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The macroeconomic impact of the ECB's expanded asset purchase programme (APP)

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Luca Gambetti, Alberto Musso The macroeconomic impact of the
ECB's expanded asset purchase
programme (APP)

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Abstract

This paper provides empirical evidence on the macroeconomic impact of the expanded asset purchase programme (APP) announced by the European Central Bank (ECB) in January 2015. The shock associated to the APP is identified with a combination of sign, timing and magnitude restrictions in the context of an estimated time-varying parameter VAR model with stochastic volatility. The evidence suggests that the APP had a significant upward effect on both real GDP and HICP inflation in the euro area during the first two years. The effect on real GDP appears to be stronger in the short term, while that on HICP inflation seems more marked in the medium term. Moreover, several channels of transmission appear to have been activated, including the portfolio rebalancing channel, the exchange rate channel, the inflation re-anchoring channel and the credit channel.

JEL classification: C32; E44; E52; E58.

Keywords: Asset Purchase Programme; Quantitative Easing; Euro Area; time-varying VAR.

Non-technical summary

On the 22nd of January 2015 the Governing Council of the European Central Bank (ECB) decided to launch an expanded asset purchase programme (APP) to address the risks of euro area HICP inflation remaining too low for a prolonged period. These large scale asset purchases implied that the ECB joined other central banks in adopting quantitative easing (QE) in addition to other non-standard monetary policy measures, as the margin for standard monetary policy changes in the form of interest rate cuts had eroded.

While a number of studies have provided estimates of the APP on euro area financial markets, very few papers have addressed the macroeconomic implications of these purchases. The purpose of this paper is to quantify the contribution of the APP to euro area real GDP and HICP inflation in the context of an empirical model featuring time variation in the parameters and volatility, a novel identification approach and quarterly data from 2009 to 2016. The model used, a time-varying parameter VAR with stochastic volatility, allows taking into account potentially important changes in the euro area macroeconomy as well as the transition of monetary policy towards a regime characterised by an effective zero lower bound of key ECB policy interest rates which took place in recent years. Our novel identification scheme includes a combination of sign, timing and magnitude restrictions, allowing us to focus on the effects of the APP shock which took place in the first quarter of 2015 by exploiting the results of the available literature on the financial implications of the APP and factual information available on the timing and amounts of the purchases, thereby representing an approach combining sign and narrative-based restrictions. The data used include, in addition to real GDP and the HICP as main variables of interest, Eurosystem security purchases for monetary policy purposes and the long-term interest rate, that are needed for the identification.

The main results of the empirical analysis are the following. First, we find a significant impact of the APP on both real GDP and HICP inflation. More precisely, it is estimated that the contribution of the APP shock to real GDP was 0.18 percentage point during the first quarter of 2015, similar to that estimated by the end of 2015, becoming then very small by the fourth quarter of 2016. By contrast, the contribution of the APP shock to the HICP was very small in the first quarter of 2015, increasing to 0.18 percentage point by the end of 2015 and to 0.36 percentage point by the fourth quarter of 2016. Second, several channels appear to have been activated by the APP, including the portfolio rebalancing channel, the exchange rate channel, the inflation re-anchoring channel and the credit channel. A caveat to be borne in mind is that the analysis only provides a quantification of the impact of the initial APP package introduced in early 2015, while not including also the sub-subsequent re-calibrations of the APP announced in December 2015, March 2016 and December 2016. Overall, the analysis suggests that the APP was

useful to support the recovery in real economic activity and HICP inflation during 2015 and 2016, as a sustained adjustment in the path of inflation had not yet materialised.

1 Introduction

On the 22nd of January 2015 the Governing Council of the European Central Bank (ECB) decided to launch an expanded asset purchase programme (APP) to address the risks of euro area HICP inflation remaining too low for a prolonged period. Under this programme the combined purchases of public and private sector securities between March 2015 and September 2016 would amount to €1.14 trillion, corresponding to 11.3% of 2014 euro area nominal GDP. These large scale asset purchases implied that the ECB joined other central banks in adopting quantitative easing (QE) in addition to other non-standard monetary policy measures, as the margin for standard monetary policy changes in the form of interest rate cuts had eroded. The APP programme was subsequently extended and re-calibrated on various occasions, increasing the duration and total amount of purchases. Given the objective of the APP to address the medium term risks to price stability and considering that several channels of transmission from the purchases to HICP inflation would operate via an expansion in economic activity, it is essential to assess the impact of these measures to the euro area macroeconomy, namely real GDP and HICP inflation.

While a number of studies have provided estimates of the APP on euro area financial markets (see for example Altavilla et al., 2015; De Santis, 2016; Andrade et al., 2016; Kojien et al., 2016) very few papers have addressed the macroeconomic implications of these purchases. Against this background, the purpose of this paper is to quantify the contribution of the APP to euro area real GDP and HICP inflation in the context of an empirical model featuring time variation in the parameters and stochastic volatility and a novel identification approach. The model used, a time-varying parameter VAR with stochastic volatility, allows to take into account potentially important changes in the euro area macroeconomy as well as the transition of monetary policy towards a regime characterised by an effective zero lower bound of key ECB policy interest rates which took place in recent years. Our novel identification scheme includes a combination of sign, timing and magnitude restrictions, allowing us to focus on the effects of the APP shock which took place in the first quarter of 2015 by exploiting the results of the available literature on the financial implications of the APP and factual information available on the timing and amounts of the securities purchased, thereby representing an approach combining sign and narrative-based restrictions. Results from our approach can be seen as complementary to other estimates of the impact of the APP on the euro area macroeconomy, either based on calibrated DSGE models (Andrade et al., 2016; Altavilla et al., 2016) or based on Bayesian VARs with fixed parameters and constant

volatility and alternative identification schemes (Wieladek and Garcia Pascual, 2016).

The main results of the empirical analysis are the following. First, we find a significant impact of the APP on both real GDP and HICP inflation. The effect on real GDP is stronger in the short term, while that on the HICP increases over time. More precisely, it is estimated that the contribution of the APP shock to real GDP was 0.18 percentage point during the first quarter of 2015, similar to that estimated by the end of 2015 (0.16 percentage point), becoming then very small (0.02 percentage point) by the end of the sample period (i.e. the fourth quarter of 2016). By contrast, the contribution of the APP shock to the HICP was 0.06 percentage point in the first quarter of 2015, increasing to 0.18 percentage point by the end of 2015 and to 0.36 percentage point by the end of the sample period. Second, several channels appear to have been activated by the APP, including the portfolio rebalancing channel, the exchange rate channel, the inflation re-anchoring channel and the credit channel. It should be kept in mind that the analysis only provides a quantification of the impact of the initial APP package introduced in early 2015, while not including also the sub-sequent re-calibrations of the APP announced in December 2015, March 2016 and December 2016.

The remainder of the paper is structured as follows. Section 2 provides a discussion of the main features of the APP, the associated channels of transmission and the relevant literature. Section 3 illustrates the empirical approach and describes the data. Section 4 reports and discusses the results. Section 5 provides conclusions.

2 The APP: main features and channels of transmission

Since the summer of 2007 the euro area economy experienced various periods of economic and financial instability of different nature, origin, degree of severity and duration. As a result, the ECB adopted several standard and non-standard monetary policy measures to support the euro area economy. As regards standard monetary policy measures the ECB implemented multiple cuts in key interest rates, bringing the interest rate on the main refinancing operations down from 4.25% in September 2008 to 1.00% in May 2009 and from 1.50% in October 2011 to 0.00% in March 2016 (see Chart 1). These cuts also led to various interest rates touching negative territory, such as the rate on the deposit facility since June 2014 and the Eonia since early 2015 (Chart 2). The non-standard measures include various security purchase programmes, such as covered bond purchase programmes starting in 2009 (CBPP1) and in 2011 (CBPP2) and a securities markets programme (SMP) starting in 2010, largely aimed at restoring the functionality of various fragments of financial markets and supporting the banking sector which plays a key role in the transmission of monetary policy in the euro area. Annex I provides an overview of all of the main measures adopted by the ECB since 2007.

<CHARTS 1 AND 2 AROUND HERE>

More recently, the ECB launched a set of measures which can be characterised as quantitative easing. More precisely, on the 22nd of January 2015 the Governing Council of the ECB decided to initiate an expanded asset purchase programme, against the background of low inflation (Chart 3), signs of decreasing longer-term inflation expectations (Chart 4) and a gradual recovery in economic activity (Chart 5), which pointed to an increased likelihood that inflation would remain too low for a prolonged period. The APP encompassed the existing asset-backed securities purchase programme (ABSPP) and the third covered bond purchase programme (CBPP3), which were both launched in September 2014, and a new public securities purchase programme (PSPP) aimed at purchasing bonds issued by euro area central governments, agencies and European institutions, to start in March 2015. Under this expanded programme the combined monthly purchases of public and private sector securities amounted to €60 billion, starting in March 2015 and intended to be carried out until at least September 2016 and in any case until the Governing Council would see a sustained adjustment in the path of inflation that is consistent with its aim of achieving inflation rates below, but close to, 2% over the medium term. Thus, the announced APP entailed combined purchases of public and private sector securities between March 2015 and September 2016 by €1.14 trillion, corresponding to 11.3% of 2014 euro area nominal GDP. Since progress towards a sustained adjustment in the path of inflation continued to be disappointing, the APP programme was subsequently re-calibrated on various occasions, extending the duration and total amount of purchases. On the 3rd of December 2015 the Governing Council extended the APP, announcing that the monthly purchases of €60 billion were intended to run until the end of March 2017, or beyond, if necessary, thus adding another total amount of (at least) €360 billion, corresponding to 3.6% of 2014 nominal GDP. On the 10th of March 2016 the Governing Council decided to expand the monthly purchases under the APP from €60 billion to €80 billion, including a new corporate securities purchase programme (CSPP), starting from April 2016, still intended to run until the end of March 2017, or beyond, if necessary, implying an additional amount of (at least) €240 billion of purchases, corresponding to 2.3% of 2015 nominal GDP. On the 8th of December 2016 the Governing Council decided to extend the purchases by nine months and, from April 2017, the net asset purchases are intended to continue at a monthly pace of €60 billion until the end of December 2017, or beyond, if necessary, thereby adding a total amount of (at least) €540 billion to the purchases, corresponding to 5.2% of 2015 nominal GDP. Annex II provides more details on the APP, as well as on the other monetary policy measures adopted in parallel to APP in 2015 and 2016, including targeted longer-term refinancing operations and further cuts in key ECB interest rates.

<CHARTS 3 TO 5 AROUND HERE>

All these non-standard monetary policy measures implied significant changes in the size and composition of the Eurosystem balance sheet from 2007 onwards (Chart 6). While several of the liquidity providing operations in the initial phase of the financial crisis can be characterised as passive central bank balance sheet policies, the subsequent credit easing and large-scale asset purchase policies implemented by the Eurosystem, similar to other major central banks, saw the ECB taking a more active stance on determining the size and composition of the assets on its balance sheet (ECB, 2015a). In this context the various Eurosystem purchase programmes, ranging from the CBPP1 launched in July 2009 to the CSPP announced in March 2016, play an important role. Indeed, these programmes represent a core component of the Eurosystem active balance sheet policies, having gained relevance since 2010 and having become central since 2015 (Chart 7). The knowledge on the exact timing and magnitude of these purchases can be very useful in the process of identifying the effect of the APP, as will be explained in detail in the section on identification.

<CHARTS 6 AND 7 AROUND HERE>

The APP, similar to other large-scale asset purchases undertaken by the Fed and the Bank of England, can be expected to stimulate economic activity and raise inflation through various channels (ECB, 2015b). First, according to the portfolio rebalancing channel, asset purchases by the central bank will lead sellers of these assets to rebalance their portfolios towards other assets, thereby increasing the price of a broad range of financial assets, reducing their yields. Among other effects, the compression of yields will reduce the cost of external financing to both banks and non-financial corporations and increase the supply of bank lending which becomes a more attractive option for banks than investing in securities. From a theoretical perspective, for the portfolio rebalancing channel to be active some friction causing imperfect substitutability between assets must be present, for example in the form of preferred habitat among some investors (Vayanos and Villa, 2009).¹ Available evidence suggests that this channel is among the most important channels of transmission of QE policies to financial markets (see Altavilla et al., 2015, for the euro area; Joyce et al., 2011 for the UK; and Gagnon et al., 2011, and D'Amico et al., 2012, for the US). The exchange rate channel, according to which asset purchases might lead to a depreciation of the exchange rate, can be seen as a specific category within the more general class of the portfolio rebalancing channel, as portfolio

¹Other specific channels highlighted in the literature, such as the duration channel (reduction of duration risk) or the scarcity channel (creation of scarcity in the assets purchased by the central bank), can be subsumed under the more general portfolio rebalancing channel category.

rebalancing flows might include an increased demand for external assets by domestic residents and/or a repatriation of funds by non-residents. Some evidence on the relevance of the exchange rate channel is presented by Glick and Leduc (2013) and Rogers et al. (2014). A second general category of channels is represented by the signalling channel, according to which asset purchases signal the commitment of the central bank to maintain an accommodative policy for a longer period of time to achieve its price stability objective, implying downward revisions in market expectations of future policy rates. This channel can be interpreted in a similar way as forward guidance, as the central bank signals its commitment to maintain short-term interest rates at the effective lower bound for a longer period. The quantitative relevance of this channel is uncertain, as the empirical evidence points to different conclusions (see Altavilla et al., 2015, for the euro area; Krishnamurthy and Vissing-Jorgensen, 2013, Bauer and Rudebusch, 2014, and Christensen and Rudebusch, 2012, for the UK and US). The inflation expectations or inflation re-anchoring channel, according to which asset purchases increase longer-term inflation expectations, can be subsumed under the signalling channel category as it also operates via the central banks commitment to its mandate. Finally, the broad credit channel, which relates to the effects of asset purchases on the supply of bank lending and lending rates, is also likely to be relevant, although it is likely to operate at least in part via the increased asset prices and decreased yields induced by the asset purchases, as discussed above, thereby representing a subsequent step in the chain reaction activated by the portfolio rebalancing channel. At the same time, the related but more specific direct pass-through channel can be seen as a different channel compared to the portfolio rebalancing channel to the extent that specific asset purchases, such as asset-backed securities purchases, increase the price of the targeted assets encouraging banks to increase the supply of loans that can be securitised which tends to lower bank lending rates. All these channels ultimately support income, investment and consumer spending as well as consumer price inflation.

3 The empirical approach

In this section we provide details on the econometric model and the identification used to assess the impact of the APP on the macroeconomy.

