Assessing the Macroeconomic Impact of the ECB's Asset Purchase Programme in a Dynamic Nelson–Siegel Modelling Framework

Zhou, Siwen

University of Hamburg

8 February 2019

Assessing the Macroeconomic Impact of the ECB's Asset Purchase Programme in a Dynamic Nelson–Siegel Modelling Framework

Siwen Zhou

8 February 2019

Abstract

This paper examines the macroeconomic impact of the Asset Purchase Programme (APP) in the euro area on the basis of a set of macro-finance variables included in a Dynamic Nelson–Siegel modelling framework. The empirical results emphasise the role of the APP's portfolio balance channel in stimulating economic growth and inflation, both at the aggregate euro area level and at the disaggregated country-specific level. The portfolio balance channel works at the aggregated level through greater international price competitiveness, easier conditions on capital markets, and higher asset prices. Moreover, the results suggest that the initial APP announcement has increased the annual real GDP growth rates and HICP inflation in the euro area by up to 0.7% and 0.8%, respectively. At the disaggregated level, there is evidence for the stimulation of bank lending through the portfolio balance channel in the core countries. Moreover, the stronger rise in stock prices in the core countries shows that the wealth effect triggered by portfolio rebalancing is mainly concentrated in the richer member countries. A comparison of the country-specific macroeconomic impact of APP shows that while overall GDP responses are broadly comparable across countries, the peripheral countries that have implemented effective labour market reforms have benefited significantly from bond purchases in stimulating inflation. This points to the need for further labour market reforms in Italy. A reform package of labour and product market reforms can help to reduce the resulting transition costs.

Keywords: Quantitative Easing, Asset Purchase Programme, European Central Bank, Term Structure Model, Portfolio Balance Channel

1 Introduction

Quantitative easing (QE), which describes an unconventional monetary policy in which significant amounts of financial assets are purchased to lower long-term interest rates and stimulate the economy, has been the most crucial measure used by central banks in developed economies since the onset of the 2008 financial crisis, with policy rates reaching the effective lower bound. The Federal Reserve was the first central bank to implement a series of QE programmes starting in 2008. Similar programmes were launched by the Bank of England in 2009 and by the Bank of Japan in 2010. The European Central Bank (ECB) was the last of the major central banks to launch its QE programme, under the name Asset Purchase Programme (APP), in early-2015.

To date, a number of event studies have analysed the intermediate objective of the APP to lower long-term yields and interest rates in the euro area. The consensus findings of these studies show that APP has had a significant impact on the decline in long-term sovereign bond yields of up to more than 100 basis points. Countries with the highest credit risk, such as the peripheral countries, have had the most benefit (see, e.g. De Santis, 2016). This is comparable with the impact of US and UK QE programmes on corresponding long-term sovereign bond yields (see, e.g. Gagnon et al., 2011; Christensen and Rudebusch, 2012; Joyce et al., 2011), albeit the APP was launched during relatively calm financial markets. Altavilla et al. (2015) note that low uncertainty in the euro area financial markets has facilitated the spillover to non-targeted corporate bonds because their spreads have narrowed by around 20 basis points. More importantly, the majority of these studies underline the role of the APP's portfolio balance channel, as demonstrated by the rebalancing towards riskier assets (see, e.g. Koijen et al., 2016), the stimulation of bank lending (see, e.g. Albertazzi et al., 2018) and the lowering of exchange rates (see, e.g. Varghese and Zhang, 2018). While these studies acknowledge that the APP has succeeded in steering the euro area's financial markets in the desired direction, the key question for policymakers and researchers remains whether the resulting favourable financial conditions will ultimately translate into higher GDP and inflation.

The objective of this paper is to estimate the macroeconomic effect of the APP in the euro area by employing the macro-augmented term structure model of Diebold et al. (2006) based on a set of monthly frequented macro-finance variables, both at the aggregate euro area level and the disaggregated country-specific level. To the authors' best knowledge, the only empirical studies dealing with the macroeconomic impact of APP were done by Wieladek and Pascual (2016) and Gambetti and Musso (2017), who use strict sign and zero restrictions in structural VAR frameworks. Wieladek and Pascual (2016) find that real GDP and core CPI would have been 1.3% and 0.9% lower without the initial APP announcement by using a Bayesian VAR model framework. Gambetti and Musso (2017) employ a time-varying parameter VAR model with stochastic volatility and note that the APP introduction raised the annualised quarterly real GDP growth

rate by about 0.7% in the first quarter of 2015 and HICP annualised quarterly growth rate by about 0.4% in the third quarter of 2015. Both of these papers conclude that APP is transmitted through the portfolio balance channel and its subchannels, the credit easing and the exchange rate channel. In contrast, the results presented in this paper are based on less restrictive assumptions, relying only upon common variable orderings in the macro-finance VAR literature. Consequently, they can be seen as a mostly narrative-free alternative to the results of the authors mentioned above.

The main empirical results are as follows. At the aggregated level, the results suggest that the portfolio balance channel broadly operates across the euro area, transmitting easier financial conditions on capital markets and higher asset prices through greater international price competitiveness. However, there is no evidence that the portfolio balance channel can stimulate bank lending at the aggregate euro area level. Regarding the macroeconomy, the results suggest that the initial APP announcement has increased the annual real GDP growth rates and HICP inflation by up to 0.7% and 0.8%, which is broadly in line with the finding of Wieladek and Pascual (2016) and Gambetti and Musso (2017).

However, at the country-specific level, the portfolio balance channel seems to stimulate lending in the core countries. This is in line with findings by Albertazzi et al. (2018), who report that in less stressed countries where there are fewer restrictions on lending, a rebalancing towards bank lending has been more strongly observed. Moreover, the rise of stock prices is most pronounced in the core countries, while those in peripheral countries are less responsive. This provides some evidence that the wealth effect triggered by portfolio rebalancing occurs mainly in the richer core countries. However, the housing wealth effects observed at the aggregated level are insignificant at the country-specific level. This provides some evidence that the rebalancing towards housing markets is likely to take place outside the countries listed in this paper.

The macroeconomy of the core and peripheral countries also benefits differently from the APP. Regarding the real GDP, the overall responses are roughly comparable, with a slightly stronger effect in the core countries. However, responses of HICP inflation to an APP shock are more heterogeneous. The core countries Germany and France show moderate responses of inflation, which can be explained by weak wage growth and persistently high unemployment, respectively. Regarding the peripheral countries, Spain seems to have benefited the most from the APP in stimulating inflation, while Italy seems to have benefited the least in this respect. To strengthen the pass-through of output growth to prices in Italy, further structural reforms are needed to significantly loosen its labour market. Simultaneous implementation of labour and product market reforms can help to reduce transition costs, such as higher unemployment and wage cuts. Simulation results from Cacciatore et al. (2016) and Cacciatore et al. (2017) suggest that such a reform package does not cause any notably deflationary effects and exerts a stronger influence when the effective lower bound is binding. Given that the ECB has started unwinding

its APP policy and is expected to gradually raise interest rates in the foreseeable future, decisive structural reforms should be timely implemented in Italy to maximise their impact.

The rest of this paper is structured as follows. Section 2 outlines the transmission channels of the APP. Section 3 then explains the construction of the APP measure. Next, Section 4 describes the model framework. Furthermore, Section 5 presents the empirical results. Finally, Section 6 concludes this paper.

