The effects of the ECB's Expanded Asset Purchase Programme

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Abstract

This paper provides empirical evidence on the financial and macroeconomic impact of the news associated to the announcements relating to the ECB's expanded asset purchase programme (APP). The APP announcement shocks are identified with a combination of zero, timing and magnitude restrictions derived from the institutional features of the APP in the context of an estimated time-varying parameter VAR model with stochastic volatility. The evidence suggests that these shocks had a significant upward effect on both real economic activity and HICP inflation in the euro area. The response of long-term interest rates gave rise to a flattening of the yield curve in the short term, followed by a steepening in the medium term. Several channels of transmission appear to have been activated, including the portfolio rebalancing channel, the exchange rate channel and the credit channel.

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1 Introduction

In response to the financial crisis starting in the summer of 2007, the global economic recession of 2008/2009 and the European sovereign debt crisis starting in 2010, the European Central Bank (ECB) adopted a sequence of standard and non-standard monetary policy measures to support the euro area economy. Among these measures, a large-scale asset purchase programme, referred to as expanded asset purchase programme (APP) by the Governing Council of the ECB, was launched in January 2015 to address the risks of euro area HICP inflation remaining too low for a prolonged period. Given the objective of the APP to address the medium-term risks to price stability and considering that several channels of transmission of these security purchases to HICP inflation would operate via both a stimulation of financial markets and an expansion in economic activity, it is essential to assess the impact of these measures on financial markets and the macroeconomy in the euro area.

Virtually all empirical studies on the financial and macroeconomic effects of large-scale asset purchases conclude that most of the impact of these policies takes place at the moment of the announcement of the policy, or even before their announcement in case central bank officials gave hints that such policy measures were serioulsly being considered or would be implemented soon.[1] By contrast, the effects of the actual purchases which follow the announcements appear to be more limited, as economic agents and financial markets have already adjusted their expectations, decision-making and portfolios.

There is by now a large empirical literature providing several estimates on the financial and macroeconomic impact of large-scale asset purchase programmes, or quantitative easing (QE) polices, in advanced economies, based on alternative approaches ranging from event studies to structural VARs to calibrated or estimated DSGE models (see for example the review of this literature provided by Borio and Zabai, 2016). For the euro area the literature is more limited, not surprisignly since the ECB's APP programme started at a later stage compared to the QE policies of the US, UK or Japan. Nevertheless, a number of studies on the financial and macroeconomic impact of the ECB's APP have been published in recent years (see for example Altavilla et al., 2015; Altavilla et al., 2016; Andrade et al., 2016; Blattner and Joyce, 2016; De Santis, 2016; Koijen et al., 2016; Wieladek and Garcia Pascual, 2016; De Santis and Holm-Hadulla, 2017). At

[1]See for example, the evidence reported by D'Amico et al. (2012), Gagnon et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011) for the US; Altavilla et al. (2015), Andrade et al. (2016), De Santis (2016) and Blattner and Joyce (2016) for the euro area; and Joyce et al. (2011) for the UK.

the same time, there is a lack of studies on the effects of the APP based on empirical approaches which allow for changes in the financial and macroeconomic environment, both in terms of structural change and in terms of volatility, as well as non-linearities which can be particularly important in a monetary policy regime when unconventional monetary policy measures prevail.

Against this background, the purpose of this paper is to measure the effects of the APP on euro area financial markets and the macroeconomy. The model used, a standard VAR with time-varying parameter and 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. From a methodological point of view, the main novelty of the paper is represented by the identification approach. Our identification scheme is based on a proxy variable capturing the unexpected component of the APP announcements. The proxy is derived by exploiting the specific institutional features of the APP concerning the announced time profile and monthly amounts of the securities to be purchased. We focus on the APP announcement shock which took place in January 2015 as well as subsequent APP re-calibrations shocks.

The main results of the empirical analysis are the following. First, the APP announcement shocks had a significant positive impact on both HICP inflation and real economic activity growth. Second, we find also a significant effect of these shocks on the yield curve, mainly driven by changes in the long-term interest rates, such that in response to the shocks a flattening of the yield curve can be observed in the short term, followed by a steepening in the medium term. Third, also other financial variables appear to have been markedly affected, including stock prices and credit volumes, on the upside, and the exchange rate, on the downside (depreciation of the euro). Overall, in terms of channels of transmission, the evidence points to an activation of the portfolio rebalancing channel, the exchange rate channel and the credit channel, while the evidence on the relevance of the inflation re-anchoring channel and the signalling channel is more uncertain.

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, the main data used and the identification approach. Section 4 reports and discusses the results. Section 5 provides conclusions.

2 Main features and channels of transmission of the APP

In response to the various financial, macroeconomic and sovereign debt crises affecting the euro area since 2007, 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. In parallel, the ECB also adopted a set of non-standard measures, including 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.[2]

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, signs of decreasing longer-term inflation expectations and a gradual recovery in economic activity, 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), both of which were 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 would amount to €60 billion, on average, starting in March 2015 and 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 recalibrated 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 would 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 average purchases under the APP from €60 billion to €80 billion, starting from April 2016, including a new corporate securities purchase programme (CSPP) starting in June 2016, still intended to run until the end of March

[2] See Gambetti and Musso (2017) for details on the standard and non-standard monetary policy measures adopoted by the ECB since 2007.

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 would continue at a monthly average 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.

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, 2015). First, according to the portfolio rebalancing channel, asset purchases by the central bank would 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 substitability between assets must be present, for example in the form of preferred habitat among some investors (Vayanos and Villa, 2009).[3] Available evidence suggests that this channel is amongs 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 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 committment 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,

[3]Other 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.

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 operates 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, thereby encouraging banks to increase the supply of loans that can be securitised, which tends to lower bank lending rates. All of 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 proxy variable we construct to capture the unexpected component of the APP announcements, the econometric model we estimate, the data we use and the identification we propose to assess the impact of the APP announcement shocks on financial markets and the macroeconomy in the euro area.

3.1 Proxy for APP announcement news

As discussed above, there have been four announcements associated to the APP: the initial announcement of the APP in January 2015 and three subsequent re-calibration announcements (December 2015, March 2016 and December 2016). We focus on the initial APP announcement in January 2015 and the re-calibration announced in March 2016, as the re-calibration of December 2015 did not entail changes in the amounts of monthly purchases (at least between the month of the announcement and the subsequent re-calibration in March 2017), while for the December 2016 announced changes, to start in March 2017, we still do not have enough data. We construct the proxy for these two APP announcements (January 2015 and March 2016) using the publicly available information on the unique features of the ECB's APP, which in constrast to most other QE programmes included information on the specific amounts of securities to be purchased (on average) in each month for the duration of the programme.

We construct a variable a_t as a proxy for the APP announcements. We postulate that the proxy for the announcement, a_t, is the sum of two components: one which is expected by the markets and one which is unpredictable

$$a_t = E_{t-1}a_t + b_t$$

where a_t captures the total monthly amounts of purchases announced in January 2015, March 2016 and December 2016, $E_{t-1}a_t$ is the anticipated part and b_t is the unexpected part that we call announcement shock, or announcement news proxy.

The proxy for the announcement, a_t, is equal to zero before January 2015, it is equal to €60 billion between January 2015 and February 2016, it becomes equal to €80 billion between March 2016 and November 2016 and is again equal to €60 billion from December 2016 onwards (see Chart 1). As baseline scenario, we assume that the expected component of the announcement, $E_{t-1}a_t$, corresponds to half of the amounts associated to the announcement proxy just described.

