD/GBP and YEN/USD), and the main stock market indices of the whole euro area, Germany, France, Italy, the US and Japan. Furthermore, we evaluate the impact of our monetary policy surprises on the medium and long term premia implied in government bonds (at the 2-year, 5-year and 10-year maturity). To this end we first compute the term premia using a Gaussian Affine Term Structure Model with three factors with the methodology described in Pericoli (2013) and Adrian et al. (2013). We also look at movements in expected inflation implied in inflation swaps (at the 5-year and the 5-year forward 5-year maturity), as well as sovereign CDS and corporate spreads. Finally, we assess the impact of monetary surprises on some measures of volatility in bond markets (the US MOVE index and the implied volatility of futures on the 10-year German Bund), volatility of the foreign exchange market (the implied volatility of futures on the main cross-exchange rates), a measure of investors asymmetries in the foreign exchange market (the 25δ risk reversal of options on the EUR/USD), the relative cost of funding in USD versus euro

(the 1-year cross-currency USD/EUR basis) and the price of oil (USD per Brent barrel).

US daily bond yields and inflation swaps are collected at 16:30 GMT; German, French, Italian and UK bond yields and inflation swaps at 17:30 Greenwich Meridian Time (GMT); stock market indices are collected at 5:30 GMT; exchange rates at 16:00 GMT (at 15:00 GMT during British Summer Time). The Fed FOMC announcement are released between 12:30 and 14:15 US Eastern Time that correspond to 17:30 and 19:15 GMT in standard time. For this reason we use a two-day average for those data released before 17:30 GMT. Conversely, ECB GC announcement are usually released at 12:45 GMT.

Our measures of monetary policy surprises are constructed by using a mix of short-term interest rates and medium- and long-term bond yields – see Section 5 for a precise description. For the United States, to capture the short end of the curve we use the same set of federal funds futures and eurodollar futures rates, with one year or less to expiration as in Gürkaynak et al. (2005). To this set we add yields from longer dated bonds, namely the 2-year, 5-year and 10-year Treasury bond yields.

For the euro area, to capture the short end of the term structure, we use the 1-month, 3-month, 6-month, 9-month and 1-year euro Overnight Interest Rate Swaps (OIS). These are a good proxy for expected risk-free interest rates, as they are linked to the overnight interest rates prevailing in the euro-area interbank market. As to longer dated bonds, we include the 2-year, 5-year and 10-year bond yields of the four largest economies in the euro area, to account for the heterogenous evolution in sovereign credit risk: therefore we look at the market benchmarks for German Bunds, French OAT, Italian BTP and Spanish Bonos.

Our sample only refers to monetary policy announcements, scheduled or unscheduled, leading to a surprise in financial markets.

3.2 Monetary policy announcement days

Monetary policy days are selected as those with scheduled and unscheduled central bank board meetings as well as those with important central bank announcements regarding monetary policy. For the ECB we follow a narrative approach and we identify not only the days of the meetings of the Governing Council (GC) but also consider relevant speeches of the ECB President – such as the pronouncement about the intention to preserve the integrity of the single currency in July 2012, e.g. the "whatever it takes ..." speech, and the explicit introduction of the "forward guidance" in July 2013. For the US, we use the regular meetings of the FOMC, semi-annual Congress testimonies by the Fed Chairman, relevant hearings of the Fed Chairman before the Congress Joint Economic Committee, and yearly speeches taken at the Jackson Hole conference.[3] A detailed list of announcement dates is reported in the Appendix for the euro area and for the US starting from the crisis period (Tables A-3 and A-4).

In days with monetary policy announcements interest rates display greater volatility than in the rest of the sample (see Table 2).[4] In the first period, before the financial crisis,

[3]We thank John Rogers for kindly sharing his dataset on announcement days as well as for high-frequency asset price changes around them.

[4]This difference is the key assumption underlying the identification of Rigobon (2003)

the standard deviation of interest rates is significantly larger than on non-event days, and decreasingly along yields tenor. During the second period, in the US the difference between meeting and no-meeting increases especially at longer tenors, underscoring the role of risk premia in driving yield changes. In the euro area the volatility of yields becomes increasing in tenors only in the third sub-period, as short-term interest rates reached the zero lower bound.

4 Monetary policy surprises

Monetary policy surprises are constructed according to the spirit of Kuttner (2001), using data from the futures market to disentangle the expected and unexpected component of interest rates changes on the dates of central bank announcements.

In principle, it should be straightforward to compare the effects of a 25 bp unexpected change in the central bank policy rates. However, when dealing with periods characterized by the zero lower bound it is not obvious what particular tenor in yields to consider as a "reference" for the central bank. Since our goal is to compare the effect of similar surprises also across periods, we need to adapt the original method of Kuttner (2001) to account for the unconventional monetary-policy phases.

Rather than choosing a specific horizon, as for instance in Hanson and Stein (2015) who look at two-year Treasury yields, we follow the more general approach in Wright (2012), who exploits the response of the entire US term structure. In his setup, monetary policy surprises are defined as a linear combination of the change in short-, medium - and long-term interest rates on central bank announcement dates.

However, since our study spans both conventional and unconventional monetary policy periods, we depart from Wright (2012) and focus only on a particular component of the monetary policy surprise, the one stemming from the communication of policy beyond immediate target changes. As already documented by Gürkaynak et al. (2005), by far the most important component of monetary policy decisions is the one which moves expectations on future policy, rather than immediate changes in the policy rate. This already held true in the years before the global financial crisis, when policy rate changes, thanks also to improvements in central banks' communication, had become more and more well-anticipated by financial markets.

To this end, we consider a particular rotation of the principal component of interest rate changes, so to capture movements driven only by surprises regarding the "future-path" of monetary policy, while excluding the news regarding the nearby "target" for reference rates. Like in Gürkaynak et al. (2005) on monetary policy days, we assume a 2 factor model holds for N yield changes ($X_{T\times N}$).[5] Because the two principal component factors ($F_{T\times 2}$) have no structural interpretation, one can rotate them (preserving orthonormality) in such a way to

[5]Using formal tests to determine the number of factors, the null hypothesis that two factors are sufficient to account for most of the variation in yields cannot be rejected at teh 1% level of significance.

provide a structural interpretation:

$$X_{T\times N} = F_{T\times 2}\,\Lambda_{2\times N} + \upsilon_{T\times N} \quad (1)$$
$$\tilde{F}_{T\times 2} = F_{T\times 2}\,U_{2\times 2} \quad (2)$$

where U is an orthogonal matrix.

Gürkaynak et al. (2005) propose to rotate the factors in such a way that the second factor (labelled *path-factor*) does no to load the short-end of the curve. The resulting first factor (labelled *target-factor*), by construction orthogonal to the second one, hence will resemble very closely movements in the short end of the curve (see Appendix 8).

Instead of searching for a particular rotation as in Gürkaynak et al. (2005), we consider an alternative approach where we *orthogonalize* the first principal component factor from unexpected jumps in the short end of the curve

$$X_{T\times N} = F_{T\times 2}\,\Lambda_{2\times N} + \epsilon_{T\times N} \quad (3)$$
$$\bar{F}_{T\times 1} = M_r\,F_{T\times 1} \quad (4)$$

where M_r is the residual projection matrix on the nearby future contract for the central bank reference rate (r_t).[6].

4.1 Path and target surprises before the financial crisis: an aside

In this section we show how, even before 2008, the component of monetary policy surprises pertaining to changes in the policy path was a relevant driver in yield curve changes, and how it compared to the component relating to changes in the "target" of rates. In essence, our results replicate, but with daily rather than intraday data, the estimated in Gürkaynak et al. (2005) for the US and in Brand et al. (2010) for the euro area. The only difference is that we use a slightly modified version of the factors, as defined in equation 3, rather than their original definition (see equation 9 in the Appendix). For each yield, short term futures or Treasury rates, we run 2 regressions on our path factor $\bar{F}_{1,t}$ and on the futures contract for the reference rate (r_t):

$$\Delta y_t = \gamma + \alpha_{target}\,r_t + u_t \quad (5)$$
$$\Delta y_t = \gamma + \alpha_{target}\,r_t + \alpha_{path}\bar{F}_{1,t} + u_t \quad (6)$$

The yields used here are only the ones up 12 months. For the US, as in Gürkaynak et al. (2005), these are the federal funds futures current month and 3-months ahead rates, and the two-,three-, and four-quarter ahead eurodollar future rates.

Results for the US are reported in Table 3. As can be seen in the table, the effect of the path-factor is greater for the long-end of the yield curve, with a 1 percentage point innovation to the factor leading to a 25 basis points (bp) response at the horizon of 6 months, and the

[6]The two approaches are found to give similar results: the correlation between the GSS path factor $\tilde{F^1}_t$ and the orthogonalized factor $\bar{F}^1_{T\times 2}$ is is almost 0.9 for the US and the euro area, in pre-crisis period

effect remaining quite persistent at the 5 year horizon (19 bp). In contrast, FOMC statements that involve changes in federal funds target rate itself with the same effect at the 6 months horizon (scaled to be so by construction), have a monotonically decaying impact on longer maturities. Moreover, as can be seen from the R^2 statistics from the one- and two-factor regressions, the large majority of variation in the long-term Treasury yields seems to be due to communication regarding future policy rather than target changes.

For the euro area we use the euro-denominated Overnight Index Swap up to twelve months (1, 3, 6, 9 and 12 months). Results are reported in Table 4. The maturities are chosen to match those in Table 3, for the US. Yields on the 6- and 12-month refer to the euro-area OIS rates, while those for 2-, 5- and 10-year refer to German Bunds.[7] The results are not very different, with path surprises having a significant and sizeable impact across all maturities and exhibiting a hump-shaped maturity response pattern. Also, similarly with what found in Brand et al. (2010), the explanatory power of the regressions is somewhat lower than for the US, more so at longer horizons. Brand et al. (2010) also exploit the institutional feature of ECB communication, characterized by rate announcements followed by a press-conference, to disentangle *directly* the decision from the communication dimension of monetary policy. They show how *indirect econometric methods*, exploited also in our approach, provide information that is consistent with the one obtained from a *direct* approach.

5 Measuring the impact of monetary policy

Since our analysis spans the years from 1999 to 2016, we distinguish three different periods to account for the substantial changes in monetary policy frameworks and instruments over these years. Namely, we define a **pre-crisis** period from January 1999 until November 2008, the official start of the first Quantitative Easing program in the US. The second period, which we label **crisis**, runs from November 2008 to December 2012, just before the first "tapering" announcement by the US Fed. The last period, which we label **post-crisis**, runs from January 2013 to September 2016, the end of our sample.

Of course, our definition may not fully be consistent with the timing of the unconventional monetary policies of the ECB in the same period. In particular, in the second "crisis" period, the ECB adopted a series of measures aimed at smoothing the transmission mechanism of monetary policy as well as at at eliminating the euro-area break-up risk related to the sovereign debt crisis. Conversely, in the same period, the Fed introduced a stream of unconventional measures, among them the LSAP and an explicit forward guidance. In the third period, which includes the more recent years, the ECB started its explicit "forward guidance" and a private and public bond purchase program – APP – while the Fed gradually unwound its unconventional measures.

To ensure that surprises have "comparable" nature across different periods we will focus on the response to path-factor shocks. Indeed, as shown in Section 4.1, even before the global financial crisis the evidence for the US as well as for the euro area was that news

[7]Results would have remained very similar had we used French or Italian yields, because before the euro sovereign crisis interest rates on government bonds moved in lockstep across the eurozone.

stemming from the communication component of monetary policy had a more substantial and longer-lasting impact on the yield curve than news stemming from decisions on policy interest rates. The relevance of the path-factor component has undoubtedly risen since the onset of the global financial crisis, when the Fed and the ECB progressively reached the zero-lower-bound and resorted to strategies hinging on quantitative easing and forward guidance.

Our approach will therefore use as a yard-stick the effect of monetary policy surprises shifting the 10-year by a predetermined amount point, and examining how this translates into changes in the other assets.