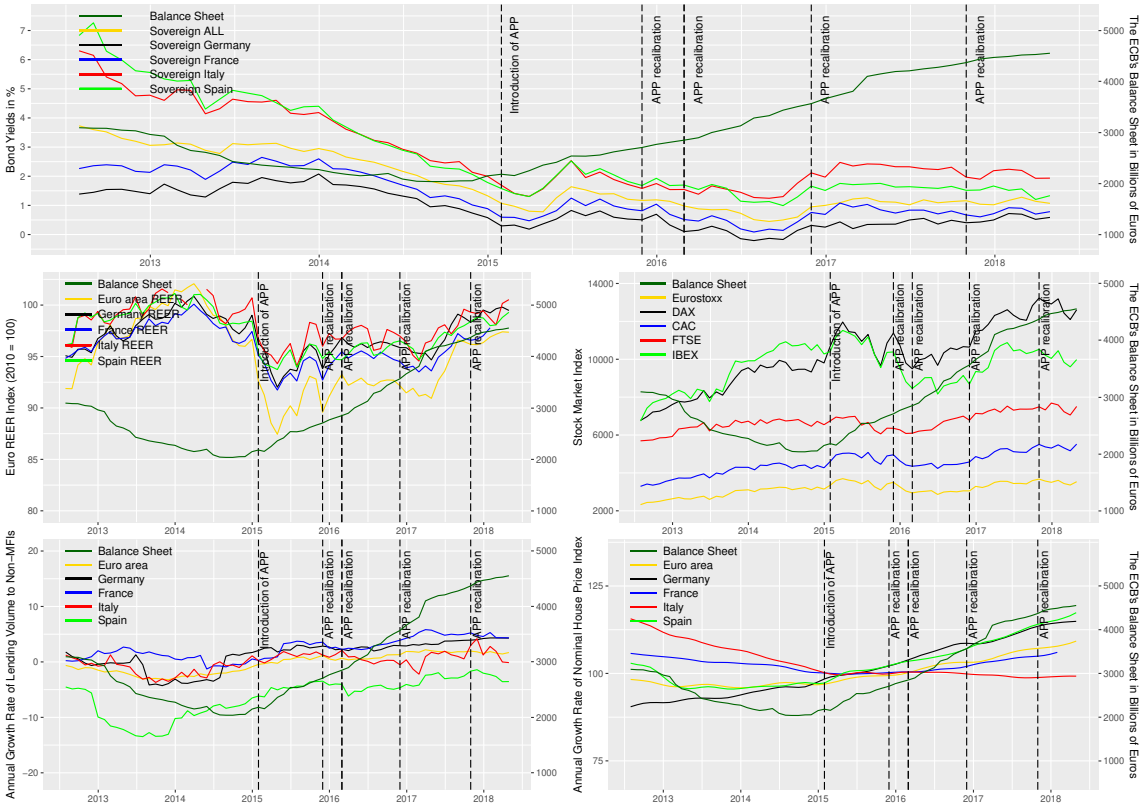
2 The Transmission Channels of the APP

The literature emphasises the role of two key transmission channels, which broadly ease financial conditions and stimulate the economy. The first channel is the signalling channel, which provides forward guidance for the future path of short-term interest rates by signalling that short-term interest rates will be held at the effective lower bound for a more extended period, or by signalling a more pessimistic assessment of the economic outlook by the central bank. Consequently, QE announcements lead to expectations of lower interest rates over the next years, directly stimulating the investment and consumption, and also pushing down all longer-term interest rates via the expectation hypothesis. The effectiveness of the signalling channel is still under debate and uncertain to date because it is challenging to observe market participants' expectations of the future interest rate path (see, e.g. Bauer and Rudebusch, 2014; Gagnon et al., 2011; Christensen and Rudebusch, 2012; Altavilla et al., 2015; Andrade et al., 2016; Urbschat and Watzka, 2017). Macro and financial economists often use money market futures or interest rate swaps to gauge these expectations. These longer-term instruments also include term premiums, which makes it difficult to evaluate the expected interest rate path beyond one year. A popular alternative is to use the term structure models to determine model-based expectations of the future interest rate path. The key challenge is to choose an appropriate model framework for the estimation. Overall, a macroeconomic assessment of the signalling channel of the APP is complicated for two reasons. First, the effective lower bound in the euro area makes the use of shadow rate-based term structure models mandatory to determine interest rate expectations, which is very time-consuming. Second, it is unlikely that the immediate adjustment of market expectations can be observed in a monthly model, such as that in this paper. Therefore, this transmission channel is not further explored in this paper.[1]

The second channel is known as the portfolio balance channel, which reduces the term premiums of long-term sovereign yields to induce investors buying riskier investments, thereby reducing a wide range of interest rates and yields, and potentially result-

[1]The intermediate goal of the APP's signalling channel to ease the financial conditions was discussed in detail in the previous paper.

Figure 1: The APP and the euro area financial markets



Source: Reuters Datastream; Reuters Eikon; European Central Bank; author's calculations

Note: The Sovereign AAA is the synthetic 10-year yields composed of all the zero-coupon yields of euro area countries provided by the ECB. Sovereign Germany to Spain are the 10-year zero-coupon bond yields of the respective countries provided by Reuters Eikon. Euro REER and country-specific REERs are the real effective exchange rates for the euro based on 42 trading partners and HICP of 2010 using the indirect quotation provided by Eurostat. The lending volume to non-MFIs is that to the private sector, which is defined as domestic non-financial enterprises and residential individuals provided by Eurostat. The nominal house price index is cubic-interpolated from the respective quarterly time series provided by the OECD.

ing in: (i) lower financing costs in the capital markets, (ii) an increase in asset prices, (iii) an increase in the supply of bank loans, and (iv) a currency depreciation to eventually bring GDP and inflation back on track. Some literature classifies the latter three mechanisms as the wealth channel, the credit easing channel, and the exchange rate channel, but they can be regarded as subchannels of the portfolio balance channel because their effects are ultimately triggered by the decline of yields through portfolio rebalancing. Many researchers and policymakers regard the portfolio balancing channel as the primary transmission channel of a QE programme (see, e.g. Gagnon et al., 2011; Joyce et al., 2011; Andrade et al., 2016). This has recently been supported by the observation that the steady increase in the Eurosystem's balance sheet through the APP is accompanied by a weaker euro, rising asset prices and lower long-term yields.

Plotting the ECB's balance sheet against financial market time series in the euro area

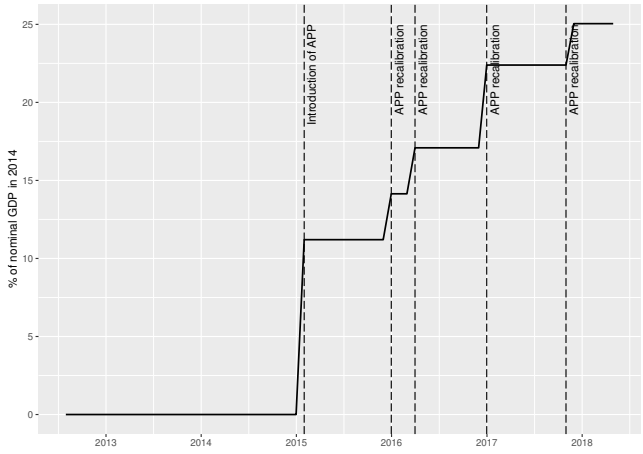
and its four largest countries, Figure 1 suggests that the first two rounds of the APP—namely, the introduction of the APP in 2015 and the expansion of the APP in 2016, in particular—have steered the financial markets in the desired direction. First, the general trend in long-term yields strongly suggests improving financing conditions on the bond market over time because the introduction of APP and its expansion has led to a broad decline in sovereign yields, pushing investors to rebalance their portfolio towards non-targeted corporate bond yields.[2] Second, following an APP announcement in spring 2015, the euro REER, and also the country-specific REERs, declined steadily and significantly. This provides some evidence for the thesis of a decline in long-term yields due to the sale of euro area bonds by foreign investors. Third, euro area stock markets have mostly shown a positive correlation with the ECB's balance sheet since the initial announcement of the APP. The highest correlation for the DAX is in Italy at 76% and the lowest for the PSI is in Spain at -6%. Fourth, the APP seems to stimulate lending in the euro area because the previously negative growth rate of loans in the euro area became consistently positive after the introduction of the APP. In addition to stimulating the lending volume of the core countries, the declining lending volume of the peripheral countries has also been stabilising. Fifth, there is a close correlation between the balance sheet of the ECB and the nominal house price indices of the OECD from 2015 onwards, which is reflected in a correlation of at least 97%. An exception is the nominal housing index for Italy, which shows a negative correlation of -77%. However, the evolution over time shows that the decline in house prices in Italy has stabilised since 2015. Overall, the average of the absolute correlations of these financial market variables to the ECB's balance sheet from 2015 onwards is 72%. This supports the transmission of the APP programme to the financial markets via the portfolio balance channel.

3 The APP Measure

A key challenge in the related literature is the quantification of monetary policy measures, which is especially true for unconventional monetary policy. This circumstance makes the construction of an APP measure particularly delicate. It is well-known that the start of the APP programme and some of its recalibrations were very much expected by the financial market. Mr Draghi and other members of the Governing Council had repeatedly hinted at the start of the APP and its reassessment depending on the expectations for inflation dynamics in the euro area. A fully anticipated monetary policy event implies that the economy would not react significantly to the related announce-

[2] Yields on euro area corporate bonds are not reported because they are not available at the country-specific level. However, euro area benchmark indices for investment and non-investment grade corporate bonds move consistently with sovereign yields, which is widely recognised by economic theory and empirical evidence.

Figure 2: Total announced purchase of the APP as a percentage of nominal GDP in 2014



Source: Reuters Datastream; European Central Bank; author's calculations

ment and implementation because it would be already priced-in. However, the ECB managed to surprise the markets, both in terms of the size and duration of the purchasing programme. According to a Reuters poll, many economists and analysts expected a monthly purchase volume of €50 billion for 12 months before the announcement of the APP in early 2015, only to be surprised by the announcement of €60 billion per month for 19 months. This amounts to a total of €1.14 trillion and is equivalent to 11.3% of the euro area nominal GDP in 2014. At the end of 2015, many expected the monthly purchase to rise to €70 billion but were disappointed that only the extension of the APP by six months was announced. However, the announcement in spring 2016 to increase the monthly pace to €80 billion once again exceeded the expectations of the financial markets by €10 billion. The final surprise was the announcement at the end of 2016 that the monthly volume would be reduced to €60 billion and extended by nine more months, while many economists polled by Reuters had expected the pace to remain unchanged. The subsequent announcements of a gradual halving of the purchasing volume to €30 billion and €15 billion and the termination of the APP programme at the end of 2018 were ultimately correctly assessed by market participants.