The announcement of the APP in January 2015 was to some extent expected, following various references by ECB Executive Board members in speeches in previous months.[4] However, available market polls and anecdotal evidence from newspapers support the view that the extent of the purchases was not fully expected. For example, on the day after the APP announcement in January 2015, the Financial Times published 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). Similarly, on the day after the March 2016 re-calibration announcement by the ECB, the Financial Times included an article entitled "ECB cuts rates and boosts QE to ratchet up eurozone stimulus" reporting that "The ECB raised the amount of bonds the eurozone's central bankers buy each month under QE from €60bn to €80bn - a greater amount than many analysts had expected. It also expanded the range of assets it will buy to include high quality corporate bonds." (Financial Times, 11 March 2016, p. 1). In the robustness analysis we will show that results are very similar if we assume that only one tenth of the announced purchases were unexpected, thus suggesting that the adopted scheme is valid to the extent that at least some of the announced amounts of purchases were not expected.

<Chart 1 around here>

[4] For example, President Draghi mentioned during the ECB Press Conference of December 2014 that in early 2015 the ECB would, among other things, reassess "the expansion of the balance sheet".

3.2 The TVC-VAR model

We estimate a VAR with time-varying parameters and stochastic volatility (TVC-VAR) with four variables ($n = 4$), two of which are needed for the identification (actual Eurosystem security purchases, cb_t, and the proxy for the announcement shock, b_t) and two more variables of interest (x_t and z_t), which in turn will include pairs of financial and/or macroeconomic variables, as listed below. We assume that the four variables included in the model, $y_t = [cb_t\ b_t\ x_t\ z_t]'$, follow

$$y_t = A_{0,t} + A_{1,t}y_{t-1} + ... + A_{p,t}y_{t-p} + \varepsilon_t \tag{1}$$

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, $i = 1, ..., p$. Let $A_t = [A_{0,t}, A_{1,t}..., A_{p,t}]$, and $\theta_t = vec([A_{0,t}\ A_t]')$, $vec(\cdot)$ being the stacking column operator. The VAR coefficients evolve as a random-walk

$$\theta_t = \theta_{t-1} + \omega_t \tag{2}$$

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 $\phi_{i,t}$, $i = 1, ..., 4$, be a column vector containing the first i elements of the $(i+1)$-th row of F_t^{-1}. We assume

$$\log \sigma_t = \log \sigma_{t-1} + \xi_t \tag{3}$$

$$\phi_{i,t} = \phi_{i,t-1} + \psi_{i,t} \tag{4}$$

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 $\phi_t = [\phi'_{1,t}, \ldots, \phi'_{n-1,t}]$, $\psi_t = [\psi'_{1,t}, \ldots, \psi'_{n-1,t}]$ 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 $C_{k,t} = S_{n,n}(\mathbf{A}_t^k)$, where $\mathbf{A}_t = \binom{A_t}{I_{n(p-1)}\quad 0_{n(p-1),n}}$ and $S_{n,n}(X)$ is a function which selects the first n rows and n columns of the matrix X.

3.3 Identification of the announcement shock

The aim of the analysis is to assess quantitatively the effects of the announcements associated to the introduction and re-calibrations of the APP. The identification of the APP announcement shock represents the main novelty of the paper and is discussed in details in this section.

The shock under consideration is a shock that occurs only rarely, indeed there are only three APP announcements as defined above in the sample: January 2015, March 2016 and December 2016 (although we assess the impact only of the first two, as discussed). Here we formalize the idea that the economy can be possibly driven by infrequent shocks, or shocks which might occur exclusively in few specific periods of time, and show how to incorporate this idea into our empirical model.

Let us first assume that there are m (with $m \geq n$) orthogonal structural shocks in the economy collected in the vector $u_t \sim N(0, M_t)$, where M_t is a diagonal time-varying covariance matrix. Given that the identification of structural shocks is typically obtained for orthonormal shocks, let us consider the following new vector: $u_t = \sqrt{M_t} e_t$, where $e_t \sim N(0, I)$ and $\sqrt{M_t}$ is a matrix whose elements on the main diagonal are the square root of the elements of the main diagonal of M_t. As it is standard in the VAR literature, we assume that the vector of residuals is a combination of the structural shocks $\varepsilon_t = P_t u_t$, where P_t is a $n \times m$ matrix of time varying-parameters and can be written in terms of orthonormal shocks $\varepsilon_t = Q_t e_t$, where $Q_t = P_t \sqrt{M_t}$.

Let us further assume that, at every point in time, there are only n elements of u_t which affect the economy. In other words, there are $m - n$ elements of u_t whose variance is zero.[5] For instance, the announcement shock we are after in this paper is a shock which takes place only on a few dates and is absent most of the time. We can therefore think of it as a shock whose variance is zero most of the time and then becomes non-zero in specific dates. This approach can be seen as a general modelling strategy, since it is possible to think of different types of shocks which show up only in few specific periods of time, like wars or major political events. This implies that $m - n$ elements of the main diagonal of M_t are zero and therefore there are $m - n$ columns of the matrix Q_t which are zero. This implies that the vector of residuals is a combination of a $n \times 1$ subvector of e_t. Notice that, when $m > n$, and given that the variances of the structural shocks can change over time, the shocks active in different points in time could be different.

Now let $\mathcal{I}_t$ be a $n \times m$ matrix which selects the elements of e_t corresponding to the non-zero columns of Q_t, i.e. selects the shocks which are active in t, and let $\tilde{e}_t = \mathcal{I}_t e_t$. Let $\tilde{Q}_t = Q_t \mathcal{I}_t'$, the $n \times n$ submatrix of Q_t formed by the non-zero columns of Q_t. Under these assumptions the vector of residuals can be written as $\varepsilon_t = \tilde{Q}_t \tilde{e}_t$. As an illustration consider the following example with $n = 2$ and $m = 3$ and suppose that at time t only

[5] The number of shocks could in principle be smaller than n. In this case, however, the implied matrix of residuals would be of reduced rank, which is in contrast to the empirical evidence which supports a full-rank residuals covariance matrix. At the same time, the number of shocks could be also larger than n. This would raise the problems of identification discussed in Forni et al. (2017). For sake of simplicity we assume, as it is standard, that there are only n shocks at every point in time.

$\sqrt{M_{22t}}$ is zero:

$$\begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} = \begin{pmatrix} Q_{11t} & 0 & Q_{13t} \\ Q_{21t} & 0 & Q_{23t} \end{pmatrix} \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{pmatrix}$$
$$= \begin{pmatrix} Q_{11t} & Q_{13t} \\ Q_{21t} & Q_{23t} \end{pmatrix} \begin{pmatrix} e_{1t} \\ e_{3t} \end{pmatrix}.$$

In this case $\mathcal{I}_t = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$. The structural impulse response functions are obtained as

$$B_t(L) = C_t(L)\tilde{Q}_t.$$

A few remarks are in order. First, if the variance of the structural shock is time-varying, so is the residual volatility. This implies that our framework is not consistent and cannot be implemented in a standard fixed-coefficient VAR. This emphasises the key role played by the stochastic volatility within our approach. While the VAR parameters could be constant, the residuals variance has to be time-varying. Second, it makes no sense to identify the shock in a time period where the shock is not present and therefore some information has to be used in order to select the periods in which the shocks of interest are present. This allows the researcher, as we do here, to exploit some narrative evidence in order to identify the periods of time of interest.

Once clarified our theoretical framework, we proceed with the discussion of the identification of the APP announcement shocks. First of all, the two APP announcements shocks took place in January 2015 and in March 2016. Thus, after estimating the model over the whole sample, we exclusively focus on these two dates. In practice, this means that we only consider the sets of parameters and variance-covariance matrices associated to those two periods. Second, as discussed above, it is reasonable to assume as baseline that half of the announced monthly purchases were unexpected, thus b_t assumes a value which corresponds to half of the flow of announced monthly purchases. Third, we identify the announcement shocks using a Cholesky decomposition, with the variables ordered as discussed above (the flow of asset purchases first, proxy for APP announcement shock second and then the remaining variables of interest). The second shock of the Cholesky representation is our identified APP announcement shock. Notice that the shock has no effect on the flow of actual security purchases contemporaneously. This feature is clearly stated in all APP announcements and re-calibrations considered. For example, the January 2015 announcement implied that announced purchases would start only with two months delay, i.e. in March 2015. Similarly, the March 2016 re-calibration announcement implied that the increased amount of purchases would only start in April 2016, i.e. with one month delay.