We compute the principal component factors from the entire yield curve separately over different periods and for each central bank. We use only observations on announcement days of the Fed or the ECB. To extract the Fed factors, for the short end of the curve we use the federal funds futures current month and 3-months ahead rates, and the two-,three-, and four-quarter ahead eurodollar futures rates; for the long-end we use 2-,5 and 10-year Treasury yields. For the euro-area, in light of the cross-country heterogeneity which flared up during the sovereign crisis we compute principal component factors from yields in the largest four economies. We use short rates from 1-, 3-, 6 and 12-month euro OIS, and the 2-,5 and 10-year yields on the German Bund, Italian BTP, French OAT and Spanish Bonos.

We use the same orthogonalization discussed in equation 3, where the first factor is $\bar{F}_1$ is the residual of the regression of the first principal component factor on the nearby futures rate on the respective central bank target (federal funds rate for the Fed, and 1-month OIS for the ECB). As to the target rate r_t we use directly the changes in nearby futures rate on the central bank target.[8]

In order to identify the causal effect of the monetary policy we estimate an ordinary least square regression of daily returns on several assets on our monetary policy surprises, defined in Section 4.1.

We estimate the following equations only on monetary policy announcement days, either by the ECB or the Fed:[9]

$$\Delta y_t^{(i)} \;=\; \alpha + \beta_1\, r_t^{Fed} + \gamma_1\, \bar{F}_{1,t}^{Fed} + \beta_2\, r_{1,t}^{ECB} + \gamma_2\, \bar{F}_{1,t}^{ECB} + u_t \tag{7}$$

where $\Delta y_t^{(i)}$ is the change in the i-th asset under consideration, while $\bar{F}_{1,t}^{Fed}$ and r_t are the path- and target-surprise for the Federal Reserve announcements, and $\bar{F}_{1,t}^{ECB}$ and r_t^{ECB} those for the ECB – defined in Section 4.1. In our discussion of the results in Section 6, we will only report the coefficients on the path factors, for the Fed (γ_1) and the ECB (γ_2). All equations include some control variables to avoid contamination from other news relating to the macroeconomy released in the same day. These include the Citi Economic Surprise Index (CESI) for the US and the euro area, a measure of macroeconomic surprises in these areas.[10]

[8] As short term rates approach the zero-lower-bound the variability of the target rate variable becomes smaller, and our orthogonalized path-factor is close to the original principal component factor.

[9] This is equivalent to running two distinct regressions for Fed and ECB on their respective announcements, except for the rare joint decisions. Results for the central bank specific regressions are available upon request.

[10] For example, it is well known that US weekly initial unemployment claims can occur during days of ECB

In addition we use the VIX, to control for the overall level of financial distress in financial markets.

6 Results

Before the global financial crisis: Jan. 1999 – Nov. 2008

To compare results across time frames, we scale our path-factors so that they are always associated with a predetermined 25 basis points (bp) impact on the key benchmark 10-year yields in the US (US Treasury) and in the euro area (German Bund).

We present the results for the period before the global financial crisis in Table 5. First we analyse how a Fed path surprise impacts assets returns (first column). The response of 10-year Treasury yield, by construction set to 25 bp, is associated with a slightly stronger response of shorter dated 2- and 5-year Treasury yields. This hump-shaped response across maturities is the same documented in Gürkaynak et al. (2005), which we also replicated in the Section 4.1.

Bond yields in the euro area respond as well, with rates increasing in Germany, France, Italy and Spain: the intensity is comparable across countries and maturities (hump-shaped). In response to this contractionary monetary policy surprise, the US dollar exchange rate appreciates by slightly more than 1% with respect to the €, and 1.6% with respect to the Japanese Yen. The impact on equity prices is statistically significant only for the US stock market, which would rise by approximately 1%. This contrasts with the original results of Bernanke and Kuttner (2003), who found that a 25 bp reduction in the federal funds target rate is associated with about a one percent increase in broad stock indexes. This difference can be explained by the different nature of the surprise, in their case the "target" component, in ours the "path" component of the policy which can be related to conveying information regarding the expected outlook for economic growth.

At the same time, term premia in the US respond at 2-, 5- and 10-year maturities, by approximately $\frac{1}{5}$ the size of the impact recorded for the corresponding Treasury yields, an indication that in these years long dated yields move mostly in response to changes in expected interest rates. Spreads of US corporate bonds over their sovereign counterparts fall only modestly and only for the high-yield segment.

Considering the ECB path surprise on assets, four features stand out. First, the response of yields on shorter dated bonds (2- and 5-year) is much stronger than the one estimated for the 10-year tenor (by construction pinned to 25 bp for German yields). Second, across maturities, the estimated responses of yields are similar across the four euro-area countries, underscoring the homogeneous pricing of sovereign credit risk within the euro area. Third, stock markets respond positively to an ECB contractionary surprise, both in the euro area and in the US, a result that suggest that markets interpreted the surprise as conveying positive information regarding the state of the economy. Also, credit spreads tighten, both in the investment-grade and the high-yield segment. The spillovers of ECB path-surprises onto

Governing Council meetings.

the US yield curve are significant. They appear to be only partly absorbed by the immediate response of exchange USD/EUR exchange rate, which appreciates on impact (2.3%). Fourth, the effect on euro area term premia is large and accounts for about half of the estimated increase in nominal yields. Interestingly, the rise in euro-area term premia seems to spill onto the US term premia.

Crisis years: Nov. 2008 – Dec. 2012

Results for the years of the global financial crisis and the sovereign euro area crisis are shown in Table 6.

Considering the Fed path-surprise we find that its impact on the US term structure has reversed compared to the pre-crisis years, becoming greater for longer tenors. This seems to reflect the sizable impact on US term premia, which rise almost by as much as nominal long dated yields. Also, US interest rate volatility, as measured by the MOVE index is significantly affected by these movements. Furthermore, the impact of a contractionary Fed surprise on the stock market, with an increase of approximately 1% in US equities associated to a 25 bp rise in the US 10-year Treasury yields, is even stronger than the one found for pre-crisis years. In contrast, the magnitude of the USD/EUR exchange rate response falls with respect to the one found during the pre-crisis years, while the one for the other currencies seems stronger. This result contrasts with the one presented in Glick and Leduc (2013), who document how the effect of Fed monetary surprises on the value of the US dollar before 2008 and between 2008 and 2012 remained largely unchanged.[11] Compared to the pre-crisis years, the response of euro-area yields to contractionary Fed surprises does not show widespread significance, with small increases in German and Italian longer dated yields.

The effects of the euro-area sovereign debt crisis emerge starkly when we examine the role of ECB monetary policy surprises (reported in the second column of coefficients). Given the exceptional circumstances, we scale our path-factor so to consider as "contractionary" a *reduction* in 10-year German yields of 25 bp, entailing an increase in yields of more vulnerable countries'. In fact, surprises leading to a fall in 10-year German yields of 25 bp are associated to large jumps of the corresponding Italian and Spanish yields (more than 200 bp). The response of short dated Italian and Spanish tenors is even greater than the one for 10-year yields. Interestingly, the French yields, despite still being among the highest rated sovereign issues, also increase, albeit substantially less than those in Spain and Italy. Thus, the ECB monetary policy surprises are now akin to a shock to the spread in sovereign yields between core and vulnerable countries. This provides empirical support to the assumption made by Rogers et al. (2015), who define the ECB surprise as the spread between Italian and 10-year German yields.

In this period ECB contractionary monetary policy surprises impact strongly also equity markets, which fall within the euro-area countries, as well as abroad. Interestingly, also the oil price falls markedly, underscoring the systemic relevance of euro-area events on such a key global commodity. Also, in response to the ECB surprises, yields on the whole US term

[11] Their method is somewhat different from ours, as they compare pre- and post-crisis years to infer a scaling factor for the monetary policy surprises, and show how monetary policy has the same "bang-per-unit of surprise" on the USD exchange rate.

structure respond by *falling* suggesting a strong flight to safety effect in action. Finally, the ECB surprises strongly affect the implied volatility of interest rates as well as of exchange rates.

Post-crisis years: Jan. 2013 – Sep. 2016

In the third period, starting from 2013 to date, the reaction of asset prices to monetary policy surprises has changed again. Results are presented in Table 7.

Fed surprises in this period impact again the US yield curve with a more "conventional" hump-shaped pattern. However, the term-premium component still accounts for a sizable part of the increase in yields, largely as a result of the "taper-annoucements" in the first half of 2013. The impact on US interest rates volatility, measured by the MOVE index, remains significantly positive, as found during the crisis years. Spillovers to the euro-area yields are more muted, while the one on the bilateral USD exchange rates is found to have same sign and magnitude found before the crisis years. Similarly, US corporate credit spreads are impacted negatively by a US contractionary announcement, with approximately the same magnitudes found before the crisis. In contrast, the impact of Fed surprises turns out to be not significant for all stock market indices, including the US.

Also the effect of ECB surprises in this period becomes more conventional, as a result of the fading away of the euro-area breakup fears. While interest rates across the main economies respond in the same direction, they do so with different magnitudes, flagging the different sovereign risks perceived by investors. In response to an ECB contractionary surprise, associated to a 25 bp rise in German yields, we estimate Italian yields to increase by 43 bp, i.e. a widening of sovereign spreads by 18 bp for the 10-year tenor. These are only partly explained by the corresponding increase in the 5-year Italian CDS (12 bp), suggesting that other factors beyond perceived sovereign risk may be at play. This contrasts with the crisis years, when most of the increase in vulnerable countries' yields reflected the fears related to the sovereign crisis. The difference can be attributed to the adoption of forward guidance and quantitative measures by the ECB; our estimates show that, during this last period, changes in term premia most explain most of the movements in long dated yields. The impact on equity price indices of a contractionary ECB surprise, while still negative and statistically significant on most markets, is much smaller than during the crisis period. Euro-area inflation swaps rates, a relevant measure of inflation expectations at longer horizons, fall in response to contractionary ECB surprise, suggesting that the ECB announcements are effective in contrasting deflationary pressures. In contrast, during pre-crisis years, inflation swap rates tended to comove positively with bond-yields instead.

6.1 Monetary policy surprises: a closer look during 2015

A closer look to monetary policy surprises by the Fed and the ECB can motivate our choice of relying on a daily window, as well as in the usefulness of estimating our measures of monetary policy surprises. We illustrate this, graphically, by showing asset price movements around some ECB announcement dates in 2015 for which we collected intra-day sampled at a 5-minute frequency.

With the exception of exchange rates traded around the clock, all other assets are not traded in a "continuous" fashion and there are extended intervals without a transaction and price being recorded. This is true for futures, whose trading hours depend on the exchange where they are negotiated, as well as for other OTC traded securities (e.g. for the less liquid inflation swaps reflected in their volatility). Furthermore, for some securities, such as corporate spreads or CDS, there is not even a reliable intraday price and data are only available at a daily frequency. These price data gaps may become a problem when using very narrow intraday windows, especially if one is interested in the international spillovers of monetary policies which span across different time zones. For example, the benchmark Italian and German government bonds are quoted between 7AM and 5PM London Time, while the corresponding futures are traded between 7AM and 9PM London time. This implies that, following a Fed announcement, typically at 6PM London time, the same day reaction of asset prices may fail to reflect the full price adjustment, which spills onto the following trading day. Also, the spillovers across the Atlantic of ECB and Fed announcements have the greatest impact on yields and the exchange rate, which show an immediate response. The persistence of the interest rate response is much greater, while the exchange rate and also the stock market show in several instances some reversion of the initial impact.

We focus here on three ECB announcements regarding the APP in 2015, wich surprised markets in differing ways. First, we look at the 1^{st} Public Sector Purchase Programme (PSPP) announcement in January 2015, which contributed the most to a reduction in long-term yields in the euro area and spilled over onto other markets (Figure 1). Second we look at the first announcement in September 2015 of an increase in the pool of APP eligible assets: by raising the issue share limit from 25% to 33%, it led to a further reduction in euro area long-term yields, a marked depreciation of the euro against the dollar, while US yields were not affected much (Figure 2). In contrast, the 2^{nd} APP extension announcement in December 2015, despite being clearly expansionary disappointed the markets: euro-area long-term yields as well as those in the US rose in sync, while the euro appreciated against the dollar. The reaction of equities was also negative both in the US and Europe (Figure 3).

With our estimates of the path-surprises of monetary policy in each period we can assess their contribution to the overall daily change in several asset prices. These are shown in Figure 4(a)-4(d). Most of the daily movements in the assets are accounted for by the ECB path-surprise, both for across countries' yields and for the USD/EUR exchange rate.