It may seem intuitive to use the markets' surprise reaction to these announcements and other related major events such as speeches made by Mr Draghi to quantify the APP, as is the case with many related high-frequency event studies dealing with the immediate reactions of the financial markets. However, an assessment of the portfolio balance channel within a low-frequency framework implies that not only the announcements but also the ongoing purchase of assets are crucial for reducing long-term financial conditions because they significantly determine the process of rebalancing investors' portfolios towards other assets. In this context, D'Amico and King (2013) refer to the effect of an announcement that immediately pushes down the yield due to changing expectations

about future purchases as a stock effect and also due to the effect of the ongoing purchase operation that depresses the yield over time as a flow effect. Consequently, both effects must be covered by an APP measure to be able to quantify the APP across its full range of impact. Against this background, the APP measure is defined as the total amount of announced purchases as a percentage of nominal GDP in 2014 for each announcement date and the subsequent horizon in which APP operations are conducted. This type of construction of the APP measure is in the spirit of Wieladek and Pascual (2016), and the resulting APP measure series is shown in Figure 2. Given that the bond purchases were at least partly unexpected, the surprises regarding the size and duration embedded in the announced volume may well warrant a resulting APP shock. Finally, it should be noticed that there is a significant delay between the announcement and implementation of an APP event. The APP measure follows the announcement as economic theory (such as the previously mentioned stock effect) suggests that an announcement moves the market before the actual implementation.

4 Modelling Framework

Empirical evidence suggests that the yield curve can be explained by three latent factors, which are labelled as level, slope, and curvature, each of which represents the long-, short- and intermediate-run forces behind the evolution of the yield curve. Two related term structure model classes are mainly used by macro and financial economists to draw conclusions from the yield curve: the Nelson-Siegel (NS) and arbitrage-free (AF) model classes. The NS model class is based on exponential approximating functions to model the yield curve based on a small number of parameters. The AF model class is based on the theoretical consideration of the absence of risk-free arbitrage by imposing the cross-sectional restrictions on bond yields. A trade-off between empirical performance and theoretical strength can usually be observed among these two model classes: the NS model class usually provides highly accurate estimates and forecasts but implies the existence of arbitrage possibilities. Meanwhile, the AF model class theoretically has a solid foundation but the concentration on cross-sectional fitting leads to a rather poor forecast of time series (Duffee, 2002). More recently, a new class of affine AF models, which are called arbitrage-free Nelson-Siegel (AFNS), have been developed by Christensen et al. (2011) to overcome the weaknesses of these two model classes.

However, these models provide statistical modelling of the yield curve in isolation from the development of the economy. It is widely known that there is a strong link between the economy and the yield curve. According to Dewachter and Lyrio (2006), the short-end of the yield curve represented by the slope correlates with inflation and economic activity, the intermediate yield curve proxied by the curvature reacts to changes

in the current and expected monetary policy stance, and changes at the long end of the curve measured by the level reflect the market's expectation on the long-run inflation. Therefore, incorporating macroeconomic factors should improve the predictive power in the modelling of the yield curve. Against this backdrop, a growing literature dealing with that link has emerged over the last two decades (see, e.g. Ang and Piazzesi, 2003; Hördahl et al., 2006; Diebold et al., 2006; Rudebusch and Wu, 2008; Joslin et al., 2014). One of the most prominent models was developed by Diebold et al. (2006), which incorporate macroeconomic factors into the Dynamic Nelson-Siegel model (DNS) developed by Diebold and Li (2006) and allows bidirectional macro-yield linkages. Benefiting from the superior in-sample and out-of-sample performance and parsimony of the Nelson-Siegel structure, this model (DRA) is employed in this paper to assess the impact of the APP on the economy through the portfolio balance channel.[3]

The DNS model has the following representation

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

where $y_t(\tau)$ is a zero-coupon yield of a bond at time t with residual maturity τ, the time-varying variables L_t, S_t, and C_t are the latent factors and follow a first-order vector autoregressive process, and λ is a parameter which characterises at which maturity the curvature achieves its maximum. Accordingly, the DNS model forms a state-space system with the transition equation describing the dynamics of the state variables

$$\begin{pmatrix} L_t - \mu_L \\ S_t - \mu_S \\ C_t - \mu_C \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mu_L \\ S_{t-1} - \mu_S \\ C_{t-1} - \mu_C \end{pmatrix} + \begin{pmatrix} \eta_t(L) \\ \eta_t(S) \\ \eta_t(C) \end{pmatrix}, \tag{2}$$

and the measurement equation characterising a set of N yields by the state variables

$$\begin{pmatrix} y_t(\tau_1) \\ y_t(\tau_2) \\ \vdots \\ y_t(\tau_N) \end{pmatrix} = \begin{pmatrix} 1 & \frac{1-e^{-\lambda\tau_1}}{\lambda\tau_1} & \frac{1-e^{-\lambda\tau_1}}{\lambda\tau_1} - e^{-\lambda\tau_1} \\ 1 & \frac{1-e^{-\lambda\tau_2}}{\lambda\tau_2} & \frac{1-e^{-\lambda\tau_2}}{\lambda\tau_2} - e^{-\lambda\tau_2} \\ \vdots & \vdots & \vdots \\ 1 & \frac{1-e^{-\lambda\tau_N}}{\lambda\tau_N} & \frac{1-e^{-\lambda\tau_N}}{\lambda\tau_N} - e^{-\lambda\tau_N} \end{pmatrix} \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} + \begin{pmatrix} \varepsilon_t(\tau_1) \\ \varepsilon_t(\tau_2) \\ \vdots \\ \varepsilon_t(\tau_N) \end{pmatrix}, \tag{3}$$

where a_{ij} are parameters describing the transition of the state variables, μ_L, μ_S, and μ_C are the means of the corresponding state variables, $\eta_t(L)$, $\eta_t(S)$, and $\eta_t(C)$ are transition errors, and $\varepsilon_t(\tau_1)$, $\varepsilon_t(\tau_2)$, $\ldots$, $\varepsilon_t(\tau_N)$ are measurement errors. Both errors follow a Gaussian white noise process. Also, transition and measurement errors are assumed to

[3] It is worth noting that the absence of arbitrage is not given in the model. However, Coroneo et al. (2011) conclude that the Nelson-Siegel model is compatible with the absence of arbitrage for the US market by comparing the NS factor loadings to its implied no-arbitrage counterpart estimated from an arbitrage-free affine term structure model incorporating re-sampled NS estimates.

be orthogonal to each other and the initial state, and the covariance matrix H and Q are diagonal and the lower-triangularly non-diagonal, respectively. In a nutshell, the states-space system can be rewritten in a matrix representation

$$\begin{aligned} (X_t - \mu) &= A(X_{t-1} - \mu) + \eta_t, \\ y_t &= \Lambda X_t + \varepsilon_t \\ \begin{pmatrix} \eta_t \\ \varepsilon_t \end{pmatrix} &\sim \mathrm{N}\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} Q & 0 \\ 0 & H \end{pmatrix} \right], \end{aligned} \tag{4}$$

where $X_t = (L_t, S_t, C_t)'$ is a 3×1 vector, A is a 3×3 transition matrix, μ is a 3×1 mean vector, η_t is a 3×1 measurement error, Λ is a $N \times 3$ measurement vector, and ε_t is a $N \times 1$ transition error.

In the next step, a set of macro-finance variables enter the transition equation of DNS model. For the subsequent estimation of impulse responses, a recursive identification scheme is required for the Cholesky decomposition of the covariance matrix due to the off-diagonal elements of the Q matrix, which results in an ordering of the variables. Following a standard assumption in structural VAR studies, such as Bernanke et al. (2005) and Christiano et al. (1999), macro variables are ordered first, followed by monetary policy variables and then by financial variables. The first implication of such an ordering is that the macroeconomy cannot be contemporaneously affected by monetary shocks and financial market shocks, while financial markets and monetary policy can react immediately to macro shocks. Second, positioning the monetary policy variables between macro and financial market variables ensures that financial markets can react immediately to monetary policy shocks, while monetary policy can react only with a delay to financial market shocks. Following this ordering, X_t in equation (4) is replaced by $\widetilde{X}_t = (M_t, P_t, F_t)$, where M_t, P_t, and F_t are vectors of macro, policy, and financial variables, respectively. It is worth noting that the latent factors L_t, S_t, C_t are also financial market variables and, as such, they are embedded the in the vector F_t. Finally, the derived DRA model is represented by

$$\begin{aligned} (\widetilde{X}_t - \mu) &= A(\widetilde{X}_{t-1} - \mu) + \eta_t, \\ y_t &= \Lambda \widetilde{X}_t + \varepsilon_t \\ \begin{pmatrix} \eta_t \\ \varepsilon_t \end{pmatrix} &\sim \mathrm{N}\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} Q & 0 \\ 0 & H \end{pmatrix} \right], \end{aligned} \tag{5}$$

where the dimensions of A, μ, η_t, and Q increase adequately. Λ now contains zero vectors left and right to the factor loadings because the relevant literature suggests that three latent factors are sufficient to describe the dynamics of the yield curve. In a nutshell, the transition equation is essentially a large-sized VAR containing macro-finance variables. The maximum likelihood estimation of the model parameters is based on the Kalman

filter. To find the global maximum, the log-likelihood with respect to the parameters is maximised using the simplex algorithm in the first 200 iterations to find suitable start parameters for the subsequent BFGS algorithm until convergence is achieved.[4] This change of optimisation algorithm is also necessary because standard errors cannot be determined with the simplex algorithm. The impulse response function is fairly standard in the literature and is the first derivation of the transition equation in the moving average representation with respect to orthogonalised error terms using the Cholesky decomposition. The construction of the associated confidence intervals is analytical and based on the delta method, which rearranges the first-order Taylor approximation of the response impulse function and then converges the resulting term in distribution to draw the covariance matrix. The resulting confidence intervals are thus based on asymptotic distributions, which raise questions about their validity in practice. However, given the relatively large sample size in this paper, the statistical inference drawn from these confidence intervals should be rather unproblematic. Details on the construction of confidence intervals using the delta method can be found in Lütkepohl (1990).

