Cross-country Effects of the European Central Bank Asset Purchase Programs

Sarah Zoi
Federal Reserve Board

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Abstract

I study the effects of the ECB Asset Purchase Program (APP) and Panedemic Asset Purchase Program (PEPP) announcements on the four largest European economies and on the aggregate of the Euro Area. Using a proxy variable of surprises for the size of announced purchases, I identify the APP shock in a TVP-SV-FAVAR using zero and sign restrictions. I document substantial heterogeneity in the responses of European countries to the policy: i) Southern European economies experienced the largest decrease in government bond yields but the smallest decrease in the cost of credit to households and non-financial corporations; ii) cross-country differences in the responses of interest rates reduced significantly over time and with subsequent packages of the policy; iii) the response of inflation has been stronger in Germany and Spain than in Italy and France; iv) responses of real activity and labor market show mixing signals across countries. Results on the aggregate of the Euro Area show that most of the channels of transmission of Quantitative Easing were active at the European level.

Keywords: Asset Purchase Program, Heterogeneity, Factor Augmented Vector Autoregressive Model, Stochastic Volatitlity, Time Varying Parameters
JEL: E52, E58, E44, F36, G15

1 Introduction

In the aftermath of the 2008 financial crisis, slow economic growth and declining inflation expectations induced many Central Banks to dramatically ease their policy stances bringing their reference rates to record lows and adopting unconventional measures. The European Central Bank reduced its policy rate to negative levels in June 2014 and announced its Expanded Asset Purchase Program (EAPP or APP), in January 2015 with the precise objective of driving inflation back to its long term target. After the first announcement, asset purchases by the ECB were adjusted several times, suspended at the end of 2018, launched again in 2019 and significantly expanded in 2020 through the Pandemic Emergency Purchase Program (PEPP). Under the two programs the ECB bought a total amount of around 4.9 trillion euros, around 40% of the Euro Area GDP for 2021.

To understand how the set of policies adopted under the APP and the PEPP have transmitted to the economy is of first order importance for policy makers. On the one hand, and given the still high degree of institutional and economic heterogeneity among European economies, answering this question requires an assessment of the effects of these policies on both the aggregate of the Euro Area and across countries. On the other hand, the institutional and economic framework in which different packages of purchases were adopted changed considerably from the first announcement of the APP, challenging the assessment of the overall policy under a unified econometric framework. This work provides new empirical evidence on the effects of the Asset Purchase Programs (both the APP and the PEPP) on the aggregate of the Euro Area and the four largest European economies and test whether these effects have been significantly different across countries.

In the framework of a time-varying parameters Factor Augmented Vector Autoregressive model with stochastic volatility (TVP-SV-FAVAR), I identify the APP shock building on the methodology proposed by Gambetti and Musso (2020). Specifically, I extend their analysis on the effects of the APP announcements on the aggregate of the Euro Area in two important dimensions. First, I employ a large scale multi-country setup to explore possible heterogeneities in the transmission of the APP among European countries. Second, I extend and adapt their identification strategy to evaluate the effects of the more recent PEPP. In particular, the PEPP differs from the previous Program in key institutional aspects on which their identification strategy was relying (e.g. the absence of a delay between the announcement and the implementation of purchases).

Even more importantly, the PEPP was a timely response to the economic and financial consequences related to the spread of the COVID19. Its first announcement, in March 2020, coincided with the implementation of lockdown policies and with a generalized shutdown in economic activity. These characteristics make the previous identification of the APP insufficient to isolate the effect of the policy from the effect of the pandemic. To overcome these issues, I exploit the positive effect of purchases on the Stock Market as predicted by the *Portfolio Re-balancing Channel* and documented by most event studies to identify the PEPP shock and the Covid shock separately using sign restrictions.

In order to study to which extent the responses of European countries to the policy have been significantly different, I compute their impulse response functions in deviations from Germany. I find that Asset Purchase Programs generated quite heterogeneous responses among European countries. First, they significantly contributed to reduce government credit cost for all countries, but with stronger effects for Spain and Italy. Nonetheless, lower refinancing costs for the government in these countries didn't translate in a proportional decrease in lending rates to households and non financial corporations. This piece of evidence points in the direction of existing financial frictions that may have impaired the transmission mechanisms of the policy in Southern European economies. Second, heterogeneity in cross-country responses of interest rates have been declining since the first announcement of the policy and almost disappeared for the last re-balancing. This suggests a positive contribution of the policy in reducing cross-country heterogeneities in the financial sector. Third, inflation dynamics in response to the shock have been quite subdued in Italy and France with respect to Germany and Spain, suggesting certain weakness of the *Inflation Anchoring Channel* in the two countries. Fourth, there is scarce and mixed evidence of short term effects on real activity, both at aggregate and at country-level. At the aggregate Euro Area level most of the channels of transmissions of Quantitative Easing policies were active, with strong evidence of exchange rate depreciation and anchoring of inflation expectations strengthening over time and with later re-balancing of the policy.

A large empirical literature quantified the effects of Quantitative Easing policies for the US and the UK and tested the effectiveness of different channels through which asset purchases transmit to the economy (see Borio and Zabai (2018) for a review). In the case of the Euro Area, most of the existing studies of the APP or PEPP focus on the short term effects on financial markets relying on event studies using high frequency data, see for example Altavilla et al. (2015), De Santis (2016), Eser et al. (2019) and Moessner and de Haan (2022). Only few papers assess the macroeconomic effects of the Asset Purchase Program. Wieladek and Garcia Pascual (2016)) use four alternative identification schemes based on zero and sign restrictions imposed according to the transmission channels of Quantitative Easing policies as suggested by the theory. Gambetti and Musso (2020) derive a proxy of unexpected amount of announced monthly purchases to identify the APP shock using institutional characteristics of the Program. As mentioned above, I share with these authors the same strategy to identify shocks related to the APP and I build on that to extend the analysis to the PEPP. Another set of works focused on the effects of unconventional monetary policies preceding the APP or the PEPP (TLTROs, OMTs, SMP) (see for example Altavilla et al. (2016), Markmann and Zietz (2017) and Giannone et al. (2012)) or on the broader class of all them. In general, these works find significant reductions in interest rates, especially at the long end of the yield curve, and positive effects on real activity and prices. However, these preceding policies differ substantially from the Asset Purchase Programs in that they didn't implied an expansion of the Central Bank balancesheet.

With respect to this literature the contribution of this paper is twofold. First, it provides new empirical evidence on the effects of the Quantitative Easing policies on the aggregate of the Euro Area and tests potential heterogeneities in its transmission mechanisms across European countries. Second, to the best of my knowledge, it is the first paper in quantifying the macroeconomic effects of the PEPP.

Finally, this works relates to the literature that measures the effect of monetary policy shocks on European countries using Dynamic Factor Models (DFM). Barigozzi et al. (2014) study pre and post-euro differences in transmission mechanisms of monetary policy across countries, Corsetti *et al.* (2018), study heterogeneities in the transmission of monetary policy in the Euro Area, using an high frequency identification of monetary shocks. Similarly to what I find, all these authors document substantial heterogeneity in the transmission mechanisms of monetary policy shocks.

The remind of the paper is organized as follows. Section 2 reviews the timeline of ECB announcements related to the APP and the PEPP and the main characteristics of these policies and their channels of transmission. Section 3 describes the statistical model, the estimation strategy and the dataset. Section 4 discusses the results. Section 6 concludes.

2 The ECB Asset Purchase Programs (APP and PEPP)

The European Central Bank announced its first Quantitative Easing, the Expanded Asset Purchase Program (EAPP or APP), in January 2015 with the specific objective of contrasting a scenario of declining inflation expectations and and increasing risk of inflation remaining too low for a prolonged period of time[1]With the first announcement of the APP, the 22 of January 2015, the ECB delivered an initial envelope of 1.14 tn euros, approximately 11% of the annualized European GDP of the fourth quarter of 2014, to be carried out in 60 billions euros of monthly purchases during 18 months starting from March 2015.

The initial package was re-adjusted in five subsequent re-calibrations. In December 2015 the the program was extended for 6 additional months, until March 2017, adding other 360 billions euros to the total Program. In March 2016, the Governing Council decided to increase both the size and the duration of the program. The APP was extended to non-financial corporate bonds (CSPP) starting from June 2016 and monthly purchases were increased to 80 billions per month starting from April. In December 2016, monthly purchases were reduced to 60 billions euros but the program was extended for 9 additional months, until December 2017, adding 540 billions euros more to the Program. In October 2017, the ECB announced a reduction in monthly purchases to 30 billions starting from January 2018 and an extension of APP until September 2018, or beyond if necessary. In June 2018 it was announced that monthly purchases would have run until December 2018 and were reduced to 15 billions starting from October 2018. In December 2018, when the APP was terminated the ECB announced that it would continue to fully reinvest the principal payments from maturing securities until after the first raise in policy rates, or beyond. By that time the ECB had bought 2.6 trillions euros in assets, around 25% of the Euro Area GDP.

In September 2019, motivated by a still very weak inflation and growth outlook, the

[1]The APP was not the first Unconventional Monetary Policy adopted by the ECB. Starting from July 2009, the ECB had adopted other assets purchase measures targeting different types of securities: two covered bonds purchase programs, CBPP1 and CBPP2, of 60 and 40 billions euros respectively; three Targeted Long Term Refinancing Operations (TLTRO) with the aim of providing credit to financing institutions at attractive conditions; a public sector securities purchase program, the SMP(Securities Market Purchases), that reached 210 billions euros at its peak but differed substantially from the APP in that it didn't imply an expansion of ECB balance sheet and was implemented through a *sterilization* mechanism instead.