As to the Federal Reserve surprises we report here a similar decomposition for four key announcements in 2010, which according Krishnamurthy and Vissing-Jorgensen (2011) conveyed the essence of the information relating to the QE2 program (see 5(a) 5-(d)). We see that upon these dates, the response of long-term yields is closely tracked by the contribution of the path-surprises, and it clearly shows how most of Fed surprises were successful in impacting the term-premia component. In contrast, the response of the US dollar exchange rate is largely unaccounted for by our measure of monetary policy surprises.

6.2 Robustness checks

[To BE COMPLETED: results are in general robust to these changes and are available upon request.]

We run several robustness checks of our estimates. First, we selected different subsamples to better account the different evolution of the Fed and ECB unconventional monetary policies, as well as the unfolding of the global financial crisis and the euro area sovereign crisis. Also, for the crisis periods we run the regressions excluding the days of some of the most important non-scheduled ECB and Fed monetary policy annoucements.

Second, we use the definition of path-factor suggested by Gürkaynak et al. (2005).

Third, we ran separate regressions for the Fed and ECB monetary policy announcements.

7 Conclusion

We investigate how the reaction of several asset prices – fixed-income instruments, exchange rates, stock indices, inflation swaps and corporate spreads, sovereign CDS, and implied volatilities – to monetary policy surprises varies during monetary policy regimes and through which channels these surprises are transmitted, in the euro area and in the United States.

We identify one dimension of monetary policy surprises, affecting more the longer-end of the yield curve – rather than the one leading to changes in nearby futures on the central bank reference rates.

To ensure that surprises have "comparable" nature across different periods we focus on the response to path-factor shocks. Indeed, even before the global financial crisis, the evidence for the US as well as for the euro area was that surprises stemming from the communication component of monetary policy had a more substantial and longer-lasting impact on the yield curve than surprises stemming from decisions on policy interest rates. The relevance of the path-factor component has undoubtedly become greater since the onset of the global financial crisis, when the Fed and the ECB progressively reached the zero-lower-bound and resorted to strategies hinging on quantitative easing and forward guidance.

We find a hump-shaped response of the yield curve to path-surprises, both in the "pre-crisis" period and since 2013. In contrast, during crisis years Fed surprises, largely through movements in term premia, account for the impact in interest rates, which is increasing in tenor.

In the euro area the path-surprises reflect the shifts in sovereign spreads, and have a large impact on the entire constellation of interest rates, exchange rates and equity markets. The adoption of forward guidance and quantitative measures by the ECB, successfully impacted euro-area term premia: most of the movements in long dated yields correspond to the term premia component. Euro-area inflation swap rates, a relevant measure of inflation expectations at longer horizons, fall in response to contractionary ECB surprise, suggesting that the ECB announcements are effective in contrasting deflationary pressures. In contrast, during pre-crisis years, inflation swap rates tended to comove positively with bond-yields instead.

References

Adrian, T., Crump, R. K., & Moench, E. (2013). Pricing the term structure with linear regressions. *Journal of Financial Economics*, 110(1):110–138.

Altavilla, C., Carboni, G., & Motto, R. (2015). Asset Purchase Programmes and Financial Markets: Lessons from the Euro Area. Working Paper Series 1864, European Central Bank.

Bernanke, B. S. & Kuttner, K. N. (2003). What explains the stock market's reaction to Federal Reserve policy? Staff Reports 174, Federal Reserve Bank of New York.

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

Cochrane, J. & Piazzesi, M. (2002). The fed and interest rates - a high-frequency identification. *American Economic Review*, 92(2):90–95.

Gagnon, J. E., Raskin, M., Remache, J., & Sack, B. P. (2011). Large-scale asset purchases by the Federal Reserve: did they work? *Economic Policy Review*, (May):41–59.

Georgiadis, G. & Grab, J. (2015). Global financial market impact of the announcement of the ECB's extended asset purchase programme. Globalization and Monetary Policy Institute Working Paper 232, Federal Reserve Bank of Dallas.

Gilchrist, S. & Zakrajšek, E. (2013). The Impact of the Federal Reserve's Large?Scale Asset Purchase Programs on Corporate Credit Risk. *Journal of Money, Credit and Banking*, 45(s2):29–57.

Glick, R. & Leduc, S. (2013). The effects of unconventional and conventional U.S. monetary policy on the dollar. Working Paper Series 2013-11, Federal Reserve Bank of San Francisco.

Gürkaynak, R. S., Sack, B., & Swanson, E. (2005). Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements. *International Journal of Central Banking*, 1(1).

Gürkaynak, R. S., Sack, B., & Swanson, E. (2007). Market-Based Measures of Monetary Policy Expectations. *Journal of Business & Economic Statistics*, 25:201–212.

Hanson, S. G. & Stein, J. C. (2015). Monetary policy and long-term real rates. *Journal of Financial Economics*, 115(3):429–448.

Jarrow, R. & Li, H. (2015). The Impact of a Central Bank's Bond Market Intervention on Foreign Exchange Rates. *Quarterly Journal of Finance (QJF)*, 5(02):1550009–1–1.

Krishnamurthy, A., Nagel, S., & Vissing-Jorgensen, A. (2015). Ecb policies involving government bond purchases: Impact and channels. *Unpublished working paper*.

Krishnamurthy, A. & Vissing-Jorgensen, A. (2011). The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy. *Brookings Papers on Economic Activity*, 43(2 (Fall)):215–287.

Kuttner, K. (2001). Monetary policy surprises and interest rates: Evidence from the fed funds futures market. *Journal of Monetary Economics*, 47(3):523–544.

Pericoli, M. (2013). Macroeconomic and monetary policy surprises and the term structure of interest rates. Temi di discussione (Economic working papers) 927, Bank of Italy, Economic Research and International Relations Area.

Rigobon, R. (2003). Identification through heteroskedasticity. *The Review of Economics and Statistics*, 85(4):777–792.

Rigobon, R. & Sack, B. (2003). Measuring the reaction of monetary policy to the stock market. *The Quarterly Journal of Economics*, 118(2):639–669.

Rigobon, R. & Sack, B. (2004). The impact of monetary policy on asset prices. *Journal of Monetary Economics*, 51(8):1553–1575.

Rogers, J. H., Scotti, C., & Wright, J. H. (2014). Evaluating asset-market effects of unconventional monetary policy: a multi-country review. *Economic Policy*, 29(80):749–799.

Rogers, J. H., Scotti, C., & Wright, J. H. (2015). Unconventional monetary policy and international risk premia. Technical report, XVI Jacques Polak Annual Research Conference.

Swanson, E. T. (2015). Measuring the effects of unconventional monetary policy on asset prices. Working Paper 21816, National Bureau of Economic Research.

Wright, J. H. (2012). What does monetary policy do to long-term interest rates at the zero lower bound? *The Economic Journal*, 122(564):F447–F466.

8 Appendix: factor rotation

Under the assumption of a 2-factor model holds for interest rate changes (X) on monetary policy days:

$$X_{T\times N} = F_{T\times 2}\Lambda_{2\times N} + \upsilon_{T\times N} \tag{8}$$

Let the rotated factors $\tilde{F}$ be related to the base principal component factors F through the following relationship:

$$\tilde{F} = FU \tag{9}$$

where

$$U = \begin{pmatrix} cos\,\theta & -sin\,\theta \\ sin\,\theta & cos\,\theta \end{pmatrix} \tag{10}$$

and $U(\theta)$ is an orthonormal rotation matrix, such that $U'U = I$ by construction. The identification restriction used by Gürkaynak et al. (2005) is on the second factor (the path factor), namely it requires that z_2 does not load the first element of vector of yields (Gürkaynak et al. (2005) set this to be the nearby Federal Funds futures contract), i.e. that the second factor is uncorrelated with the current monetary policy surprise. This can also be shown to be equivalent to

$$\theta^* = atan(\frac{\gamma_2}{\gamma_1}) \tag{11}$$

where γ_1 and γ_2 are the elements of the first column of the $2 \times N$ loading matrix Λ.

We replicated the analysis of Gürkaynak et al. (2005) for the US and of Brand et al. (2010) for the euro, using daily data. A path and a target factor ($\tilde{F}_1$ and $\tilde{F}_2$) were extracted by imposing the particular rotation matrix $U(\theta^*)$, and the regressions described in Tables 3-4 in the main text, were run again with these factors in place of the orthogonalized ones. As can be seen from Table A-1 and A-2 we find very similar results. In particular, the maturity response pattern to communication altering the path of policy is hump-shaped, whereas that to policy decisions is downward-sloping. That is short to medium-term maturities respond prominently to the target-factor, while the path-factor impacts the term structure at all maturities.

Tables

Table 1: Data description

asset	start	end	source	description
US 1m, 3m	01-Jan-1999	30-Sep-2016	Thomson Reuters	federal funds futures current month and 3-months ahead
US 6m, 9m, 1y	01-Jan-1999	30-Sep-2016	Thomson Reuters	two-,three-, and four-quarter ahead eurodollar future rates
euro OIS 1m, 3m, 6m, 9m, 1y	01-Jan-1999	30-Sep-2016	Thomson Reuters	euro-denominated Overnight Index Swap
2-year, 5-year, 10-year US bond	01-Jan-1999	30-Sep-2016	Thomson Reuters	yield on benchmark Treasury/Note
2-year, 5-year, 10-year German bond	01-Jan-1999	30-Sep-2016	Thomson Reuters	yield on benchmark Bund/Schatz
2-year, 5-year, 10-year French bond	01-Jan-1999	30-Sep-2016	Thomson Reuters	yield on benchmark OAT/BTAN
2-year, 5-year, 10-year Italian bond	01-Jan-1999	30-Sep-2016	Thomson Reuters	yield on benchmark BTP
2-year, 5-year, 10-year Spanish bond	01-Jan-1999	30-Sep-2016	Thomson Reuters	yield on benchmark Bonos
USD/EUR	01-Jan-1999	30-Sep-2016	Thomson Reuters	US dollar per foreign currency
USD/GBP	01-Jan-1999	30-Sep-2016	Thomson Reuters	US dollar per foreign currency
USD/YEN	01-Jan-1999	30-Sep-2016	Thomson Reuters	US dollar per foreign currency
US stock market	01-Jan-1999	30-Sep-2016	Thomson Reuters	S&P Composite
euro-area stock market	01-Jan-1999	30-Sep-2016	Thomson Reuters	EuroSTOXX50
Japan stock market	01-Jan-1999	30-Sep-2016	Thomson Reuters	Nikkei 225
German stock market	01-Jan-1999	30-Sep-2016	Thomson Reuters	DAX
French stock market	01-Jan-1999	30-Sep-2016	Thomson Reuters	CAC40
Italian stock market	01-Jan-1999	30-Sep-2016	Thomson Reuters	FTSE Mib
2-year US bond term premium	01-Jan-1999	30-Sep-2016	estimated	Affine term structure model
5-year US bond term premium	01-Jan-1999	30-Sep-2016	estimated	Affine term structure model
10-year US bond term premium	01-Jan-1999	30-Sep-2016	estimated	Affine term structure model
2-year euro-area bond term premium	4-Sep-2004	30-Sep-2016	estimated	Affine term structure model
5-year euro-area bond term premium	4-Sep-2004	30-Sep-2016	estimated	Affine term structure model
10-year euro-area bond term premium	4-Sep-2004	30-Sep-2016	estimated	Affine term structure model
5-year US inflation swap	01-Jan-1999	30-Sep-2016	Bloomberg	derivative on the domestic CPI
5-year US 5-year ahead inflation swap	01-Jan-1999	30-Sep-2016	Bloomberg	derivative on the domestic CPI
5-year euro-area inflation swap	01-Jan-1999	30-Sep-2016	Bloomberg	derivative on the domestic CPI
5-year 5-year ahead euro-area inflation swap	01-Jan-1999	30-Sep-2016	Bloomberg	derivative on the domestic CPI
US MOVE index	01-Jan-1999	30-Sep-2016	Thomson Reuters	1-month Treasury volatility index
German bond volatility	01-Jan-1999	30-Sep-2016	Thomson Reuters	1-month Bund implied volatility
VIX	01-Jan-1999	30-Sep-2016	CBOT-CME	Volatility index of the US stock market
euro-area investment grade corporate spread	01-Jan-1999	30-Sep-2016	Moody's	spread between BAA corporate and government bonds
euro-area high-yield corporate spread	01-Jan-1999	30-Sep-2016	Moody's	spread between sub-investement corporate and government bonds
US investment grade corporate spread	01-Jan-1999	30-Sep-2016	Moody's	spread between BAA corporate and government bonds
US high-yield corporate spread	01-Jan-1999	30-Sep-2016	Moody's	spread between sub-investement corporate and government bonds
1-month risk reversal	01-Jan-1999	30-Sep-2016	Bloomberg	difference between call and put option on USD/EUR
1-month USD/EUR and USD/GBP implied vol	01-Jan-1999	30-Sep-2016	Thomson Reuters	1-month implied vol
1-year USD/EUR cross-currency basis swap	01-Jan-1999	30-Sep-2016	Thomson Reuters	cross-currency basis swap
Brent	01-Jan-1999	30-Sep-2016	Thomson Reuters	Oil price: Brent USD/brl