5 Empirical results

The focus of this paper is on the aggregated euro area and its four largest countries: Germany, France, Italy, and Spain. According to Eurostat, these four countries accounted for about 75% of the nominal GDP and population of the euro area in 2015. This implies that 75% of the ECB's capital key excluding non-euro area shareholders is financed by their national central banks. Because the capital key determines the share of the respective sovereign bonds to be purchased under the APP programme, Germany, France, Italy, and Spain are both the main beneficiaries and financiers of these purchases.[5] Lastly, Germany and France are the largest representatives of the economically stronger core countries in the euro area, while Italy and Spain are the main representatives of the less wealthy peripheral countries.

The monthly nominal sovereign zero-coupon yields of the euro area, Germany, France, Italy, and Spain contain ten maturities ranging from one to ten years.[6] The

[4] Iteration lengths 500, 1000, and 10000 were also tested for the simplex algorithm, with estimates remaining approximately the same.

[5] It should be noted that the remaining 15 euro area countries are not included in this paper. In principle, the impact of APP on these countries is no less interesting and provides a comprehensive view of the macroeconomic response of the euro area but it is very time-consuming to cover all member countries. Also, periphery countries such as Portugal, Ireland, and Greece cannot be considered because the European debt crisis led to an enormous rise in yields in these countries, which cannot be fully replicated by the macro-augmented DNS model. Therefore, a full-scale country analysis is left to future research.

[6] Unlike most term structure papers dealing with QE, three- and six-month sovereign zero-coupon bond yields are not considered in this paper because these time series are only available from 2010 onwards. A shorter sample period underestimates the persistence of bond yields, ultimately leading to biased estimation. The zero-coupon yields of the euro area are synthetic yields composed of all the zero-coupon

macroeconomy of the euro area and each country is represented by the annual real GDP growth rate (REAL GDP) and HICP inflation (INFL). The APP policy is represented by the APP measure (APP). The financial market of each country respective of the euro area is represented by the annual growth rate in the monthly real effective exchange rate of the euro using the indirect quotation (REER), the bank lending volume in millions of euro to the private sector by monetary financial institutions (LENDING), the housing price index (HOUSING), and the leading stock market index (STOCKS). Monthly data also available on a daily basis, such as sovereigns and stock market indexes, which are measured as of the end of each month because they are ordered behind the macro variables. Other financial market variables, such as housing price index, lending volume, and REER are available on a monthly basis. Lastly, based on the availability of the aforementioned macro-finance data, the time series for the euro area starts in September 2004, for Germany it starts in January 1997, for France and Spain it starts in January 1995, and for Italy it starts in December 1998. All of the series end in April 2018, except for the series for France ending in January 2018.

As stressed in the previous section, the ordering of these variables follows a standard assumption in structural VAR literature with macro variables at the beginning, monetary policy variables at the middle and financial variables at the end. Consequently, the explicit ordering is GDP, INFL, APP, L, S, C, REER, LENDING, HOUSING, and STOCKS. Latent factors are prior to other financial market variables as downward movements in the sovereign bond yields should stimulate the demand in financial markets through portfolio rebalancing. The ordering among the other financial market variables is fairly arbitrarily. However, reordering leads to very familiar results. The yields data is drawn from Reuters Eikon. All other time series are drawn from Reuters DataStream.[7]

The parameter estimates for macro-finance variables of the euro area, Germany, France, Italy, and Spain shown in Tables 1–5 can be found in the Appendix, which are employed for the construction of the subsequent impulse responses and confidence intervals. Consequently, to assess the transmission of the APP policy to the macroeconomy and the financial markets, Figures 3–7 show the impulse responses of the macro-finance variables of the euro area and its four largest countries to an APP shock of 10 percentage points, which is roughly equivalent to the total purchases announced when the APP was introduced, and the corresponding 68% confidence intervals.[8]

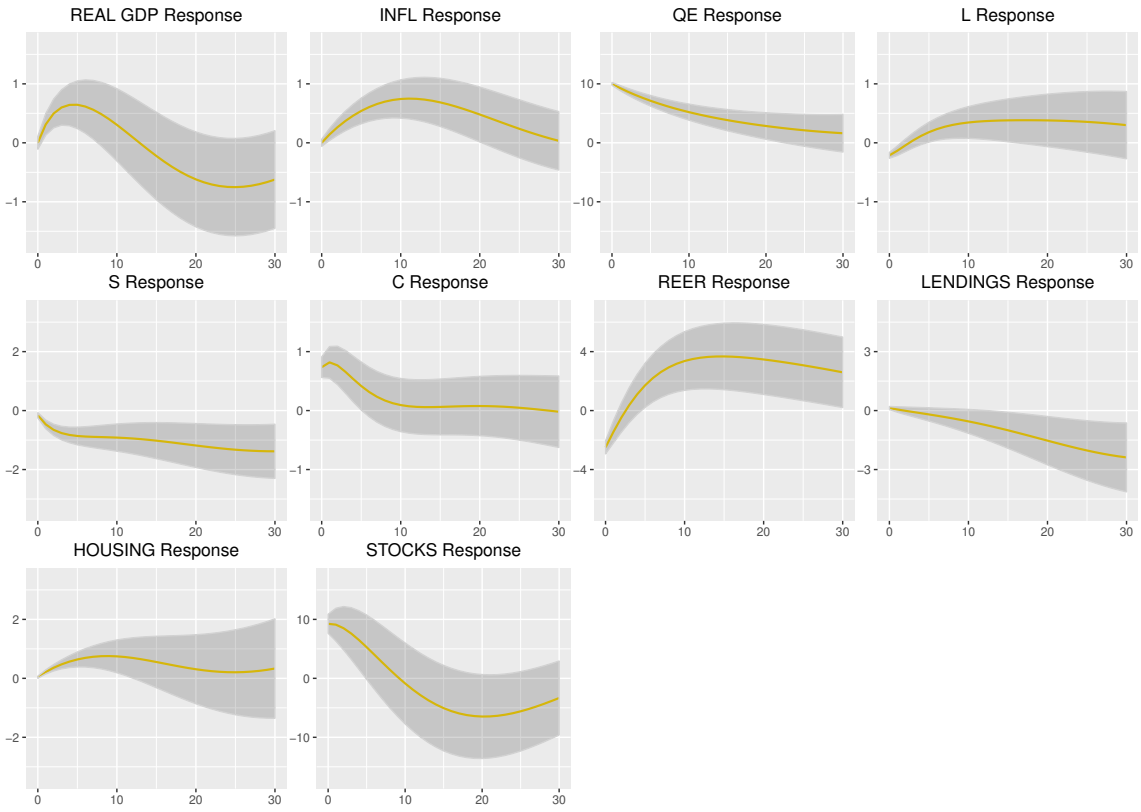
For the euro area shown in Figure 3, first, it is not surprising that the response of

yields of the euro area countries.

[7] The monthly real GDP is interpolated from quarterly real GDP with monthly industrial production using the interpolation procedure proposed by Chow and Lin (1971). HICP inflation is the annual growth rate of the corresponding HICP. The stock market index of the euro area is EuroStoxx 50, of Germany it is DAX, of France it is CAC, of Italy it is FTSE, and of Spain it is IBEX. Regarding bank lending volume to the private sector, the private sector is defined as domestic non-financial enterprises and residential individuals. The house price index is cubic-interpolated from the respective quarterly time series provided by the OECD.

[8] According to Kilian and Lütkepohl (2017), many empirical researchers prefer 68% confidence intervals over 95% confidence intervals when reporting structural VAR impulse responses.