Governing Council restarted the purchases under the APP by delivering an open-ended program[2] to be implemented at a monthly pace of 20 billions starting from November 2019.

In March 2020, the European economy experienced a severe and sudden contraction due to the lock-down measures adopted by most governments to contrast the spread of coronavirus. Most production activities were suspended, stock markets slumped and Southern European countries started experiencing an increasing financial pressure with soaring spreads over German bonds. Against this disruptive outlook, on the 12th of March the ECB undertook a package of measures including more favorable condition of financing through TLTROs and additional LTROs. Purchases under the APP were increased by additional 120 billions until the end of the year. Few days later, on the 18th of March, due to a worsening economic outlook and increasing volatility volatility in financial markets, the Governing Council approved the Pandemic Emergency Program (PEPP), a package of 750 billions of purchases to be conducted flexibly at least until the end of the year. Two main features differentiate the March 2020 announcements from previous announcements regarding the APP. First, the ECB didn't commit to a specific amount of target monthly purchases for the PEPP and the additional package of 120 billions for the APP like it used to since 2015. Second, announced purchases started immediately in March to allow the ECB to intervene promptly to contrast the effects of the pandemic. As I will discuss more in detail later on, these differences are relevant for the identification strategy.
The PEPP was expanded in two subsequent meetings, in June 2020, when 600 billions were added to the overall package, and in December 2020, when additional 500 billions of purchases were announced, bringing the total size of the program to 1.85 trillions.

In December 2021 the Governing Council re-calibrated the pace of monthly purchases under the APP to 40 bln in the second quarter of 2022, 30 billion in the third quarter of 2022 and 20 billion per month from October 2022 onwards. Figure(1) reports the composition of monthly purchases under the APP and the PEPP and summarizes the main announcements and re-balancing of the two policies.

[2] Purchases were expected to be protracted *"as long as necessary to reinforce the accommodative impact of policy rates"*, and to end shortly before the ECB started raising interest rates

2.1 The Asset Purchase Program Announcement Proxy

As explained by Gambetti and Musso (2020), one of the main challenges in identify the Asset Purchase Program shock lies in isolating the unexpected component of the total purchases from the expected one. Indeed, most of the times, the market correctly anticipated when the ECB was going to announce a Purchase Program or to re-calibrate it. However, expectations on the size of the policy have not always be in line with the announced amounts. For example, the launch of the EAPP in January 2015 was greatly anticipated by financial markets. From June 2014, and in expectation of the first announcement, interest started compressing and the euro largely depreciated against all major currencies[3]. However, the size of the announced Program doubled market expectations.

In order to identify policy surprises related to the Purchase Programs, consider the announced size of the policy at time t, a_t, as the sum of two components

$$a_t = E_t(a_t) + \psi_t \tag{1}$$

where $E_t(a_t)$ is a measure of market expectations on the size of the policy and ψ_t is the surprise component of the announcement.

The interest here is in retrieving the unexpected component ψ_t. Gambetti and Musso (2020) take a_t to be the amount of monthly purchases announced and $E_t(a_t)$ to be the median response of the Bloomberg survey of financial analysts.

With respect to their methodology, I make two important changes. First, I take a_t to be the total amount of announced purchases (monthly purchases multiplied by the number of months during which the ECB commits to target the specified amount, if announced). This is dictated by the fact that APP surprises can be related not only to changes in the amount of monthly purchases, but also to extensions in the duration of the Programs. Moreover, starting from the launch of the PEPP in March 2020, the ECB stopped targeting a specified amount of monthly purchases and announced exclusively the size of the overall package allowing for certain flexibility on the distribution of the purchases over time. Second, to construct $E_{t-1}(a_t)$ I use the information about market expectations as reported in articles issued by the Financial Times from one week before the announcement to few hours before. For example, on January the 21st, 2015, the day

[3]Yields on italian BTPs and Spanish Bonos decreased by 130 and 140 bps respectively between June 2014 and January 2015 and the exchange rate against the dollar depreciated 14.5% during the same period.

before the first announcement on APP, in the article "ECB eyes 50 billions monthly bond purchases" the FT was writing "*Monthly purchases of 50 billions would be at the higher end of market expectations...[...]The ECB is expected to buy 550 billions of government debt, analysts polled by Bloomberg earlier this week said.*"According to this information, $E_t(a_t)$ takes value 550 billions euros in January 2015. However, the policy announcement on the 22nd of January 2015 was for an overall package of purchases of 1.1 tn euros to be carried out at the pace of 60 billions euros per month for 18 months. Therefore, the value of a_t is 1.1 tn and the size of the unexpected component ψ_t in January 2015 is of 550 billions.

Following this methodology I identify four surprises related to policy announcements on Asset Purchase Programs from January 2015 to June 2020.

$$\begin{aligned}
\psi_t &= 550 \quad billions \quad if \quad t = 2015:01 \\
\psi_t &= 120 \quad billions \quad if \quad t = 2016:03 \\
\psi_t &= 570 \quad billions \quad if \quad t = 2020:03 \\
\psi_t &= 100 \quad billions \quad if \quad t = 2020:06
\end{aligned}$$

For all $t \neq 2015:01, 2016:03, 2020:03, 2020:06$, $\psi_t = 0$. The first two realizations for the surprise variable coincide in time with the proxy derived by Gambetti and Musso (2020) for the APP ended in December 2018, while the last two relates to the first announcement and the first re-calibration of the PEPP. A detailed motivation for the values of the surprise variable is reported in the Appendix. Figure (2) graphs the proxy ψ_t.

2.2 Channels of Transmission of APP

By now there is quite a large consensus on the channels through which an Asset Purchase program transmits to the financial system and, to a larger extent, to real economy and prices.

According to the *Portfolio Re-balancing Channel* (Vayanos and Vila (2021)), in the presence of investors with preferences for specific maturities, the increase in Central Bank demand for bonds reduces bonds duration and term premia and translates in a decline in government yields with two main effects. First, lower yields will induce investors to

change their portfolio composition increasing their appetite for different type of assets (i.e. equity). The increase in demand for equity pushes its price upward and boost equity financing for corporations. Second, through the banking sector, lower government credit costs translates in lower financing costs for households and corporations and, henceforth, in an increase in the stock of loans.
The increase in liquidity in the banking system due to Central Bank's purchases is predicted to have two main effects. First, it depreciates the exchange rates boosting external demand for domestic goods and exports (*Exchange Rate Channel*). Second, high supply of liquidity pushes the lending sector to increase loans to households and corporations by loosening credit conditions (*Credit Channel*)[4].
Through the *Signaling Channel* (Eggertsson and Woodford (2003)) and B. Bernanke et al. (2004) the Central Bank signals its commitment to keep its expansionary stance for a prolonged period of time, inducing a downward revision in expectations around future policy rates. The *Inflation Anchoring Channel* can be included in the broader category of *Signaling*. According to this channel, the liquidity injection through CB purchases lifts inflation expectations and translates in a positive effect on future inflation.
According to the *Reduction in Uncertainty* (Weale and Wieladek (2016)), communication about future path of monetary policy and the setting of a precise schedule for asset purchases tend to reduce uncertainty around future financial developments and pushes market volatility down.

3 Model, Identification and Estimation

In order to study the effects of ECB Asset Purchase Program on Euro Area and on the four largest economies I identify an Asset Purchase Shock in the framework of a Time Varying Parameters Structural Factor Augmented Vector Autoregressive Model with Stochastic Volatility (TVP-SV-SFAVAR).
Few facts justify the choice of the model. First, a factor model allows to conveniently handle a large number of time series and recover their responses to a unique, common shock using one single model. This makes the framework a suitable tool to study the effects of a monetary policy shock in the Euro Area on a panel of member countries. Second, since January 2015, both the composition of purchases by asset class and the

[4]Notice that this last effect can be also seen as a second order effect of the *Portfolio Rebalancing Channel*.

way new packages were announced and implemented have changed substantially, leaving room to potential time-variation in the effects of the policy. Third, the Asset Purchase Program shock is observed infrequently and this is reflected in the surprise variable ψ used for identification. Given that this variable takes value zero most of the time and displays large peaks corresponding to few announcements, assuming homosckedasticity of the error components can seriously impair inference. The shape of ψ represents an additional motivation to allow for time variation in coefficients and in volatilities.

3.1 Model

Let x_t be a vector of n variables observed at time t, f_t a vector of r latent common components (with $r < n$) and y_t a vector of m variables relevant for identification of one or more structural shocks. The TVP-SV-FAVAR model is described by the following equations:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} I & 0 \\ \Lambda_y & \Lambda_f \end{bmatrix} \begin{bmatrix} y_t \\ f_t \end{bmatrix} + \begin{bmatrix} 0 \\ \eta_t \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} y_t \\ f_t \end{bmatrix} = c_t + B_t(L) \begin{bmatrix} y_{t-1} \\ f_{t-1} \end{bmatrix} + \nu_t \tag{3}$$

$$\eta_t \sim N(0,\, \Sigma_\eta)$$

$$\nu_t \sim N(0, \Sigma_{\nu,t})$$

where Λ_y, Λ_y and $B_t(L)$ are matrices of coefficients, c_t is a vector of constants and η_t is vector of n idiosyncratic components. Matrix Σ_η is assumed to be diagonal, while $\Sigma_{\nu,t}$ is a full matrix of covariances at time t.

Equation (2) describes a factor shrinkage given by the projection of x_t on the lower dimensional space spanned by f_t. Equation (3) describes a VAR model for factors, f_t, and policy variables, y_t.