Formally, let S_t be the Cholesky factor of Σ_t, we impose $\tilde{Q}_t = S_t$ for $t = 2015 : M1$ and $t = 2016 : M3$. The structural impulse response functions to the announcement shock are the elements of the second column of $C_t(L)S_t$. The announcement shock is the second element of the vector $\tilde{e}_t = S_t^{-1}\varepsilon_t$.

Notice that if b_t is truly an unpredictable exogenous white noise shock uncorrelated with any other structural shock, then any ordering of the variables within a Cholesky approach would deliver the same results. In practice, some problems might arise. For instance, there might be some nonzero autocorrelation or the expected component of the announcement could be not perfectly estimated so that some other shocks might affect b_t. It turns out that the ordering is not relevant from an empirical perspective.

Compared to the empirical literature on the impact of QE measures, our approach has some similarities to the methodology proposed by Weale and Wieladek (2016), who apply it to assess the impact of the QE measures adopted by the Federal Reserve Board and the Bank of England from early 2009 onwards. Weale and Wieladek (2016), in the context of a fixed coefficients VAR, use as a proxy for asset purchases the cumulated purchases announced by the Federal Reserve Board and the Bank of England from early 2009 onwards as a percentage of the US and UK nominal GDP, respectively, and thus do not attempt to create a proxy for the unexpected component of the announcements. Moreover, while their approach takes into account the total amounts of purchases announced for each large-scale asset purchase programme, they do not incorporate information on the time profile and monthly amounts of the purchases, mainly because in contrast to the ECB, the Fed and the Bank of England did not provide this more specific information at the time of the announcement of the respective QE policies. Thus, our approach reflects the specific institutional features of the ECB's QE, some of which (i.e. the time profile of purchases) were not present in the QE policies implemented in other jurisdictions, which implies that our approach is more specifically suited to analyse the effects of the APP but needs some adaptations to be applied to study QE policies more in general. Moreover, recognising that part of the QE policies were expected, our approach aims at assessing the effects of the genuine news, or unexpected components, associated to the APP announcements, which would not be possible if we included in our models variables reflecting the total amounts to be purchased, as Weale and Wieladek (2016) do. Similar considerations apply to Wieladek and Garcia Pascual (2016), who analyse the effects of the ECB's APP by using the same methodology of Weale and Wieladek (2016).

3.4 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 four lags ($p = 4$). 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 assumptions 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 $i = 1, ..., n - 1$. 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 $\lambda_1 = 0.00001$, $\lambda_2 = 0.05$ 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 seven steps involved in the algorithm.

The baseline model includes four monthly variables spanning the period July 2009 to March 2017: two of these variables are needed for the identification (Eurosystem security purchases for monetary policy purposes in EUR billions, cb_t, and the proxy for the announcement shock, or the unexpected component of the announcement, b_t), while the third variable (x_t, the long-term interest rate) enhances the identification of the shocks as it captures key channels of transmission. Thus, these three variables are present in all specifications of the models we consider. The fourth variable included (z_t) refers to the alternative variables of interest, which will vary and include various financial and macroeconomic variables. We focus on the series for Eurosystem security purchases for monetary policy purposes, i.e. the sum of purchases that started in mid-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 have 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.[6] We focus on the series for total Eurosystem security purchases rather

[6] It is interesting to note that such choice is also supported by the conclusion of Haldane et al. (2016)

than that only for the APP security purchases as the latter starts only in March 2015, making the estimation period statistically too short. In the baseline macroeconomic models, the variables of interest include the harmonised index of consumer prices (HICP) and a monthly index associated to real economic activity (Eurocoin), while the effects of the APP announcements on financial markets will be assessed by including as variables of interest, in turn, long-term and short-term interest rates (to capture the effects on the yield curve), non-financial corporation credit volumes and bank lending rates (effect on credit markers) and, finally, stock prices and the Euro nominal effective exchange rate (other financial market effects). For the purpose of the assessment of the role of various channels of transmission of the APP we also consider other variables, such as measures of inflation expectations (re-anchoring channel) and short-term forward interest rates (policy signalling channel). Since the series need to be stationary, the flow of purchases, the APP announcement shock proxy and interest rates are included in first differences while consumer prices, credit volumes and stock prices are included as monthly growth rates. Annex I provides details on the definition, treatment and sources of the data.

4 Results

4.1 Evidence of time-variation in parameters and volatility

The estimated residual time-varying variances indicate that for all variables there is evidence of significant time-variation in the respective volatility. This is particularly important for the variables used in the identification of the shocks, notably the APP announcement shock proxy (Chart 2). However, for all variables considered, both financial and macroeconomic, there is strong evidence of time-varying volatility (Chart A in Annex II). For example, HICP inflation volatility increased especially since 2015. At the same time, in other cases volatility appears to be higher in the first part of the sample, such as for government bond yields. By contrast, for stock prices and the exchange rate there seem to be various temporary increases in volatility throughout the sample period. Hence, we cannot find two or few common regimes of high or low volatility across variables, which could suggest that regime-switching volatility specifications of the model should be considered. Overall, the evidence supports the use of a stochastic volatility specification for the model.

<Chart 2 around here>

In order to assess whether time-variation in the parameters might be warranted, we perform the test suggested by Cogley and Sargent (2005). Accordingly, we compute the

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).

posterior mean and 16th and 84th 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, for all models considered 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 A in Annex II). The results of this test can be interpreted as evidence pointing to the presence of time-variation in the parameters of the VAR.

4.2 The macroeconomic effects of the APP announcement shocks

The impact of the APP announcement shocks taking place in January 2015 and in March 2016 on the variables of interest are assessed on the basis of impulse response functions. Specifically, we report the posterior median of the impulse response functions of the variables to the APP announcement shocks, along with the area delimited by the 16th and the 84th percentiles, with both median responses and percentiles multiplied by the estimated size of the shock in those months. While the model is estimated with the variables in first difference or growth rates, we report the impulse responses to the variables in levels. Looking first at the effects of the January 2015 shock, the impact of the shock to the Eurosystem security purchases, after being nill in the first month (as imposed by restriction) and almost zero in the second month, jumps up from the third month onwards and remains at levels just above €30 billion, thus suggesting that indeeed about half, or slightly more, of the monthly purchases announced can be considered as unexpected (Chart 3). This interpretation is also supported by the impact of the shock on the APP announcement news proxy, which immediately jumps and remains at levels close to €30 billion. Note that these results are not an implication of the assumed size of the APP announcement news proxy, as with other sizes in the latter that we experimented with, the impact of both variables (actual purchases after the second month and APP announcement news proxy) do not necessarily converge and remain at the level of the APP announcement proxy (as discussed more in detail in the robustness section below).

The impact of the January 2015 shock on the HICP, while very close to zero on impact, increases over time stabilising around 1 percent after eight months, and remains markedly significant for at least three years. By contrast, the impact on Eurocoin, a monthly index tracking quarterly growth of euro area real GDP, appears to be mainly concentrated in the short run. More precisely, it is close to zero on impact but increases and becomes significant after six months, peaking at around eight months when the impact is about 0.3 percentage points, suggesting that in the absence of the initial APP announcement shock quarterly real GDP growth may have been about one third of a percentage point lower three quarters after the shock. The impact of the shock on Eurocoin then decreases and becomes insignificant after 18 months. While the impact of the shock on real economic activity growth is estimated to be temporary, the effects on the level of real output are persistent.