Figure 3: Euro area impulse responses to a 10 percentage point APP shock



Note: The grey area shows 68% confidence intervals. The vertical axis is expressed in percentage points, while the horizon axis indicates the number of monthly periods since an APP shock.

the long-term latent factor level is negative, which supports the common observation that the APP pushes down long-term sovereign yields. By comparing this result with the event studies on long-term sovereign bond yields, such as Andrade et al. (2016) and Altavilla et al. (2015), the immediate response of the long-term latent factor appears to be somewhat weaker by about -21 basis points, and also short-lived because the response wears off after about three months. One explanation for this weak reaction might be that the decline is strongest on the first days of a shock and diminishes in the following weeks, leading to a smaller impact at the end of the month. Moreover, the short-lived response could be due to the decline in sovereign yields, which may prompt investors to sell sovereigns to buy other bonds and riskier assets as soon as they are able to rebalance their portfolios, exerting some upward pressure on sovereign yields.

The portfolio rebalancing mechanism implies that a decline in sovereign yields translates into a broader decline in yields and interest rates of other assets, as well as an increase in international price competitiveness over time. In this regard, the responses of financial market variables provide evidence of a broadly operating portfolio balance channel across the euro area.

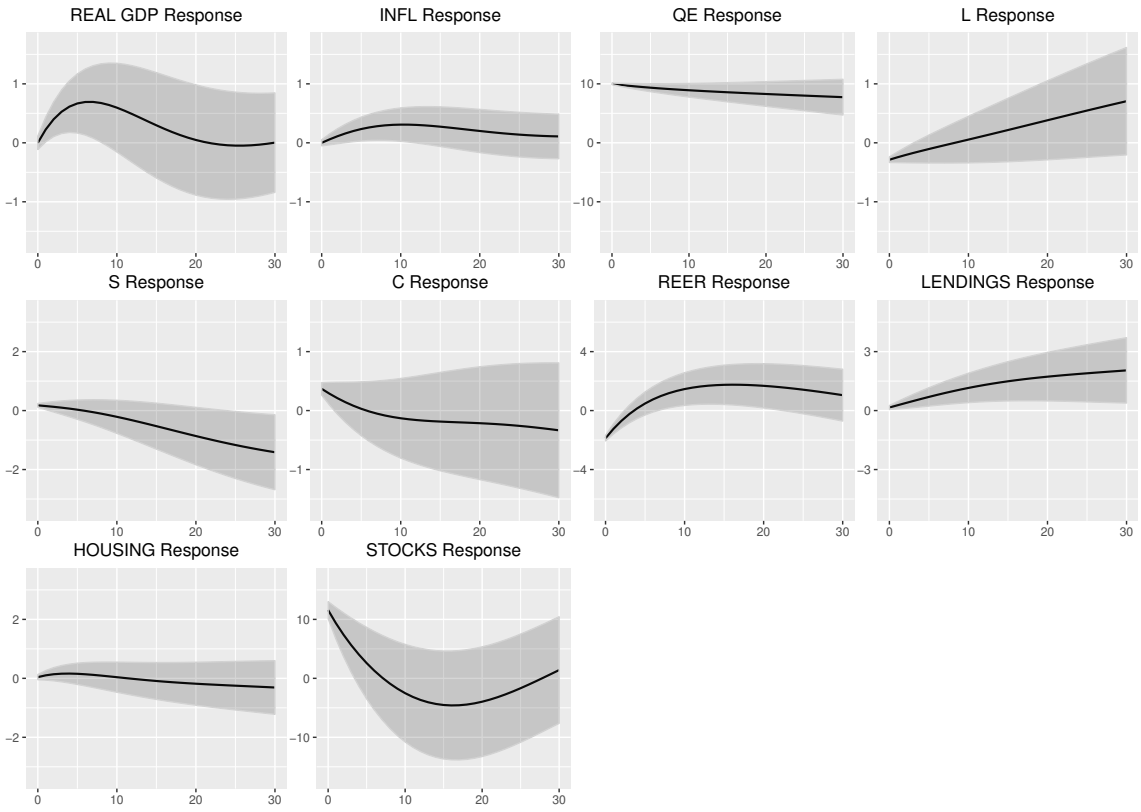
First, the results suggest that the portfolio balance channel transmits through push-

ing down financing costs in the capital markets and depreciating the domestic currency. In line with the findings of Wieladek and Pascual (2016), the REER drops by about 2.5% on impact compared to the previous year and remains significant for a month. This suggests that investors buy assets outside the euro area to achieve higher yields. It also points to a stimulation of exports through increased international price competitiveness and some upward pressure on HICP inflation. The portfolio balance channel also appears to stimulate asset prices in the euro area, as evidenced by positive reactions from stock and housing markets. Regarding the stock market, a 10 percentage point APP shock increases the annual growth rate of EuroStoxx 50 by around 10% on impact and lasts significantly for five months, generating a potential wealth effect for investors that should strengthen confidence and thus stimulate expenditure. This finding is in line that of Gambetti and Musso (2017), who state that an APP shock leads to an increase in the annualised quarterly growth of stock prices by almost 10% on impact. Also based on 68% confidence intervals, these authors find this effect significant for the next four quarters, which is more than twice as long as the one in this paper. Moreover, portfolio rebalancing seems to move investors toward the housing market. For example, the annual growth rate of the housing price index triggered by an APP shock of 10 percentage points peaks at 0.8% after nine months and is positively significant for about 13 months. Looking at the bank loans, the portfolio balancing channel does not appear to stimulate lending activities across the euro area, as shown by the adverse and partially insignificant reactions of the lending volume.

Taken together, these results suggest that the portfolio balance channel broadly operates across the euro area, transmitting through greater international price competitiveness, easier conditions on capital markets, and higher asset prices. More specifically, in addition to transmission to capital markets, two subchannels have been activated, namely: the exchange rate channel and the wealth channel. There are no signs of a functioning credit easing channel, as the portfolio balance channel does not appear to stimulate bank lending when assessing financial markets at the aggregate euro area level.

Lastly, turning to the macroeconomy, the impact of a 10 percentage point APP shock on the annual real GDP growth rate peaks at about 0.6% and wears off after 13 months. The impact of the shock on HICP inflation increases over time and reaches a peak at 0.7% after about 11 months. More specifically, given that the initially announced purchase volume is equivalent to 11.3% of the euro area nominal GDP in 2014, these macroeconomic response suggests that the initial APP announcement has increased the annual real GDP growth rates by up to 0.7% and HICP inflation by up to 0.8%. These responses are similar to the findings of Wieladek and Pascual (2016), which state that the real GDP and core HICP (HICP excluding food and energy prices) would have been lower by 1.3% and 0.9% without the initial APP announcement. These authors measure the macroeconomic impact of the initial APP announcement by the peak impulse response of the euro area real GDP and core CPI to an 11.3% APP shock corresponding to the share of the initially

Figure 4: Germany impulse responses to a 10 percentage point APP shock



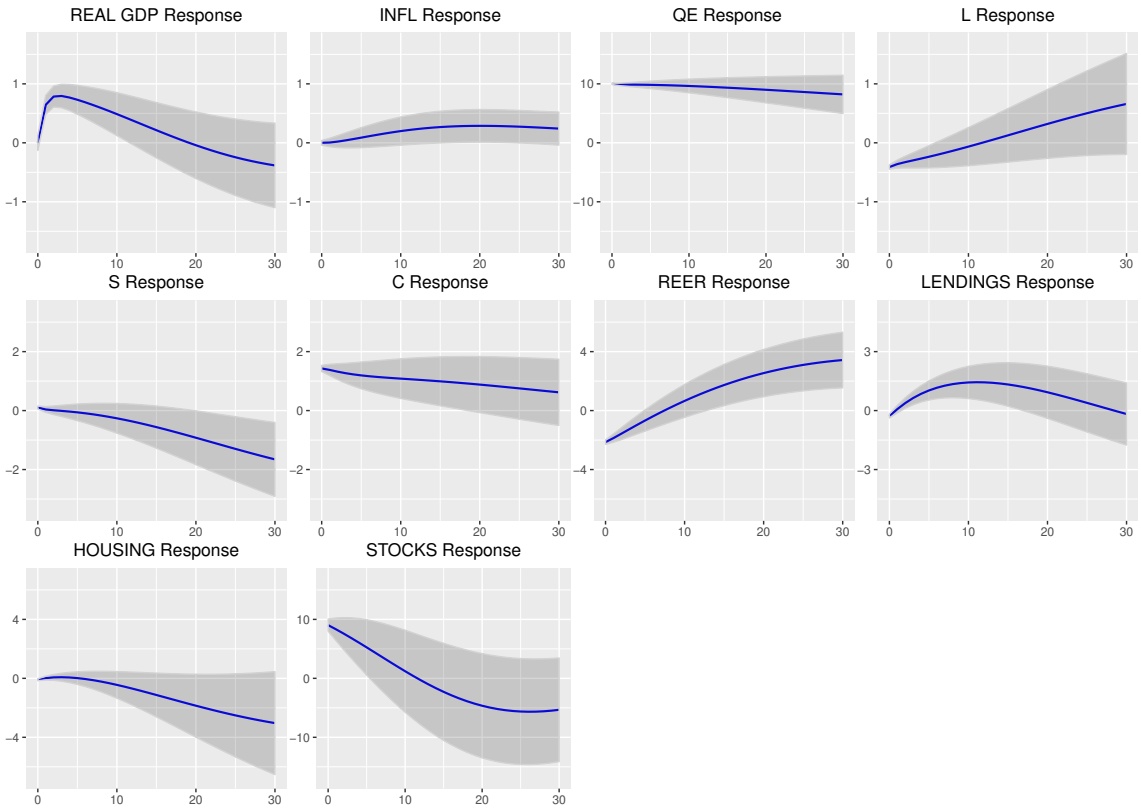
Note: The grey area shows 68% confidence intervals. The vertical axis is expressed in percentage points, while the horizon axis indicates the number of monthly periods since an APP shock.

announced total purchasing volume in the euro area's nominal GDP in 2014. It is, however, difficult to compare this result with those based on counterfactuals from Gambetti and Musso (2017) but it can be said that the estimated macroeconomic impact of the APP in this paper is also qualitatively comparable to that of these authors, according to which annualised quarterly real GDP and HICP growth rates in the euro area would have been up to 0.7% and 0.4%, respectively, lower without the initial announcement of the APP. Overall, taking into account the reactions of the financial market variables, it can be concluded that the portfolio balance channel of the APP is probably the most important force for the recovery of the macroeconomy of the euro area.