Table 2: Yields volatility on announcement and non-announcement days

Federal Reserve Board									
	Pre-crisis			Crisis			Post-crisis		
	σ_{Fed}	$\sigma_{Non-Fed}$		σ_{Fed}	$\sigma_{Non-Fed}$		σ_{Fed}	$\sigma_{Non-Fed}$	
US 1-mo	7.9	3.1	***	1.3	0.9	***	0.5	0.6	
US 3-mo	6.1	3.3	***	0.8	0.9		1.0	0.5	***
US 12-mo	6.8	5.1	***	2.2	1.8	**	1.3	1.3	
US 2-year	9.9	6.4	***	4.9	3.5	***	4.4	2.5	***
US 5-year	10.1	6.8	***	9.9	5.8	***	7.5	4.3	***
US 10-year	9.1	6.2	***	10.9	6.4	***	6.3	4.5	***
obs	123	2442		510	1019		430	1001	
European Central Bank									
	Pre-crisis			Crisis			Post-crisis		
	σ_{ECB}	$\sigma_{Non-ECB}$		σ_{ECB}	$\sigma_{Non-ECB}$		σ_{ECB}	$\sigma_{Non-ECB}$	
Eur OIS 1-mo	5.3	2.8	***	4.2	2.2	***	1.9	0.8	***
Eur OIS 3-mo	4.9	2.5	***	4.0	1.9	***	1.9	0.7	***
Eur OIS 12-mo	7.0	4.2	***	6.2	2.9	***	2.9	1.0	***
Ger 2-year	6.8	4.7	***	5.6	4.1	***	3.5	1.4	***
Ger 5-year	6.2	4.7	***	6.2	4.9	***	5.0	2.7	***
Ger 10-year	4.8	4.1	**	5.4	4.8	*	5.7	3.6	***
Ita 2-year	6.4	4.6	***	18.7	13.0	***	7.7	4.6	***
Ita 5-year	5.6	4.6	***	16.9	11.1	***	8.6	5.1	***
Ita 10-year	4.6	3.9	**	13.4	8.4	***	8.1	5.5	***
obs	125	2440		53	1017		41	1003	

The table reports the standard deviation of changes in interest rate futures (1 month and 3 month) and bond yields during monetary policy monetary policy announcements for the ECB or the Fed (σ_{Ecb}, σ_{Fed}), along with the standard deviation on the other non-event days ($\sigma_{Non-Ecb}$, $\sigma_{Non-Fed}$); (*), (**), (***) denote 10%, 5% and 1% significance, for the one sided variance difference F-test over the two samples. The pre-crisis, crisis and post-crisis periods are defined in the main text.

Table 3: US: Response of Yield Curve to Target and Path Factors

	α_{target}	$p-val$	R^2	α_{target}	$pval$	α_{path}	$p-val$	R^2
6m	18.45	0.00	0.26	25.00	0.00	25.00	0.00	0.72
12m	10.27	0.05	0.03	23.00	0.00	54.25	0.00	0.91
2y	11.41	0.00	0.09	19.36	0.00	23.84	0.00	0.59
5y	5.27	0.12	0.02	12.29	0.00	23.67	0.00	0.53
10y	1.37	0.61	0.00	7.01	0.02	18.74	0.00	0.45

Note: Regressions on Fed announcement days only, with orthogonalized factors. Sample is all monetary policy announcements from Jan. 2001 to November 2008. Target rate and path factor are defined in 5, and normalized to have a 25bp impact on the 6-months yield. The regression in the left panel only includes the target-rate, while the second also adds the path-factor. Standard errors computed with heteroskedasticity-consistent estimator: p-values calculated accordingly.

Table 4: Euro area: Response of Yield Curve to Target and Path Factors

	α_{target}	$p-val$	R^2	α_{target}	$pval$	α_{path}	$p-val$	R^2
6m	25.00	0.00	0.35	25.00	0.00	25.00	0.00	0.96
12m	22.59	0.00	0.20	22.59	0.00	33.07	0.00	0.96
2y	17.73	0.00	0.13	17.73	0.00	25.35	0.00	0.62
5y	10.13	0.01	0.05	10.13	0.00	19.97	0.00	0.43
10y	2.68	0.39	0.01	2.68	0.33	11.36	0.00	0.23

Note: Regressions on ECB announcement days only; orthogonalized factors (see 5). Sample is all monetary policy announcements from Jan. 2001 to November 2008, and normalized to have a 25bp impact on the 6-months yield. The regression in the left panel only includes the target-factor, while the second also adds the path-factor. Standard errors computed with heteroskedasticity-consistent estimator: p-values calculated accordingly.

Table 5: Impact of monetary policy surprises on asset prices before the global financial crisis

	Fed (γ_1)	s.e.	ECB (γ_2)	s.e.	R^2	obs
US 2-Year Treasury	26.74 * **	[1.41]	20.18 * **	[2.88]	0.53	175
US 5-Year Treasury	30.40 * **	[1.33]	30.86 * **	[2.71]	0.50	175
US 10-Year Treasury	25.00 * **	[1.52]	21.31 * **	[3.11]	0.40	175
Ger 2-Year Bund	1.25*	[0.74]	42.90 * **	[1.51]	0.50	175
Ger 5-Year Bund	1.44*	[0.83]	40.67 * **	[1.70]	0.48	175
Ger 10-Year Bund	7.04 * **	[1.13]	25.00 * **	[2.31]	0.38	175
Ita 2-Year BTP	1.37 * *	[0.63]	43.06 * **	[1.28]	0.52	175
Ita 5-Year BTP	5.68 * **	[0.87]	38.48 * **	[1.78]	0.50	175
Ita 10-Year BTP	4.26 * **	[0.99]	26.98 * **	[2.03]	0.41	175
Fra 2-Year OAT	2.11 * **	[0.69]	44.64 * **	[1.41]	0.53	175
Fra 5-Year OAT	3.14 * **	[0.77]	39.14 * **	[1.58]	0.52	175
Fra 10-Year OAT	9.49 * **	[1.08]	26.47 * **	[2.21]	0.43	175
Spa 2-Year Bonos	3.19 * **	[0.68]	44.87 * **	[1.38]	0.54	175
Spa 5-Year Bonos	6.08 * **	[0.94]	42.43 * **	[1.91]	0.50	175
Spa 10-Year Bonos	6.40 * **	[1.09]	29.78 * **	[2.23]	0.46	175
USD/EUR	−1.14 * **	[0.34]	2.32 * **	[0.69]	0.10	175
USD/GBP	−0.11	[0.34]	1.25*	[0.69]	0.14	175
USD/YEN	−1.63 * **	[0.38]	−0.80	[0.78]	0.12	175
US stock	1.08 * **	[0.23]	5.16 * **	[0.47]	0.50	175
€ stock	0.48	[0.40]	3.61 * **	[0.82]	0.27	175
Jap stock	−0.19	[0.46]	−0.04	[0.94]	0.07	175
Ger stock	0.66	[0.48]	3.73 * **	[0.98]	0.24	175
Fra stock	0.35	[0.44]	3.98 * **	[0.90]	0.31	175
Italy stock	−0.05	[0.39]	2.87 * **	[0.80]	0.28	175
US 2-Year term-premia	5.85 * **	[1.08]	4.37 * *	[2.23]	0.18	172
US 5-Year term-premia	6.01 * **	[1.33]	6.10 * *	[2.73]	0.16	172
US 10-Year term-premia	4.70 * **	[1.67]	4.24	[3.43]	0.14	172
€ 2-Year term-premia	0.94	[1.21]	29.01 * **	[2.47]	0.24	175
€ 5-Year term-premia	3.33*	[1.71]	26.59 * **	[3.49]	0.23	175
€ 10-Year term-premia	4.72 * **	[1.73]	16.62 * **	[3.53]	0.15	175
US 5y Inflation-swap	−0.84	[2.96]	21.14 * **	[5.20]	0.06	127
US 5y-5y Inflation-swap	−0.52	[2.53]	7.51*	[4.45]	0.09	128
€ 5y Inflation-swap	−1.04	[2.44]	14.64 * **	[4.48]	0.14	138
€ 5y-5y Inflation-swap	1.74	[1.35]	7.75 * **	[2.47]	0.13	138
US rates vol	−1.48	[1.34]	−0.09	[2.73]	0.10	175
Ger rates vol	0.29 * **	[0.09]	0.75 * **	[0.19]	0.08	175
France CDS	0.31	[0.36]	0.19	[0.63]	0.02	111
Italy CDS	−0.05	[0.21]	−0.13	[0.40]	0.03	147
€ OAS Inv. grade	−0.00	[0.05]	−0.76 * **	[0.10]	0.20	175
€ OAS HY	−0.34	[0.28]	−3.16 * **	[0.58]	0.13	175
US OAS Inv. grade	−0.13 * **	[0.04]	−0.11	[0.08]	0.05	175
US OAS HY	−2.15 * **	[0.26]	−2.99 * **	[0.54]	0.26	175
EUR 1-mo implied vol	−0.05	[0.14]	0.11	[0.29]	0.05	175
GBP 1-mo implied vol	0.07	[0.13]	−0.35	[0.26]	0.03	175
JPY 1-mo implied vol	−0.49 * *	[0.24]	−1.10 * *	[0.49]	0.11	175
USD/EUR 25δ risk-rev.	0.04	[0.03]	0.16 * **	[0.06]	0.06	148
USD/EUR 1y crosscurr basis	−0.83	[3.68]	0.02	[7.09]	0.18	41
Brent	0.72	[0.90]	−0.06	[1.83]	0.07	175

Note: Regressions of daily change of the asset price shown in each row (basis points or % points) on changes in the monetary policy suprise factors (see equation 7) for the Federal Reserve and the ECB, on announcement days only.
(*), (**), (***) denote 10%, 5% and 1% significance, based on robust standard errors shown in brackets.
Fed and ECB path factors are scaled so to have a 25bp impact on the 10-Year US-Treasury and 10-Year German-Bund yield, respectively. Sample are announcement days in pre-crisis period: Jan-2000 to Oct-2008.