The impact of the March 2016 shock is estimated to be very similar but characterised by smaller magnitude, not surprisingly given the smaller size (€20 billion) of the announced increase in the monthly flow of purchases compared to the January 2015 announcement (€60 billion). Also in this case, the impulse responses of both the Eurosystem security purchases and the APP announcement news proxy quickly reach, and stabilise at, levels close to or just above €10 billion, which correspond to levels of about half of the announced increase in purchases. The responses to the March 2016 shock of the HICP and Eurocoin appear to be displaying similar properties as those to the January 2015 shock, with a gradually increasing and persistent significant response of the HICP, reaching a maximum of about 0.4 percent after about nine months, and a short-lived impact of Eurocoin, marginally significant at the peak, where it reaches a level close to 0.1 percentage point, with a nine months lag after the shock.

<Chart 3 around here>

Available studies on the impact of the APP, and more generally on the impact of QE policies introduced in recent years in advanced economies, unambiguously point to a positive effect on real economic activity and inflation, although with estimates varying quantitatively. Indeed, alternative estimates of the effects of such QE measures 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, the different identification schemes applied as well as the different features of the QE measures implemented by various central banks in different periods. Overall, our estimates on the impact of the APP announcement shocks on real economic activity growth and the HICP do not differ much from other estimates, falling within the range of estimates reported by Borio and Zabai (2016), and not far from those reported by Andrade et al. (2016) and Wieladek and Garcia Pascual (2016) for the euro area.

4.3 The financial market effects of the APP announcement shocks

In order to shed light on the financial market effects of the APP announcement shocks, which allow to assess the role of various channels of transmission of these shocks, we consider the impact on the yield curve, stock prices, the exchange rate, credit markets, inflation expectations and short-term forward rates.

As regards the impact of these shocks on the yield curve, the January 2015 shock is estimated to have affected significantly the 10-year composite euro area government bond yield, which responds negatively in the short term (by -11 basis points on impact, and a maximum of -25 basis points after four months), while in the medium to longer term the shock has an opposite effect, pushing the yield upwards persistently (stabilising at about +40 basis points after six months) (Chart 4). By contrast, the effect on the shorter-term yield is more contained, as the 1-year composite euro area government bond yield displays a limited short-run declining impact (-3 basis points on impact and a maximum -8 basis points after four months) and then converges to about zero from the 12th month onwards. As a result, the slope of the yield curve first declines, for about four months, and sub-sequently increases, mainly driven by the dynamics of the longer-term interest rate. The March 2016 shock has a similar effect on the yield curve, but with smaller magnitudes (maximum negative effects by -7 basis points after four months, then stabilising at +13 basis points after eleven months for the 10-year yield, and a -3 basis points after two months maximum negative effect which then converges to zero for the 1-year yield). Very similar responses of the yield curve to these two shocks are found also for the largest euro area countries, i.e. when we use 10-year and 1-year yield for, in turn, Germany, France, Italy or Spain, instead of those for the euro area, in the same model with euro area purchases and APP announcement news proxy (see Chart B in Annex II).[7] Moreover, these responses turns out to be robust to alternative variables and an alternative APP announcement shock proxy, as illustrated in detail in the robustness analysis section.

<Chart 4 around here>

These estimates, specifically for the short term, are broadly in line with those from the empirical literature. For example, 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 (see the range of estimates from various studies summarised in Table 1 in Andrade et al., 2016, p.13). 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 is always negative and significant (see Table 4 in Borio and Zabai, 2016, pp. 11-12). These estimates differ somewhat from ours, in part due to the different time frame and frequency of the data, as for example event studies often use daily or even intra-daily data and focus on the effect of QE announcements over one

[7] Note that for Spain we use the 2-year government bond yield instead of the 1-year yield as the latter is not available for the whole sample period considered.

day or one week, during which presumably the impact is strongest. Beyond the short term, results are still debated. For example, Wright (2012) finds that the effect of US monetary policy news shocks from 2008 onwards have a short-term significant downward effect on 10-year yields but these effects die out after few months. By contrast, Joyce and Tong (2012) provide some evidence that the depressing effects of the UK's large-scale purchases on long-term yields are quite persistent.

Our finding of a short-term flattening, followed by a steepening, of the yield curve in response to a shock associated to the APP announcements is, to the best of our knowledge, a novel finding, warranting therefore a more detailed discussion. There are at least two possible interpretations to this finding. A first, more optimistic, interpretation is that the APP announcement shocks have a significant short-term expansionary effect on the economy through various channels, improving the financial and macroeconomic outlook, which is then eventually reflected in higher long-term interest rates. Such interpretation, also discussed by Wright (2012) with reference to his finding of a short-run negative reponse of the long-term interest rate to US monetary policy news shocks which quickly is reversed and converges towards zero after few months, would not be very different from the effects of any expansionary shock to real economic activity on the long-term interest rate, except for the lagged effect in the case of the APP shocks reflecting the fact that in the short run the portfolio rebalancing channel prevails and leads to a temporary compression of interest rates. An alternative interpretation, not necessarily incompatible with the first possible explanation discussed, relates to the excess sensitivity of long-term interest rates to monetary policy news, as documented for example by Gürkaynak et al. (2005) and Hanson and Stein (2015). For instance, Gürkaynak et al. (2005) find evidence of a high sensitivity of long-term interest rates to both macroeconomic news and monetary policy surprises which are hard to explain on the basis of standard macroeconomic models. Interestingly, they also find that monetary policy surprise tightenings cause short-term forward rates to increase but long-term forward rates to fall. While different explanations have been offered for such excess sensitivity of long-term interest rates to monetary policy news, ranging from changing long-run inflation expectations (Gürkaynak et al., 2005) to changes in term premia associated to shifts in the demand for long-term bonds from yield-oriented investors (Hanson and Stein, 2015), our analysis does not allow for an assessment of their respective potential role in driving the changes in the yield curve. Overall, we cannot exclude that both interpretations may have some explanatory power for the changing slope of the yield curve over time in response to the APP shocks.

Other financial variables such as stock prices and the exchange rate have also been affected markedly by the APP announcement shocks. For example, the January 2015 shock caused stock prices to increase in the short run (with maximum effect on the median impulse response by almost 10% after three months, stabilising at around 5% after eight months, although the 68th percentiles point to a significant impact only in the short run), while the euro nominal effective exchange rate declined markedly in the short run as a result of the shock (with a peak effect after four months, at almost -5%, then converging to almost -2% after ten months) (Chart 5). Also the March 2016 announcement shock had mainly a short-term effect on these variables, with maximum impact after three to four months (about +3% for stock prices after three months, and -1.2% for the exchange rate after four months).

<Chart 5 around here>

The estimated impact on stock prices is somewhat stronger than the estimates reported by Altavilla et al. (2015) based on an event study, although not by much in some specifications (while they find a 1% increase in their controlled event study with 2-day window, they report a 5% increase in their standard event study with 2-day window). By contrast, the impact of the shock to the exchange rate is somewhat smaller than that reported by Altavilla et al. (2015), although the comparability is imperfect as they focus on the Euro-US dollar exchange rate (a 12% depreciation of the Euro in both the controlled and standard event studies with 2-day window). At the same time, as shown by Borio and Zabai (2016), while most studies find that large scale-asset purchases have a marked negative impact on the exchange rate, estimates vary significantly (see Table 4 in Borio and Zabai, 2016, pp. 11-12). Of course, the differences can be explained by the different approaches used, as for example event studies focus on the very short-term impact of monetary policy surprises on these financial variables, without inference on the persistence of these effects over periods of time spanning at least few months, thus not being necessarily in contrast to the estimates we report. These impulse responses can shed some light on various channels of transmission of the APP shocks, notably the portfolio rebalancing channel and the exchange rate channel. In this respect, these results suggest that both the portfolio rebalancing channel and the exchange rate channel were activated.