To analyse the transmission of the portfolio balance channel at the disaggregated euro area level, the responses of the financial market variables of core and peripheral countries are taken into account, and country-specific differences in the macroeconomic impact of the APP are also assessed.

The reaction of the economy of Germany and France to an APP shock are shown in Figures 4 and 5. These results suggest that the portfolio balance channel increases the international price competitiveness of these two countries through a decline in long-term yields, as represented by the falling long-term latent factor: the REER drops by about

Figure 5: France impulse responses to a 10 percentage point APP shock

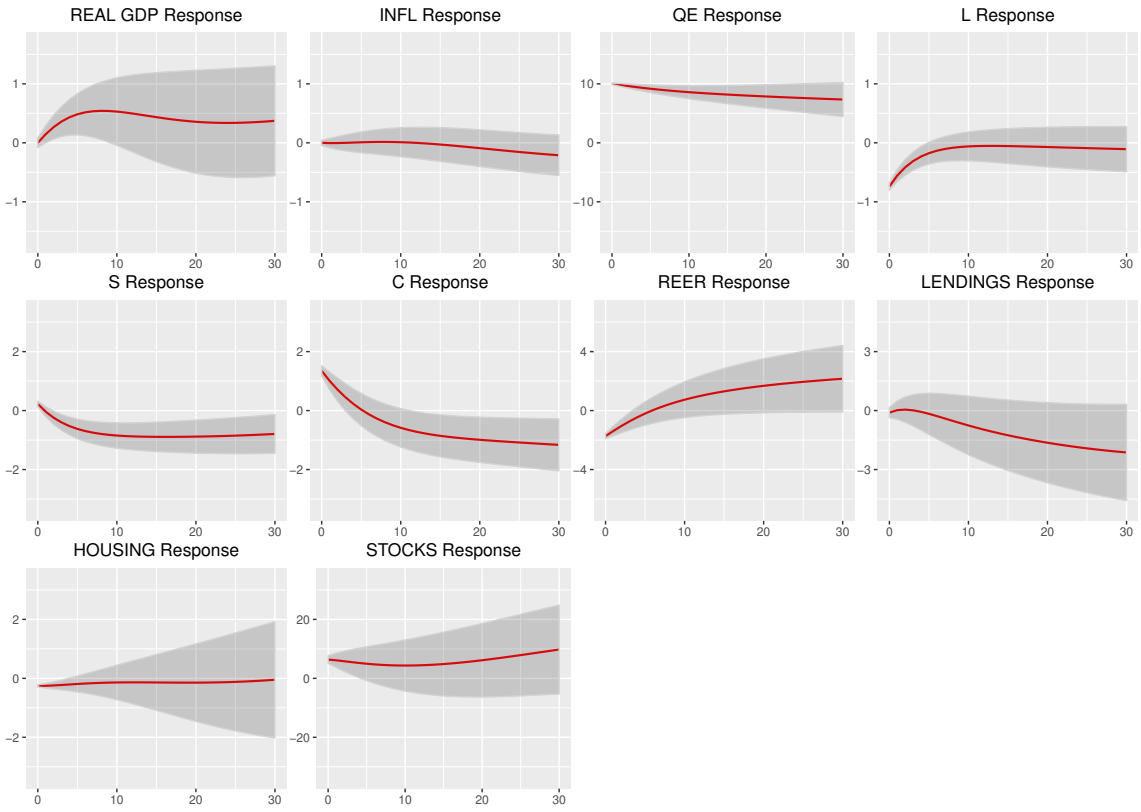


Note: The grey area shows 68% confidence intervals. The vertical axis is expressed in percentage points, while the horizon axis indicates the number of monthly periods since an APP shock.

1.9% and 2.1% on impact for Germany and France, and stays significant for two and four months, respectively. The portfolio balance channel also inflates the stock prices: an APP shock causes the corresponding stock market index to rise around 10% on impact compared to the previous year, and the response stays significantly for three months for Germany and five months for France. Moreover, there is no significant evidence that portfolio rebalancing pushes investors into German and French housing markets. Notably, the portfolio balance channel seems to boost lending in the core countries. The lending volume rises steadily after an APP shock of 10 percentage points and reaches its maximum of around 2.0% and 1.4% after 30 months and 11 months respectively compared with the previous year. Consequently, these results conclude that the portfolio balance channel works through all its subchannels in the core countries.

As regards the impact of an APP shock on the macroeconomy of Germany and France, the responses of the annual real GDP growth rates and HICP inflation of these two countries are quite comparable, with peaks of around 0.7% and 0.8% for the real GDP, and around 0.3% for HICP inflation. Responses of inflation in Germany and France are somewhat weaker compared to that of the aggregated euro area. For Germany, one possible explanation for the weak response of inflation could be the traditionally weak wage

Figure 6: Italy impulse responses to a 10 percentage point APP shock



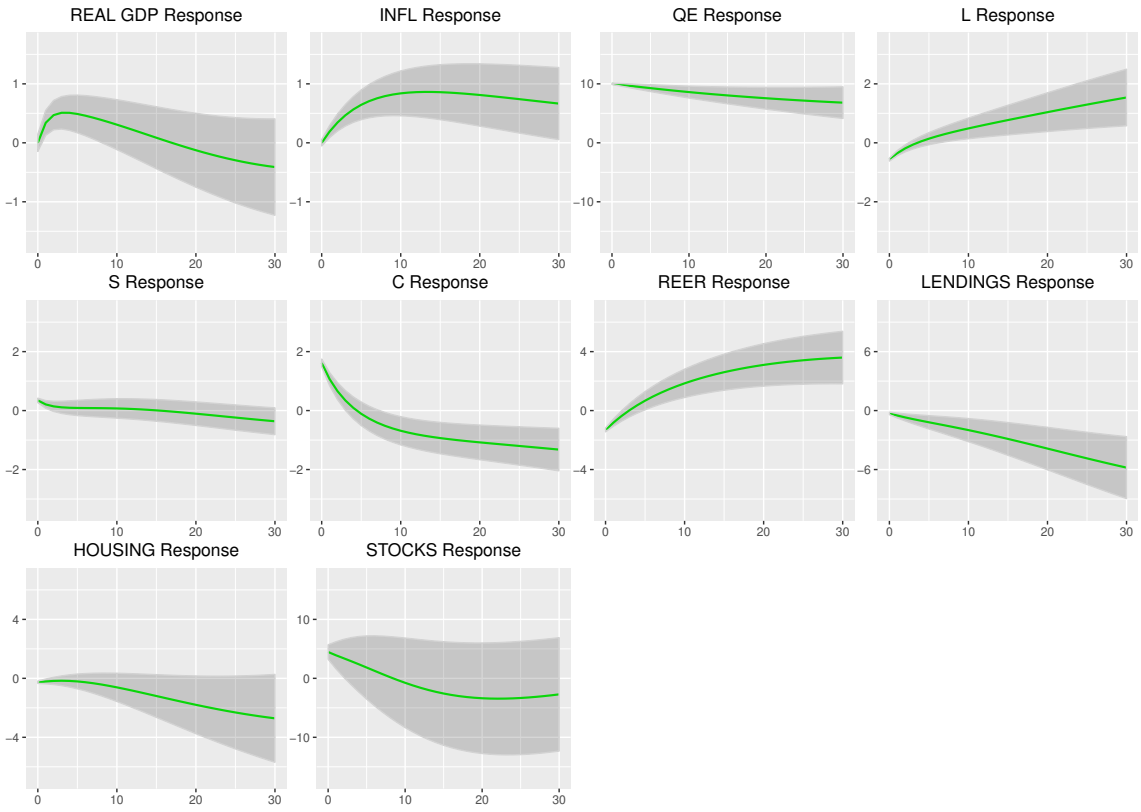
Note: The grey area shows 68% confidence intervals. The vertical axis is expressed in percentage points, while the horizon axis indicates the number of monthly periods since an APP shock.

growth compared to other countries, despite unemployment at record lows and robust economic growth in recent years.[9] Stronger wage growth could further fuel inflation, but this may be at the expense of the strategically strong international price competitiveness of German exports. For France, the main obstacle to a more pronounced inflationary response could be persistently high unemployment, which is responsible for subdued aggregate demand and thus for low price increases. A series of ambitious labour market reforms, such as wage bargaining at firm level for small companies, revision of vocational training and reform of social protection, were introduced from 2017 onwards to curb unemployment. However, it is still too early to assess their impact because success can take several years.