3.1 The model

The empirical model adopted to undertake the analysis is represented by a structural VAR model with time-varying parameters and stochastic volatility (see Primiceri, 2005). Let y_t be a vector including the variables of interest as well as the variables needed for the identification. The baseline model includes four variables ($N = 4$): the two variables

of interest, real GDP growth and HICP inflation, and two more variables needed for identification, the flow of Eurosystem securities purchased for monetary policy purposes and the long-term interest rate. For the purpose of the assessment of the role of various channels we include a fifth variable, such as stock prices, inflation expectations, loan volumes or the composite lending rate ($N = 5$). We assume that y_t follows

$$y_t = A_{0,t} + A_{1,t}y_{t-1} + \dots + A_{p,t}y_{t-p} + \varepsilon_t \quad (1)$$

where ε_t is a $N \times 1$ Gaussian white noise vector of innovations with time-varying covariance matrix Σ_t , $A_{0,t}$ is a $N \times 1$ vector of time-varying coefficients and $A_{i,t}$ are $N \times N$ matrices of time-varying coefficients, $i = 1, \dots, p$. Let $A_t = [A_{0,t}, A_{1,t}, \dots, A_{p,t}]$, and $\theta_t = \text{vec}([A_{0,t} \ A_t]')$, $\text{vec}(\cdot)$ being the stacking column operator. The VAR coefficients evolve as a random-walk

$$\theta_t = \theta_{t-1} + \omega_t \quad (2)$$

where ω_t is a Gaussian white noise vector with covariance Ω .

We decompose the innovation variance as follows: $\Sigma_t = F_t D_t F_t'$, where F_t is a lower triangular matrix with ones on the main diagonal and D_t a diagonal matrix. Let σ_t be a column vector containing the diagonal elements of $D_t^{1/2}$ and let $\phi_{i,t}$, $i = 1, \dots, 4$, be a column vector containing the first i elements of the $(i + 1)$ -th row of F_t^{-1} . We assume

$$\log \sigma_t = \log \sigma_{t-1} + \xi_t \quad (3)$$

$$\phi_{i,t} = \phi_{i,t-1} + \psi_{i,t} \quad (4)$$

where ξ_t and $\psi_{i,t}$ are Gaussian white noise vectors with zero mean and variance Ξ and Ψ_i respectively. Let us define $\phi_t = [\phi'_{1,t}, \dots, \phi'_{n-1,t}]$, $\psi_t = [\psi'_{1,t}, \dots, \psi'_{n-1,t}]$ and let Ψ be the covariance matrix of ψ_t . We make two additional assumptions. First, $\psi_{i,t}$ and $\psi_{j,t}$ are uncorrelated for $j \neq i$. Second ξ_t , ψ_t , ω_t , ε_t are mutually uncorrelated.

The time-varying impulse response functions are $C_t(L) = \sum_{k=0}^{\infty} C_{k,t} L^k$, with $C_{0,t} = I_n$ and $C_{k,t} = \mathcal{S}_{N,N}(\mathbf{A}_t^k)$, where $\mathbf{A}_t = \begin{pmatrix} A_t & \\ & 0_{n(p-1),n} \end{pmatrix}$ and $\mathcal{S}_{n,n}(X)$ is a function which selects the first n rows and n columns of the matrix X . The structural impulse response functions are obtained as follows. Let S_t be the Cholesky factor of Σ_t ($S_t S_t' = \Sigma_t$) and let H_t be an orthogonal matrix ($H_t H_t' = I$) satisfying the identifying restrictions of Table 1 discussed in subsection 3.3. The structural impulse response functions are $C_t(L) S_t H_t$ and the structural shocks are $e_t = H_t' S_t^{-1} \varepsilon_t$.

Although alternative modelling approaches exist to account for possible changes in parameters and/or volatility, such as Markov-switching VAR models or Threshold VAR models, time-varying VAR models with stochastic volatility have an advantage in terms of flexibility, as they allow for important changes in the economy, from structural changes to changes in volatility, to be captured, while at the same time imposing little structure

(and no need to impose a specific number of regimes). This framework seems particularly appropriate to analyse empirically economies which may have been subject to various and uncertain types of change, ranging from the Great Recession to the sovereign debt crisis to a transition to a zero lower bound monetary policy regime, leading to potentially important but uncertain changes in economic behavior and policy rules. At the same time, it has to be recognised that the high computational costs implied by the chosen model imply that the number of variables that can be included in the VAR is very limited.

3.2 Specification and estimation

Estimation is standard and is performed along the lines of Gali and Gambetti (2015) which basically follows Del Negro and Primiceri (2015). Here we describe a few details of the prior density choice and calibration.

The VAR is estimated with two lags. Following the literature we assume that Ω , Ξ , Ψ , θ_0 , ϕ_0 and $\log \sigma_0$, are all independent from each other. Denoting $W(S, d)$ a Wishart distribution with scale matrix S and degrees of freedom d , we make the following assumption about the prior distributions:

$$\begin{aligned}\theta_0 &\sim N(\hat{\theta}, \hat{V}_\theta) \\ \log \sigma_0 &\sim N(\log \hat{\sigma}_0, I_n) \\ \phi_{i0} &\sim N(\hat{\phi}_i, \hat{V}_{\phi_i}) \\ \Omega^{-1} &\sim W(\underline{\Omega}^{-1}, \underline{\rho}_1) \\ \Xi^{-1} &\sim W(\underline{\Xi}^{-1}, \underline{\rho}_2) \\ \Psi_i^{-1} &\sim W(\underline{\Psi}_i^{-1}, \underline{\rho}_{3i})\end{aligned}$$

Scale matrices are parametrized as follows: $\underline{\Omega} = \underline{\rho}_1(\lambda_1 \hat{V}_\theta)$, $\underline{\Xi} = \underline{\rho}_2(\lambda_2 I_n)$ and $\underline{\Psi}_i = \underline{\rho}_{3i}(\lambda_3 \hat{V}_{\phi_i})$. The degrees of freedom $\underline{\rho}_1$ and $\underline{\rho}_2$ are equal to the number of rows $\underline{\Omega}^{-1}$ and I_n plus one respectively while $\underline{\rho}_{3i}$ is $i + 1$ for $i = 1, \dots, n - 1$. The parameters $\hat{\phi}_i, \hat{V}_{\phi_i}, \log \hat{\sigma}_0, \hat{\theta}, \hat{V}_\theta$ are imposed equal to the OLS estimates obtained from a time invariant VAR estimated for the full sample. Finally, we assume $\lambda_1 = 0.0005$, $\lambda_2 = 0.05$ and $\lambda_3 = 0.05$. The choice of the λ 's is relatively conservative especially for λ_1 and is motivated by the fact that we want time variations not to be inflated by our priors. The posterior distribution of the parameters is obtained with the Gibbs sampler. See the online appendix of Gali and Gambetti (2015) for the details of the of the seven steps involved in the algorithm.

The baseline model includes four quarterly variables spanning the period 2009Q3 to 2016Q4: euro are real GDP annualised quarterly growth, annualised quarterly growth of the euro area HICP, the flow of Eurosystem security purchases for monetary policy

purposes (in EUR billions) and the first difference of the euro area composite 10-year government bond yield (as the series need to be stationary, and this yield exhibits a clear downward trend in the sample considered, as shown in Chart 2). Annex III provides details on the definition, treatment and sources of the data.

3.3 Identification

The aim of the analysis is to assess quantitatively the effects of the introduction of the APP. Thus, we identify one shock, which we will call the APP shock. For this purpose we use a combination of sign, timing and magnitude restrictions, exploiting the results of the literature on the financial market effects of QE policies and the detailed information on the specific application of the APP in the euro area in early 2015. For clarity purposes, it should be mentioned that we identify the shock that relates to the initial introduction of the APP, thus abstracting from the subsequent changes in terms of re-calibrations of the APP in December 2015, March 2016 and December 2016. Our identification scheme is the result of the combination of various sources of information.

First, a number of event studies have shown that the announcement of the APP in January 2015 had a significant downward effect on long-term interest rates in the euro area (Altavilla et al., 2015, De Santis, 2016, Andrade et al., 2016). Indeed, according to these studies, the short-term effect of the APP on the euro area composite 10 year sovereign bond yield was between about 30 basis points and about 70 basis points, with a median of about 40 basis points. The estimated impact of QE policies adopted in recent years in other jurisdictions, namely in the US, UK or Japan, on the respective 10 year government bond yield, according to the available empirical studies, varies but tends to always be negative and significant (see for example the summary Table 1 in Andrade et al., 2016). Overall, despite the fact that to some extent the introduction of the APP was expected, as was the case for other instances of recent QE policies introduced in other countries, all these studies find a significant downward effect of the policy announcement and/or introduction on long-term interest rates even after controlling for expectations and other events of potential macroeconomic and financial relevance.

Second, as discussed in the previous section, the implementation of the APP in the euro area entailed combined monthly purchases by the Eurosystem of public and private sector securities by €60 billion from March 2015 onwards. It is fair to recognise that such purchases were to some extent expected, as reported by the press, following various references by ECB Executive Board members in speeches in previous months to further accommodative monetary policy measures as well as the statement by President Draghi during the ECB Press Conference of December 2014 that in early 2015 the ECB will, among other things, reassess "the expansion of the balance sheet", not to mention that some of the purchase programmes that were absorbed by the APP had already been

announced in September 2014 and started in October 2014 (CBPP3) or November 2014 (ABSPP). However, it can be argued that the extent of the purchases was not fully expected. For example, on the day after the APP announcement, the Financial Times included an article entitled "Central bank bond-buying proposal beats all expectations" reporting that "Market analysts polled by Bloomberg earlier this week had expected some €550bn-worth of government bond purchases. The ECB now intends to buy double that amount, launching a €1.1tn bond-buying spree, the vast majority of which will involve purchases of sovereign debt." (Financial Times, 23 January 2015, p. 3). Accordingly, it is reasonable to assume that at least part of the purchases were unexpected and thus can be associated to a positive APP shock. Note that using quarterly data allows to avoid the complications of differentiating the impact of the APP announcement in January 2015 from that of the start of the actual APP purchases in March 2015, as both events took place in the first quarter of 2015.

Third, available studies on the impact of the APP and more generally on the impact of QE policies introduced in recent years clearly point to a positive effect on real GDP and inflation, although with estimates varying quantitatively. These include estimates of the APP for the euro area (Andrade et al., 2016; Altavilla et al., 2016; Wieladek and Garcia Pascual, 2016) and estimates of the impact of large-scale asset purchases on output and inflation in Japan, the UK and the US in recent years (see for example Table 7 in Borio and Zabai, 2016). At the same time, some uncertainty remains on the time needed for QE policies to be transmitted to real GDP and inflation. Indeed, while the positive lagged effect on output and prices is very likely, it is questionable whether the immediate effect might be significant.

Taking into account this information and considerations, we identify the APP shock as follows. First, we assume that the APP shock had an immediate positive effect on the Eurosystem security purchases for monetary policy purposes and an immediate negative effect on the euro area composite 10 year sovereign bond yield, and that these effects also persisted for three more quarters (in the robustness analysis we show that reducing this lag to two or one does not change results significantly). We focus on the series for Eurosystem security purchases for monetary policy purposes, i.e. the sum of purchases that started in 2009 with CBPP1, instead of the total Eurosystem balance sheet (i.e. total assets) because the latter reflects several changes that affected the total balance sheet but had nothing to do with monetary policy (such as gold revaluations) or policies other than those of interest in the present study and taking place around the same periods, complicating the identification. It is interesting to note that such choice is also supported by the conclusion of Haldane et al. (2016) that "it is only when central bank balance sheet expansions are used as a monetary policy tool that they have a significant macro-economic impact" (p.1). We focus on the series for total Eurosystem security

purchases rather than that only for the APP security purchases as the latter starts only in the first quarter of 2015, making the estimation period statistically too short. Second, we identify only the shock that took place in the first quarter of 2015, thus imposing the restrictions only on the effects (immediate and delayed) of the shock that took place in that quarter. This reflects the fact that we know exactly when the APP policy was first introduced and are interested mainly on the impact of the initial package. Third, we impose a magnitude restriction and assume that on impact at least €10 billion of the Eurosystem purchases were unexpected, i.e. the effect of the APP shock on impact is at least €10 billion (in the robustness analysis we show that changing this magnitude to €0 billion, €5 billion, €15 billion or €20 billion does not change results significantly). Finally, we assume that the APP shock had a positive effect on real GDP and the HICP with a lag, namely in lags one to three, leaving the impact effect unrestricted (in the robustness analysis we show that reducing this lag to two or one does not change results significantly). These set of sign, magnitude and timing restrictions are summarised in Table 1.

<TABLE 1 AROUND HERE>

These restrictions are enough to ensure that we identify an APP shock (specifically, the APP shock that took place in the first quarter of 2015) and not other shocks such as aggregate demand shocks or aggregate supply shocks. Indeed, aggregate demand shocks or aggregate supply shocks, if positive (i.e. having a positive effect on real GDP) are likely to have a zero impact effect on Eurosystem security purchases and a positive effect on long-term interest rates, while if negative even if they were to lead to an expansion of the Eurosystem security stock (in case of a large adverse shock leading the central bank to react with purchases given the lower zero bound on interest rates) they still would have a negative effect on real GDP at least in the short term. Similar considerations could be made for other shocks such as standard monetary policy shocks, uncertainty shocks or financial stability shocks. However, in the sensitivity analysis we show that adding a fifth variable associated to such shocks, such as the short-term interest rate (the Eonia rate), some proxy for uncertainty (the VSTOXX) or a composite indicator of systemic stress in the financial sector (the CISS indicator), does not change results significantly.²

The fact that we aim at assessing the impact of one specific shock taking place only in one quarter, without precedents in the sample considered, may raise concerns about the

²The combination of various sets of restrictions to reduce the set of admissible model solutions adopted in the present paper is similar in spirit to the approach proposed by Kilian and Murphy (2012) to identify oil price shocks, consisting of a combination of sign and economically motivated inequality (magnitude) restrictions.

general representativeness of results, which would not arise in case of a multi-country analysis, for example in the context of a panel VAR, including data for multiple QE shock episodes. However, we should stress that the aim of the analysis is not to draw conclusions on the macroeconomic effects of QE shocks in general but only to assess the effects of that implemented by the ECB in the first quarter of 2015, which is likely to differ from other QE episodes in other countries, among other reasons given the different macroeconomic environment when it was introduced (such as prevailing negative interest rates in the euro area). Moreover, the specific identification scheme adopted can only be applied to the case of the early 2015 APP case, as other QE measures applied by the US, UK and Japan differed somewhat in terms of specific features, such as the lack of precise amounts of purchases targeted each month, which would not allow us to apply the same identification scheme to these other episodes. The set of restrictions adopted allows us to be confident that we identify the specific shock we are interested in, and each of the three sets of restrictions (sign, timing and magnitude) aims at sharpening the identification. Thus, we avoid the risk of capturing also other shocks, which would be non-negligible if we were to adopt other identification schemes, such as that proposed by Baumeister and Benati (2013) and Kapetanios et al. (2012), based on sign and zero restrictions with respect to the spread between long-term and short-term interest rates (to identify a so-called spread shock), which is likely to capture also financial market shocks other than QE shocks.