Evidence can also be found that the credit channel was operational following the APP announcement shocks. Indeed, looking at credit markets, specifically for credit to non-financial corporations, we find that the response of total credit to firms increased significantly in the short term following both the January 2015 APP announcement shock (with peak effect, at almost 7%, after three months) and the March 2016 re-calibration announcement shock (with maximum impact, at almost 2%, after three months) (Chart 6). In parallel, the impact on bank lending rates for loans to enterprises appears to be more muted and very uncertain (with signs of marginal and persistent negative impact after five months following both the January 2015 and the March 2016 shocks, but the

68th percentiles clearly suggest that the effect on lending rates is very uncertain).

<Chart 6 around here>

In order to assess to which extent other channels of transmission of the APP announcement shocks might have been activated, we also estimated models with alternative variables, specifically long-term inflation expectations (Consensus inflation expectations, 6 to 10 years ahead) to quantify the role of the inflation re-anchoring channel and short-term forward rates (three-month overnight index swap, OIS, forward rates two-years ahead) to analyse the signalling channel. The estimates for the model with long-term inflation expectations suggest that indeed some re-anchoring of inflation expectations took place as a result of APP announcement shocks, with long-term inflation expectations increasing by 6 basis points following the January 2015 shock and by 2 basis points as a result of the March 2016 shock (see upper panel in Chart C in Annex II). At the same time, these estimates seem very uncertain, as signalled by the wide range of the 68th percentiles. The activation of the signalling channel is even more uncertain, as for example the impulse responses of the short-term forward rates are negative in the short term but of very small magnitude (-14 basis points after four months following the January 2015 shock, and -2 basis points with a four-months lag after the March 2016 shock) and surrounded by a wide range delimited by the 16th and 84th percentiles (see lower panel in Chart C in Annex II).[8]

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 financial and macroeconomic variables resulting from the baseline model with different specifications, by using an alternative proxy for the announcement shock, by using alternative financial and macroeconomic variables and by considering an alternative identification scheme with sign restrictions.

First, we consider an alternative APP announcement shock proxy implying different magnitude restrictions. In the baseline specification we assumed that at least half of the announced monthly purchases was unexpected, and now we ask how results would change if we assume that a much smaller fraction of announced monthly purchases, namely one tenth, was unanticipated (see Chart A in Annex III). Overall, we find that impulse responses are very similar to the baseline case. For example, the impulse responses of euro area HICP and Eurocoin to the APP announcement shocks are very similar to

[8]Similar results, including the wide range of the 68th percentiles, is found for the three-month OIS forward rates six-months, one-year and three-years ahead.

the baseline case (see Chart B in Annex III, compared to Chart 3), and so are those of the Eurosystem purchases flow, suggesting that indeed about half of the announced purchases were unexpected, even when using an APP announcement shock proxy with smaller magnitude (which of course explains the smaller responses of the latter to the shocks). Very similar results are also obtained when comparing the responses of financial variables to the APP shocks with the smaller APP announcement shock proxy, including the yield curve (i.e., the 10-year and 1-year yields), stock prices, the exchange rate and credit to firms (see Charts C and D in Annex III, compared to Charts 4, 5 and 6).

Second, it can be interesting to examine whether the impact of the APP announcement shocks changes if alternative financial and macroeconomic variables are included in the model. As regards other macroeconomic variables, we consider the HICP excluding energy and food prices (HICPex, often used as a proxy for underlying inflation) instead of the headline HICP and consider total employment instead of Eurocoin. The impulse responses of these alternative macroeconomic variables are similar to the baseline ones, as for example the response of HICPex converges quickly to almost 1 percent following the January 2015 shock and close to 0.3 percent following the March 2016 shock (Chart E in Annex III). Employment increases gradually and stabilises at aroud +0.7 percent and +0.3 percent shortly after 12 months following the January 2015 and March 2016 shocks, respectively, confirming that the impact of shocks on the real economy is persistent (Chart F in Annex III). As regards financial variables, we consider the composite (GDP-weighted) euro area 10-year and 2-year government bond yields instead of the composite euro area 10-year and 1-year spot government bond yields of the baseline models. Also in this case the impulse response of the yield curve is very similar to the baseline one, with dynamics driven by the long-term interest rate and a short-term flattening followed by a subsequent steepening of the curve (see Chart G in Annex III, compared to Chart 4).

Third,we assess how estimates change when we impose an alternative set of identification restrictions in models with five variables. The idea is to assess the results with slightly bigger models and also with sign restrictions based on the institutional features of the APP programme, the results of previous studies and other economic considerations. We focus here on the impact of the January 2015 APP announcement shock for simplicity. The alternative identification scheme, applied to models with Eurosystem security purchases, the baseline APP announcement shock proxy, the long-term interest rate, Eurocoin and a fifth variable of interest, includes the above-mentioned baseline restrictions (zero, magnitude and timing) and adds a number of sign restrictions, as summarised in Table A in Annex III: 1) a positive lagged effect (by two months) of the shock on Eurosystem purchases (on top of the zero impact restriction), as implied by the institutional features of the January 2015 APP announcement; 2) a positive effect on impact on the APP announcement news proxy, to ensure we capture the effect of the shock under consideration in that specific month; 3) a negative effect on the long-term interest rate on impact and with one month lag, which is an effect estimated by all studies on the impact of QE measures (see for example, Borio and Zabai, 2016, Table 4 in pp.11-12) and is in line with the results reported in the main section that the negative effect is not only on impact but persists for some time; 4) a positive lagged effect (by three months, i.e. at the beginning of the sub-sequent quarter after the shock) on Eurocoin, to ensure we do not capture other shocks which might have the above-mentioned effects, such as adverse shocks to aggregate demand or aggregate supply which would also have a negative effect on long-term interest rates (given the worsened macroeconomic outlook caused by the shock) and if large enough might endogenously trigger an expansionary APP announcement measure; 5) a sign on the response of the fifth variable as would be expected by theoretical or conceptual considerations, such as a positive lagged effect on HICP inflation, a positive lagged effect on stock prices, a negative lagged effect on both the exchange rate and the 1-year yield, a positive lagged effect on credit to firms and a negative lagged effect on lending rates applied to firms, in all cases imposed with a lag of three months, i.e. at the beginning of the quarter following the shock, in line with the expected macroeconomic lagged response and the results reported in the main section and previous studies that the maximum effects are estimated with a lag.[9] Overall, in the context of these models and sign restrictions, most often the response of the Eurosystem purchases, after being nill in the first month (as imposed by restriction) and almost zero in the second month, jumps up from the third month onwards and remains at levels close to €20 billion, while the APP announcement news proxy immediately jumps and remains at levels close to €15 billion, thus suggesting that about about one third, or slightly less, of the monthly purchases announced can be considered as unexpected, only slightly less than estimated in the baseline model (Chart H in Annex III). Moreover, the estimated effects of the APP announcement shock considered on financial and macroeconomic variables are very similar qualitatively and often also quantitatively to those estimated in the context of the baseline four-variables models and identification scheme. In particular, Eurocoin increases significantly only in the short term, although in most cases to a slightly smaller extent than in the baseline model (for all cases except for the model with the short-term interest rate, for which the response is very similar), and the HICP response gradually increases and stabilises at significant levels, around 0.9 percent, i.e. only marginally lower than in the baseline estimation (see Chart H in Annex III,

[9] In the absence of this fifth set of sign restrictions, impulse responses for the fifth variables are very similar but in some cases of somewhat smaller magnitude and characterised by higher uncertainty. Moreover, results are very similar if restrictions on the fifth variables are imposed only with one or two, instead of three, months delay, but in some cases results are characterised by higher uncertainty.

compared to the Chart 2). Moreover, stock prices respond by rising especially in the short term, reaching a similar maximum response but more persistently compared to the baseline model, and the exchange rate declines, to a similar extent in the short term but appears to decline more persistently compared to the baseline model. As regards the yield curve, the responses are also similar in several respects, although compared to the baseline case the short-term decline of the long-term interest rate is somewhat stronger and less uncertain, its reversal to positive levels appears to be present for a shorter period in most cases and the 1-year yield declines more persistenlty. Hence, the short-term flattening of the yield curve, followed by a steepening later on, is also found in this alternative models. Finally, credit to firms increases persistently, to a similar extent compared to the baseline model, while the lending rate declines more significantly.