Table 6: Impact of monetary policy surprises on asset prices during the crisis

	Fed (γ_1)	s.e.	ECB (γ_2)	s.e.	R^2	obs
US 2-Year Treasury	10.07 ∗ ∗∗	[0.85]	−6.03	[6.55]	0.38	104
US 5-Year Treasury	22.03 ∗ ∗∗	[1.44]	−21.52∗	[11.13]	0.51	104
US 10-Year Treasury	25.00 ∗ ∗∗	[1.54]	−27.10 ∗ ∗	[11.90]	0.50	104
Ger 2-Year Bund	1.64	[1.16]	−10.51	[8.96]	0.18	104
Ger 5-Year Bund	3.77 ∗ ∗	[1.49]	−30.68 ∗ ∗∗	[11.46]	0.22	104
Ger 10-Year Bund	4.64 ∗ ∗∗	[1.41]	−25.00 ∗ ∗	[10.89]	0.21	104
Ita 2-Year BTP	0.46	[1.98]	335.01 ∗ ∗∗	[15.25]	0.43	104
Ita 5-Year BTP	3.76 ∗ ∗∗	[1.33]	279.40 ∗ ∗∗	[10.27]	0.49	104
Ita 10-Year BTP	−0.88	[1.70]	218.31 ∗ ∗∗	[13.13]	0.44	104
Fra 2-Year OAT	1.64	[1.18]	32.70 ∗ ∗∗	[9.10]	0.22	104
Fra 5-Year OAT	1.69	[1.65]	29.97 ∗ ∗	[12.72]	0.17	104
Fra 10-Year OAT	1.41	[1.61]	42.24 ∗ ∗∗	[12.42]	0.19	104
Spa 2-Year Bonos	1.32	[2.33]	325.44 ∗ ∗∗	[18.00]	0.31	104
Spa 5-Year Bonos	2.00	[2.02]	245.02 ∗ ∗∗	[15.57]	0.45	104
Spa 10-Year Bonos	0.92	[1.77]	198.36 ∗ ∗∗	[13.66]	0.41	104
USD/EUR	−0.54 ∗ ∗	[0.17]	−8.57 ∗ ∗∗	[2.84]	0.21	104
USD/GBP	−0.79 ∗ ∗	[0.34]	−6.43 ∗ ∗	[2.65]	0.17	104
USD/YEN	−2.06 ∗ ∗∗	[0.30]	0.47	[2.33]	0.22	104
US stock	1.65 ∗ ∗∗	[0.28]	−9.47 ∗ ∗∗	[2.17]	0.55	104
€ stock	0.95 ∗ ∗	[0.42]	−16.47 ∗ ∗∗	[3.20]	0.30	104
Jap stock	0.44	[0.47]	−5.61	[3.61]	0.05	104
Ger stock	0.72∗	[0.41]	−13.11 ∗ ∗∗	[3.19]	0.21	104
Fra stock	1.08 ∗ ∗	[0.44]	−16.94 ∗ ∗∗	[3.36]	0.31	104
Italy stock	0.35	[0.48]	−26.07 ∗ ∗∗	[3.72]	0.35	104
US 2-Year term-premia	11.15 ∗ ∗∗	[1.08]	−14.61∗	[8.67]	0.37	103
US 5-Year term-premia	19.50 ∗ ∗∗	[1.70]	−25.68∗	[13.64]	0.44	103
US 10-Year term-premia	23.23 ∗ ∗∗	[2.20]	−33.98∗	[17.60]	0.37	103
€ 2-Year term-premia	−0.25	[1.24]	101.55 ∗ ∗∗	[9.54]	0.23	104
€ 5-Year term-premia	1.90	[2.19]	115.66 ∗ ∗∗	[16.87]	0.17	104
€ 10-Year term-premia	2.32	[1.79]	95.07 ∗ ∗∗	[13.77]	0.29	104
US 5y Inflation-swap	0.80	[2.34]	−21.65	[18.02]	0.08	104
US 5y-5y Inflation-swap	−1.94	[1.61]	−25.35 ∗ ∗	[12.41]	0.14	104
€ 5y Inflation-swap	−6.00 ∗ ∗	[2.94]	40.65∗	[22.66]	0.09	101
€ 5y-5y Inflation-swap	3.11 ∗ ∗	[1.45]	−31.50 ∗ ∗∗	[11.20]	0.12	103
US rates vol	6.67 ∗ ∗∗	[1.10]	6.68	[8.49]	0.16	104
Ger rates vol	−0.14	[0.10]	−0.15	[0.76]	0.03	104
France CDS	−0.54	[0.99]	50.75 ∗ ∗∗	[7.60]	0.22	104
Italy CDS	−6.62 ∗ ∗∗	[2.42]	189.35 ∗ ∗∗	[18.68]	0.31	104
€ OAS Inv. grade	−0.06	[0.07]	0.52	[0.57]	0.10	104
€ OAS HY	−0.24	[0.27]	5.11 ∗ ∗	[2.11]	0.23	104
US OAS Inv. grade	−0.08∗	[0.05]	1.05 ∗ ∗∗	[0.35]	0.12	104
US OAS HY	−1.60 ∗ ∗∗	[0.25]	4.16 ∗ ∗	[1.91]	0.27	104
EUR 1-mo implied vol	−0.75 ∗ ∗∗	[0.25]	3.82 ∗ ∗	[1.93]	0.16	104
GBP 1-mo implied vol	−0.09	[0.22]	2.33	[1.69]	0.07	104
JPY 1-mo implied vol	−1.20 ∗ ∗∗	[0.23]	0.36	[1.78]	0.09	104
USD/EUR 25δ risk-rev.	−0.13 ∗ ∗	[0.06]	−1.07 ∗ ∗	[0.45]	0.16	104
USD/EUR 1y crosscurr basis	−2.63 ∗ ∗∗	[0.68]	−20.01 ∗ ∗∗	[5.26]	0.18	104
Brent	1.52 ∗ ∗	[0.65]	−8.84∗	[5.00]	0.20	104

Note: Regressions of daily change of the asset price shown in each row (basis points or % points) on changes in the monetary policy suprise factors (see equation 7) for the Federal Reserve and the ECB, on announcement days only.
(*), (**), (***) denote 10%, 5% and 1% significance, based on robust standard errors shown in brackets.
Fed and ECB path factors are scaled so to have a 25bp impact on the 10-Year US-Treasury and 10-Year German-Bund yield, respectively. Sample are central bank announcement days during the global financial and sovereign crisis years, between Nov-2008 to Dec-2012.

Table 7: Impact of monetary policy surprises on asset prices after the sovereign crisis

	Fed (γ_1)	s.e.	ECB (γ_2)	s.e.	R^2	obs
US 2-Year Treasury	16.10 * **	[1.18]	1.67	[1.51]	0.47	84
US 5-Year Treasury	31.71 * **	[1.46]	0.66	[1.88]	0.61	84
US 10-Year Treasury	25.00 * **	[2.21]	1.75	[2.84]	0.50	84
Ger 2-Year Bund	0.52	[0.97]	14.66 * **	[1.25]	0.29	84
Ger 5-Year Bund	2.77*	[1.64]	26.93 * **	[2.11]	0.40	84
Ger 10-Year Bund	3.96*	[2.21]	25.00 * **	[2.84]	0.21	84
Ita 2-Year BTP	−0.89	[2.54]	32.14 * **	[3.27]	0.33	84
Ita 5-Year BTP	0.90	[2.07]	45.06 * **	[2.67]	0.52	84
Ita 10-Year BTP	0.10	[2.30]	42.56 * **	[2.96]	0.56	84
Fra 2-Year OAT	1.18	[0.93]	16.75 * **	[1.20]	0.38	84
Fra 5-Year OAT	0.67	[1.57]	27.20 * **	[2.02]	0.39	84
Fra 10-Year OAT	3.01	[2.14]	24.58 * **	[2.76]	0.31	84
Spa 2-Year Bonos	−0.40	[2.10]	28.23 * **	[2.70]	0.41	84
Spa 5-Year Bonos	5.50 * **	[2.00]	36.30 * **	[2.57]	0.48	84
Spa 10-Year Bonos	−0.81	[2.53]	41.91 * **	[3.26]	0.47	84
USD/EUR	−1.66 * **	[0.58]	4.30 * **	[0.74]	0.35	84
USD/GBP	−0.47	[0.47]	1.50 * *	[0.60]	0.23	84
USD/YEN	−1.32 * *	[0.65]	1.85 * *	[0.84]	0.17	84
US stock	−0.01	[0.25]	−1.39 * **	[0.32]	0.61	84
€ stock	−0.27	[0.63]	−4.21 * **	[0.81]	0.25	84
Jap stock	0.61	[0.92]	0.09	[1.18]	0.08	84
Ger stock	−0.14	[0.64]	−4.38 * **	[0.83]	0.20	84
Fra stock	−0.32	[0.71]	−4.53 * **	[0.92]	0.25	84
Italy stock	−0.44	[0.99]	−5.55 * **	[1.27]	0.22	84
US 2-Year term-premia	1.12	[1.96]	2.21	[2.56]	0.16	83
US 5-Year term-premia	10.53 * **	[2.58]	3.87	[3.37]	0.29	83
US 10-Year term-premia	6.10*	[3.54]	1.53	[4.62]	0.14	83
€ 2-Year term-premia	−2.17	[1.41]	17.90 * **	[1.82]	0.43	84
€ 5-Year term-premia	−3.79	[2.73]	29.32 * **	[3.52]	0.34	84
€ 10-Year term-premia	−4.38	[2.84]	27.17 * **	[3.65]	0.28	84
US 5y Inflation-swap	−4.93 * *	[2.15]	−0.93	[2.76]	0.07	84
US 5y-5y Inflation-swap	0.25	[2.16]	−0.69	[2.78]	0.03	84
€ 5y Inflation-swap	2.44 * **	[0.95]	−3.01 * *	[1.22]	0.17	84
€ 5y-5y Inflation-swap	0.33	[1.20]	−4.09 * **	[1.55]	0.07	84
US rates vol	5.56 * **	[1.75]	3.05	[2.25]	0.20	84
Ger rates vol	−0.09	[0.19]	0.35	[0.24]	0.02	84
France CDS	0.29	[0.40]	0.73	[0.52]	0.03	84
Italy CDS	−2.57	[2.50]	12.44 * **	[3.22]	0.13	84
€ OAS Inv. grade	−0.14	[0.09]	0.05	[0.11]	0.09	84
€ OAS HY	−0.39	[0.33]	−0.42	[0.42]	0.09	84
US OAS Inv. grade	−0.21 * **	[0.06]	0.14*	[0.08]	0.21	84
US OAS HY	−2.19 * **	[0.30]	0.27	[0.38]	0.38	84
EUR 1-mo implied vol	1.13 * **	[0.42]	−0.48	[0.55]	0.12	84
GBP 1-mo implied vol	0.38	[0.27]	−1.01 * **	[0.35]	0.16	84
JPY 1-mo implied vol	0.41	[0.47]	−2.09 * **	[0.60]	0.16	84
USD/EUR 25δ risk-rev.	−0.20 * *	[0.08]	0.04	[0.10]	0.07	84
USD/EUR 1y crosscurr basis	−0.54	[0.78]	2.22 * *	[1.00]	0.13	84
Brent	−1.11	[1.07]	−0.74	[1.37]	0.02	84

Note: Regressions of daily change of the asset price shown in each row (basis points or % points) on changes in the monetary policy suprise factors (see equation 7) for the Federal Reserve and the ECB, on announcement days only.
(*), (**), (***) denote 10%, 5% and 1% significance, based on robust standard errors shown in brackets.
Fed and ECB path factors are scaled so to have a 25bp impact on the 10-Year US-Treasury and 10-Year German-Bund yield, respectively. Sample are central bank announcement days between Jan-2013 and Sep-2016.

Table A-1: US: Response of Yield Curve to Target and Path Factors

	α_{target}	$p-val$	R^2	α_{target}	$pval$	α_{path}	$p-val$	R^2
06m	25.00	0.00	0.82	25.00	0.00	25.00	0.00	0.90
12m	29.03	0.00	0.43	29.03	0.00	98.40	0.00	0.91
02y	21.64	0.00	0.63	21.64	0.00	26.25	0.00	0.72
05y	17.39	0.00	0.45	17.39	0.00	32.25	0.00	0.60
10y	12.01	0.00	0.31	12.01	0.00	28.35	0.00	0.48

Note: Regressions on Fed announcement days only; orthogonalized factors. Sample is all monetary policy announcements from Jan. 2001 to November 2008. Target factor and path factor are defined in equation 9, and normalized to have a 25bp impact on the 6-months yield. The regression in the left panel only includes the target-factor, while the second also adds the path-factor. Standard errors computed with heteroskedasticity-consistent estimator: p-values calculated accordingly.