From a technical perspective, we impose the restrictions using draws of the joint distribution of the coefficients in 2015Q1 since our narrative evidence allows us to pin down the date of the shock. More specifically, for each draw of the reduced form coefficients we draw H_t in such a way that the elements of each row represent the coordinates of a point uniformly distributed over the unit hypersphere and that is orthogonal to the other points defined by the remaining columns, see Rubio-Ramirez et al. (2010). We keep the draw in case the restrictions are satisfied.³

4 Results

4.1 Evidence of time-variation in parameters and volatility

The estimated residual time-varying variances indicates that for all variables there is evidence of significant time-variation (Chart 8). While for output there is evidence that residual variances were higher around 2010, for inflation and Eurosystem security purchases they increased especially since 2015. By contrast, long-term interest rates

³A drawback of this approach is that, as shown in Baumeister and Hamilton (2015), the standard algorithm of Rubio-Ramirez et al. (2010) is not innocuous in that it might affect the shape of the impulse response functions.

display a temporarily higher residual variance around 2013. Thus, it appears that the various phases of the economic and financial crisis may have impacted in a different way on the volatility of the variables considered. Overall, the evidence supports the use of a stochastic volatility specification for the model.

<CHART 8 AROUND HERE>

As regards time-variation in the parameters, we perform the test suggested by Cogley and Sargent (2005). Accordingly, we compute the posterior mean and 16th and 86th percentiles of the trace of Ω as well as the trace of Ω_0 (i.e. the prior variance-covariance matrix). It turns out that the trace of Ω_0 is lower than the 16th percentile, suggesting that the sample points towards greater time-variation in the parameters than that of the prior selected (see Table 2). The results of this test can be interpreted as evidence pointing to the presence of time variation in the parameters of the VAR.

<TABLE 2 AROUND HERE>

4.2 The effect of the APP shock

The posterior median of the impulse response functions of the variables considered to the APP shock taking place in the first quarter of 2015 are shown in Chart 9, along with the area delimited by the 16th and the 86th percentiles. Accordingly, the impact of the shock to the Eurosystem security purchases appears to be long lasting and of duration well beyond the four quarters imposed. Moreover, it seems that while the effect on impact amounts to just above €10 billion, very close to the threshold imposed, subsequently this effect increases reaching a peak around after two years. By contrast, the impact of the shock on the long-term interest rate appears muted and short lasting. Admittedly, it is significant only for the first year, as imposed in the identification restrictions, during which the average effect is just less than 10 basis points. This estimate is much lower than those reported by the above-mentioned event studies, but results are difficult to compare given the different frequency of the data. Indeed, it could well be that the impact of the shock in the first week is much higher and decreases in the following weeks, such that when considering the first quarter as a whole the estimated impact is much smaller. The effect of the shock on real GDP appears to be mainly concentrated in the short run. More precisely, it is significant on impact and for subsequent three quarters, becoming insignificant later on. The impact on the HICP, while barely significant on impact, increases over time and peaks after about two years. Moreover, it remains markedly significant for at least five years.

<CHART 9 AROUND HERE>

An alternative way to present the impact of the APP shock is to examine counterfactuals, which indicate how each variable would have evolved in the absence of the shock. These are shown in Chart 10. Concentrating on the macroeconomic impact, it can be observed that real GDP annualised quarterly growth would have been about 2.6% in the first quarter of 2015, which compares to an observed growth rate of about 3.3% in the same quarter. Thus, on impact the APP shock supported real GDP growth by about 0.7 percentage point. However, in subsequent quarters it appears that observed real GDP growth would have not been significantly different than without the APP shock, in line with the above-mentioned evidence on the short-term impact of the APP shock on real output. By contrast, the evolution of the HICP annualised quarterly growth rate would have been lower than that observed throughout the period 2015-2016, with the maximum difference observed in the third quarter of 2015, when observed HICP annualised growth was -0.8% which compares to a counterfactual growth of -1.2% in the absence of the APP shock. In terms of annual growth rates, as HICP inflation is typically monitored, the difference is also marked throughout the period and is highest in the second quarter of 2016, when observed HICP inflation was 0.1% while it would have been -0.1% in the absence of the APP shock.

<CHART 10 AROUND HERE>

Table 3 summarises the macroeconomic impact of the APP shock. Comparing the evolution of the observed levels of real GDP and the HICP to those estimated in the context of our model in the absence of the APP shock, it is estimated that the contribution of the APP shock to real GDP was 0.18 percentage point on impact (i.e., in 2015Q1) and 0.16 percentage point by the end of 2015, decreasing to 0.02 percentage point by the end of 2016. By contrast, the contribution of the APP shock to HICP was 0.06 percentage point on impact, then gradually increasing to 0.18 percentage point by the end of 2015 and to 0.36 percentage point by the end of 2016.

<TABLE 3 AROUND HERE>

These estimates may appear relatively small compared to other estimates of the impact of the ECB's APP or QE implemented by the US and UK. For example, Andrade et al. (2016) using a calibrated DSGE model based on Gertler and Karadi (2013) find that "the APP increases inflation gradually by around 40 basis points and output by around 1.1 percent reaching their peak in around 2 years." (p.42). Wieladek and Garcia Pascual (2016) in the context of a Bayesian VAR with fixed parameters and constant volatility and a somewhat different identification approach find that "the January 2015 QE announcement, together with the anticipation effect since President Draghi's August

2014 Jackson Hole speech, led to a rise in real GDP and core CPI of 1.3% and 0.9%, respectively " (p. 12). More in general, alternative estimates of the effects of various QE measures implemented in recent years in advanced economies based on alternative approaches vary significantly, as exemplified in the systematic comparisons of the peak effects on real GDP and inflation reported in Table 7 of Borio and Zabai (2016) (p.23). Of course, the different magnitude of all of these estimates reflects the different modelling approaches adopted, ranging from DSGE (calibrated or estimated) to VARs (either allowing for time variation in parameters and volatility or assuming constant parameters and volatility), the different identification schemes applied as well as the different features of the QE measures implemented by various central banks in different periods. In relative terms, it can be argued that our approach, based on an empirical structural model allowing for time-varying parameters and stochastic volatility and a sharp identification approach combining sign, magnitude and timing restrictions, enhances the credibility of the results.

4.3 Channels of transmission

In order to assess the activation of some of the channels of transmission discussed in the previous sections, we estimate the model with a fifth variable. The first four variables and the respective identification restrictions are the same as the baseline model presented above, but we add, in turn as a fifth variable, stock prices, the exchange rate, long-term inflation expectations, bank lending rates and bank loan volumes. Each of these variables is associated to one channel of transmission. The identification restrictions imposed on the fifth variable are shown in Table 4.

First, in order to examine whether the portfolio rebalancing channel was operational, we add stock prices growth (annualised quarterly growth) as a fifth variable to the model. The idea is that the portfolio rebalancing channel would imply a broad increase in asset prices which would be reflected in an increase in stock prices growth. We assume that the APP shock has a positive impact on stock prices both on impact, as financial variables tend to react fast to shocks, as well as in the following three quarters, given the likely persistence of the positive effect of the shock. Overall, we find that the reaction of stock prices to the APP shock is strong and persistent, with an increase of almost 10% in stock prices on impact, and a significantly positive effect for the subsequent four quarters (i.e. one quarter beyond what imposed by identification) (see impulse responses reported in the first row of Chart 11). These results suggest that the portfolio rebalancing channel was clearly activated.

Second, by adding the exchange rate to the model it is possible to examine the response of this variable to the APP shock thereby assessing the extent of the activation of the exchange rate channel. We use the nominal effective exchange rate of the euro, but

results are very similar if the real effective exchange rate is used. For this variable, since there are possibly several types of transactions triggered by the APP shock with possible different effect on the exchange rate (i.e. transactions by residents and non-residents involving foreign and domestic assets), we do not impose any restriction. Overall, the results of the estimates of the model with the exchange rate point to a clear marked and persistent negative effect of the APP shock on the euro exchange rate, with a peak depreciation of about 5% after two quarters (see impulse responses reported in the second row of Chart 11). These results are consistent with an activation of the exchange rate channel.

Third, some inference on the expectations channel, or inflation re-anchoring channel, can be derived by adding a longer-term inflation expectations variable to the model. We use the five years ahead inflation expectations from the Survey of Professional Forecasters (SPF) as reference variable and assume that it responds positively on impact to the APP shock. Overall, we find that the APP shock had a significant impact on longer-term inflation expectations, of about 0.1 percentage point in the medium run (see impulse responses reported in the third row of Chart 11). Thus, the APP shock appears to also have been effective in activating the inflation re-anchoring channel. This result is in line with the analysis of Ciccarelli et al. (2017) who find that the expansion of Federal Reserve's balance sheet contributed to a re-anchoring of US long-term inflation expectations during the 2009-2014 period.

Fourth, in order to examine the activation of the credit channel we add, in turn, a composite bank lending rate (in first differences) and bank loan volumes (annualised quarterly growth), to the model. For these variables, associated to bank loans to the non-financial private sector (i.e. the sum of loans to non-financial corporations and loans to households), we do not impose any restriction on impact, as often lending decisions take time to be finalised, but assume a downward impact on lending rate and a positive impact on loan volumes from one to three quarters lag, respectively. As discussed above, while these restrictions could be consistent with an expansionary loan supply shock (see Gambetti and Musso, 2016, for example), it is likely that the latter shock would have a different impact on the Eurosystem security purchases (zero or even negative, as less monetary policy accommodation might be needed in the presence of a shock with favourable macroeconomic implications, if sufficiently large) and long-term interest rates (possibly positive, reflecting the positive macroeconomic impact) compared to an APP shock. Overall, we find that the credit channel was activated, in the short term mainly via a significant decline in lending rates, by about 5 percentage points in the first year (see impulse responses reported in the fourth row of Chart 11), and subsequently mainly via increased loan volumes, with a peak effect of more than 1% increase in the second year after the APP shock (see impulse responses reported in the fifth row of Chart 11).

<TABLE 4 AROUND HERE>

<CHART 11 AROUND HERE>

4.4 Sensitivity analysis

In order to assess whether the estimated macroeconomic impact of the identified APP shock is robust, we perform various sensitivity exercises. More precisely, we compare the estimated impact of the APP shock on real GDP and the HICP resulting from the baseline model with different specifications, by varying the magnitude of the threshold of the Eurosystem security purchases, by varying the number of quarters over which restrictions are imposed and by augmenting the baseline model with a fifth variable.

First, the estimated impact of the APP shock on real GDP and the HICP does not seem to vary significantly when using different values for the threshold associated to the magnitude restriction of the APP shock on the Eurosystem purchases on impact, other than the baseline threshold value of €10 billion. Indeed, when varying this minimum impact effect over the set [€0 billion, €5 billion, €15 billion, €20 billion] estimates are almost unchanged (Chart 12).

<CHART 12 AROUND HERE>

Second, we assess how estimates change when we impose the restrictions for a different number of quarters, including up to 3 quarters only (i.e., on impact and 2 lags), up to 2 quarters (i.e., on impact and 1 lag) and only on impact. Overall, results are almost unchanged if we impose restrictions for only 3 or 2 quarters, compared to the baseline identification where restrictions were imposed for 4 quarters (i.e., on impact and 3 lags) (Chart 13). Results are almost identical also if on top of the baseline set of restrictions we also impose a positive effect of the APP shock on real GDP and the HICP on impact. However, results change when the baseline restrictions are imposed only on impact, that is without restrictions on the lagged effects on any of the variables and no impact restriction on real GDP and the HICP: in this case estimates of the impact of the APP shock on real GDP and the HICP become insignificant.⁴ However, we think that the latter minimalistic set of restrictions can hardly represent a sufficient set of restrictions to identify the APP shock and it is easy to justify the additional restrictions imposed in the baseline identification scheme, as explained above.

<CHART 13 AROUND HERE>

⁴If we impose restrictions only on impact and include also a positive effect of the APP shock on real GDP and the HICP on impact we get a positive but mitigated effect on real GDP in the short term (on impact and after one quarter) and a positive and stronger effect on HICP inflation in the short and medium run (on impact and over the subsequent four quarters), compared to the baseline specification.

Third, it can be interesting to examine whether the macroeconomic impact of the APP shock changes if other specific variables are added to the model (as a fifth variable). For this purpose we look first at the estimates based on the various models considered to assess the role of the various channels as reported in the previous sub-section. The very similar nature of the estimated effect of the APP shock on both real GDP and the HICP is clearly suggested by the impulse responses reported in Chart 11 and this is confirmed by the counterfactual estimates in Chart 14. Indeed, the significant impact of the APP shock on real GDP in the short run and the significant impact of the shock on the HICP in the medium run emerges from all models, although in the case of the model with stock prices the impact of the APP shock on real GDP appears somewhat stronger, especially after three or more quarters, while the corresponding impact in the model with the exchange rate is somewhat smaller. We also consider other models with five variables, aimed at reducing the possibility that we might confuse the APP shock with other shocks, such as a standard monetary policy shock, an uncertainty shock or a financial stability shock. For this purpose, we augment the baseline model with the Eonia short-term interest rate, the VSTOXX⁵ and the CISS indicator.⁶ In the model with the Eonia we assume that the APP shock has a negative effect on it on impact as well in the subsequent three quarters (see Table 5). Notice that the Eonia went into negative territory since April 2015 and can therefore hardly be characterised as subject to a zero lower bound. It can be argued that in this model an expansionary standard monetary policy shock (i.e., a short-term interest rate cut) would have similar effects on all variables with the exception of the Eurosystem security purchases (whose effect would be either zero or negative, as discussed above) and the long-term interest rate (whose effect would likely be positive given the positive macroeconomic prospects resulting from the expansionary shock). As regards the models with the VSTOXX and the CISS indicators we assume that the APP shock has a negative effect on impact as it can be assumed to lead to a decrease in uncertainty and/or a decrease in financial systemic stress. Note that, also in this case, expansionary uncertainty shocks (i.e., an unexpected decrease in uncertainty) or financial stability shocks (i.e., an unexpected increase in financial stability) would have similar effects on the macroeconomic variables and the corresponding uncertainty and systemic stress indices but the effect on the Eurosystem security purchases would be either zero or negative, as discussed above. Overall, the estimates of the macroeconomic impact of the APP shock based on these three alternative models with five variables are very similar to the estimates based on the baseline model with four variables (Chart 15).