To close the model, I assume that the dynamics of time-varying coefficients is well described by a random walk process:

$$\beta_t = \beta_{t-1} + \epsilon_t \tag{4}$$

where $\beta_t = [c_t, vec(B_t), vec(B_{t-1}), ...vec(B_{t-p+1})]$ and $\epsilon_t \sim N(0, Q)$, with Q diagonal.

Finally, for the stochastic volatility, consider the triangular reduction $A_t \Sigma_{\nu,t} A_t' = \Omega_t \, \Omega_t'$, with A_t being lower triangular with principal diagonal of numeraries and Ω_t being a diagonal matrix of standard deviations of residuals. Let α_t to be the vector of non-zero elements of A_t and σ_t the vector of diagonal elements of Ω_t. Standard assumptions, as in Primiceri (2005), imply α_t and σ_t to follow:

$$\alpha_{\mathbf{t}} = \alpha_{\mathbf{t-1}} + \zeta_t \tag{5}$$

$$log\sigma_{\mathbf{t}} = log\sigma_{\mathbf{t-1}} + \omega_t \tag{6}$$

where $\begin{bmatrix} \omega_t \\ \zeta_t \end{bmatrix} \sim N(0, V)$ with V block diagonal: $\begin{bmatrix} W & 0 \\ 0 & \Psi \end{bmatrix}$ and Ψ being block diagonal. Like in a standard VAR, identification of structural shocks is obtained by orthogonal rotations of residuals ν_t:

$$\begin{bmatrix} y_t \\ f_t \end{bmatrix} = D_t(L)^{-1} R u_t \tag{7}$$

where $u_t = (S_t H')^{-1} \nu_t$ is a vector of structural shocks and $R = S_t H$ with S_t is a lower triangular matrix such that $S_t S_t' = \Sigma_{\nu,t}$, and H is an orthogonal matrix. Identification implies choosing matrix H so to impose economic meaningful restrictions on $D_t(L)$.
The representation of x_t and y_t in terms of structural shocks can be obtained by substituting 7 in 2:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} I & 0 \\ \Lambda_y & \Lambda_f \end{bmatrix} D(L)^{-1} R u_t + \begin{bmatrix} 0 \\ \eta_t \end{bmatrix}$$

where $x_t = [\Lambda_y \quad \Lambda_f] \, D(L)^{-1} R$ are the impulse responses of x_t to the structural shocks u_t.
Estimation of the model is fully bayesian. I first draw the factors f_t using the Carter-Khon algorithm. Conditional on those, I draw coefficients Λ_f, Λ_y and the coefficients of Σ_η. Conditional on factors and non-time-varying coefficients, I draw β_t and, finally, the stochastic volatilities. The details of the MCMC adopted for estimation and prior choices are reported in the Appendix.

3.2 Identification

Gambetti and Musso (2020) use ψ_t as external instrument to proxy the unexpected component of asset purchases and use a parsimonious identification scheme based on institutional features of the announcements and on the statistical properties of ψ. Let z_t be the amount of ECB monthly purchases for monetary policy purposes. They identify the APP shock by ordering z_t first and ψ_t second followed by other variable of interest and apply a recursive identification scheme[5]. This identification implies that a shock in ψ_t, an unexpected news on the size of the APP, affects ECB purchases for monetary policy purposes, z_t, only with some delay, but not contemporaneously.

Given the institutional characteristics of the announcements related to the first two surprises (January 2015 and March 2016), this parsimonious identification strategy is sufficient to identify the Purchase Program shock for these events. Indeed, all the policy announcements between January 2015 and December 2019 were providing a target for monthly purchases and a precise date in which the ECB would have started to buy the specified amount (usually one or two months after the announcement). However, when extending the analysis to the PEPP, there are at least three reasons why a simple recursive scheme becomes insufficient to identify the shock. First, announcements around the PEPP were not specifying a target for monthly purchases but only the overall amount that the Central Bank was committing to buy during the following months. Second, purchases under the PEPP were starting few days after the announcement making the non-contemporaneous response of ECB assets to the shock an implausible assumption. Third, the announcement of the PEPP in March 2020 coincides with the implementation of lockdown policies in most countries. Indeed, it is reasonable to think that both the PEPP and its subsequent re-calibration were mostly policy responses to the economic and financial consequences of the pandemic. In this case, identification through a simple recursive scheme would not be sufficient to disentangle the PEPP shock from the Covid shock.

To overcome these issues, I separately identify the PEPP shocks and the Covid shock in March and June 2020 by exploiting variations in the European Stock Market Index (Euro Stoxx 50) and using sign restrictions. Indeed, one of the most immediate and disruptive effects of Covid in March 2020 was the huge slump in Stock Market Indices all over the World [6]. Against this background, the PEPP was positively received by financial markets by stimulating a significant increase in the Euro Stoxx 50 and a compression of the spreads of Southern European bonds[7] immediately after the announcement. Mo-

[5]They take S_t in equation 7to be the lower triangular matrix given by the choleski factorization of $\Sigma_{nu,t}$, and H to be the identity.

[6]As mentioned by Ms Schnabel, Member of ECB Executive Board, during the press conference following the meeting of March 18th: *"The EURO STOXX 50 was down by nearly 40% since 20 February 2020, when the coronavirus epidemic had started to turn into a global pandemic."*

[7]By means of an event study Aguilar et al. (2020) estimate the effects of the first announcement of the PEPP on the Euro Stoxx 50 to be around +3% and to be milder, around 0.5%, for the the first re-calibration. The Italian BTP- German Bund spread decreased by more than 80bps

tivated by this evidence of opposing effects of these two shocks on the Stock Market, I consider the following system of variables:

$$\begin{bmatrix} z_t \\ \psi_t \\ s_t \\ f_t \end{bmatrix}$$

where s_t is the European Stock Price Index (Euro Stoxx 50) and f_t are the common components of model (2) but may also be interpreted as a vector of observable which can be affected contemporaneously by an Asset Purchase Program shock or by a Covid shock.

According to the above discussion, I identify a Covid shock in March and June 2020 as a shock with a positive impact effect on ψ_t and z_t and a negative impact effect on the Stock Market s_t. At the same time a PEPP shock is identified has having a positive impact effect on ψ_t, z_t and s_t.

Few remarks are in order. First, the identification of an asset purchase policy shock through a positive sign restriction on the Stock Market Index is not only justified by previous empirical evidence (see De Santis (2016), Aguilar et al. (2020)) but it is also suggested by the *Portfolio Re-balancing Channel* and has been previously adopted by Wieladek and Garcia Pascual (2016). Second, the identification of the Covid shock is based on the fact that the PEPP announcement have been a policy response to the economic and financial consequences generated by the pandemic. This announcement, in turn, exceeded market expectations resulting in a PEPP shock.

Table (1) summarizes the identification of the shocks for the four events in which variable ψ takes positive values. For the first two events, identification is recursive as in Gambetti and Musso (2020).

3.3 Data and factors selection

The database includes 195 monthly series for the aggregate of the Euro Area (19 countries) and for the four largest European economies (Germany, France, Italy and Spain[8]). All the variables have been properly transformed to insure stationarity. A detailed

after the first announcement and around 25bps after the re-claibration.

[8]Being the first four countries by *capital key*, these countries were the ones benefitting the most from the asset purchases

	January 2015	March 2016	March 2020		June 2020	
	APP	APP	Covid	PEPP	Covid	PEPP
z_t	0	0	+	+	+	+
ψ_t			+	+	+	+
s_t			-	+	-	+

Table 1: Summary of identification of the APP, PEPP and Covid shocks - Contemporaneous effects.

description of the data and the transformations applied is provided in the Appendix. Figure(15) reports the percentage of variance explained as a function of factors for this dataset. The number of common components is fixed to $r = 5$. The Bai and Ng (2002) IC_1 and IC_2 criteria for the number of static factors suggest 7 and 5 factors, respectively. Five factors explain around 51% of the total variance of the dataset. The explained variance of the variables of interest (the ones for which I report impulse responses) is 54% in total. Three variables are used for identification of the APP shock, the surprise variable constructed according to the methodology reported in Section 2.1, the ECB monthly purchases for monetary policy purposes and the Euro Stoxx 50. The model is estimated using data from July 2009 to December 2021. For the TVP-SV-FAVAR, I choose three lags. Results are based on a MCMC with 60000 draws of which the first 30000 are discarded.

4 Results

Figure ((3)) reports the posterior mean and the 18th and 84th percentiles of the posterior distribution of the IRFs of the three variables used for identification for each of the four announcements. Impulse responses are resized by the size of the corresponding estimated shock. As imposed by the recursive identification scheme, in January 2015 and March 2016, the amount of monthly ECB purchases for monetary policy purposes doesn't react contemporaneously to the shock. After the first period, monthly purchases increase and, in the third period, reach approximately 20 billions in January 2015 and 20 billions in March 2016, suggesting that indeed a significant proportion of the increase in asset purchases corresponding to the first two announcements was not expected. The response of the Eurostoxx is positive, between 0.5% and 1.5%, for both episodes, as predicted by the *Portfolio Re-balancing Channel.* Notice that the response of the stock market was

not imposed with identification which, for the first two shocks, is recursive. This piece of evidence provides additional support to the the identification strategy used for the PEPP shocks in March and June 2020. Turning to the effects of the announcements of the PEPP, the shock increases the surprise variable by a bit less than 500 billions, a bit less than the value of ψ for that period (570 billions). Interestingly, the covid shock is also generating a significantly large response of the announcement surprise variable ψ, which increases by around 100 billions in March and 100 in June. Even if this is partly imposed through identification, the non-negligible size of the response suggests that more than one fifth of the surprise in the announcement is explained by covid. The responses of purchases for monetary policy purposes are positive and reach 40 billions and 100 billions after 3 month in March and June respectively. The response of Stock Prices is also positive, even if much smaller than for the previous APP shocks.
The estimated stochastic volatility of residuals (Figure(5)) gives evidence of considerable time variations in the variance of the residuals of three variables used in identification. In particular the four peaks in the residuals of ψ corresponding to the four events discussed suggest that they represent true surprises which could not be forecasted given available information.