5 Conclusions

This paper provides some evidence on the financial and macroeconomic impact of the ECB's expanded asset purchase programme (APP), concentrating on the announcement news effects specifically of the January 2015 announcement and the March 2016 re-calibration, based on a structural VAR featuring time-varying parameters and stochastic volatility and a novel identification scheme combining zero, timing and magnitude restrictions derived from the specific institutional features of the APP programme. Overall, the analysis points to a significant positive macroeconomic impact of the APP announcement shocks, with significant short-term responses of both real economic activity growth and HICP inflation and more persistent responses on the level of real output and the HICP. Several financial variables appear to have also been affected by these shocks, including the yield curve, mainly driven by changes in the long-term interest rate, giving rise to a flattening of the yield curve in the short term, followed by a steepening in the medium term. The significant impact of the APP announcement shocks on stock prices points to an activation of the portfolio rebalancing channel, while the persistent depreciation of the exchange rate suggests that also the exchange rate channel was operational. Credit market variables also appear to have responded significantly, indicating that the credit channel played a role in the transmission of APP shocks, while the evidence on the relevance of the inflation re-anchoring channel and the signalling channel is more uncertain.

Some caveats to be borne in mind when assessing more in general the impact of the APP in the euro area is that the analysis reported in our study only provides a quantification of the impact of the APP announcement shocks of January 2015 and March 2016, thus not including also the effects of the re-calibrations of the APP announced in December 2015 and December 2016, and it does not provide an assessment of the impact of the actual purchases.

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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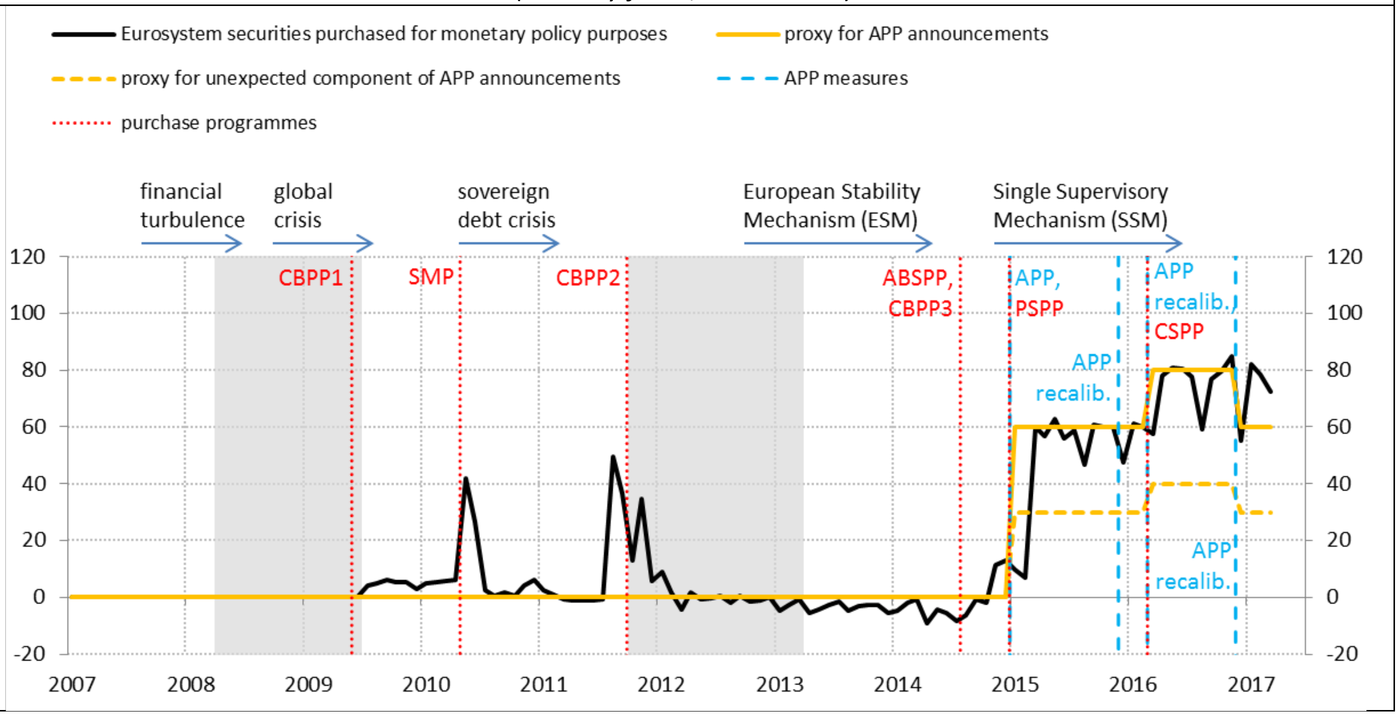
Chart 1 – Eurosystem security purchases for monetary policy purposes and proxy for APP announcements, January 2007 to March 2017

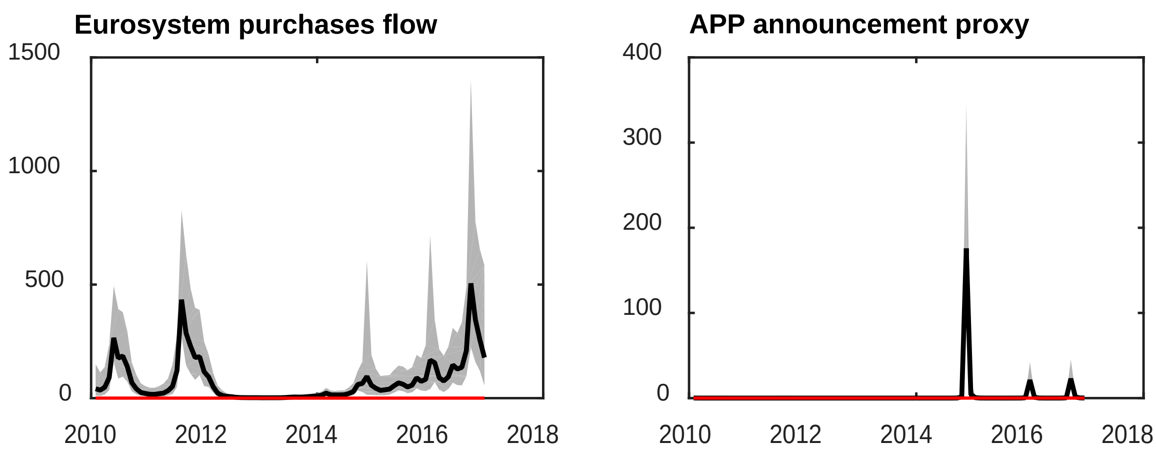
(monthly flows, EUR billions)



Source: CEPR and 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. Vertical dashed blue lines and associated text delimit the dates of the introduction and subsequent re-calibrations of the expanded asset purchase programme (APP). Shaded areas delimit Euro Area recessions as dated by the CEPR Euro Area Business Cycle Dating Committee.