⁵The VSTOXX (Euro Stoxx 50 Volatility Index), also known as the “European VIX“, is a European volatility index and measures the implied volatility of real-time options on the EuroStoxx 50 index (Eurozone blue chip stock index with very liquid futures and options).

⁶For more details on the composite indicator of systemic stress (CISS) in the financial sector see Holló et al. (2012).

In particular, the significant impact of the APP shock on real GDP in the short run and the significant impact of the shock on the HICP in the medium run are very similar to those of the baseline model.

<TABLE 5 AROUND HERE>

<CHARTS 14 AND 15 AROUND HERE>

5 Conclusions

This paper provides some estimates on the macroeconomic impact of the ECB's expanded asset purchase programme (APP) based on a time-varying parameters VAR with stochastic volatility and a novel identification scheme combining sign, timing and magnitude restrictions and using the Eurosystem security purchases and the long-term interest rate as instruments. Overall, the analysis points to a significant impact of the APP on both real GDP and HICP inflation. More precisely, it is estimated that the contribution of the APP shock to real GDP was stronger in the short term (0.18 percentage point during the first quarter of 2015 and 0.16 percentage point by the end of 2015), becoming then very small by the fourth quarter of 2016 (0.02 percentage point). By contrast, the contribution of the APP shock to the HICP increases over time, being small in the first quarter of 2015 (0.06 percentage point) and becoming substantial by the end of 2015 (0.18 percentage point) and especially by the fourth quarter of 2016 (0.36 percentage point). Moreover, several channels appear to have been activated by the APP, including the portfolio rebalancing channel, the exchange rate channel, the inflation re-anchoring channel and the credit channel. A caveat to be borne in mind is that the analysis only provides a quantification of the impact of the initial APP package introduced in early 2015, while not including also the sub-sequent re-calibrations of the APP announced in December 2015, March 2016 and December 2016.

As a follow-up to this work, it would be interesting to undertake a similar analysis to other jurisdictions which applied similar policies, such as QE implemented in the US, UK and Japan in recent years, with an appropriate adaptation of the identification scheme such as to reflect the common features of all of these measures, to compare their macroeconomic impact and try to understand what factors might explain possible differences, including the presence of negative interest rates or the interaction of QE with different non-standard monetary policy measures.

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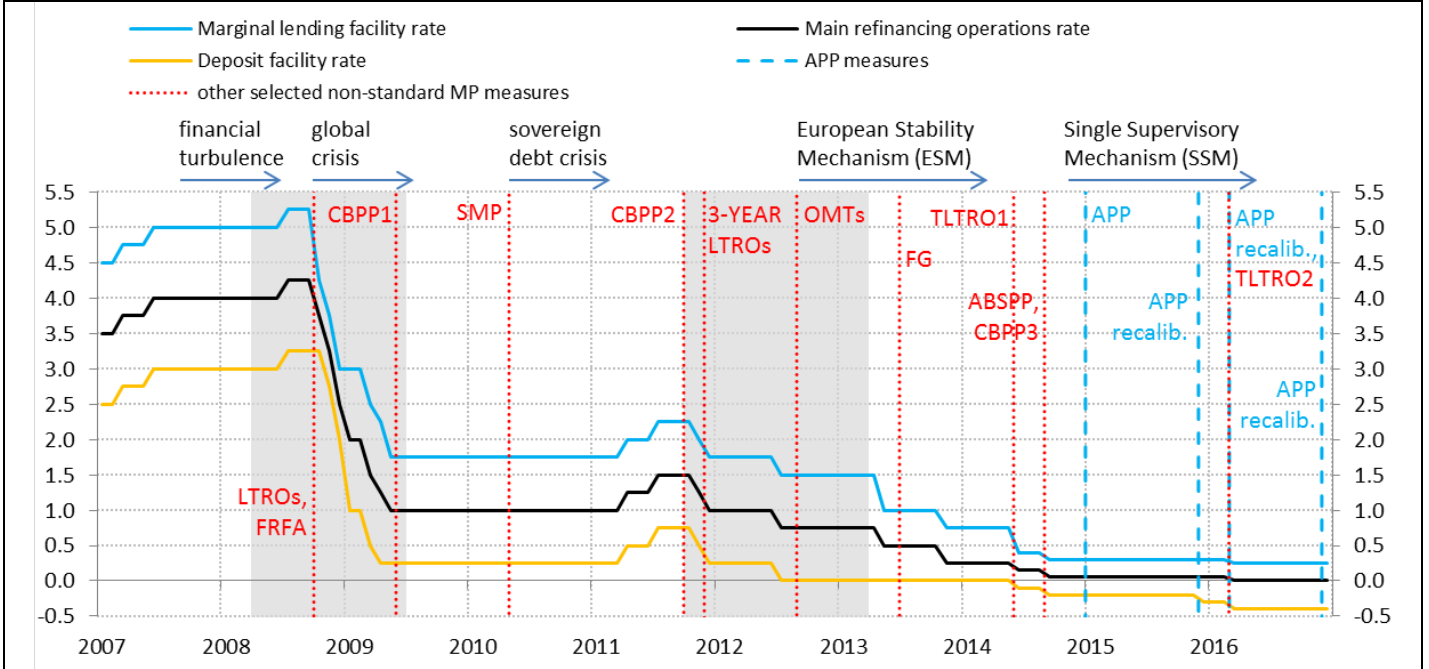
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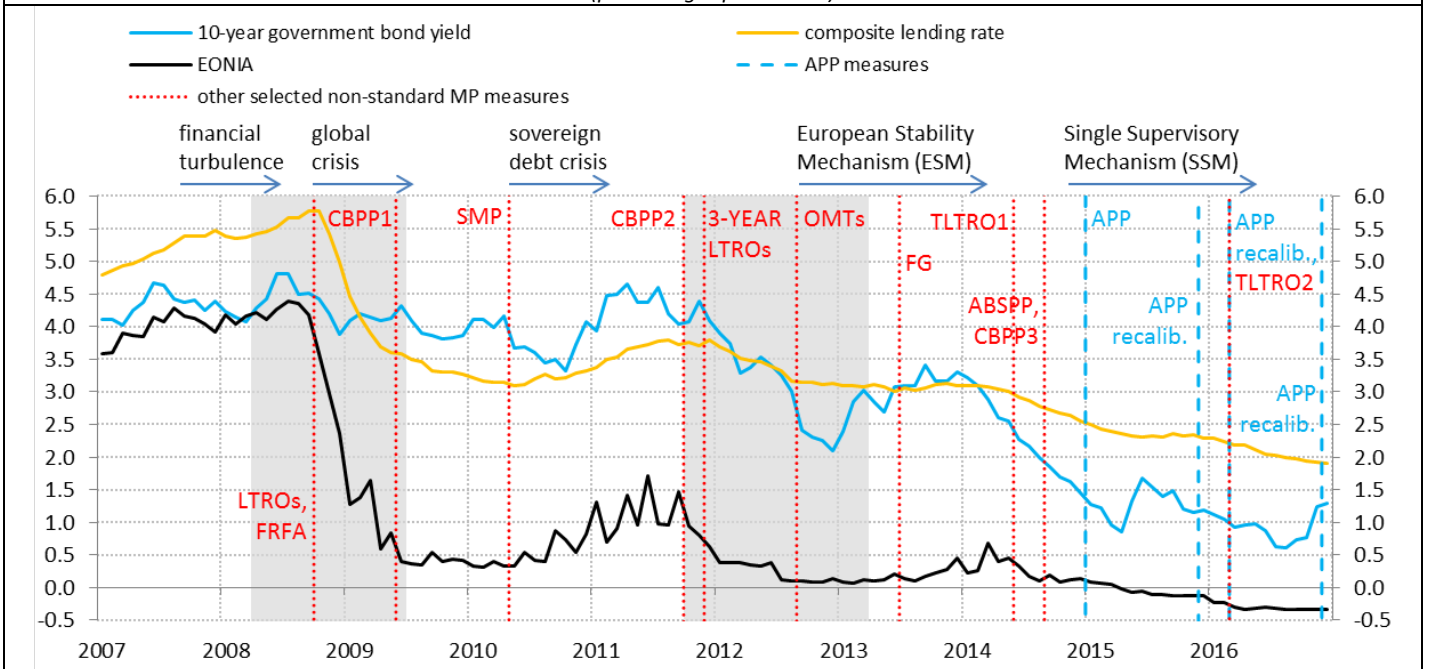
Chart 1 – ECB policy rates, January 2007 to December 2016
(percentages per annum)



Source: European Central Bank.

Note: The arrows and associated text refer to major events or phases. Vertical red dotted lines and associated acronyms refer to major non-standard monetary policy measures adopted by the ECB (see Annex I for details). Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP) (see Annex II for more details). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.

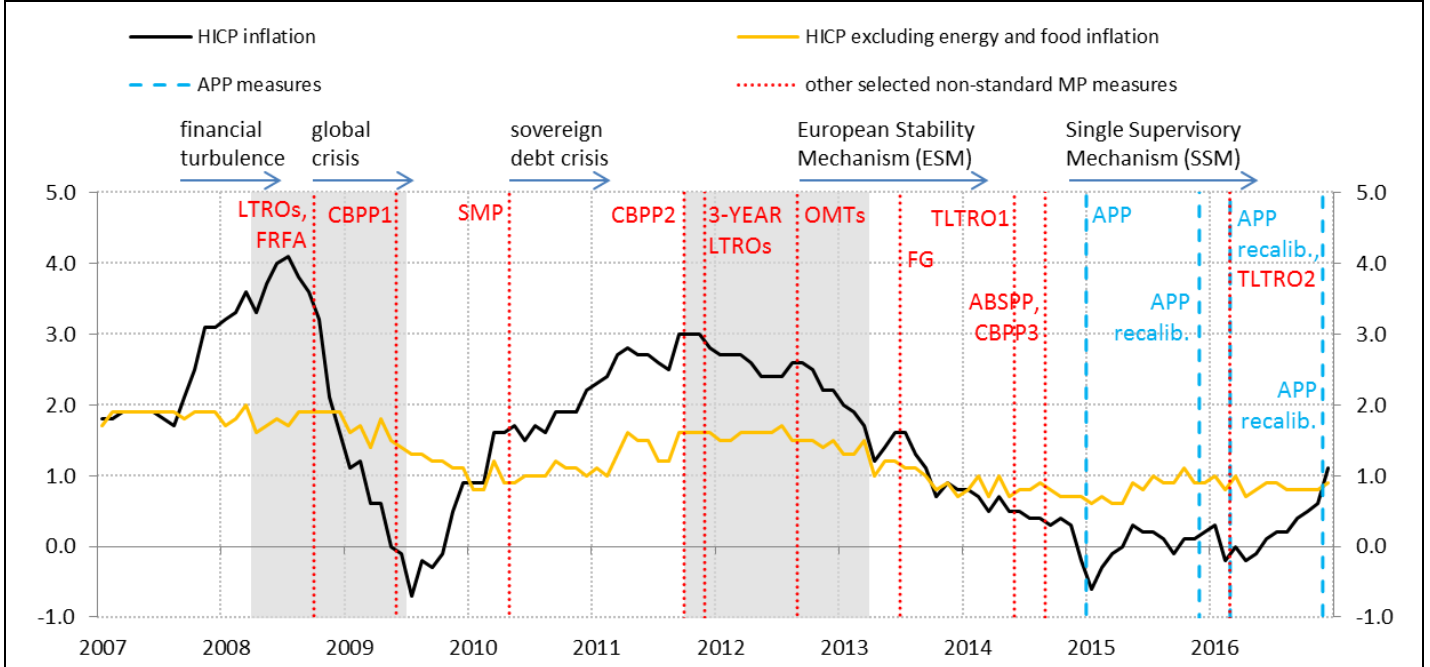
Chart 2 – Selected market interest rates, January 2007 to December 2016
(percentages per annum)



Source: European Central Bank.

Note: The arrows and associated text refer to major events or phases. Vertical red dotted lines and associated acronyms refer to major non-standard monetary policy measures adopted by the ECB (see Annex I for details). Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP) (see Annex II for more details). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.

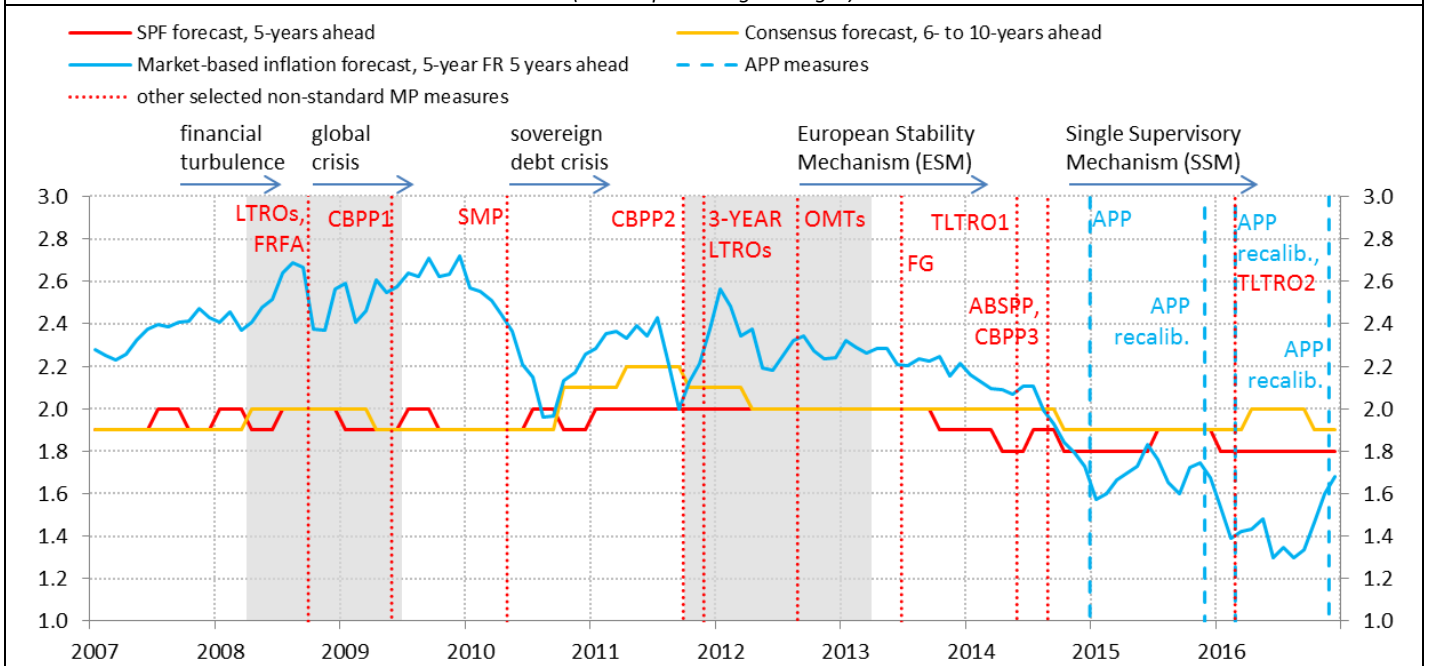
Chart 3 – HICP inflation, January 2007 to December 2016
(annual percentage changes)



Source: European Central Bank and Eurostat.