4.1 Macroeconomic effects on the Euro Area

Figures (6) to (8) reports the responses of variables related to the aggregate of the Euro Area. IRFs point to the evidence that the majority of the channels through which QE policies typically transmit to the economy were active. One exception is June 2020, when most of these channels seem to have reduced significantly their relevance.
The *Reduction in Volatility Channel* was particularly strong in March 2020, when the shock reduced Stock Market volatility by 10% approximately. The responses of the EA composite 10-year yield show a strong reduction in government credit costs, especially for the first APP announcement in January 2015 and the first PEPP announcement in March 2020. However, both interest rates on loans to non-financial corporations and households do not show significant responses. On the other hand, the stock of loans to non-financial corporations was boosted by the shock, pointing towards a positive effect through the *Credit Easing Channel*. Results suggest a quite strong *Inflation Anchoring Channel*, through positive effects of the shock on inflation and both short and long-term inflation expectations. These effects have been milder for the first announcement and have been gaining relevance in March 2016 and March 2020 until being almost

insignificant in June 2020.
The *Exchange Rate Channel* have been also active through a depreciation of the Nominal Effective Exchange Rate (NEER) of the euro.
Effects on real activity are controversial. While most of the time the shock had no effect on Industrial Production, it contributed to a substantial decrease in unemployment until 2016. A positive effect on New Industrial Orders and Retail Sales is also estimated for January 2015 but vanished for the subsequent events. Finally, the policy has shown a positive effect on Consumer Confidence starting from the first announcement. This effect was especially strong in March 2020, signalling a positive assessment from the consumers' side of the ECB response to covid.

4.2 Heterogeneities in the transmission of APP

Figures (9) to (14) reports the responses of the four largest European economies to the shock. Responses for Italy, Spain and France are expressed in deviations to the response of Germany. Results reveal a substantial degree of heterogeneity in the transmission of the shock.

First, the policy reduced government credit cost in Southern European economies substantially more than in Germany. The difference in the reduction of 10-year bond yields is estimated to be between 10 and 50 basis points for Italy and Spain and between 5 and 10 for France. Similar effects are documented in event studies by Altavilla et al. (2015), De Santis (2016) and Moessner and de Haan (2022). Differences in responses were larger for the first announcements of APP and PEPP in January 2015 and March 2020, less pronounced in March 2016 and disappeared for the last announcement in June 2020. This suggests that what contributed the most to reduce risk premia and close government spreads among Southern European and German yields was the initial commitment of the Central Bank rather than subsequent extensions of the purchases.

Second, the larger decline of government yields for Italy and Spain didn't find a symmetric correspondence in the decrease of borrowing costs for non-financial corporations and households. Figures (10) and (11) show a larger decline in German rates on retail lending with respect to other economies, pointing to a stronger effect of the *Credit Easing Channel* in this country. A plausible explanation to this cross-country asymmetry may be found in the presence of frictions in the lending market in Italy and Spain as argued by Elbourne et al. (n.d.), Burriel and Galesi (2018) and Boeckx et al. (2014). Analysing the effects of a broader class of unconventional monetary policies, these authors find larger positive responses of real activity for North European economies and notice that these effects correlate positively with the level of capitalization of the banking sector. A poorer financial health of Southern European banks with respect to Germany and the need of strengthening their asset positions by retaining liquidity could explain the higher costs of retail lending in these countries.

Third, heterogeneities in the responses of interest rates to the policy have significantly reduced over time and almost disappeared in June 2020. This is true for both government and retail credit costs, suggesting that the forementioned financial frictions in the Southern European banking sector may have disappeared over time due to the prolonged injection of liquidity provided by the Purchase Programs.

Fourth, the response of inflation displays a large degree of heterogeneity across countries. The strongest positive effects are for Germany and Spain while Italy and France shows negative inflation dynamics in response to the shock. These maybe due, in turn, to subdued inflation expectations in these countries as opposed to Spain and Germany which deserve a further assessment. It is worth to notice that, differently from interest rates, these differences in responses persist over time and reduced only slightly with respect to the first event in January 2015.

Fifth, as for the aggregate of the Euro Area, responses of indicators of real activity and labor market are also quite heterogeneous and do not point toward a clear conclusion. The countries benefiting the most in terms of a reduction in unemployment were Italy and France followed by Germany. However, the response of Retail Sales, an indicator of industrial activity and demand was significantly stronger for Germany.

5 Conclusions

This paper investigates the effects of announcements on the APP and the PEPP of the European Central Bank, on the aggregate of the Euro Area and on the panel of the four largest European economies. In the framework of a TVP-SV-FAVAR, I identify the APP and PEPP shocks using a proxy of the unexpected size of the announcements and extend the identification strategy in Gambetti and Musso (2020) to include the PEPP. I evaluate cross-country differences in the effects of the Asset Purchase Program shock by computing the responses in deviations from Germany. I find that Asset Purchase Programs generated quite heterogeneous responses among European countries. In particular, they significantly contributed to reduce government credit cost for all countries, but with stronger effects for Spain and Italy. Nonetheless, lower refinancing costs for the government in these countries didn't translate in a proportional decrease in lending rates to households and non financial corporations. This piece of evidence points in the direction of existing financial frictions that may have impaired the *Credit Easing Channel* in Southern European economies. Inflation dynamics in response to the shock have been quite subdued in Italy and France with respect to Germany and Spain, suggesting certain weakness of the *Inflation Anchoring Channel* in the two countries. For the aggregate of the Euro Area, almost all the traditional channels of transmission of QE policies were active. The policy had positive effects in decreasing governments bond yields and increased retail credit, boosted equity markets, reduced market volatility, depreciated the exchange rate, and stimulated inflation and inflation expectations. However, there is scarce and mixing evidence of short term effects on real activity, both at aggregate and at country-level. Finally, heterogeneity in cross-country responses of interest rates have been declining since the first announcement of the policy while some of the aggregate channels of transmission have been strengthening. This possibly suggests a positive contribution of the policy in reducing cross-country heterogeneities in the financial sector.

Figures

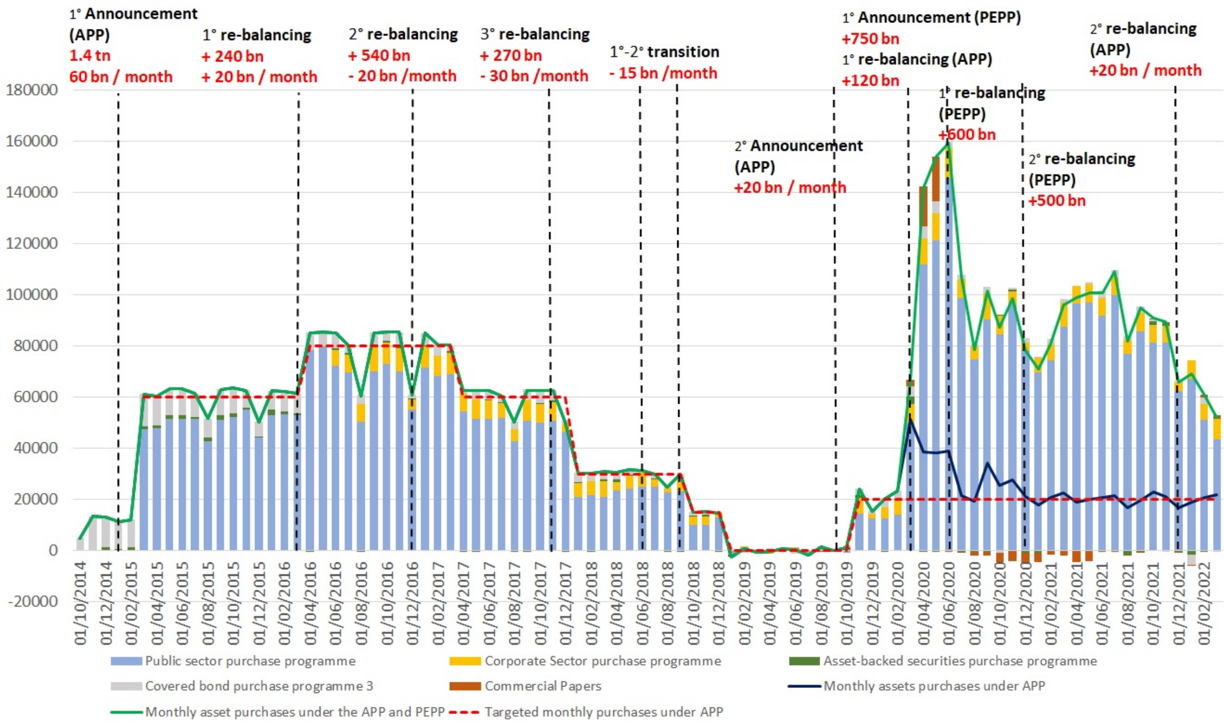

Figure 1: ECB Asset Purchases under the APP. Author's computation on ECB data. Data on composition of monthly purchase after March 2020 are bi-monthly. Monthly data are imputed based on monthly amounts of overall purchases