Figure 6 and 7 show the responses of the economies of Italy and Spain to a 10 percentage point APP shock. First, it is not surprising that the portfolio balance channel pushes down the long-term latent factor more than that in the core countries, which is consistent with empirical evidence and several event studies. Second, the response of

[9]It should be noted that Germany has recently started to catch up with other countries in terms of wage growth. During the question-and-answer session at the ECB press conference on 13 December 2018, Mr Draghi said that nominal wage growth in Germany in the third quarter of 2018 was 4.1%, which is twice as high as that in the euro area.

Figure 7: Spain impulse responses to a 10 percentage point APP shock



Note: The grey area shows 68% confidence intervals. The vertical axis is expressed in percentage points, while the horizon axis indicates the number of monthly periods since an APP shock.

REER indicates a weaker impact of the APP programme on international price competitiveness in these countries than that of the core countries: it decreases by about 1.7% and 1.3% on impact for Italy and Spain, respectively, and becomes insignificant after three and two months. It should also be noted that the response of REER does not allow us to conclude that countries with a higher share of foreign trade enjoy a higher increase of international price competitiveness because Spain ranks second after Germany in the euro area in terms of trade-to-GDP ratio in recent years. The portfolio balance channel also inflates the stock prices in Italy and Spain, albeit somewhat weaker than in the core countries: both stock market indexes increase by around 5% on impact upon an APP shock of 10 percentage points and the response stays significant for four and two months, respectively. More specifically, the response of stock prices is about half that of the core countries. This provides some evidence that investors rebalance their portfolios towards the stock markets of the core countries. Regarding the housing market, the APP initially has virtually no impact on housing prices in Italy and Spain, and then the response shortly becomes insignificant. Given that the Italian housing market has been under pressure for years, an optimistic explanation for Italy is that the APP has stabilised the housing market there and at least has prevented a further drop in prices. In contrast, housing prices

in Spain have returned to pre-crisis levels and remained bullish for years. This makes it difficult to find an adequate explanation for the reaction of the Spanish housing market to an APP shock. Overall, the wealth effect appears to be weaker in Italy and Spain. Bank lending appears to be unaffected or depressed by an APP shock in both countries: the response of the lending volume in Italy is overall insignificant, and that in Spain is consistently negative and highly persistent. This implies a decrease by around 6% compared to the previous year after 30 months. This result is highly counterintuitive because the APP aims to improve the lending situation in the euro area. The fragile banking sector in Italy, and to a lesser degree, in Spain may explain this result because it leads banks in these countries to avoid new lending. This is to some extent consistent with the findings of Albertazzi et al. (2018), which find that rebalancing has been more observed in terms of bank loans in less stressed countries where credit demand and supply constraints are less significant. Overall, these results suggest that the portfolio balance channel operates through increased international price competitiveness, better capital market conditions, and higher stock prices in Italy and Spain, while lending remains weak.

Turning to the APP's macroeconomic impact, the responses of the real GDP are quantitatively comparable in Italy and Spain, which both have peaks of 0.5% and which is slightly lower than in the core countries. However, Italy's response of HICP inflation to an APP shock remains subdued and is statistically insignificant, while that of Spain peaks of 0.9%. This naturally raises the question of why the recovery of the Italian economy triggered by the APP has failed to be translated into higher prices. A key element in the pass-through of output growth to prices is wage growth: it is well known that a pick-up in wage eventually leads to higher companies' costs and prices. Therefore, it is reasonable to take a look at the evolution of wage growth in Italy.

The primary source of low wage growth in Italy is its dual labour market, where younger workers on temporary contracts lack continuous work experience and older workers on permanent contracts enjoy a high level of employment protection regardless of their actual efficiency, which has led to an overall stagnating labour productivity in Italy over the last two decades. This, in turn, hampers wage growth because wage increases tend to follow productivity growth broadly. Italy's labour reforms of 2012 and 2014 have failed to address the problem of duality and were minimally successful. According to the OECD indicators on employment protection, the protection of permanent workers against individual and collective dismissals, and the specific requirements for collective dismissal in Italy are the highest among the countries listed in this paper. Consequently, low productivity and wage growth combined with persistent unemployment indicate a defunct pass-through of output growth to prices and thus may explain why the response of HICP inflation to APP remains subdued in Italy. Against this background, further structural reforms are essential to increase employment in Italy. Far-reaching measures, such as the reversal of sectoral collective bargaining, will temporarily lead to higher unemployment and wage cuts. However, the results of simulations carried out

by Anderson et al. (2014) using the IMF's multi-region DSGE model show that these transition costs can be minimized or even eliminated by simultaneous implementation of labour and product market reforms. In this context, product market reforms aimed at reducing the price mark-up lead to higher real wages and more jobs, thus effectively mitigating the transition costs resulting from labour market reform.[10] While there is no consensus on the optimal timing for reform implementation, a recent DSGE paper by Cacciatore et al. (2016) shows that reforms do not cause deflation. This suggests that the current effective lower bound in the euro area should not be an obstacle to a timely implementation of structural reforms. Rather, the currently extraordinary monetary accommodation offers a favourable window for advancing the structural reforms, supported by the results of the structural modelling of Cacciatore et al. (2017) that the impact of labour and product market reforms is typically stronger when the lower bound is binding. As this window narrows due to the unwinding of the APP programme and soon gradually rising interest rates, Italy should seize the opportunity in time to strengthen its labour market through such a reform package.

In contrast to Italy, Spain's labour market reform introduced in 2012 was widely considered to be successful in reducing its record level of unemployment. A critical difference of the Spanish labour market reform from the Italian one is that the wage bargaining process in Spain has been shifted from sectoral to firm level, which has led to a remarkable boost in employment. A report by OECD (2014) shows that by the second quarter of 2013, at least 25,000 new perpetual contracts per month were due to a shift towards firm-level bargaining. Compared to other euro area countries, employment in Spain rose by 2.1 million between 2013 and 2018 according to a speech by Draghi (2018), which is more than twice as much as in France and Italy each with 1 million and was only surpassed by the economic powerhouse Germany with 2.6 million. The recovery in the international price competitiveness of the Spanish economy also appears to have resulted from the labour market reform that started in 2012. European Central Bank (2015) finds a positive correlation between export performance and labour and product market reforms in Spain. Therefore, Spain's restored international price competitiveness, combined with a cheaper euro, and an increasing employment rate, have most likely reinforced the response of HICP inflation to an APP shock.

Summarising these country-specific results, while the estimates for the aggregated euro area suggest that the portfolio balance channel of the APP transmits through forcing down borrowing costs on capital markets, depreciating the domestic currency, and increasing wealth, the portfolio balance channel of the APP also works by increasing lending at the disaggregated level in the core countries. In addition, the wealth effect

[10] For example, potential areas for improvement in Italy may include vertical agreement policy, barriers to entrepreneurship in the services sector, trade and investment, and sectoral regulation in road transport, retail and mechanical engineering, which (according to the OECD indicators for product market regulation, competition law and policy, and regulation in non-manufacturing sectors) rank last among the countries listed in this paper. See https://www.oecd.org/economy/growth/indicatorsofproductmarketregulationhomepage.htm.

may be most potent in the core countries because the portfolio balance channel appears to increase stock prices in Germany and France by about twice as much as in Italy and Spain. However, the responses of housing prices are insignificant across the euro area, which suggests that the rebalancing towards housing markets that can be observed at the aggregated level is likely to take place outside these countries. The country-specific macroeconomic effect of the APP generally supports the aggregated euro area results that the APP has stimulated the economy via the portfolio balance channel, with member countries benefiting differently from the purchasing programme. Measured in terms of output, responses of the annual real GDP growth rate to an APP shock are roughly comparable in quantitative terms, with a slightly stronger effect in the core countries. However, the responses of HICP inflation to an APP shock are more heterogeneous. The core countries, Germany and France, show moderate responses of inflation. This can be explained by country-specific characteristics, such as weak wage growth and persistently high unemployment, which prevent higher inflation. In the periphery countries, Spain appears to have drawn the greatest momentum in stimulating inflation from the APP, which is most likely to be a result of effective labour market reforms, as evidenced by the encouraging employment data of recent years. In contrast, Italy appears to have benefited least from the APP in stimulating inflation, probably because of the absence of effective labour reforms, which have crippled the pass-through of output growth to prices. Italy's weak inflation response suggests that further structural reforms are essential to improve its employment situation. Given the initially sharp rise in unemployment and the wage cuts resulting from far-reaching labour market reforms, simultaneous implementation of the labour market and product market reforms can help to ease these transition costs. Recent studies suggest that this reform package is mainly free of deflationary effects and exerts a stronger impact when the lower bound is binding. Consequently, Italy should take the opportunity to carry out further structural reforms before interest rates return to normal.