Note: The arrows and associated text refer to major events or phases. Vertical red dotted lines and associated acronyms refer to major non-standard monetary policy measures adopted by the ECB (see Annex I for details). Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP) (see Annex II for more details). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.

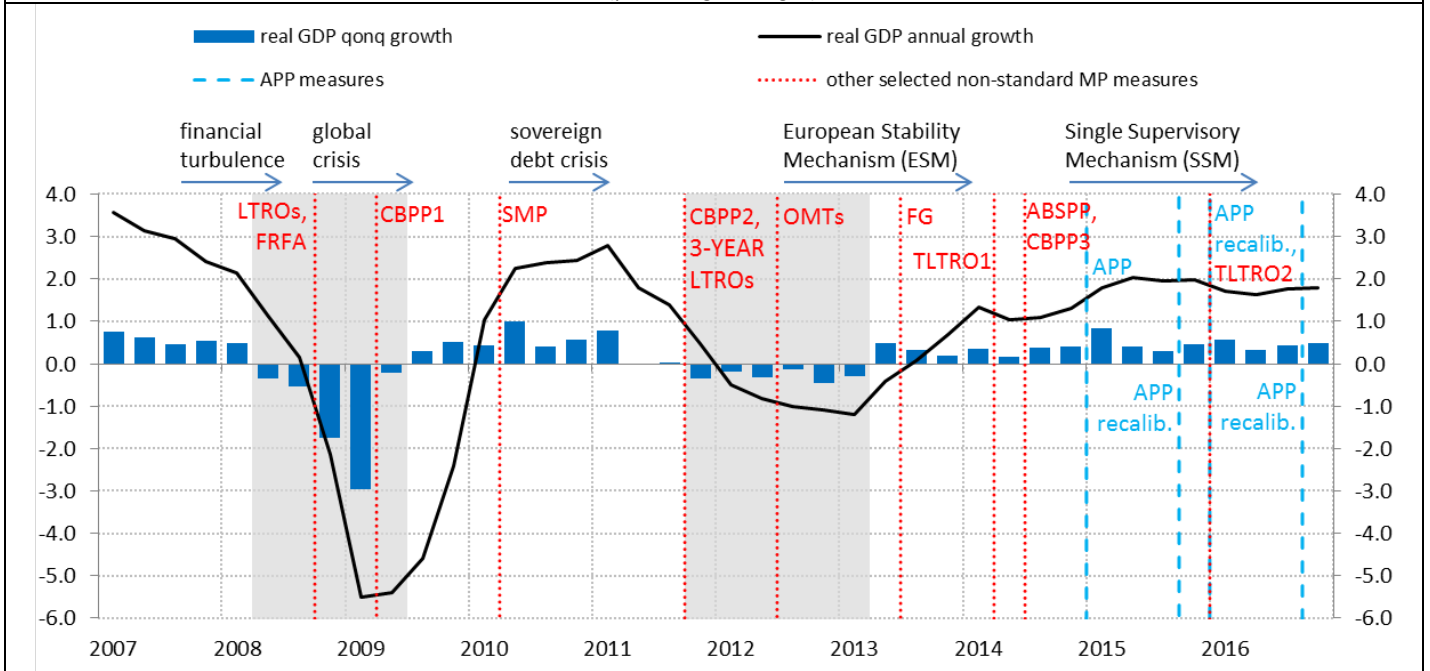
Chart 4 – HICP inflation longer term expectations, January 2007 to December 2016
(annual percentage changes)



Source: Consensus Economics and European Central Bank and Eurostat.

Note: The arrows and associated text refer to major events or phases. Vertical red dotted lines and associated acronyms refer to major non-standard monetary policy measures adopted by the ECB (see Annex I for details). Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP) (see Annex II for more details). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.

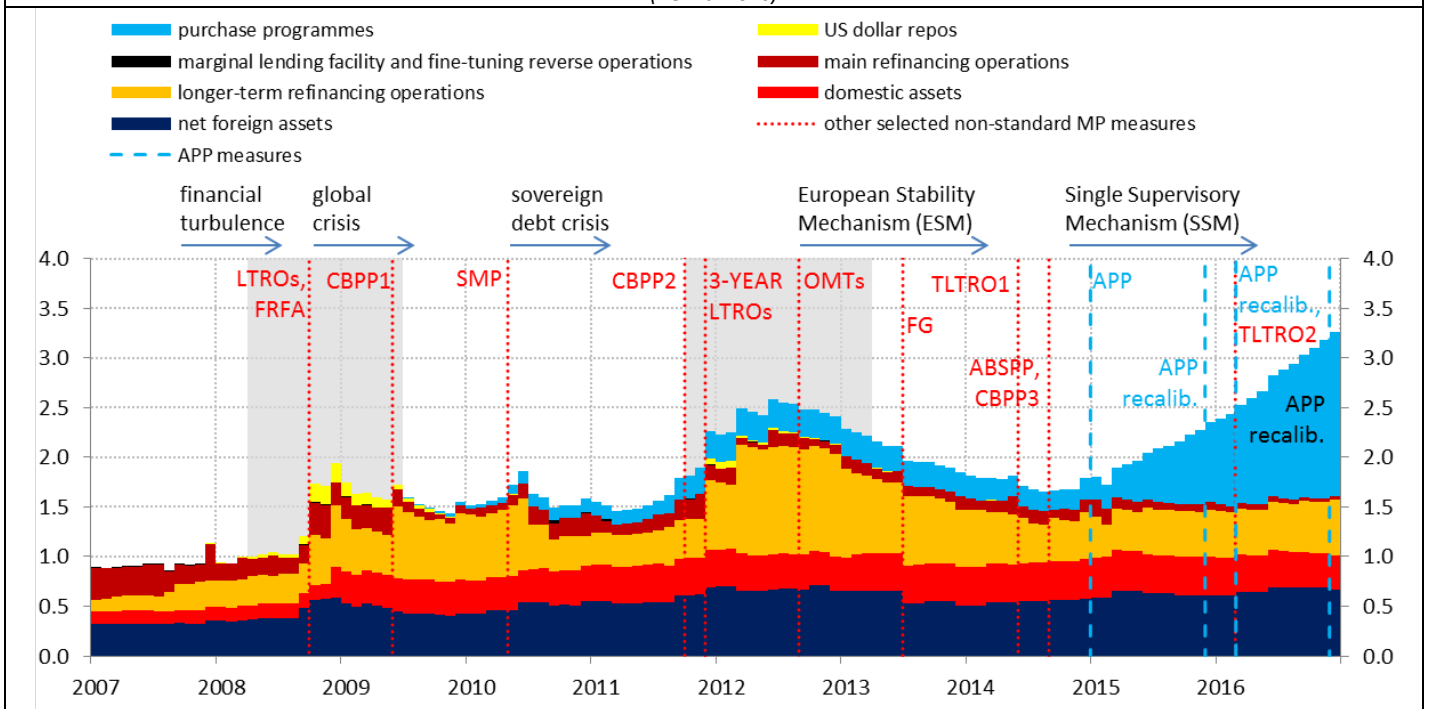
Chart 5 – Real GDP, 2007Q1 to 2016Q4
(percentage changes)



Source: European Central Bank and Eurostat.

Note: The arrows and associated text refer to major events or phases. Vertical red dotted lines and associated acronyms refer to major non-standard monetary policy measures adopted by the ECB (see Annex I for details). Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP) (see Annex II for more details). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.

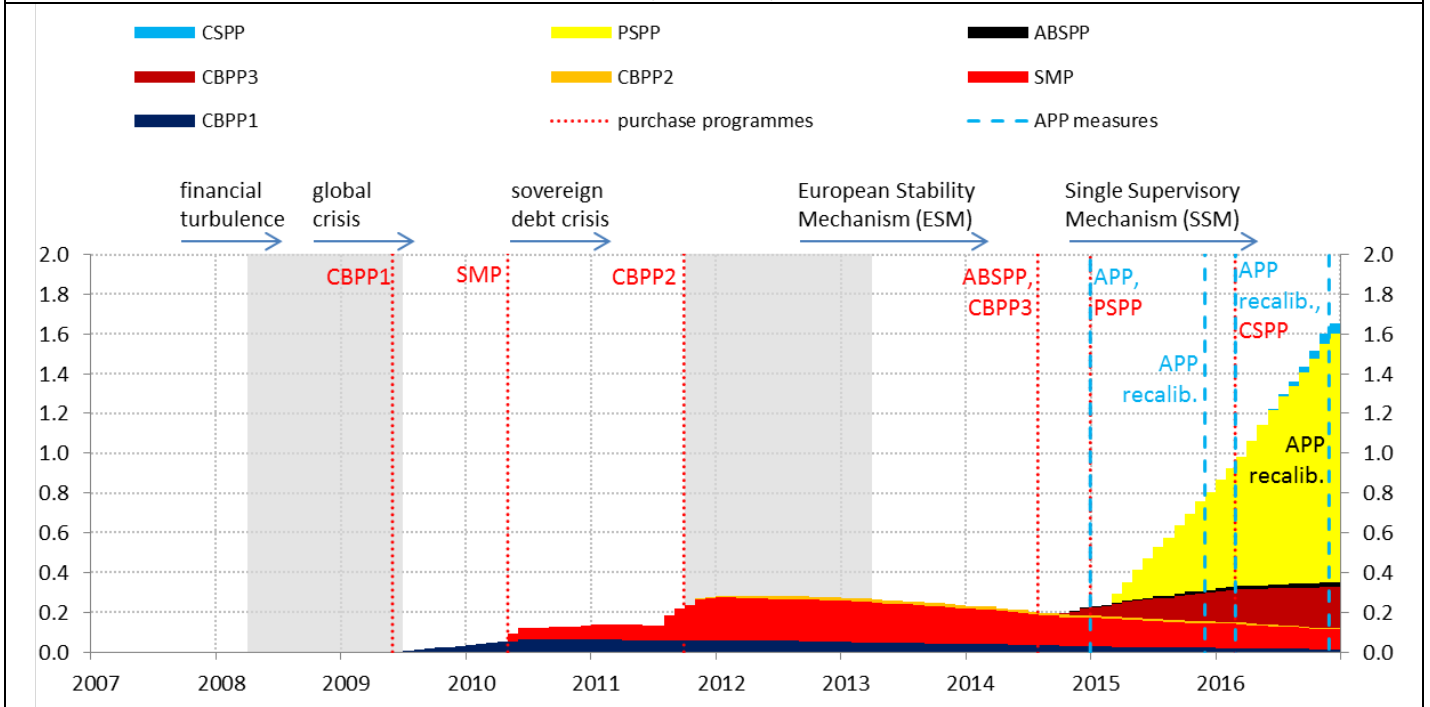
Chart 6 – Simplified Eurosystem balance sheet asset composition, January 2007 to December 2016
(EUR billions)



Source: European Central Bank.

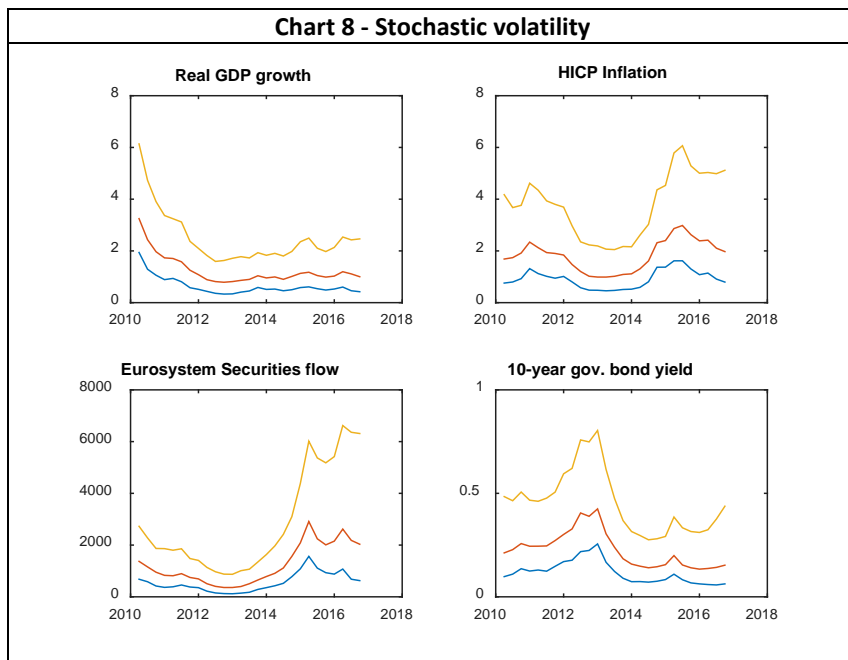
Note: The arrows and associated text refer to major events or phases. Vertical red dotted lines and associated acronyms refer to major non-standard monetary policy measures adopted by the ECB (see Annex I for details). Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP) (see Annex II for more details). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.