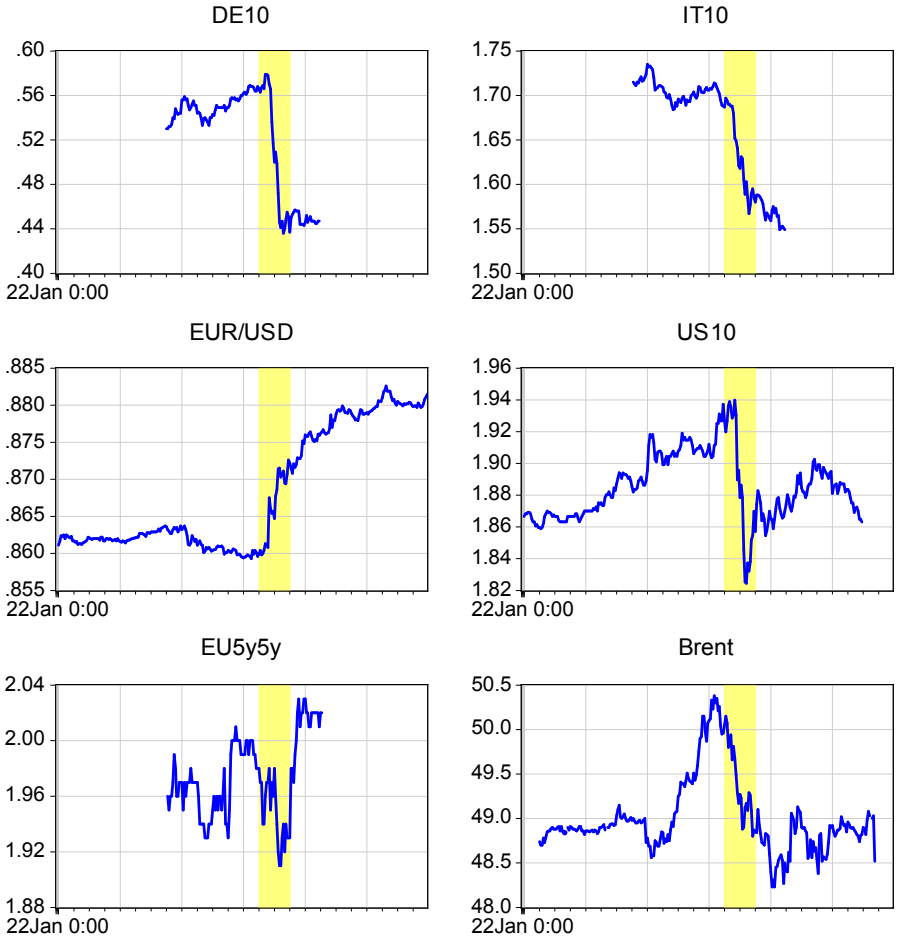
Table A-2: Euro area: Response of Yield Curve to Target and Path Factors

	α_{target}	$p-val$	R^2	α_{target}	$pval$	α_{path}	$p-val$	R^2
6m	25.00	0.00	0.32	25.00	0.00	25.00	0.00	0.96
12m	20.43	0.00	0.15	20.43	0.00	33.69	0.00	0.97
02y	15.58	0.00	0.10	15.58	0.00	26.12	0.00	0.63
05y	7.11	0.10	0.02	7.11	0.03	21.10	0.00	0.46
10y	0.03	0.99	0.00	0.03	0.99	12.35	0.00	0.27

Note: Regressions on ECB announcement days only; orthogonalized factors. Sample is all monetary policy announcements from Jan. 2001 to November 2008. Target factor and path factor are defined in equation 9, and normalized to have a 25bp impact on the 6-months yield. The regression in the left panel only includes the target-factor, while the second also adds the path-factor. Standard errors computed with heteroskedasticity-consistent estimator: p-values calculated accordingly.

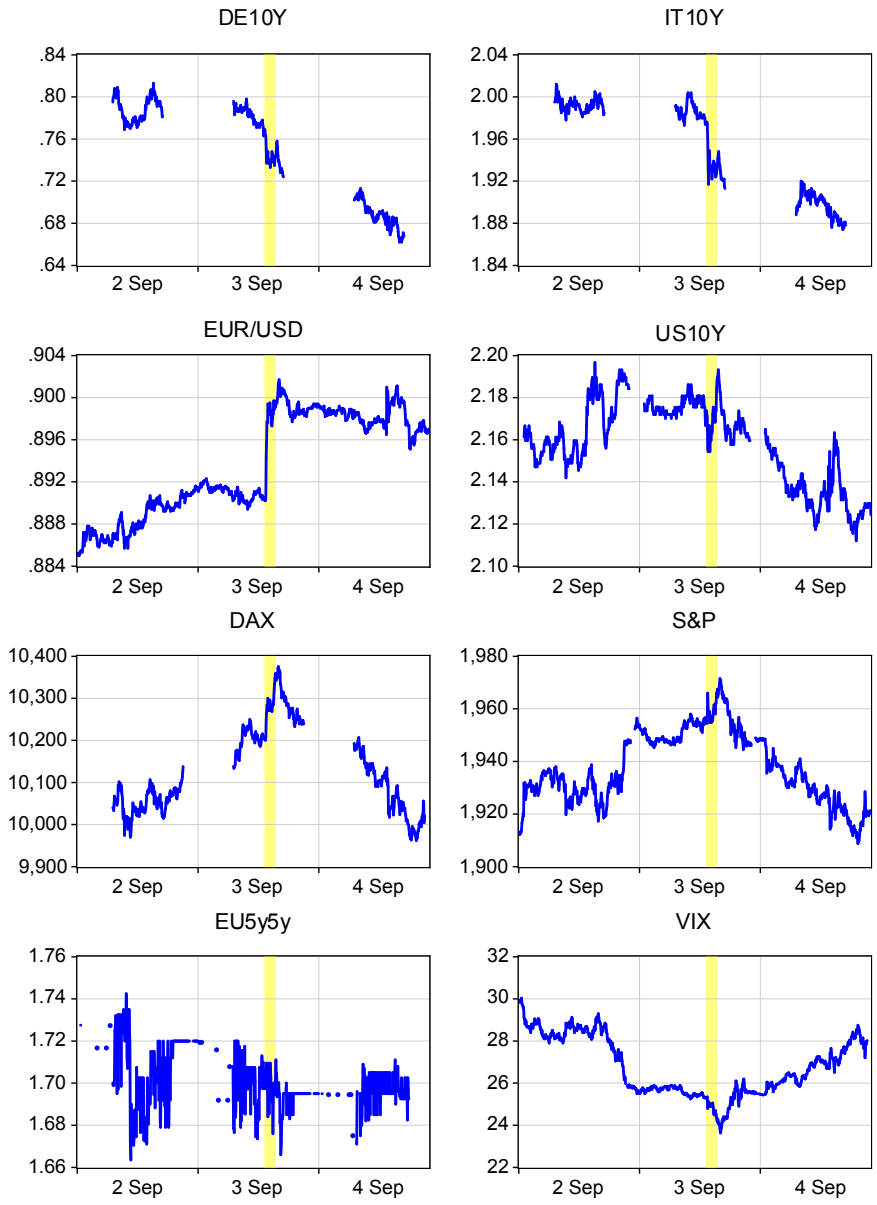
Figures

Figure 1: ECB announcement on 22 Jan 2015: introduction of the PSPP



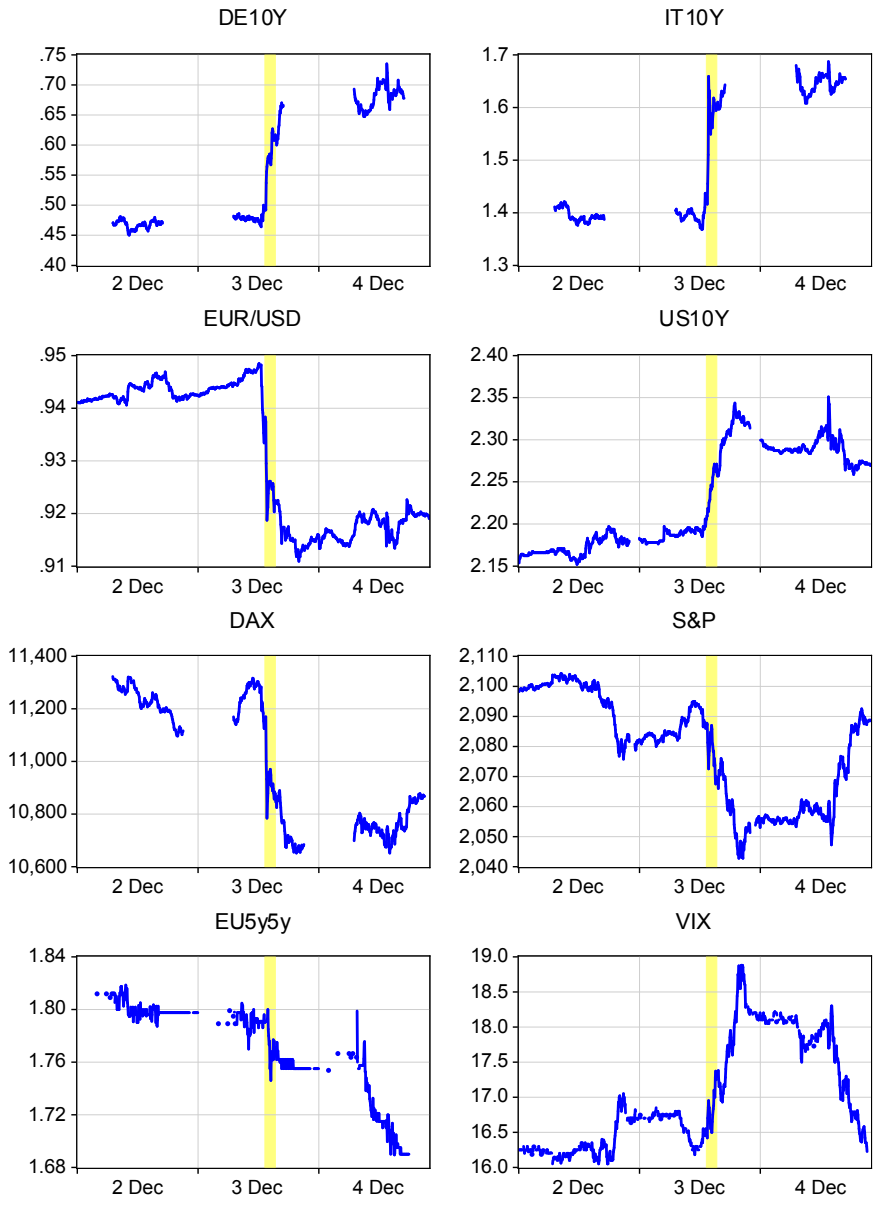
Notes: Vertical shading between 1pm and 3pm GMT on 22-Jan-2015, i.e. from the start of the ECB press conference and 2 hours aftwerward. DE10Y=yield on German 10 year benchmark Bund; IT10Y=yield on Italian 10 year benchmark BTP yield; US10=yield on 10Y US treasury benchmark; EUR/USD= euro per US dollar exchange rate; EU5y5y=euro area 5year forward 5year inflation swap rate; Brent= Brent crude spot price US/bbl. [Stock prices are not available]

Figure 2: ECB announcement on 3 September 2015: 1^{st} PSPP extension



Notes: Vertical shading between 1pm and 3pm GMT on 3-Sep-2015, i.e. from the start of the ECB press conference and 2 hours aftwerward. DE10Y=yield on German 10 year benchmark Bund; IT10Y=yield on Italian 10 year benchmark BTP yield; US10=yield on 10 year US treasury benchmark; EUR/USD= euro per US dollar exchange rate; S&P=US Standard & Poor stock market index; DAX=German DAX stock market index; EU5y5y=euro area 5 year forward 5 year inflation swap rate; VIX=VIX index.