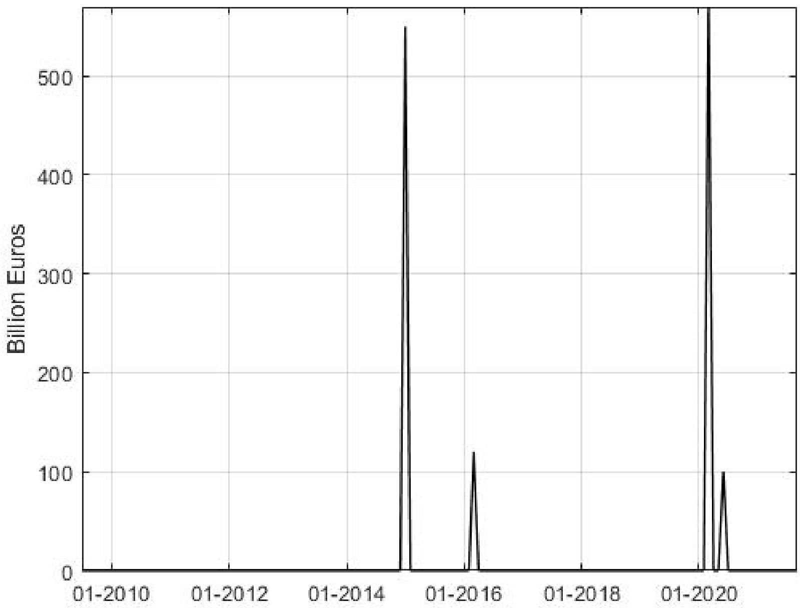

Figure 2: Unexpected component, ψ_t, of announcements related to the APP and the PEPP.

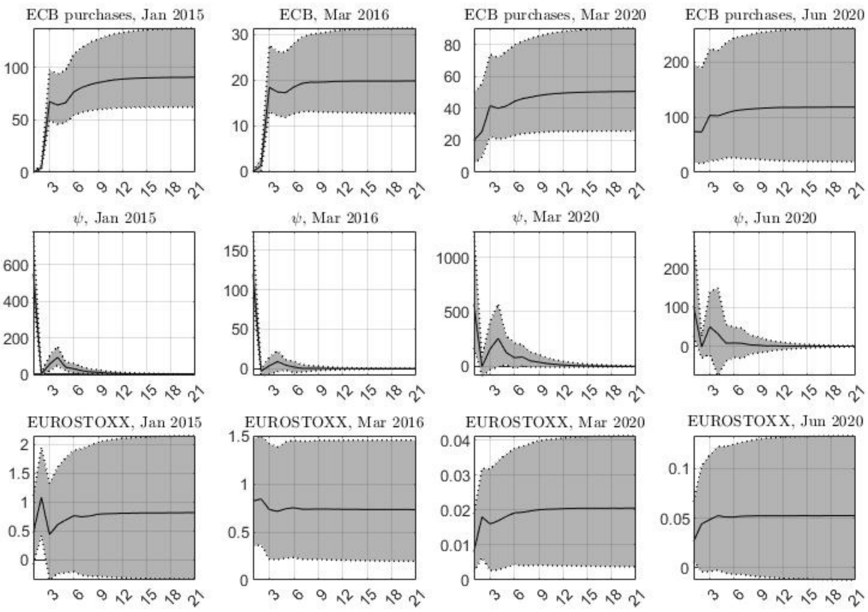

Figure 3: IRFs to an APP shock - Mean and 16-84 percentiles of posterior distribution.

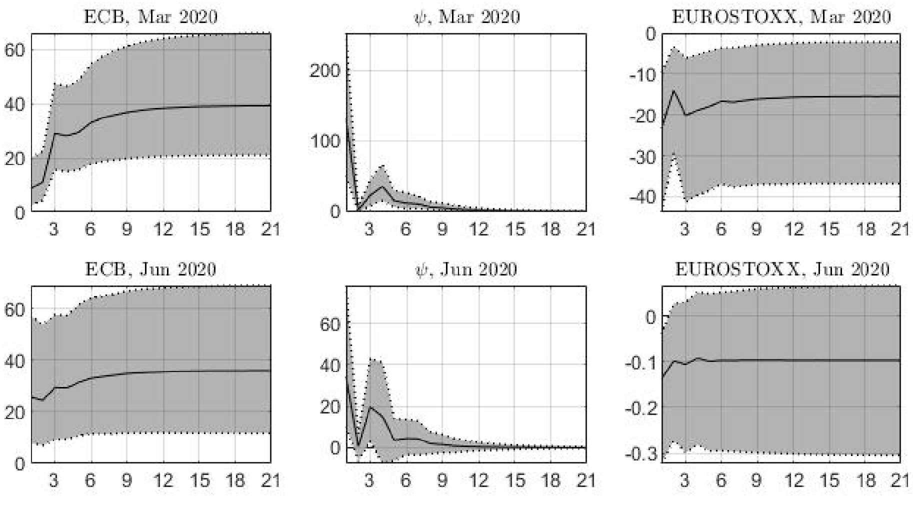

Figure 4: IRFs to a Covid shock - Mean and 16-84 percentiles of posterior distribution.

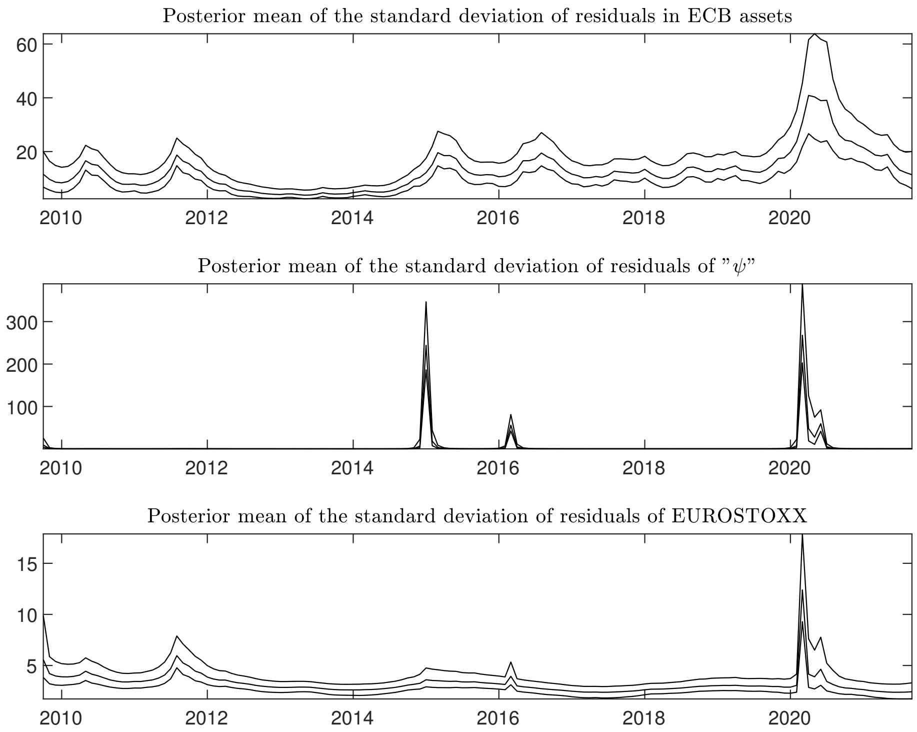

Figure 5: Posterior mean and 16-84 percentiles of the standard deviations in monthly ECB securities held for monetary policy purposes, surprise ψ and Euro Stoxx 50

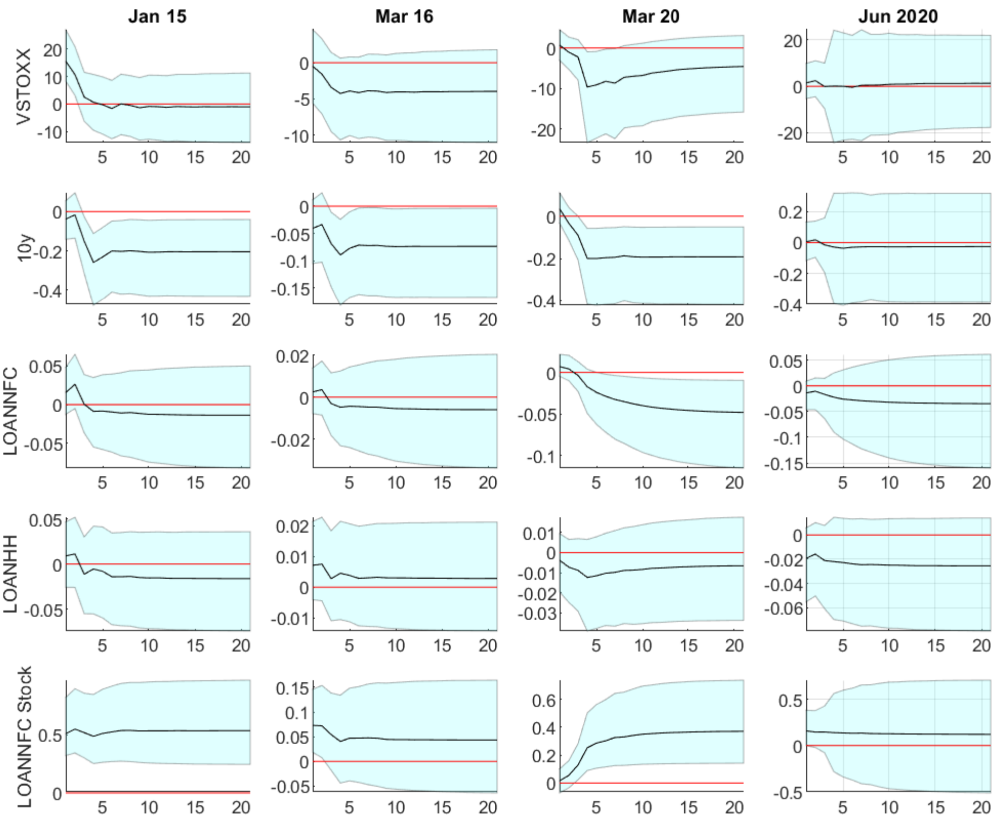

Figure 6: IRFs to an APP shock. Euro Area. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