Chart 7 – Eurosystem purchase programmes for monetary policy purposes, January 2007 to December 2016
(EUR billions)

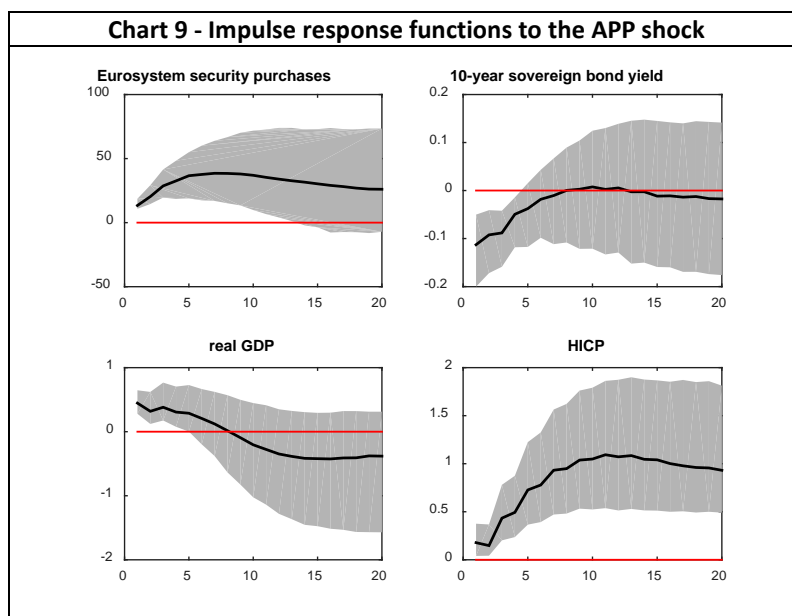


Source: European Central Bank.

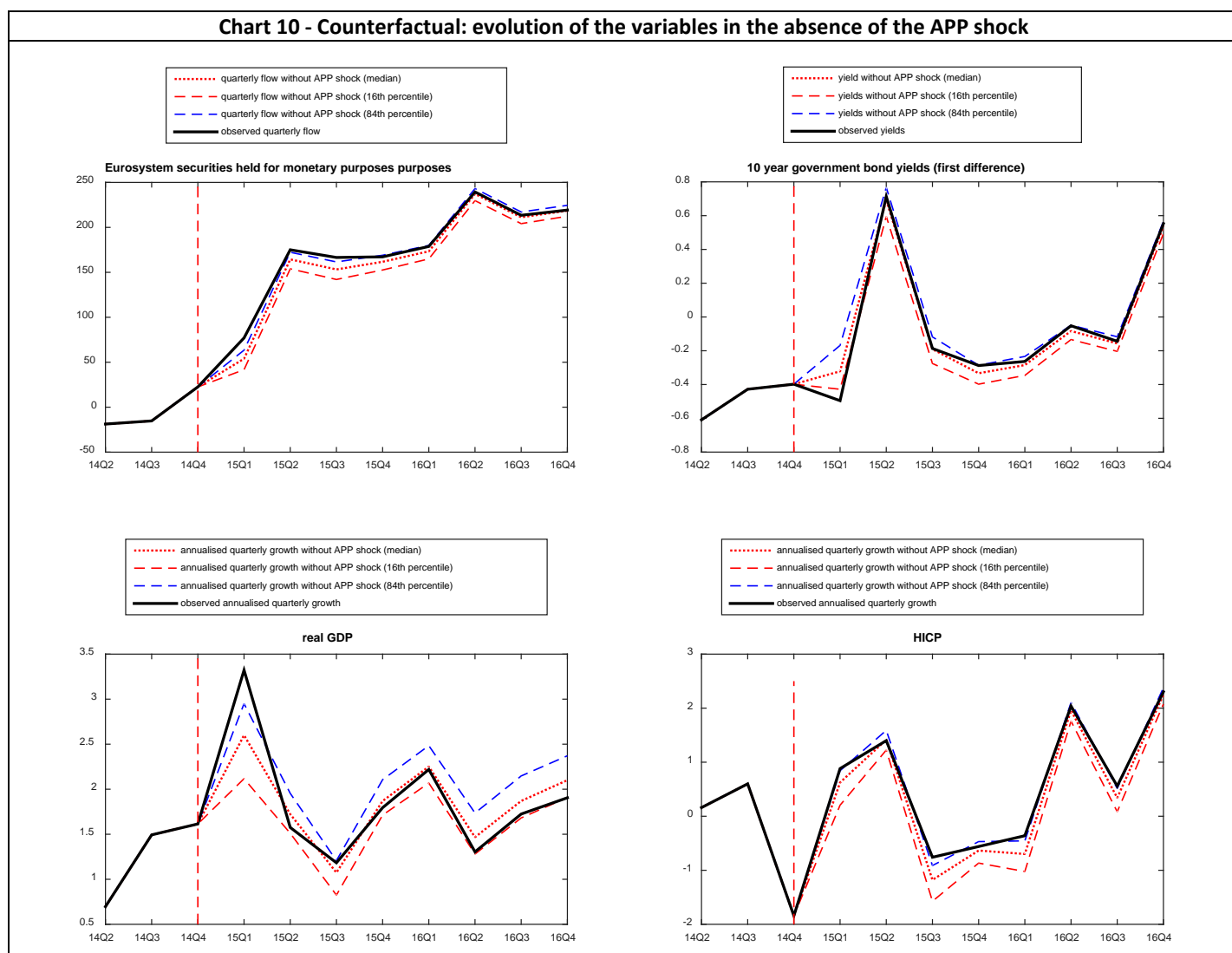
Note: The arrows and associated text refer to major events or phases. Vertical red dotted lines and associated acronyms refer to major non-standard monetary policy measures adopted by the ECB (see Annex I for details). Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP) (see Annex II for more details). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.



Note: Residual time-varying variances, posterior medians and 16th and 84th percentiles.



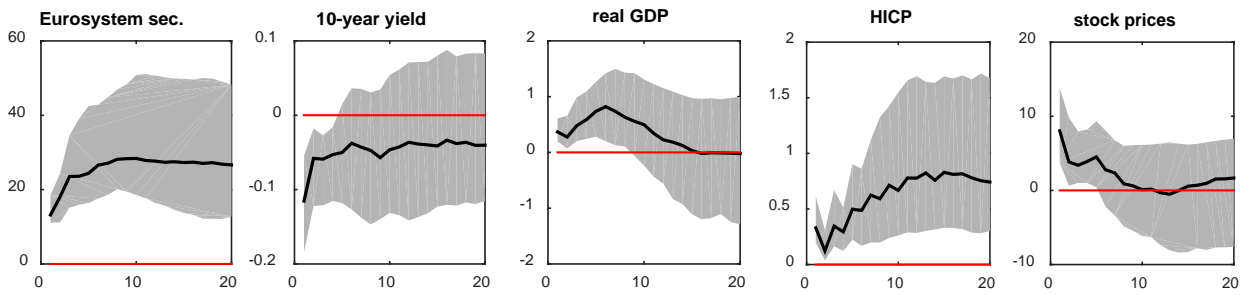
Note: Line is the median, grey are delimits the space between the 16th and 84th percentiles.



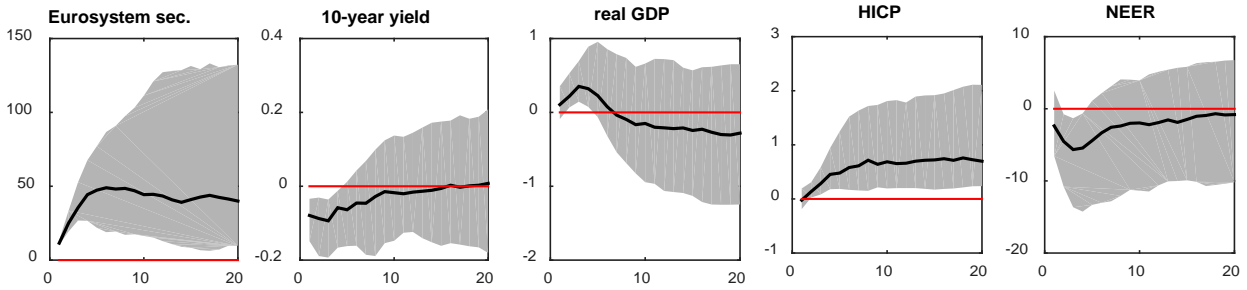
Note: Counterfactual exercises: evolution of variables in the absence of the APP shock (medians, 16th and 84th percentiles). Vertical dashed lines denote the start of the APP.