Chart 2 - Stochastic volatility

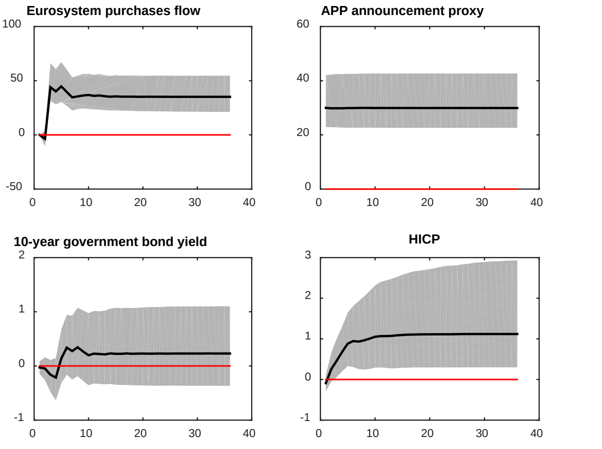


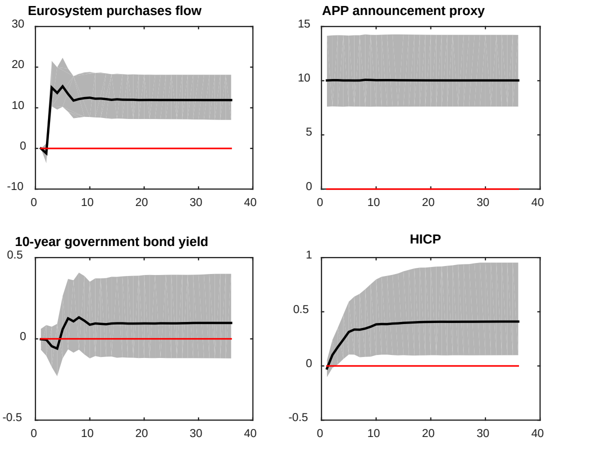
Note: Residual time-varying variances. Black full lines: posterior medians. Grey areas: areas delimited by the 16th and 84th percentiles.

Chart 3 - Impulse response functions of macroeconomic variables to the January 2015 and the March 2016 announcement shocks

Model with the HICP

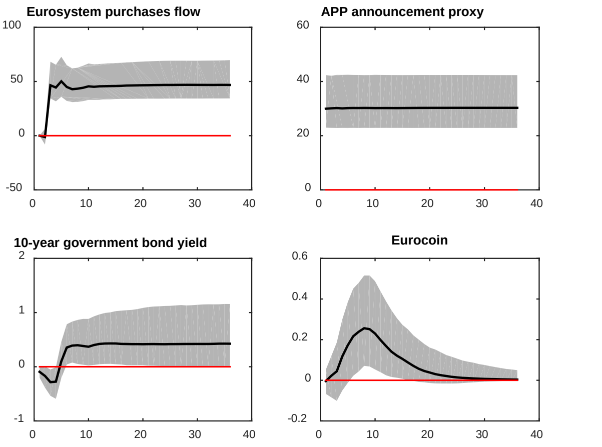
January 2015 APP announcement shock	March 2016 APP recalibration announcement shock

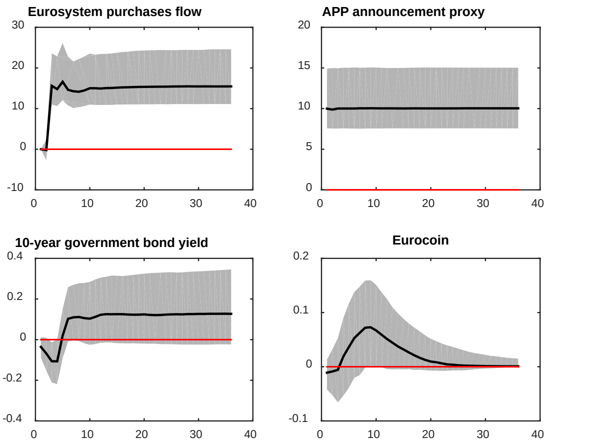




Model with Eurocoin

January 2015 APP announcement shock	March 2016 APP recalibration announcement shock

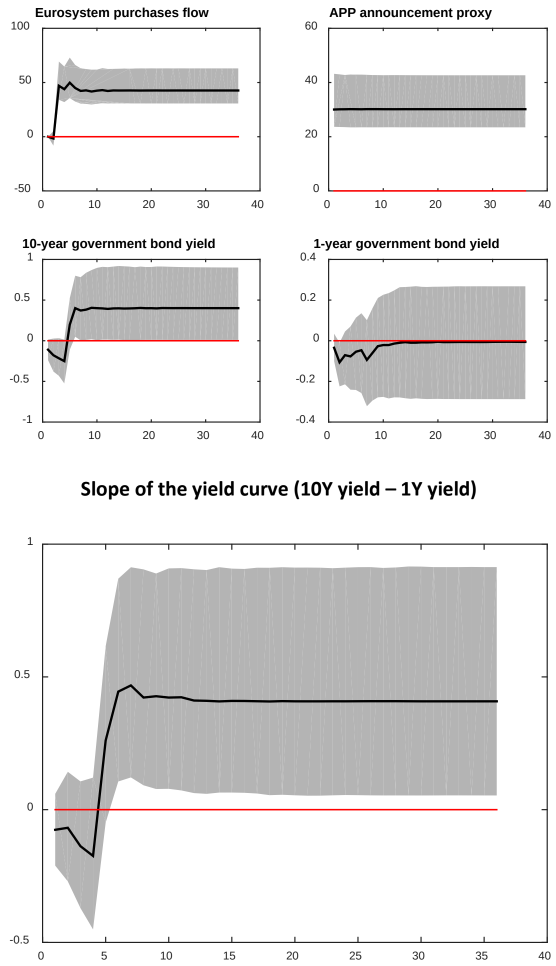


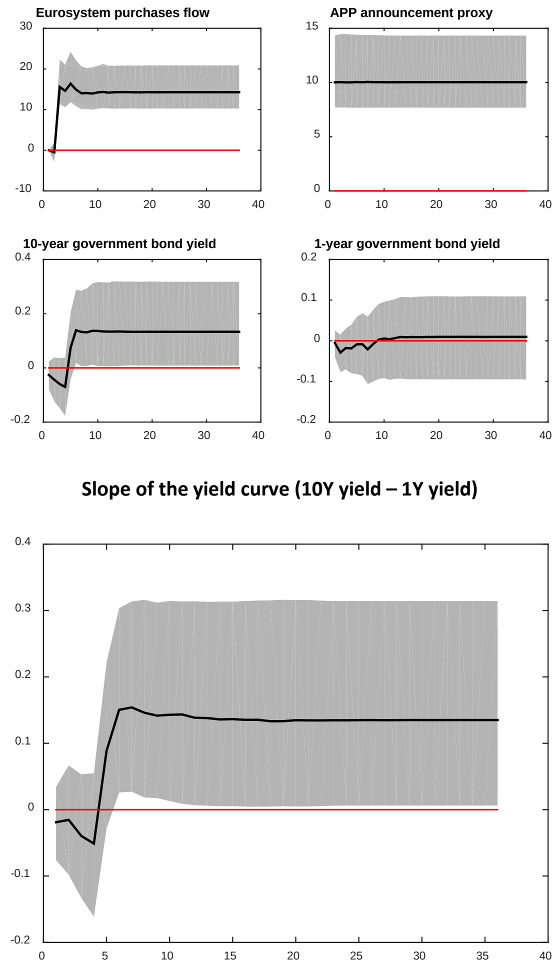


Note: Full black lines are the median impulse response functions, grey areas delimit the space between the 16th and 84th percentiles of impulse response functions. Median responses and percentiles multiplied by the estimated size of the shock in the respective month. Horizontal axes refer to number of months, while vertical axes refer to billions of euros (for Eurosystem purchase flow and APP announcement proxy), percentages (for the HICP) or percentage points (for long-term interest rates and Eurocoin).