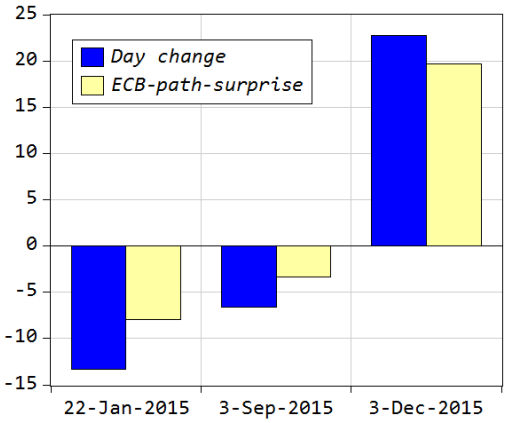
Figure 3: ECB announcement on 3 December 2015: 2^{nd} PSPP extension



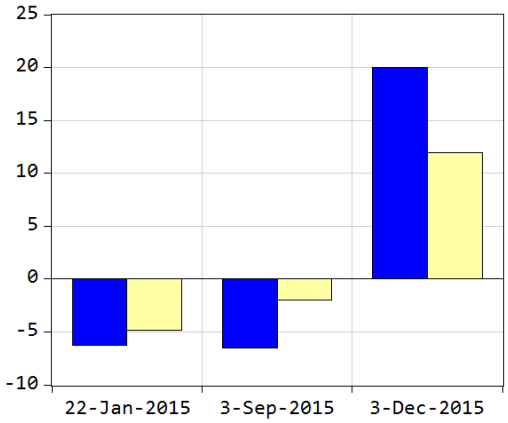
Notes: Vertical shading between 1pm and 3pm GMT on 3-Dec-2015, i.e. from the start of the ECB press conference and 2 hours aftwerward. DE10Y=yield on German 10 year benchmark Bund; IT10Y=yield on Italian 10 year benchmark BTP yield; US10=yield on 10 year US treasury benchmark; EUR/USD= euro per US dollar exchange rate; S&P=US Standard & Poor stock market index; DAX=German DAX stock market index; EU5y5y=euro area 5 year forward 5year inflation swap rate;VIX=VIX index.

Figure 4: Asset price changes around specific ECB APP dates *(basis points)*

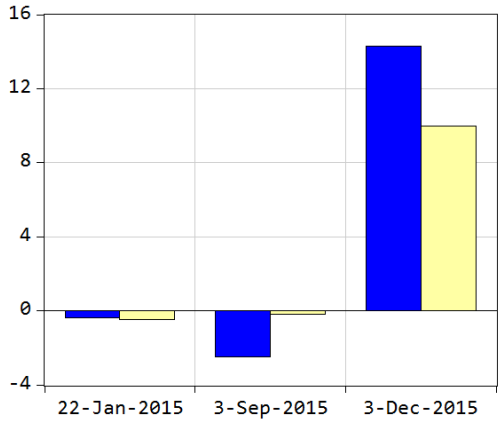
(a) Italy 10 Year BTP



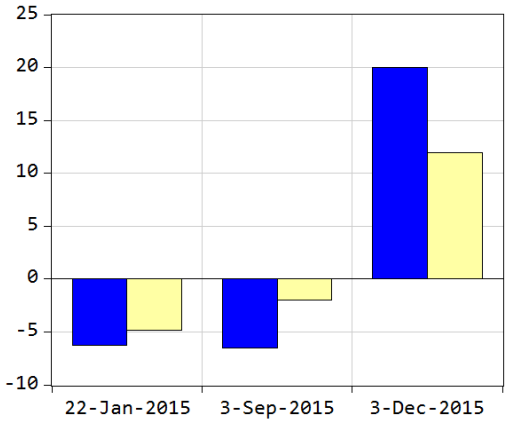
(b) Germany 10 Year Bund



(c) US 10 Year Treasury



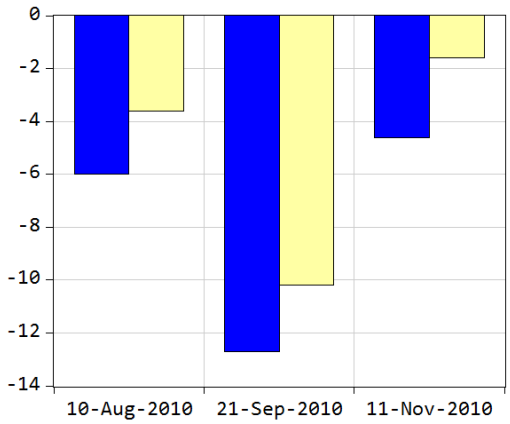
(d) USDEUR (% change)



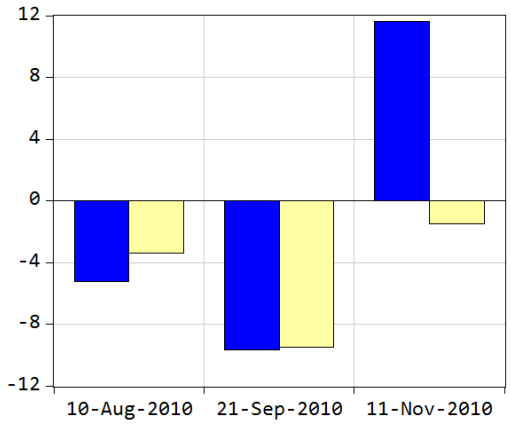
Notes: On 22-Jan-2015 the ECB officialy announced the Public Sector Purchase Program (PSPP). On 3-Sep-2015 the ECB raised the issue share limit for the purchasable assets, thereby extending the PSPP. On 3-Dec-2015 the ECB announced an extension of the PSPP horizon. of the APP.

Figure 5: Asset price changes around specific Fed QE2 dates *(basis points)*

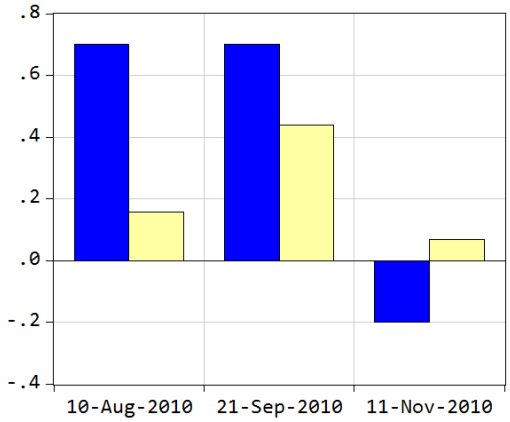
(a) US 10 Year Treasury



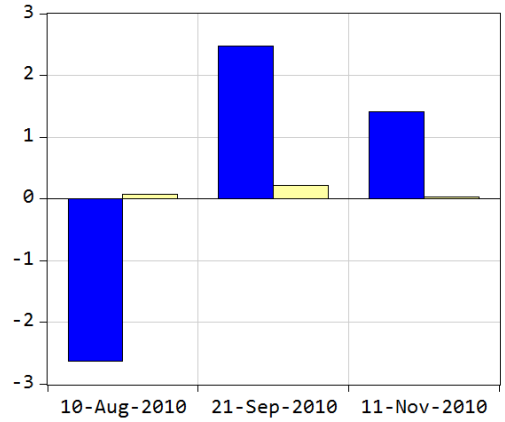
(b) US 10 Year Term-premia



(c) OAS on US High-Yield bonds



(d) USDEUR (% change)



Notes: The statements accompanying the August, September and November 2010 FOMC meetings, collectively conveyed the essence of the information about the Fed QE2-program (see Krishnamurthy and Vissing-Jorgensen (2011)).

Table A-3: ECB Monetary Policy: August 2007 - September 2016

date	conv. mon. policy	forward guidance (FG)	quantitative easing
2-Aug-07	GC meeting		
09-ago-07	Special fine tuning operations		
22-Aug-07			Supplementary LTRO (announcement)
23-Aug-07			Supplementary LTRO (allotment)
6-Sep-07	GC meeting		
4-Oct-07	GC meeting		
8-Nov-07	GC meeting		
6-Dec-07	GC meeting		
10-Jan-08	GC meeting		
7-Feb-08	GC meeting		
6-Mar-08	GC meeting		
28-Mar-08	introduce 6-m LTROs		
10-Apr-08	GC meeting		
8-May-08	GC meeting		
5-Jun-08	GC meeting		
3-Jul-08	GC meeting, MRO increased to 4.25%		
7-Aug-08	GC meeting		
4-Sep-08	GC meeting		
2-Oct-08	GC meeting		
8-Oct-08	unscheduled GC meeting, MRO decreased to 3.75%, coordinated action with BoC, BoE, Fed, Sveriges Riksbank, SNB, BoJ		
13-Oct-08	FX swap arrangements announced joint with BoC, BoE, Fed, SNB, BoJ – tenders of U.S. dollar funding at 7-day, 28-day, and 84-day maturities at fixed interest rates for full allotment		
15-Oct-08	Fixed-rate full allotment (FRFA) on MRO		
6-Nov-08	GC meeting, MRO decreased to 3.25%		
4-Dec-08	GC meeting, MRO decreased to 2.50%		
15-Jan-09	GC meeting, MRO decreased to 2.00%		
5-Feb-09	GC meeting		
5-Mar-09	GC meeting, MRO decreased to 1.50%		
2-Apr-09	GC meeting, MRO decreased to 1.25%		
7-May-09	GC meeting, MRO decreased to 1.00%,		1-year LTRO, CBPP
4-Jun-09	GC meeting,		CBPP details announced
2-Jul-09	GC meeting		
6-Aug-09	GC meeting		
3-Sep-09	GC meeting		
8-Oct-09	GC meeting		
5-Nov-09	GC meeting		
3-Dec-09	GC meeting,		Phasing out of 6m LTROs, indexation of 1y LTROs
14-Jan-10	GC meeting		
4-Feb-10	GC meeting		
4-Mar-10	GC meeting,		Phasing out of 3m LTROs, indexation of 6m LTROs

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date	conv. monetary policy	forward guidance	quantitative easing
8-Apr-10	GC meeting		
6-May-10	GC meeting		
9-May-10	GC meeting,		Securities Market Programme (SMP)
10-Jun-10	GC meeting		
8-Jul-10	GC meeting		
28-Jul-10			Collateral rules tightened, revised haircuts
5-Aug-10	GC meeting		
2-Sep-10	GC meeting		
7-Oct-10	GC meeting		
4-Nov-10	GC meeting		
2-Dec-10	GC meeting		
13-Jan-11	GC meeting		
3-Feb-11	GC meeting		
3-Mar-11	GC meeting,		FRFA extended to July 2011
7-Apr-11	GC meeting, MRO increased to 1.25%		
5-May-11	GC meeting		
9-Jun-11	GC meeting		
7-Jul-11	GC meeting, MRO increased to 1.50%		
4-Aug-11	GC meeting,		SMP covers Spain and Italy
7-Aug-11			SMP on Italy and Spain acknowledged by ECB
8-Sep-11	GC meeting		
6-Oct-11	GC meeting,		CBPP2 launched
3-Nov-11	GC meeting, MRO decreased to 1.25%		
8-Dec-11	GC meeting, MRO rate decreased to 1%		Two 3-year LTROs, reserve ratio to 1%,
21-Dec-11			Results of first 3-year LTRO
12-Jan-12	GC meeting		
9-Feb-12	GC meeting,		ECB approved criteria for credit claims for 7 NCBs
28-Feb-12			Results of second 3-year LTRO
8-Mar-12	GC meeting		
4-Apr-12	GC meeting		
3-May-12	GC meeting		
6-Jun-12	GC meeting		
5-Jul-12	GC meeting, MRO rate decreased to 0.75%, deposit facility rate to 0		
26-Jul-12			"Whatever it takes" London speech of Draghi
2-Aug-12	GC meeting		OMT
6-Sep-12	GC meeting		OMT details
4-Oct-12	GC meeting		
8-Nov-12	GC meeting		
6-Dec-12	GC meeting		
10-Jan-13	GC meeting		
7-Feb-13	GC meeting		
7-Mar-13	GC meeting		
22-Mar-13			Collateral rule changes for some uncovered gov-guaranteed bank bonds
4-Apr-13	GC meeting		
2-May-13	GC meeting, MRO rate decreased to 0.5%,		FRFA extended to July 2014
6-Jun-13	GC meeting		
4-Jul-13	GC meeting,	expects the key ECB interest rates to remain at present or lower levels for an extended period of time	
1-Aug-13	GC meeting	Same as previous	
5-Sep-13	GC meeting	Same as previous	