Chart 11 - Impulse response functions to the APP shock

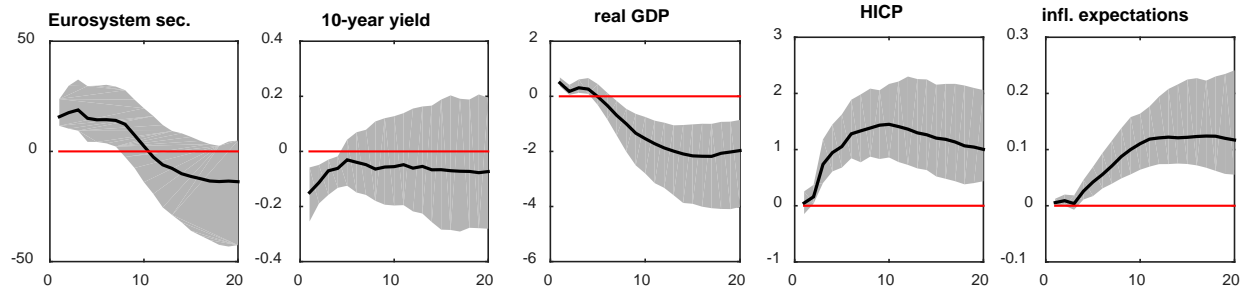
Model with stock prices growth



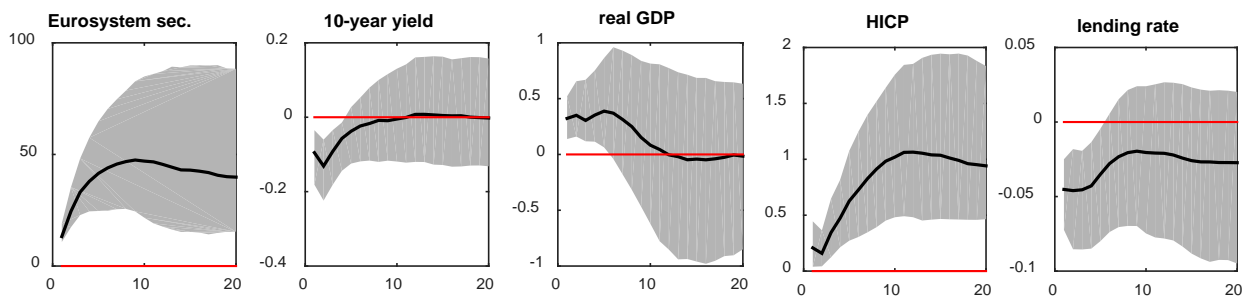
Model with the exchange rate



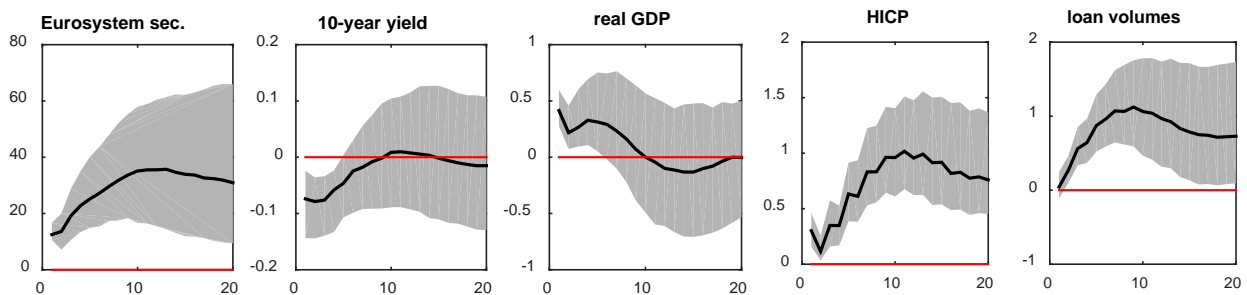
Model with inflation expectations



Model with lending rates

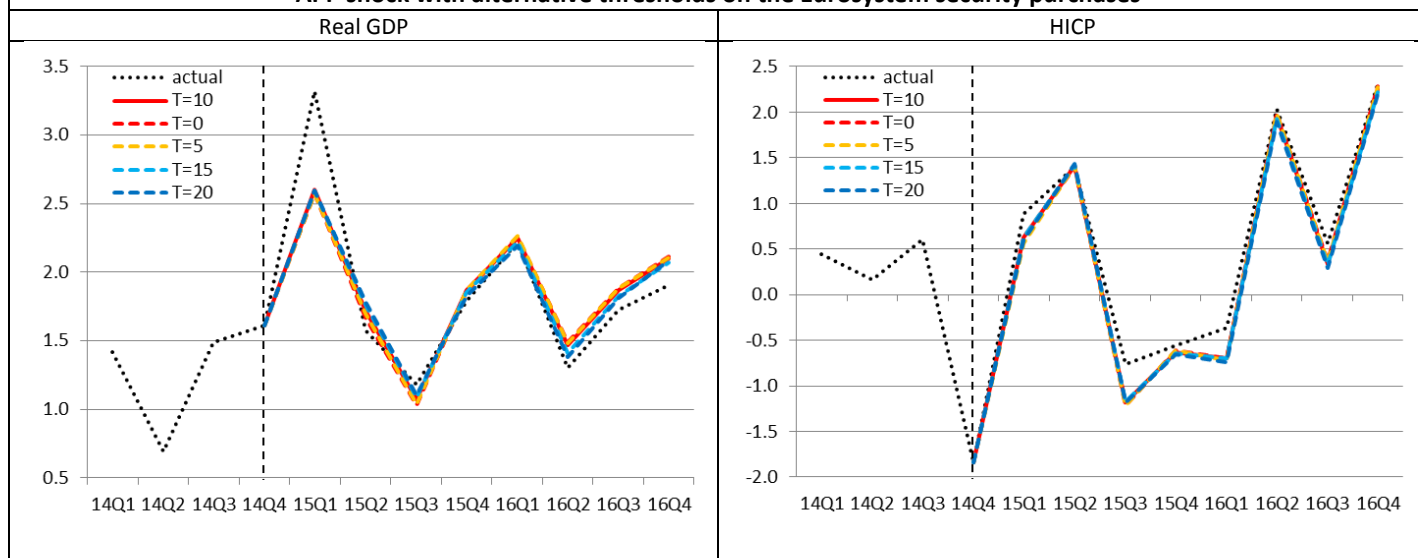


Model with loan volumes



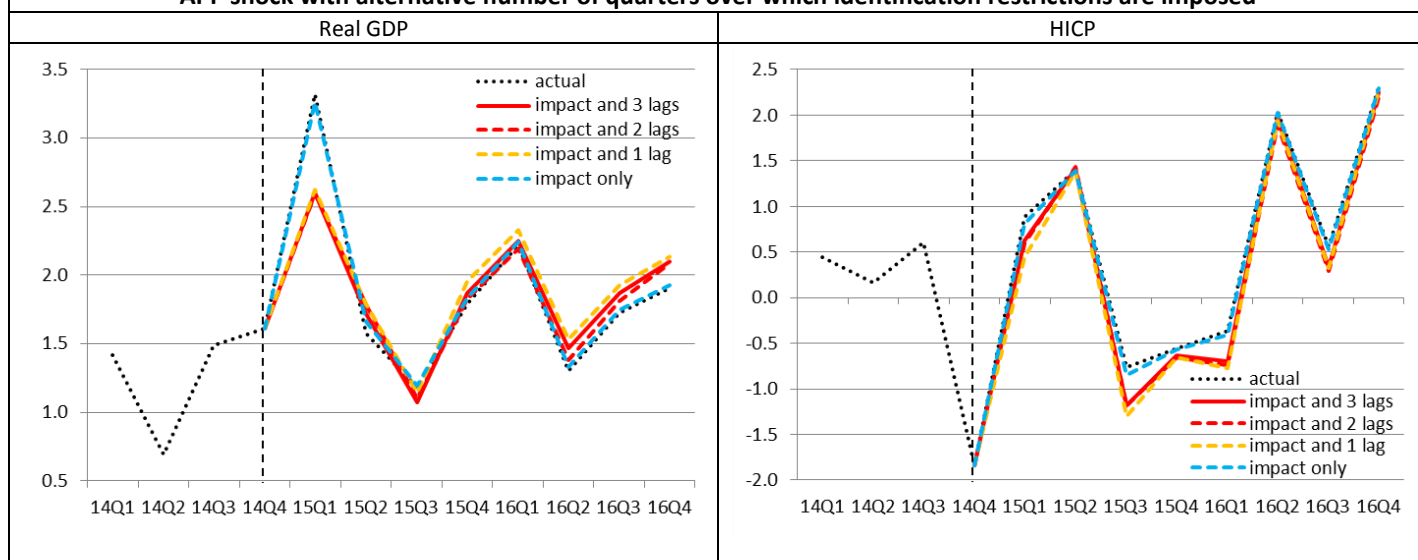
Note: Line is the median, grey are delimits the space between the 16th and 84th percentiles.

Chart 12 – Sensitivity analysis: alternative counterfactual evolutions of the macroeconomic variables in the absence of the APP shock with alternative thresholds on the Eurosystem security purchases



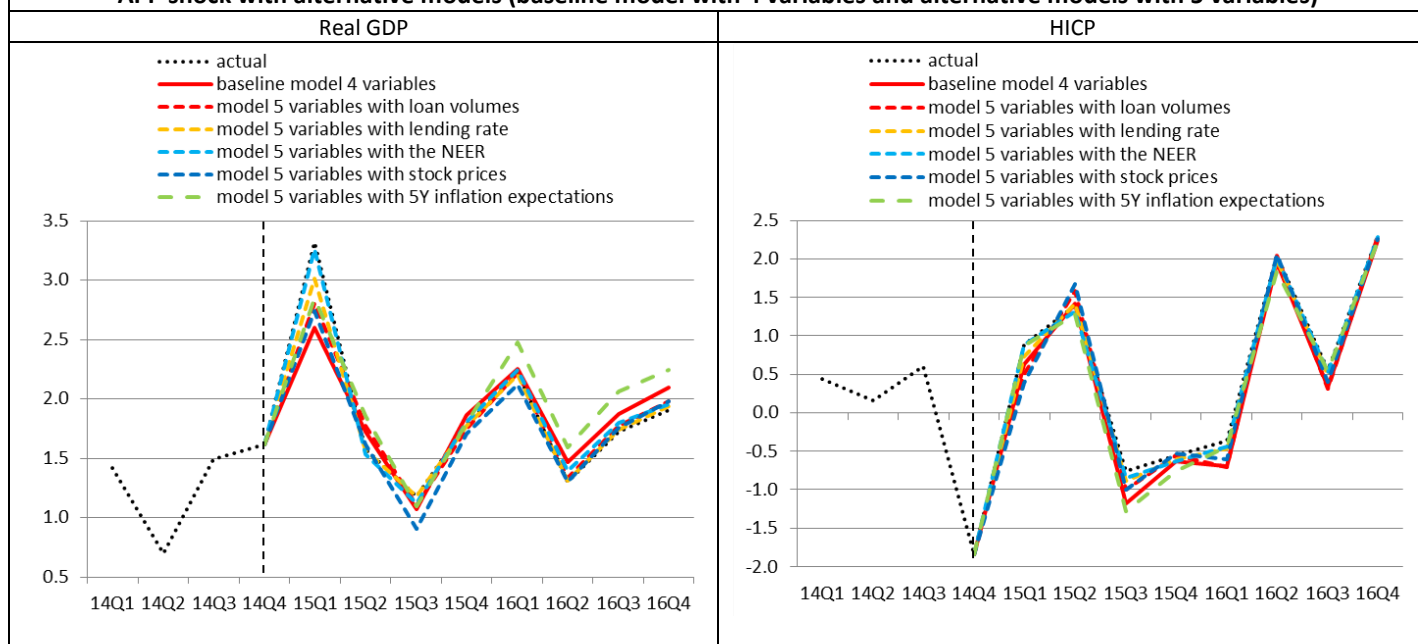
Note: Counterfactual exercises: evolution of variables in the absence of the APP shock (medians, 16th and 84th percentiles) based on alternative magnitude threshold values for the Eurosystem security purchases. The vertical dashed line denotes the start of the APP.

Chart 13 – Sensitivity analysis: alternative counterfactual evolutions of the macroeconomic variables in the absence of the APP shock with alternative number of quarters over which identification restrictions are imposed



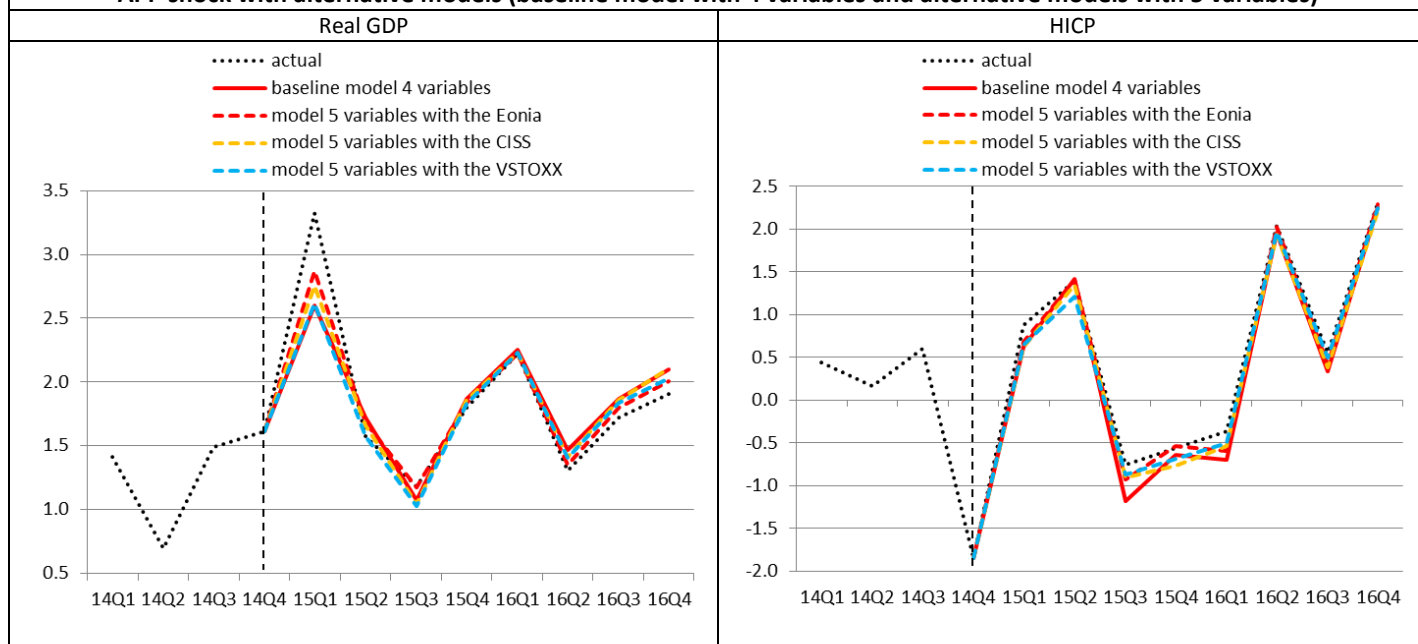
Note: Counterfactual exercises: evolution of variables in the absence of the APP shock (medians, 16th and 84th percentiles) based on alternative number of quarters over which identification restrictions are imposed. The vertical dashed line denotes the start of the APP.

Chart 14 – Sensitivity analysis: alternative counterfactual evolutions of the macroeconomic variables in the absence of the APP shock with alternative models (baseline model with 4 variables and alternative models with 5 variables)



Note: Counterfactual exercises: evolution of variables in the absence of the APP shock (medians, 16th and 84th percentiles) based on alternative models with five variables. The vertical dashed line denotes the start of the APP.

Chart 15 – Sensitivity analysis: alternative counterfactual evolutions of the macroeconomic variables in the absence of the APP shock with alternative models (baseline model with 4 variables and alternative models with 5 variables)



Note: Counterfactual exercises: evolution of variables in the absence of the APP shock (medians, 16th and 84th percentiles) based on alternative models with five variables. The vertical dashed line denotes the start of the APP.

Table 1 – Identification restrictions

	on impact	lagged effects		
	0 (2015Q1)	1 (2015Q2)	2 (2015Q3)	3 (2015Q4)
Eurosystem security purchases for MP purposes	+ & > 10 bn	+	+	+
composite 10-year government bond yield	-	-	-	-
real GDP		+	+	+
HICP		+	+	+

Table 2 – Trace tests

<u>16th perc.</u>	<u>50th perc.</u>	<u>84th perc.</u>	<u>trace(Q0)</u>
1.436	2.977	6.913	0.142

Note: The first three columns with figures show the 16th, 50th and 84th percentiles of the posterior of the trace of the variance-covariance matrix of the error term of the law of motion of the parameters of the VAR, while the fourth column shows the trace of the prior variance-covariance matrix. Following Cogley and Sargent (2005), since the value of the trace of the prior variance-covariance matrix is smaller than even the 16th percentile, this can be interpreted as evidence pointing to the presence of time variation in the parameters of the VAR (i.e. the sample points towards greater time variation in the parameters than that of the prior selected).

Table 3 – The macroeconomic impact of the APP shock

	real GDP	HICP
impact in 2015Q1	0.18	0.06
impact up to 2015Q4	0.16	0.18
impact up to 2016Q4	0.02	0.36
maximum impact	0.18	0.36
	(2015Q1)	(2016Q4)

Table 4 – Identification restrictions for models with five variables

	on impact	lagged effects		
	0 2015Q1	1 2015Q2	2 2015Q3	3 2015Q4
Eurosystem security purchases for MP purposes	+ & > 10 bn	+	+	+
composite 10-year government bond yield	-	-	-	-
real GDP		+	+	+
HICP		+	+	+
A) stock prices	+	+	+	+
B) exchange rate				
C) Inflation expectations	+			
D) lending rates		-	-	-
E) loan volumes		+	+	+

Table 5 – Identification restrictions for alternative models with five variables

	on impact	lagged effects		
	0 2015Q1	1 2015Q2	2 2015Q3	3 2015Q4
Eurosystem security purchases for MP purposes	+ & > 10 bn	+	+	+
composite 10-year government bond yield	-	-	-	-
real GDP		+	+	+
HICP		+	+	+
A) Eonia	-	-	-	-
B) CISS	-			
C) VSTOXX	-			

Annex I – 2007 to 2016: Chronology of events and Eurosystem monetary policy measures

Date	Events	Policy measures
August 2007 and following months	Turmoil in financial markets, including euro money market	Liquidity and funding measures ¹
September 2008 and following months	Lehman Brothers bankruptcy and intensification of the crisis	Liquidity and funding measures, interest rate cuts ²
Summer 2009		Enhanced credit support measures, including a covered bond purchase programme (CBPP1) ³
May 2010	Sovereign debt crisis, Economic Adjustment Programme for Greece	Securities Markets Programme (SMP) ⁴
December 2010	Economic Adjustment Programme for Ireland	
May 2011	Economic Adjustment Programme for Portugal	
Summer 2011	Re-intensification of sovereign debt crisis	Reactivation of SMP purchases (August 2011) ⁵
November 2011		Second covered bond purchase programme (CBPP2), ⁶ interest rate cuts
December 2011		Announcement of two three-year liquidity-providing long-term refinancing operations (3-year LTROs) ⁷
March 2012	Private sector involvement (PSI) debt-restructuring deal for Greece	
July 2012	Financial assistance programme for Spain	

¹ Liquidity management measures implemented from August 2007 onwards included liquidity injections, more frequent use of fine-tuning operations and supplementary longer-term refinancing operations (LTROs) with maturities of three months and later also six months. From December 2007 the ECB launched in cooperation with the Fed and other major central banks US dollar liquidity-providing operations to address difficulties faced by euro area banks in accessing US dollar funding. For more details see the ECB Monthly Bulletin article “The implementation of monetary policy since 2007” (July 2009).

² In September and October 2008 the Eurosystem implemented special term-refinancing operations, fixed rate tender procedures with full allotment (FRFA) in the marginal refinancing operations, a narrowing of the corridor formed by the rates on the standing facilities, expanded the list of assets eligible as collateral and conducted further liquidity-providing operations in US dollars and Swiss francs, among other measures. For more details see the ECB Monthly Bulletin article “The implementation of monetary policy since 2007” (July 2009).

³ In May 2009 the Eurosystem adopted a set of credit support enhancement measures comprising various non-standard measures to support financing conditions and credit flows above and beyond what could be achieved through reductions in key ECB interest rates alone. These measures included a series of refinancing operations with a maturity of 12 months and outright purchases in the covered bond market. The covered bond purchase programme (CBPP) was launched on 2 July 2009 and ended, as planned, on 30 June 2010 when it reached a nominal amount of €60 billion. Assets bought under this programme by the Eurosystem are held to maturity. For more details see the ECB Monthly Bulletin article “The implementation of monetary policy since 2007” (July 2009) and the ECB Monthly Bulletin article “The ECB’s monetary policy stance during the financial crisis” (January 2010).