Chart 4 - Impulse response functions of the yield curve to the January 2015 and the March 2016 announcement shocks

January 2015 APP announcement shock	March 2016 APP recalibration announcement shock



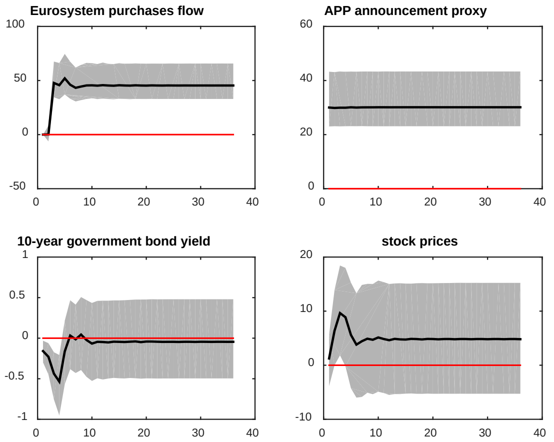


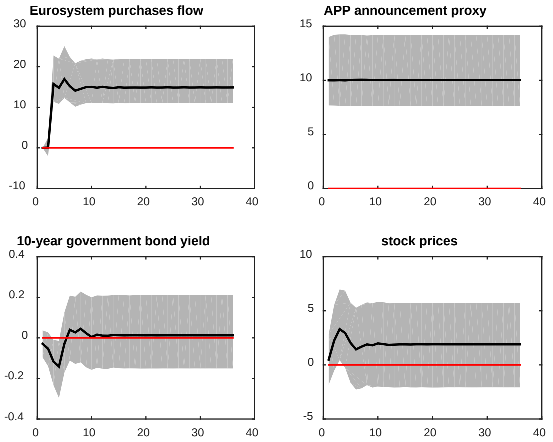
Note: Full black lines are the median impulse response functions, grey areas delimit the space between the 16th and 84th percentiles of impulse response functions. Median responses and percentiles multiplied by the estimated size of the shock in the respective month. Horizontal axes refer to number of months, while vertical axes refer to billions of euros (for Eurosystem purchase flow and APP announcement proxy) or to percentage points (for interest rates).

Chart 5 - Impulse response functions of financial variables to the January 2015 and the March 2016 announcement shocks

Model with stock prices

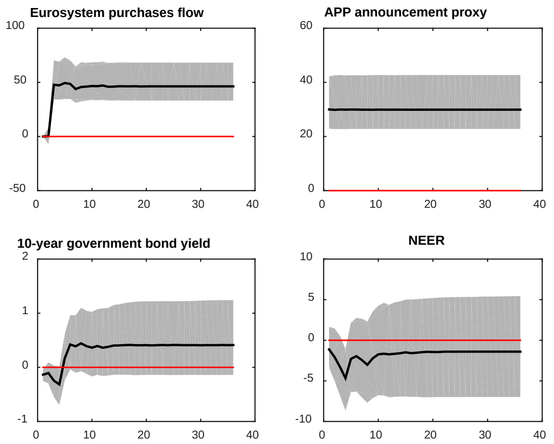
January 2015 APP announcement shock	March 2016 APP recalibration announcement shock

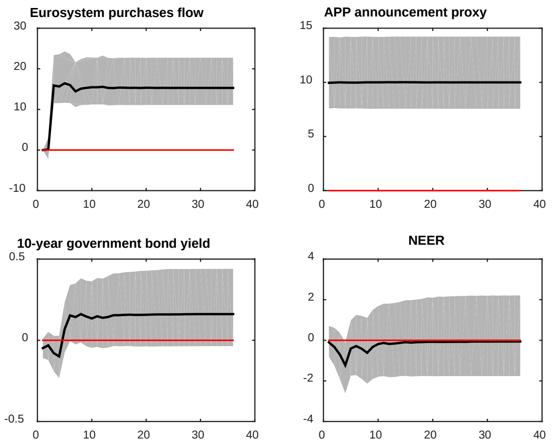




Model with the nominal effective exchange rate (NEER)

January 2015 APP announcement shock	March 2016 APP recalibration announcement shock



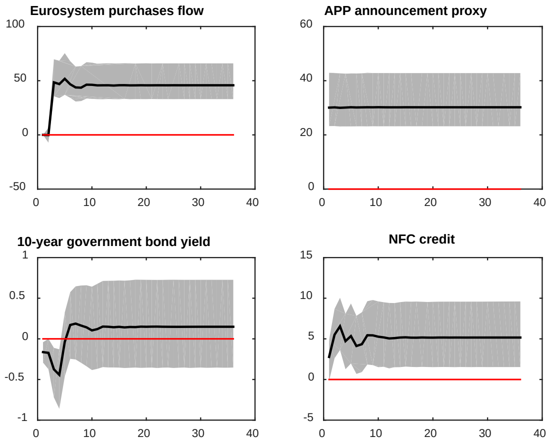


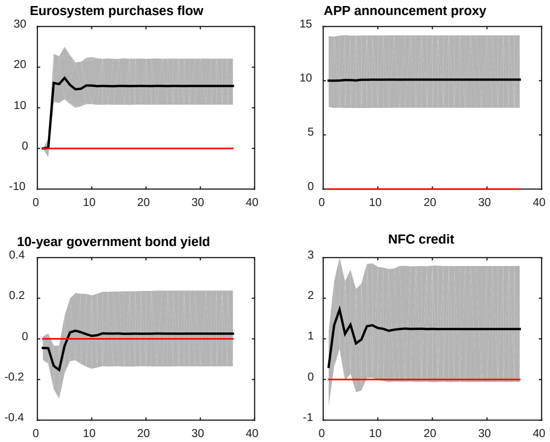
Note: Full black lines are the median impulse response functions, grey areas delimit the space between the 16th and 84th percentiles of impulse response functions. Median responses and percentiles multiplied by the estimated size of the shock in the respective month. Horizontal axes refer to number of months, while vertical axes refer to billions of euros (for Eurosystem purchase flow and APP announcement proxy) or percentages (for stock prices and exchange rates).

Chart 6 - Impulse response functions of credit market variables to the January 2015 and the March 2016 announcement shocks

Model with credit to non-financial corporations (NFCs)

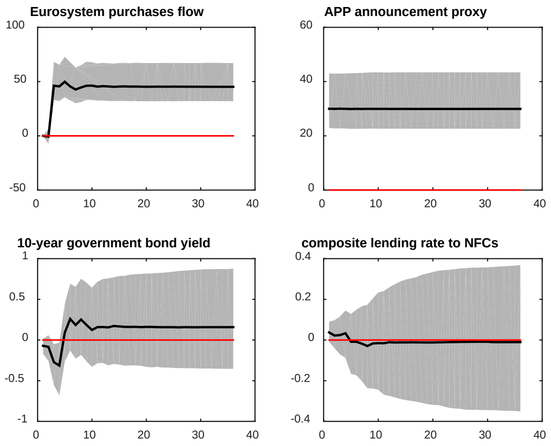
January 2015 APP announcement shock	March 2016 APP recalibration announcement shock

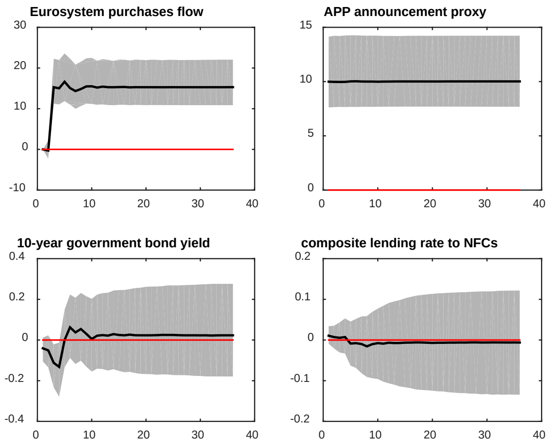




Model with the bank composite lending rate to non-financial corporations (NFCs)

January 2015 APP announcement shock	March 2016 APP recalibration announcement shock





Note: Full black lines are the median impulse response functions, grey areas delimit the space between the 16th and 84th percentiles of impulse response functions. Median responses and percentiles multiplied by the estimated size of the shock in the respective month. Horizontal axes refer to number of months, while vertical axes refer to billions of euros (for Eurosystem purchase flow and APP announcement proxy), percentage points (for lending rates) or percentages (for credit). NFC stands for non-financial corporations.