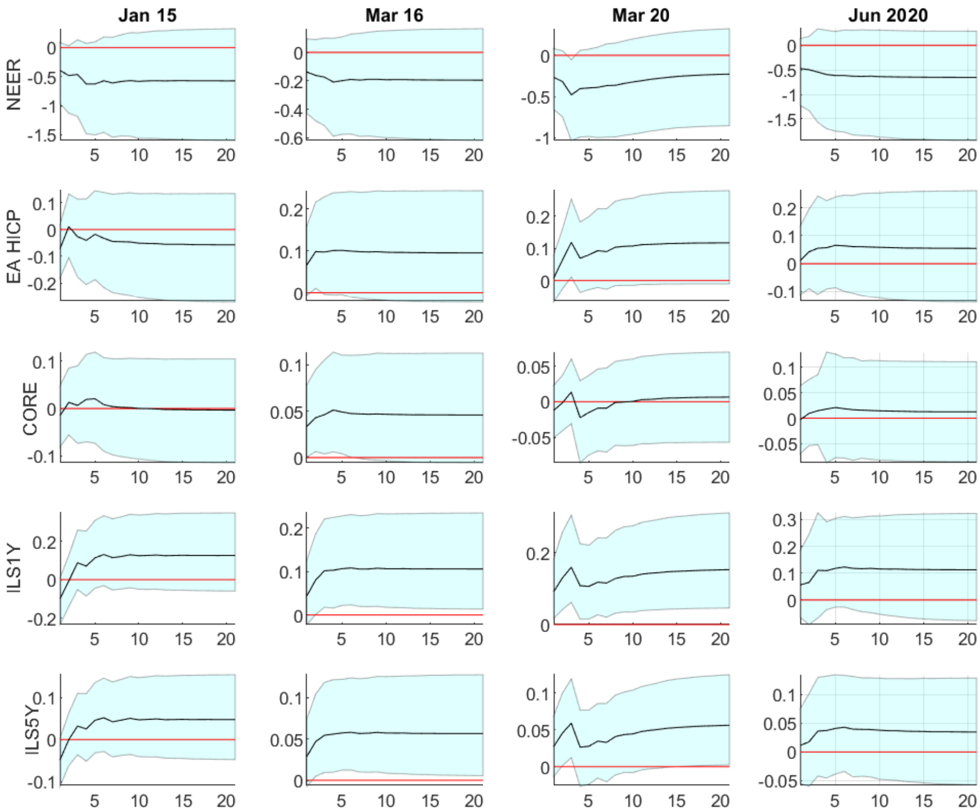

Figure 7: IRFs to an APP shock. Euro Area. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

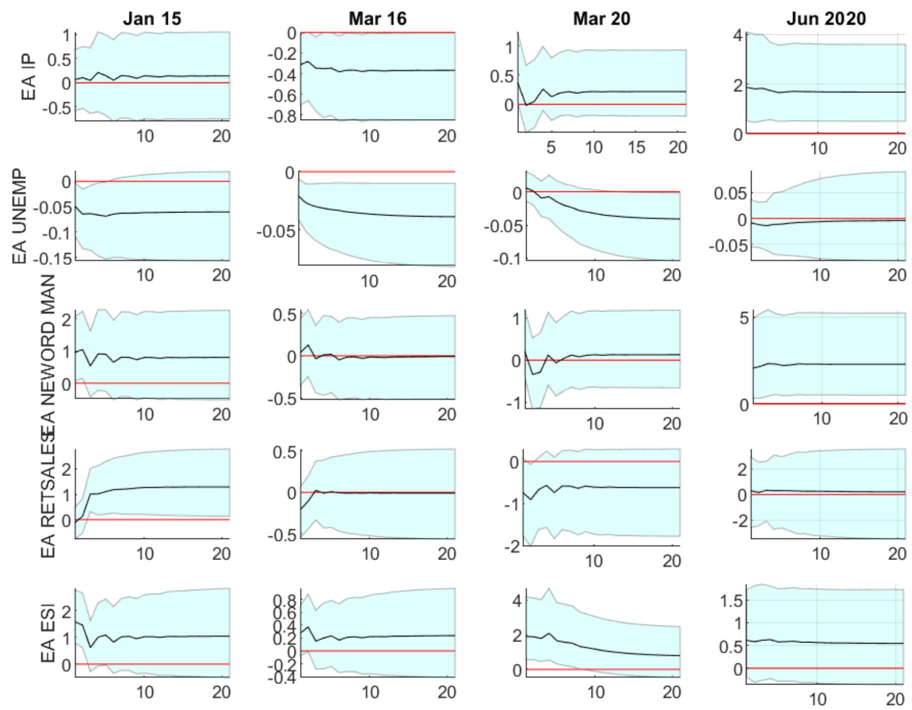

Figure 8: IRFs to an APP shock. Euro Area. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

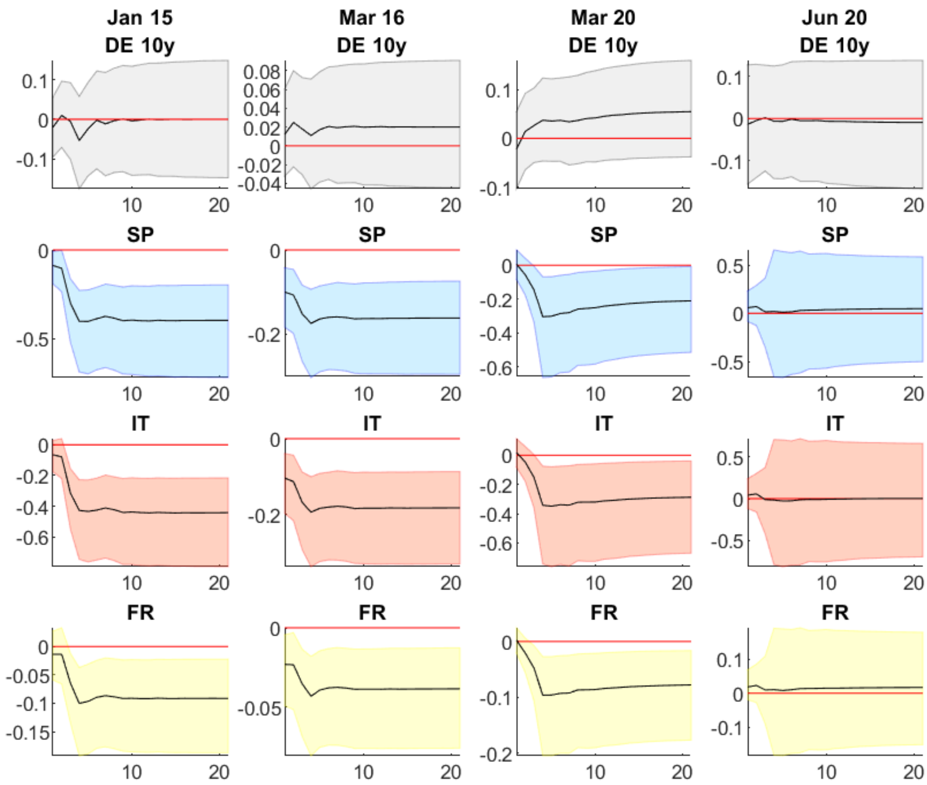

Figure 9: IRFs to an APP shock. Germany and countries differences with respect to Germany - 10-year government bond yield. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

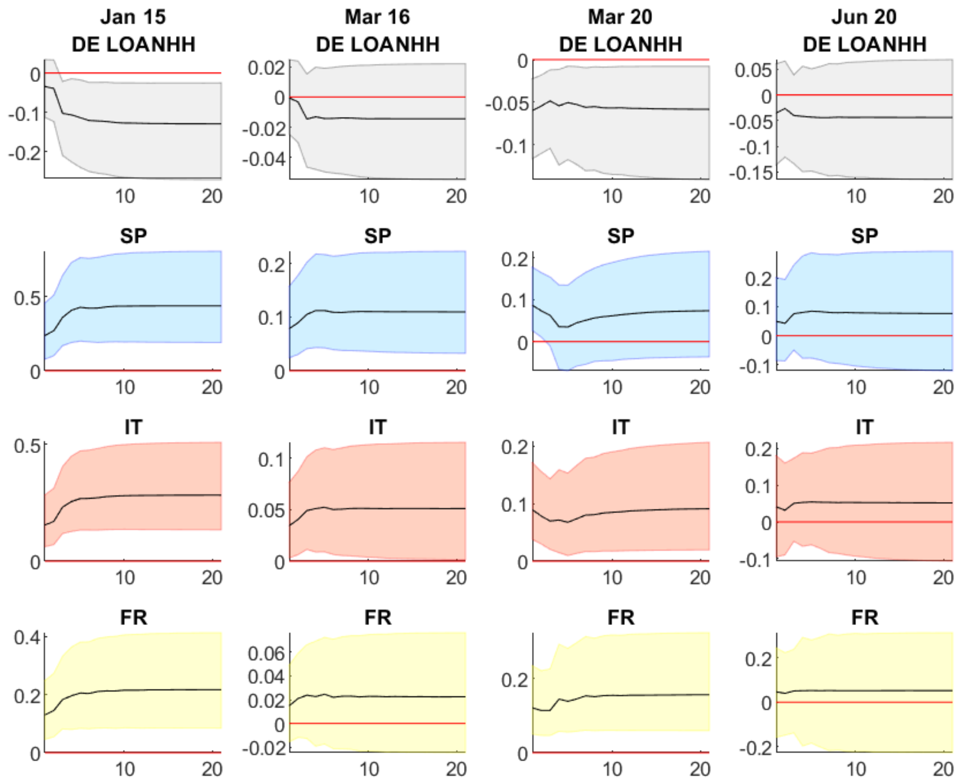

Figure 10: IRFs to an APP shock. Germany and countries differences with respect to Germany - Lending to Households for consumption, Composite interest rate. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