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date	conv. monetary policy	forward guidance	quantitative easing
2-Oct-13	GC meeting	Same as previous	
7-Nov-13	GC meeting, MRO rate decreased to 0.25%	Same as previous	MROs at FRFA until July 2015...we decided to conduct the three-month LTROs to be allotted until the end of the second quarter of 2015 as FRFA
5-Dec-13	GC meeting	Same as previous	
9-Jan-14	GC meeting	Same as previous	
6-Feb-14	GC meeting	Same as previous	
6-Mar-14	GC meeting	Same as previous	
25-Mar-14			QE announcement Draghi (Science Po - Paris): A consistent strategy for a sustained recovery
3-Apr-14	GC meeting	Same as previous	The Governing Council is unanimous in its commitment to using also unconventional instruments within its mandate in order to cope effectively with risks of a too prolonged period of low inflation.
24-Apr-14			QE announcement Draghi (NDL Conf - Amsterdam): Monetary policy communication in turbulent times
8-May-14	GC meeting	Same as previous	Same as previous
5-Jun-14	GC meeting, MRO rate decreased to 0.15%,	conditional FG: the key ECB interest rates will remain at present levels for an extended period of time in view of the current outlook for inflation	announcement of TLTROs - The Governing Council is unanimous in its commitment to using also unconventional instruments within its mandate should it become necessary to further address risks of too prolonged a period of low inflation
3-Jul-14	GC meeting,	Same as previous	Same a previous + details of TLTROs a period of low inflation
7-Aug-14	GC meeting	Same as previous	Same as previous
4-Sep-14	GC meeting, MRO rate decreased to 0.05%	ABSPP and CBPP3 "should also strengthen 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"	Same a sprevious + announcement of CCBP3 & ABSPP
2-Oct-14	GC meeting,	Same as previous	Same a previous + details of ABSPP CBPP3
6-Nov-14	GC meeting	Same as previous	Same as previous
4-Dec-14	GC meeting,	Same as previous	Same a previous + introduction of the QE-PSPP - Draghi: 'More stimulus is likely on the way, but the final decision wont be taken until early next year'
22-Jan-15	GC meeting,	Same as previous	announcement of PSPP
9-Mar-15			start of the PSPP purchases
5-Mar-15	GC meeting	Based on our regular economic and monetary analysis, and in line with our forward guidance, we decided to keep the key ECB interest rates unchanged	
15-Apr-15	GC meeting	Same as previous	
3-Jun-15	GC meeting	Same as previous	Same as previous
16-Jul-15	GC meeting	Same as previous	Same as previous
3-Sep-15	GC meeting,	Same as previous	possible extension of QE program (Draghi) - the Governing Council decided to increase the issue share limit from the initial limit of 25% to 33%
22-Oct-15	GC 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

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date	conv. monetary policy	forward guidance	quantitative easing
03-Dec-15	GC meeting		new period for PSPP - to extend the APP. The monthly purchases of 60 billion under the APP are now intended to run until the end of March 2017, or beyond, if necessary
21-Jan-16	GC meeting	Based on our regular economic and monetary analyses, and after the recalibration of our monetary policy measures last month, we decided to keep the key ECB interest rates unchanged and we expect them to remain at present or lower levels for an extended period of time.	The decisions taken in early December to extend our monthly net asset purchases of 60 billion to at least the end of March 2017, and to reinvest the principal payments on maturing securities for as long as necessary, were fully appropriate.
10-Mar-16	GC meeting, MRO rate decreased to 0.00%, the deposit facility to -0.40%		CSPP, APP expanded the from 60 to 80 billion, 4-year TLTRO II starting in June 2016
21-Apr-16	GC meeting	key ECB interest rates unchanged	asset purchases of 80 billion are intended to run until the end of March 2017, or beyond, if necessary, and in any case until the Governing Council sees a sustained adjustment in the path of inflation consistent with its inflation aim.
02-Jun-16	GC meeting	Same as previous	Same as previous
21-Jul-16	GC meeting	Same as previous	Same as previous
08-Sep-16	GC meeting	Same as previous	Same as previous

Source: ECB. https://www.ecb.europa.eu/press/pressconf/ .

Table A-4: Fed Monetary Policy Decision: October 2008 - September 2016

date	conv. mon. policy	forward guidance (FG)	quantitative easing
8-Oct-08	unscheduled FOMC meeting, fed funds rate decreased by 0.5 pp to 1.50%, coordinated action with BoC, BoE, Fed, Sveriges Riksbank, SNB, BoJ		
13-Oct-08	FX swap arrangements announced jpoint with BoC, BoE, Fed, SNB, BoJ – tenders of U.S. dollar funding at 7-day, 28-day, and 84-day maturities at fixed interest rates for full allotment		
20-Oct-08			Federal Reserve offers $150 billion in 28-day credit through its Term Auction Facility
29-Oct-08	FOMC meeting, FOMC decreases fed funds rate by 0.5 pp to 1.00%		
25-Nov-08	Fed announces results of auction of $150 billion in 13-day credit		QE1 starts
1-Dec-08	Federal Reserve announces results of auction of $150 billion in 84-day credit		
16-Dec-08	FOMC meeting, FOMC decrease fed funds rate by 0.25 pp to the range 0-0.25%	economic conditions are likely to warrants exceptionally low levels of the fed funds rate for extended period	-
28-Jan-09	FOMC meeting	Same as previous	-
18-Mar-09	FOMC meeting	Same as previous	-
29-Apr-09	FOMC meeting	Same as previous	-
24-Jun-09	FOMC meeting	Same as previous	-
12-Aug-09	FOMC meeting	Same as previous	-
23-Sep-09	FOMC meeting	Same as previous	extend asset purchase program by an additional 3 months, through 2010Q1 rather than 2009Q4
4-Nov-09	FOMC meeting	Same as previous	-
16-Dec-09	FOMC meeting	Same as previous	-
27-Jan-10	FOMC meeting	Same as previous	-
16-Mar-10	FOMC meeting	Same as previous	QE1 ends
28-Apr-10	FOMC meeting	Same as previous	-
9-May-10	unscheduled FOMC meeting	Same as previous	-
23-Jun-10	FOMC meeting	Same as previous	-
10-Aug-10	FOMC meeting	Same as previous	the Committee will keep constant the Federal Reserves holdings of securities at their current level by reinvesting principal payments from agency debt and agency [MBSs] in longer-term Treasury securities.
27-Aug-10	Bernanke Jackson Hole speech		
21-Sep-10	FOMC meeting	Same as previous	The Committee also will maintain its existing policy of reinvesting principal payments from its securities holdings
15-Oct-10	unscheduled FOMC meeting		

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date	conv. mon. policy	forward guidance (FG)	quantitative easing
3-Nov-10	FOMC meeting	Same as previous	QE2 starts - In addition, the Committee intends to purchase a further $600 billion of longer term Treasury securities by the end of the second quarter of 2011
14-Dec-10	FOMC meeting	Same as previous	-
26-Jan-11	FOMC meeting	Same as previous	-
15-Mar-11	FOMC meeting	Same as previous	-
27-Apr-11	FOMC meeting	Same as previous	announcement of QE2 end by June 2011
22-Jun-11	FOMC meeting	Same as previous	
1-Aug-11	unscheduled FOMC meeting		-
9-Aug-11	FOMC meeting	economic conditions . . . are likely to warrant exceptionally low levels of the federal funds rate at least through mid-2013.	-
26-Aug-11	Bernanke Jackson Hole speech		-
21-Sep-11	FOMC meeting	Same as previous	Maturity Extension Programme ("Operation Twist") - The Committee intends to purchase, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of 6 years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less.
2-Nov-11	FOMC meeting	Same as previous	-
28-Nov-11	unscheduled FOMC meeting	Same as previous	-
13-Dec-11	FOMC meeting	Same as previous	-
25-Jan-12	FOMC meeting	Calendar FG: exceptionally low levels for the federal funds rate at least through late 2014.	-
13-Mar-12	FOMC meeting	Same as previous	
25-Apr-12	FOMC meeting	Same as previous	
20-Jun-12	FOMC meeting	Same as previous	Maturity Extension Programme - The Committee intends to purchase, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of 6 years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less.
1-Aug-12	FOMC meeting	Same as previous	
31-Aug-12	Bernanke Jackson Hole speech		
13-Sep-12	FOMC meeting	Calendar FG: that exceptionally low levels for the federal funds rate are likely to be warranted at least through mid-2015	QE3 starts
24-Oct-12	FOMC meeting	Same as previous	
12-Dec-12	FOMC meeting	Conditional FG: exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6.5%, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committees 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored.percentage point above the Committee's 2% longer-run goal, and longer-term inflation expectations continue to be well anchored	
30-Jan-13	FOMC meeting	Same as previous	

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Table A-4 – continued from previous page

date	conv. mon. policy	forward guidance (FG)	quantitative easing
20-Mar-13	FOMC meeting	Same as previous	Bernanke warns of 'premature tightening' in monetary policy (taper tantrum) - In determining the size, pace, and composition of its asset purchases, the Committee will continue to take appropriate account of the likely efficacy and costs of such purchases as well as the extent of progress toward its economic objectives
1-May-13	FOMC meeting	Same as previous	Same as previous
22-May-13	The Economic Outlook. Before the Joint Economic Committee, U.S. Congress		Bernanke warns of 'premature tightening' in monetary policy (taper tantrum)
19-Jun-13	FOMC meeting	Same as previous	Bernanke warns of 'premature tightening' in monetary policy (taper tantrum). The Committee is prepared to increase or reduce the pace of its purchases to maintain appropriate policy accommodation as the outlook for the labor market or inflation changes.
31-Jul-13	FOMC meeting	Same as previous	Same as previous
18-Sep-13	FOMC meeting	Same as previous	the Committee decided to await more evidence that progress will be sustained before adjusting the pace of its purchases
16-Oct-13	unscheduled FOMC meeting		Same as previous
30-Oct-13	FOMC meeting	Same as previous	Same as previous
18-Dec-13	FOMC meeting	Same as previous	the Committee will likely reduce the pace of asset purchases in further measured steps at future meetings. However, asset purchases are not on a preset course, and the Committee's decisions about their pace will remain contingent on the Committee's outlook for the labor market and inflation as well as its assessment of the likely efficacy and costs of such purchases.
29-Jan-14	FOMC meeting	Same as previous	Same as previous
4-Mar-14	unscheduled FOMC meeting		
19-Mar-14	FOMC meeting	Same as previous	Same as previous
30-Apr-14	FOMC meeting	In determining how long to maintain the current 0 to 1/4 percent target range for the federal funds rate, the Committee will assess progress–both realized and expected–toward its objectives of maximum employment and 2 percent inflation.	Same as previous
18-Jun-14	FOMC meeting	Same as previous	Same as previous
15-Jul-14	Semiannual Monetary Policy Report to the Congress		
30-Jul-14	FOMC meeting	Same as previous	Same as previous
22-Aug-14	Yellen Jackson Hole speech		
17-Sep-14	FOMC meeting	the Committee today reaffirmed its view that the current 0 to 1/4 percent target range for the federal funds rate remains appropriate.	Same as previous
29-Oct-14	FOMC meeting	Same as previous	
17-Dec-14	FOMC meeting	Same as previous	
28-Jan-15	FOMC meeting	Same as previous	
24-Feb-15	Semiannual Monetary Policy Report to the Congress		
18-Mar-15	FOMC meeting	Same as previous	
29-Apr-15	FOMC meeting	Same as previous	

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date	conv. mon. policy	forward guidance (FG)	quantitative easing
17-Jun-15	FOMC meeting	Same as previous	
15-Jul-15	Semiannual Monetary Policy Report to the Congress		
29-Jul-15	FOMC meeting	Same as previous	
17-Sep-15	FOMC meeting	Same as previous	
28-Oct-15	FOMC meeting	Same as previous	
16-Dec-15	FOMC meeting, FOMC increases fed funds rate by 0.25% pp to the range 0.25-0.50%		
27-Jan-16	FOMC meeting, the Committee decided to maintain the target range for the federal funds rate at 1/4 to 1/2 percent		
10-Feb-16	Semiannual Monetary Policy Report to the Congress		
16-Mar-16	FOMC meeting - same as previous		
27-Apr-16	FOMC meeting - same as previous		
15-Jun-16	FOMC meeting - same as previous		
21-Jun-16	Semiannual Monetary Policy Report to the Congress		
27-Jul-16	FOMC meeting - same as previous		
26-Aug-16	Yellen Jackson Hole speech		
21-Sep-16	FOMC meeting - the Committee decided to maintain the target range for the federal funds rate at 1/4 to 1/2 percent.	The Committee judges that the case for an increase in the federal funds rate has strengthened but decided, for the time being, to wait for further evidence of continued progress toward its objectives.	

Source: Federal Reserve Board. http://www.federalreserve.gov/newsevents/press/monetary/ .