6 Conclusion

In this paper, the impact of the APP in the euro area has been examined by using the macro-augmented Dynamic Nelson–Siegel model of Diebold et al. (2006) and a set of macro-finance variables. In brief, the empirical results emphasise the role of the APP's portfolio balance channel in stimulating the economy and bring the inflation back on track, both at the aggregated euro area level and at the disaggregated country-specific level. Examining the results in more detail, the estimates suggest the portfolio balance channel works at the aggregated level through greater international price competitiveness, easier conditions on capital markets, and higher asset prices. Moreover, the results

suggest that the initial APP announcement has increased the annual real GDP growth rates and HICP inflation in the euro area by up to 0.7% and 0.8%. At the disaggregated level, there is also evidence of stimulation of bank lending through the portfolio balance channel in the core countries. More specifically, the rise of stock prices is most pronounced in the core countries, providing some evidence that the wealth effect triggered by portfolio rebalancing occurs mainly in the richer member countries. Overall, core and peripheral countries have benefited to about the same extent from these purchases in stimulating output, while the response of HICP inflation to an APP shock is more heterogeneous. The core countries, Germany and France, show moderate responses of inflation, which can be explained by weak wage growth and persistently high unemployment, respectively. In the peripheral countries, Spain seems to have benefited the most from the APP in stimulating inflation, while Italy seems to have benefited the least. A possible source of the opposite inflation response in these two countries appears to be the divergent success of the labour market reforms that they have implemented. In fact, further structural reforms are needed to significantly loosen the labour market in Italy and thus ultimately strengthen the pass-through of output growth to prices. A reform package consisting of labour and product market reforms can help to reduce transition costs. Recent studies suggest that this reform package does not cause deflationary effects and exerts a stronger influence at a binding lower bound. Therefore, Italy should implement these structural reforms before interest rates return to normal again.

Given that the APP programme completed its purchase in December 2018, it is of interest for further studies to ask whether the future inflation path for the euro area will remain sustainable. The continuing favourable financial conditions, strong economic momentum, and the ECB's commitment to open-ended reinvestments in maturing purchased bonds support the assessment of a firm reanchoring of inflation. However, this assessment is contrasted with increasing global protectionism, which is expected to reduce export demand and increase uncertainty about the business environment in the euro area, which will potentially lead to a general tightening of financial conditions and a decline in consumption and investment. None of this will contribute to promoting growth and employment, eventually risking slowing down inflation again. Whether the deterioration in global trade relations will ultimately have a decisive impact on the recovery of the euro area economy remains to be seen.

References

Albertazzi, U., Becker, B., and Boucinha, M. (2018). Portfolio rebalancing and the transmission of large-scale asset programmes: evidence from the euro area. Working Paper Series 2125, European Central Bank.

Altavilla, C., Carboni, G., and Motto, R. (2015). Asset purchase programmes and financial markets: lessons from the euro area. ECB Working Paper No. 1864.

Anderson, D., Barkbu, B., Lusinyan, L., and Muir, D. (2014). Assessing the Gains from Structural Reforms for Jobs and Growth. In Schindler, M., Berger, H., Bakker, B. B., and Spilimbergo, A., editors, *Jobs and Growth: Supporting the European Recovery*, chapter 7, pages 151–172. IMF, Washington.

Andrade, P., Breckenfelder, J., Fiore, F. D., Karadi, P., and Tristani, O. (2016). The ECB's asset purchase programme: an early assessment. ECB Working Paper No. 1956.

Ang, A. and Piazzesi, M. (2003). A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables. *Journal of Monetary Economics*, 50(4): 745–787.

Bauer, M. and Rudebusch, G. (2014). The Signaling Channel for Federal Reserve Bond Purchases. *International Journal of Central Banking*, 10(3): 233–289.

Bernanke, B. S., Boivin, J., and Eliasz, P. (2005). Measuring the effects of monetary policy: A factor-augmented vector autoregressive (FAVAR) approach. *The Quarterly Journal of Economics*, 120(1): 387–422.

Cacciatore, M., Duval, R., Fiori, G., and Ghironi, F. (2016). Short-term pain for long-term gain: Market deregulation and monetary policy in small open economies. *Journal of International Money and Finance*, 68: 358–385.

Cacciatore, M., Duval, R., Fiori, G., and Ghironi, F. (2017). Market Reforms at the Zero Lower Bound. Working Paper No. 23960, National Bureau of Economic Research.

Chow, G. C. and Lin, A.-l. (1971). Best linear unbiased interpolation, distribution, and extrapolation of time series by related series. *The review of Economics and Statistics*, 53(4): 372–375.

Christensen, J. H., Diebold, F. X., and Rudebusch, G. D. (2011). The affine arbitrage-free class of Nelson–Siegel term structure models. *Journal of Econometrics*, 164(1): 4–20.

Christensen, J. H. and Rudebusch, G. D. (2012). The response of interest rates to US and UK quantitative easing. *The Economic Journal*, 122(564): F385–F414.

Christiano, L. J., Eichenbaum, M., and Evans, C. L. (1999). Monetary policy shocks: What have we learned and to what end? *Handbook of Macroeconomics*, 1: 65–148.

Coroneo, L., Nyholm, K., and Vidova-Koleva, R. (2011). How arbitrage-free is the Nelson–Siegel model? *Journal of Empirical Finance*, 18(3): 393–407.

D'Amico, S. and King, T. B. (2013). Flow and stock effects of large-scale treasury purchases: Evidence on the importance of local supply. *Journal of Financial Economics*, 108(2): 425–448.

De Santis, R. A. (2016). Impact of the Asset Purchase Programme on Euro Area Government Bond Yields Using Market News. ECB Working Paper No. 1939, European Central Bank.

Dewachter, H. and Lyrio, M. (2006). Macro factors and the term structure of interest rates. *Journal of Money, Credit and Banking*, 18(1): 119–140.

Diebold, F. X. and Li, C. (2006). Forecasting the term structure of government bond yields. *Journal of Econometrics*, 130(2): 337–364.

Diebold, F. X., Rudebusch, G. D., and Aruoba, S. B. (2006). The macroeconomy and the yield curve: A dynamic latent factor approach. *Journal of Econometrics*, 131(1-2): 309–338.

Draghi, M. (2018). The outlook for the euro area economy. Speech by Mario Draghi, President of the ECB, Frankfurt European Banking Congress, Frankfurt am Main, 16 November 2018.

Duffee, G. R. (2002). Term premia and interest rate forecasts in affine models. *The Journal of Finance*, 57(1): 405–443.

European Central Bank (2015). Progress with structural reforms across the euro area and their possible impacts. *ECB Economic Bulletin*, 2: 59–71.

Gagnon, J., Raskin, M., Remache, J., Sack, B., et al. (2011). The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases. *International Journal of Central Banking*, 7(1): 3–43.

Gambetti, L. and Musso, A. (2017). The Macroeconomic Impact of the ECB's Expanded Asset Purchase Programme (APP). ECB Working Paper No. 2075, European Central Bank.

Hördahl, P., Tristani, O., and Vestin, D. (2006). A joint econometric model of macroeconomic and term-structure dynamics. *Journal of Econometrics*, 131(1-2): 405–444.

Joslin, S., Priebsch, M., and Singleton, K. J. (2014). Risk premiums in dynamic term structure models with unspanned macro risks. *The Journal of Finance*, 69(3): 1197–1233.

Joyce, M., Lasaosa, A., Stevens, I., Tong, M., et al. (2011). The Financial Market Impact of Quantitative Easing in the United Kingdom. *International Journal of Central Banking*, 7(3): 113–161.

Kilian, L. and Lütkepohl, H. (2017). *Structural vector autoregressive analysis*. Cambridge University Press.

Koijen, R. S., Koulischer, F., Nguyen, B., and Yogo, M. (2016). Quantitative Easing in the Euro Area: The Dynamics of Risk Exposures and the Impact on Asset Prices. Working paper No. 601, Banque de France.

Lütkepohl, H. (1990). Asymptotic Distributions of Impulse Response Functions and Forecast Error Variance Decompositions of Vector Autoregressive Models. *The Review of Economics and Statistics*, 72(1): 116–25.

OECD (2014). *The 2012 labour market reform in Spain: A preliminary assessment*. OECD Publishing.

Rudebusch, G. D. and Wu, T. (2008). A macro-finance model of the term structure, monetary policy and the economy. *The Economic Journal*, 118(530): 906–926.

Urbschat, F. and Watzka, S. (2017). Quantitative Easing in the Euro Area - An Event Study Approach. CESifo Working Paper No. 6709, CESifo Group Munich.

Varghese, R. and Zhang, Y. S. (2018). A New Wave of ECBs Unconventional Monetary

Policies: Domestic Impact and Spillovers. IMF Working Papers 18/11, International Monetary Fund.

Wieladek, T. and Pascual, A. I. G. (2016). The European Central Bank's QE: A New Hope. CESifo Working Paper No. 5946, Munich.