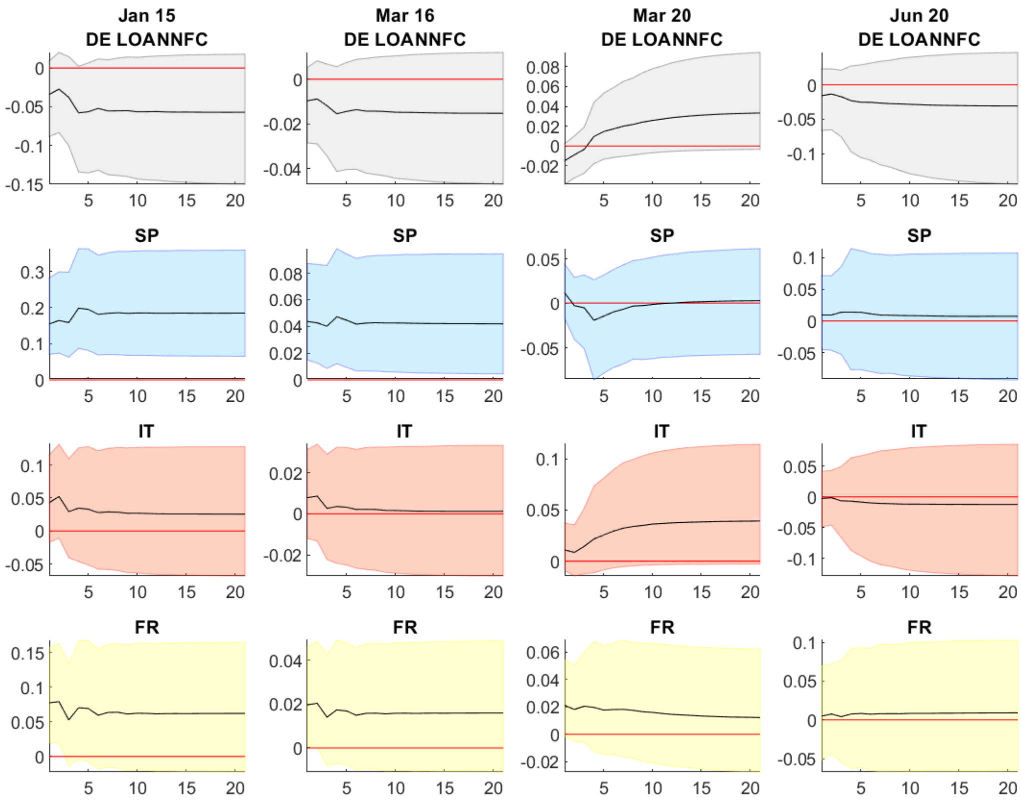

Figure 11: IRFs to an APP shock. Germany and countries differences with respect to Germany - Lending to Non-financial corporations. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

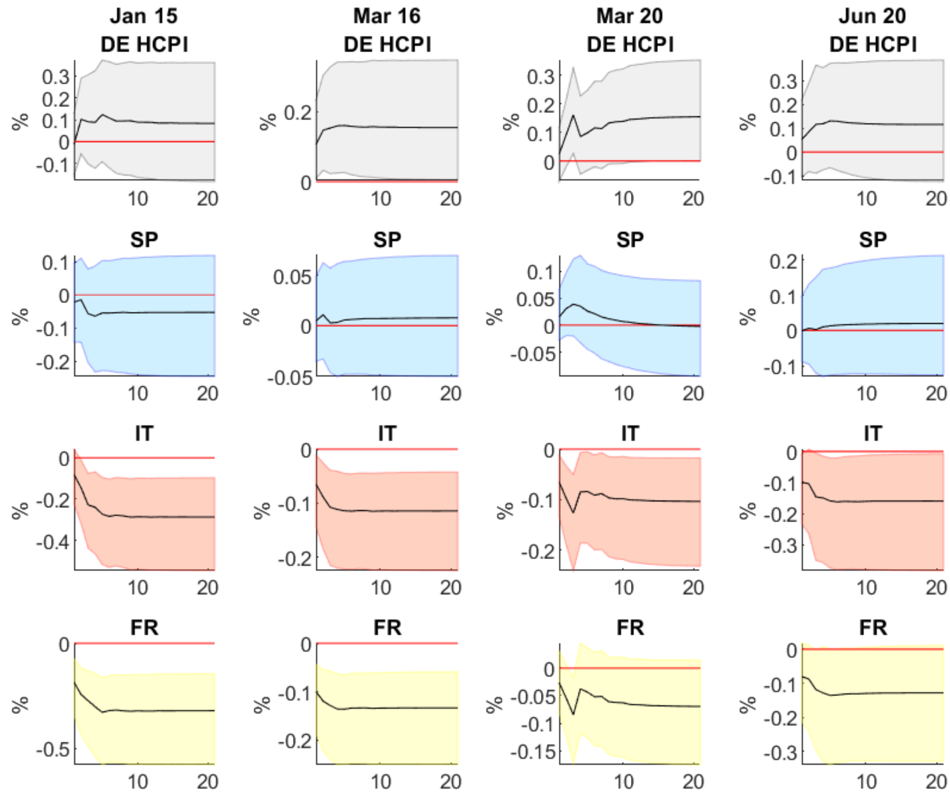

Figure 12: IRFs to an APP shock. Germany and countries differences with respect to Germany - HCPI. Mean and 16-84 percentiles of posterior distribution. Percentage changes.

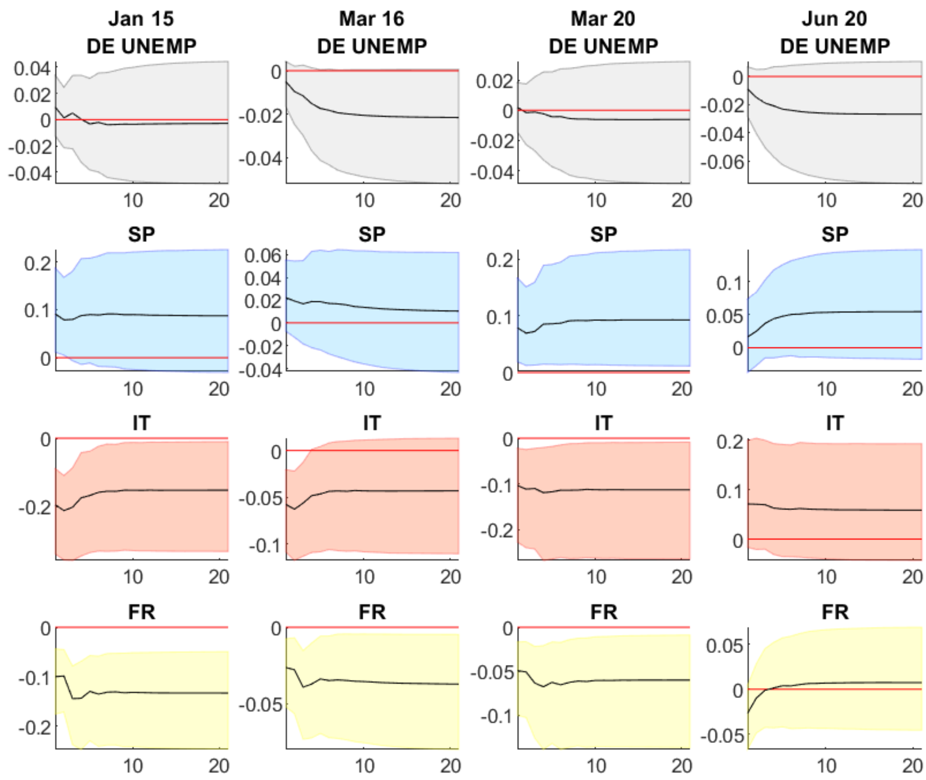

Figure 13: IRFs to an APP shock. Germany and countries differences with respect to Germany - Unemployment. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