⁴ On 10 May 2010, the central banks of the Eurosystem started purchasing private and public debt securities in the context of the SMP, with a view to addressing the severe tensions in certain market segments which had been hampering the monetary policy transmission mechanism. The programme targeted mainly small peripheral euro area countries. Following a Governing Council decision on 6 September 2012 to initiate outright monetary transactions, the SMP was terminated. The existing securities in the SMP portfolio will be held to maturity. With a view to leaving liquidity conditions unaffected by the programme, the Eurosystem re-absorbed the liquidity provided through the SMP by means of weekly liquidity-absorbing operations until June 2014. On 5 June 2014, the ECB suspended the weekly fine-tuning operations sterilising the liquidity injected by the programme and the last operation was allotted on 10 June 2014.

⁵ On 7 August 2011 the President of the ECB announced that purchases of government bonds under the SMP would be re-activated to help restore the monetary policy transmission and address specific dysfunctional market segments.

⁶ In November 2011, the Eurosystem launched a second covered bond purchase programme. It ended, as planned, on 31 October 2012 when it reached a nominal amount of €16.4 billion. The Eurosystem intends to hold the assets bought under this programme until maturity.

⁷ Two longer-term refinancing operations (LTROs) with a maturity of 36 months were announced on 8 December 2011. They were conducted in December 2011 and February 2012.

Summer 2012	Draghi speech in London (26 July 2012)	Outright monetary transactions (OMTs) announced ⁸
October 2012	Establishment of the European Stability Mechanism (ESM)	
July 2013		Forward guidance ⁹
June 2014		Targeted longer-term refinancing operations (TLTRO1), deposit facility rate (DFR) cut to become negative (-0.10%) ¹⁰
September 2014		Announcement of third covered bond purchase programme (CBPP3), an asset-backed securities purchase programme (ABSPP) and a further DFR cut ¹¹
November 2014	Single Supervisory Mechanism (SSM)	
January 2015		Announcement of the Expanded Asset Purchase Programme (APP), including a public sector asset purchase programme (PSPP) ¹²
March 2015		Start of purchases under APP
December 2015		Announcement of re-calibration of APP
March 2016		Announcement of re-calibration of APP, corporate securities purchase programme (CSPP) ¹³ and further targeted longer-term refinancing operations (TLTRO II) ¹⁴
December 2016		Announcement of re-calibration of APP

Source: ECB.

Note: For a summary of measures up to December 2014 see the Annex on *Chronology of monetary policy measures of the Eurosystem* in each issue of the ECB's *Monthly Bulletin*. The chronology of monetary policy measures taken by the Eurosystem from 2015 onwards can be found in the ECB's Annual Report for 2015 and in boxes of the ECB's *Economic Bulletin*. Moreover, see ECB website, in particular <http://www.ecb.europa.eu/mopo/implement/html/index.en.html>.

⁸ The Governing Council of the ECB announced on 2 August 2012 that it may undertake outright open market operations if needed, the modalities of which are announced on 6 September 2012. Specifically, Outright Monetary Transactions (OMTs) in secondary sovereign bond markets would be undertaken to safeguard an appropriate monetary policy transmission and the singleness of the monetary policy.

⁹ On 4 July 2013 the Governing Council of the ECB communicated that it "expects the key ECB interest rates to remain at present or lower levels for an extended period of time." For more details see the ECB Monthly Bulletin article "The ECB's forward guidance" (April 2014).

¹⁰ On 5 June 2014 the Governing Council decided to lower the key ECB the interest rates by 10 basis points, bringing the deposit facility rate into negative territory for the first time (-0.10%) and to conduct a series of targeted longer-term refinancing operations (TLTROs). The TLTROs are Eurosystem operations that provide financing to credit institutions for periods of up to four years and are targeted operations, as the amount that banks can borrow is linked to their loans to non-financial corporations and households.

¹¹ On 4 September 2014 the Governing Council decided to lower the key ECB the interest rates by 10 basis points, bringing the deposit facility rate to -0.20%, to launch an asset-backed securities purchase programme (ABSPP) and to initiate a new covered bond purchase programme (CBPP3). The detailed modalities of these programmes were announced on 2 October 2014 and interventions under these programmes started in October 2014. On 20 October 2014 the Eurosystem started to buy covered bonds under the CBPP3 programme to enhance the functioning of the monetary policy transmission mechanism, support financing conditions in the euro area, facilitate credit provision to the real economy and generate positive spillovers to other markets. The ABSPP, with underlying assets consisting of claims against the euro area non-financial private sector, started on 21 November 2014 and aimed at helping banks to diversify funding sources and stimulate the provision of credit to the real economy.

¹² Following the announcement on 22 January 2015 of the Expanded Asset Purchase Programme (APP), on 9 March 2015 the Eurosystem started to buy public sector securities under the public sector purchase programme (PSPP). The securities covered by the PSPP include nominal and inflation-linked central government bonds and bonds issued by recognised agencies, regional and local governments, international organisations and multilateral development banks located in the euro area. The Eurosystem intends to allocate 90% of the total purchases to government bonds and recognised agencies, and 10% to securities issued by international organisations and multilateral development banks (from March 2015 until March 2016 these figures were 88% and 12% respectively). See Annex II for details on the APP announcement and subsequent re-calibrations.

¹³ The Eurosystem started to buy corporate sector bonds under the corporate sector purchase programme (CSPP) on 8 June 2016. The measure helps to further strengthen the pass-through of the Eurosystem's asset purchases to financing conditions of the real economy, and, in conjunction with the other non-standard monetary policy measures in place, provides further monetary policy accommodation.

¹⁴ The second series of TLTROs (TLTRO II) was announced on 10 March 2016 with operations to start in June 2016 and consists of four targeted longer-term refinancing operations, each with a maturity of four years.

Annex II – Details of APP

Date	APP decision	Other decisions	Comment
22 January 2015: APP announcement	<p>ECB launches an expanded asset purchase programme (APP), encompassing the existing purchase programmes for asset-backed securities and covered bonds. Under this expanded programme, the combined monthly purchases of public and private sector securities amount to €60 billion, intended to be carried out until end-September 2016 and in any case conducted until the Governing Council sees a sustained adjustment in the path of inflation which is consistent with our aim of achieving inflation rates below, but close to, 2% over the medium term. In March 2015 the Eurosystem starts to purchase euro-denominated investment-grade securities issued by euro area governments and agencies and European institutions in the secondary market. The purchase of securities issued by euro area governments and agencies is based on the Eurosystem NCBs' shares in the ECB's capital key. Some additional eligibility criteria apply in the case of countries under an EU/IMF adjustment programme.</p>	<ul style="list-style-type: none"> • Key ECB interest rates unchanged, in line with forward guidance. • ECB changes the pricing of the six remaining targeted longer-term refinancing operations (TLTROs). Accordingly, the interest rate applicable to future TLTRO operations is equal to the rate on the Eurosystem's main refinancing operations prevailing at the time when each TLTRO is conducted, thereby removing the 10 basis point spread over the MRO rate that applied to the first two TLTROs. 	<p>€60 billion of monthly purchases from March 2015 to September 2016 amount to €1.140 trillion, corresponding to 11.3% of 2014 GDP</p>
3 December 2015: APP first re-calibration	<p>ECB extends the asset purchase programme (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, and in any case until the Governing Council sees a sustained adjustment in the path of inflation consistent with its aim of achieving inflation</p>	<ul style="list-style-type: none"> • ECB lowers the interest rate on the deposit facility by 10 basis points to -0.30%. • ECB to continue conducting the main refinancing operations and three-month longer-term refinancing operations as fixed rate tender procedures with full allotment for as long as necessary, and at least until 	<p>Six months added of €60 billion of monthly purchases from October 2016 to March 2017 amount to €360</p>

	<p>rates below, but close to, 2% over the medium term. ECB to reinvest the principal payments on the securities purchased under the APP as they mature, for as long as necessary. ECB to include, in the public sector purchase programme, euro-denominated marketable debt instruments issued by regional and local governments located in the euro area in the list of assets that are eligible for regular purchases by the respective national central banks.</p>	<p>the end of the last reserve maintenance period of 2017.</p>	<p>billion, corresponding to 3.6% of 2014 GDP (or 3.5% of 2015 GDP)</p>
<p>10 March 2016: APP second re-calibration</p>	<p>ECB decides to expand the monthly purchases under our asset purchase programme from €60 billion at present to €80 billion. They 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 aim of achieving inflation rates below, but close to, 2% over the medium term. To ensure the continued smooth implementation of our asset purchases, the issuer and issue share limits for the purchases of securities issued by eligible international organisations and multilateral development banks is increased from 33% to 50%. ECB to include investment-grade euro-denominated bonds issued by non-bank corporations established in the euro area in the list of assets that are eligible for regular purchases under a new corporate sector purchase programme.</p>	<ul style="list-style-type: none"> • ECB lowers key interest rates: MRO by 5 basis points to 0.00%, MLF by 5 basis points to 0.25%, and DFR by 10 basis points to -0.40%. • ECB to launch a new series of four targeted longer-term refinancing operations (TLTRO II), starting in June 2016, each with a maturity of four years. • Forward guidance: “Looking ahead, taking into account the current outlook for price stability, the Governing Council expects the key ECB interest rates to remain at present or lower levels for an extended period of time, and well past the horizon of our net asset purchases.” 	<p>Twelve months added of €20 billion of monthly purchases between April 2016 and March 2017 amount to €240 billion, corresponding to 2.3% of 2015 GDP (or 2.4% of 2014 GDP)</p>
<p>8 December 2016: APP third re-calibration</p>	<p>ECB decides to continue to make purchases under the asset purchase programme (APP) at the current monthly pace of €80 billion until the end of March 2017. From April 2017, net asset</p>	<ul style="list-style-type: none"> • Key ECB interest rates unchanged, in line with forward guidance. • Forward guidance: “The key ECB interest rates were kept unchanged and we 	<p>Nine months added of €60 billion of monthly purchases</p>

	<p>purchases are intended to continue at a monthly pace of €60 billion until the end of December 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. If, in the meantime, the outlook becomes less favourable, or if financial conditions become inconsistent with further progress towards a sustained adjustment of the path of inflation, the Governing Council intends to increase the programme in terms of size and/or duration. The net purchases will be made alongside reinvestments of the principal payments from maturing securities purchased under the APP. To ensure the continued smooth implementation of the Eurosystem's asset purchases, the Governing Council decided to adjust the parameters of the APP as of January 2017 as follows. First, the maturity range of the public sector purchase programme will be broadened by decreasing the minimum remaining maturity for eligible securities from two years to one year. Second, purchases of securities under the APP with a yield to maturity below the interest rate on the ECB's deposit facility will be permitted to the extent necessary.</p>	<p>continue to expect them to remain at present or lower levels for an extended period of time, and well past the horizon of our net asset purchases”</p>	<p>between April 2017 and December 2017 amount to €540 billion, corresponding to 5.2% of 2015 GDP</p>
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Real GDP

Gross domestic product at market price, Chain linked volume, calendar and seasonally adjusted, Euro area 19 fixed composition, ESA2010 National Accounts.

Source: Eurostat.

Consumer prices

Harmonised index of consumer prices (HICP), Euro area (changing composition), quarterly data derived as end-of-quarter monthly values, seasonally adjusted, not working day adjusted, ECB calculation based on Eurostat data.

Sources: European Central Bank and Eurostat.

Long-term interest rates

Euro area 10-year Government Benchmark bond yield, percent per annum, Euro area (changing composition), quarterly data derived as end-of-quarter monthly values, data collected and compiled by the ECB.

Source: European Central Bank.

Eurosystem balance sheet

Asset side of the (simplified) Eurosystem balance sheet, quarterly data derived as end-of-quarter daily/weekly outstanding amounts. For the amounts of the Eurosystem public and private security purchases under the APP as well as the previous Eurosystem security purchase programmes for monetary policy purposes see <http://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html>. For more details on the Eurosystem balance sheet see the ECB Economic Bulletin article entitled “The role of the central bank balance sheet in monetary policy”, issue 4, 2015.

Source: European Central Bank.

Stock prices

Dow Jones Euro Stoxx Broad Stock Exchange Index, historical close, quarterly data derived as end-of-quarter monthly data.

Source: European Central Bank.

Exchange rate

Real effective exchange rate, CPI deflated, quarterly data derived as end-of-quarter monthly data, Euro area-19 countries vis-a-vis the EER-19 group of trading partners (AU, CA, DK, HK, JP, NO, SG, KR, SE, CH, GB, US, BG, CZ, HU, PL, RO, HR and CN) against Euro.

Source: European Central Bank.

Inflation expectations

Long-term inflation expectations, five years ahead, mean point estimates, ECB survey of professional forecasters. See http://www.ecb.europa.eu/stats/prices/indic/forecast/html/table_hist_hicp.en.html.

Source: European Central Bank.

Loans to the non-financial private sector

Sum of (nominal) outstanding amounts of loans to households and loans to non-financial corporations, derived by rescaling indices of notional stocks with base equal to the outstanding amounts for 2010Q1. Series adjusted to include loan sales and securitisation.

Sources: European Central Bank.

Composite lending rate

Composite lending rate, derived as weighted average of interest rates charged on loans to households and loans to non-financial corporations, with weights based on the nominal outstanding amounts of loans to households and to non-financial corporations.

Sources: Own calculations based on data from the European Central Bank.

Short-term interest rates

Euro Interbank Offered Rate (EONIA), percent per annum, quarterly data derived as end-of-quarter daily values, ECB calculation based on data provided by the European Banking Federation. Weighted rate for the overnight maturity, calculated by collecting data on unsecured overnight lending in the euro area provided by banks belonging to the EONIA panel.

Sources: European Central Bank and European Banking Federation.

CISS

Composite Indicator of Systemic Stress (CISS), Euro area (changing composition), quarterly data derived as end-of-quarter monthly values. The CISS is unit-free and constrained to lie within the interval (0, 1). For more details see Hollo, D., Kremer, M. and Lo Duca, M. (2012): "CISS - a composite indicator of systemic stress in the financial system", Working Paper Series, No 1426, ECB, March 2012.

Source: European Central Bank.

VSTOXX

Dow Jones EURO STOXX 50 Volatility Index (VSTOXX), historical close, end of period, Euro area (changing composition), quarterly data provided by Bloomberg.

Source: Bloomberg.

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