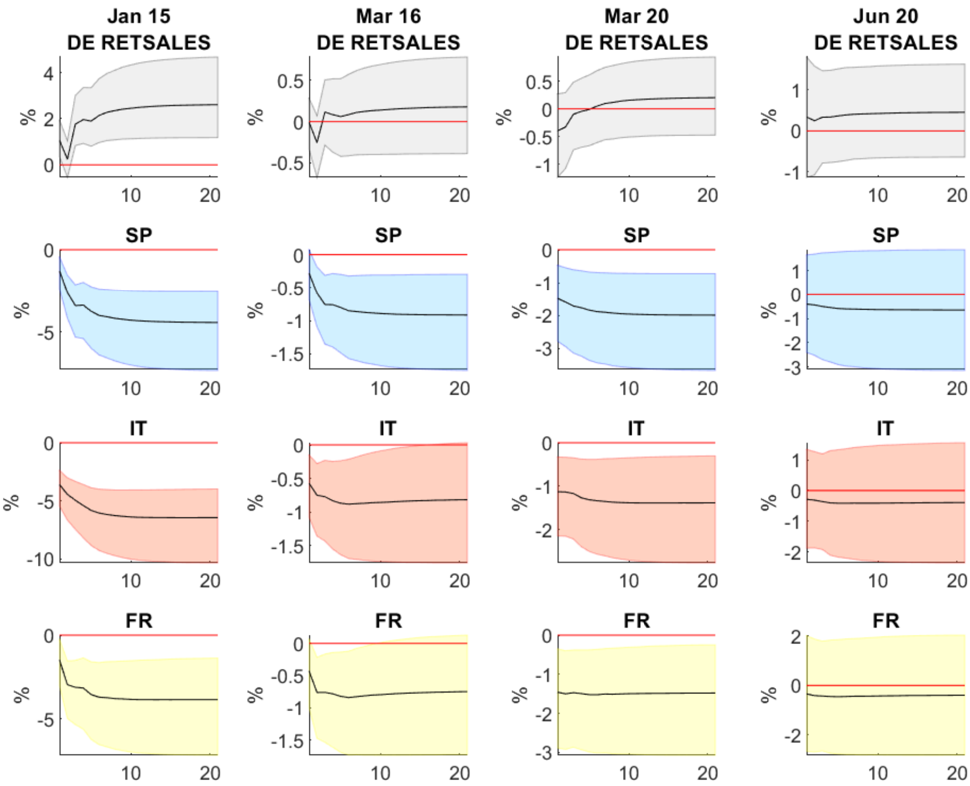

Figure 14: IRFs to an APP shock. Germany and countries differences with respect to Germany - Retail Sales. Mean and 16-84 percentiles of posterior distribution. All changes in percentage points.

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A APP news Proxy

This appendix describes the details of the construction of the proxy for the unexpected components of the APP announcements (the ψ_t term in Equation (1).

22 January 2015: Mario Draghi announced an Assets Purchase Program targeting European government bonds of 60 billions euros per month over 18 months starting from March 2015, for a total amount of 1.14 tn euros. However, news reported in previous days by the Financial Times were describing a general consensus over an expected program of 50 billions of monthly purchases carried over 12 months, for a total amount of 550 billions euros[9]. This means that the unexpected amount was 550 billions.

3 December 2015: The Governing Council decided a cut in the official refinancing rate of 10 bps and opted for a six months extension of the APP, from September 2016 to March 2017. In addition, purchases under the APP were extended to regional and municipal bonds. This means that a_t takes value 240 billions (60 billions/month from October 2016 to March 2017) The announcement deeply disappointed investors who were expecting a much greater easing. According to many newspaper and financial analysts interviewed on the days immediately before, the general market consensus over the announcement was for an interest rate cut ranging from 10 to 20 bps, an extension of the APP duration from 0 to 3 months, and an expansion of monthly purchases between 10 and 20 billions euros starting from January[10].

The lower bound of market expectations would be for a change in the size of the program of 90 billions (10 billions more per month until September 2016). The upper bound is for a change in the size of the program of 420 billions euros (20 billions more for 9 months and 80 billions from October 2016 to December 2016). Considering an average of this two I fix $E_t(a_t)$ to be between 250 and 260. Accordingly the surprise on ECB announcement takes value between -10 and -20 billions. Since this amount is economically irrelevant compared to the size of the policy, I do not include this shock in the final version of the model. Robustness checks

[9] "Mario Draghis bond-buying plan outstrips expectations" - The Financial Times, January 22, 2015. https://www.ft.com/content/8f215db8-a256-11e4-9630-00144feab7de

[10] See for example: "Five questions about the ECBs Thursday Meeting" - The Wall Street Journal, 2 December 2015 (https://blogs.wsj.com/briefly/2015/12/02/5-questions-about-the-ecbs-thursday-meeting/)

including this shock, do not give sensibly different results.

10 March 2016: The ECB announced the adoption of a new package of six expansionary measures including cuts in official interest rates and a new series of Targeted Long Term Refinancing operations (TLTRO II). Purchases under APP were expanded by 20 billions euros per month starting from April 2016 and were extended to investment grade non-financial corporate bonds. Again, interest rates cut, like in December meeting, was fully expected by financial markets operators but the change in the APP had been underestimated. On the 7 of March in its article "How low can Mario Draghi go to lift the eurozone?"[11], The Financial Times reported : "*The ECB intends to buy 60billions-worth of mostly government bonds each month from now until March 2017 [...]. Many analysts expect the Governing Council to take that figure from 60 billions to 70 billions.*". In this case a_t takes value 240 billions (20 billions per month during 12 months), while $E_t(a_t)$ is 120 billions. Hence the positive shock due to the meeting, ψ_t, amounts at 120 billions.

08 December 2016: The Governing Council announced a reduction of 20 billions euros in monthly purchases starting from April 2017, but extended the duration of the APP for 9 additional months (until December 2017) and allowed purchases of securities with negative rates. This implied an increase in the total size of the program, a_t of 540 billions (60 billions euros per month for 9 months). Even if few analysts had correctly forseen the measure[12], financial markets operators were mostly expecting the ECB to keep the current amount of monthly purchases (80 billions euros) and to extend the program from 6 to 8 months. Being at the lower end of expectations implies that $E_t(a_t)$ takes value 480 billions resulting in a surprise of 60 billions. Being at the upper end of expectations implies that $E_t(a_t)$ takes value 720 billions resulting in a negative surprise of 100 billions. Taking the average between the two implies a negative surprise of 10 billions, which is irrelevant if compared with the overall size of the policy. The value of ψ is again set to zero.

26 October 2017: The ECB extended the APP to September 2018 but reduced the amount of monthly purchases to 30 billions, starting in January 2018. In this case

[11] https://www.ft.com/content/1e3f9c76-e482-11e5-a09b-1f8b0d268c39

[12] See for example:How ECB chiefs will be reading markets ahead of QE vote - The Financial Times, December 7, 2016. https://www.ft.com/content/5b6a7da4-bb0b-11e6-8b45-b8b81dd5d080

a_t takes value 270 billions (30 billions per month during 9 additional months). Financial markets had very precisely forseen the policy change. For example, the day before the announcement the FT article "*The future of QE: what to expect from Mario Draghi?*"[13] was reporting: "*Most analysts have predicted that Peter Praet, ECB chief economist, will recommend a slow taper, a view reflected in market expectations of a further nine months of purchase at a pace of 30billions a month.*". In this case $E_t(a_t)$ takes the same value of a_t, resulting in no surprise.

12 September 2019: The ECB lowered the interest rate on the deposit facility by 10 basis points to -0.50% and retook asset purchases under the APP at the pace of 20 billions per month *"for as long as necessary to reinforce the accomodative impact of policy rates, and to end shortly before raising the key interest rates".* For the first time the ECB delivered an open-ended purchase program. In this case, market expectations as reported by The Financial Time before the announcement had foreseen an interest rate cut between 10 and 20 bps and expected a program from 20 to 40 billion of monthly purchases protracted for 1 year[14] ($E_t(a_t)$ ranges between 240 and 480 billion). However, the open-ended nature of the package makes it unfeasible to infer a measure for a_t without additional arbitrary assumptions. Looking at market reactions to the announcement, these were also mixed (see "To QE infinity and beyond", The Financial Times, 12 September 2019). For these reasons, I exclude considering the announcement of September 2019 a surprise in APP.

12 March 2020: At the regular meeting, the Governing Council decided on a number of measures to respond to the economic consequences of Covid19. The ECB granted additional LTROs, offered more favourable conditions on TLTROs and expanded the APP by 120 billion to be carried out until the end of the year. Markets were pricing a decrease of 10bps in the refinancing rate, the changes in the TLTROs and the LTROs and increase of 20 billions in monthly purchases during the following 8 or 9 months[15]. In this case, the surprise for the markets was negative and ψ takes value 40 billions.

18 March 2020: In an extraordinary meeting, the Governing Council approved the

[13] https://www.ft.com/content/71463b7c-b993-11e7-9bfb-4a9c83ffa852

[14] "Draghi under pressure to deliver fresh stimulus package" - The Financial Times, 8 September 2019
"Draghi delves into policy toolbox to bolster growth" - The Financial Times, 12 September 2019

[15] "Will the ECB deliver?" - The Financial Times, 12 March 2020

PEPP, a package of 750 billions of purchases to be carried out flexibly until the end of the year. This measure greatly surprised the markets, which expectations were set to a package of 180 billions[16] at most. ψ takes value 570 billions.

4 June 2020: The ECB added 600 billions to the PEPP until June 2021. The market was expected a measure of 500 billions[17], resulting in a surprise ψ of 100 billions.

[16] "Markets Now" - The Financial Times, 19 March 2020
[17] "US jobs report, ECB meeting, Covid-19 easing" - The Financial Times, 31 May 2020

B Data

The dataset is composed by 176 time series related to real activity, prices and financial markets for the aggregate of the Euro Area (EA 19 countries) and for Germany, France, Italy and Spain. All the time series have been properly transformed to guarantee stationarity and are reported in the next tables.
On the tables in the next pages, the acronym "EA" stands for the fact that the variable is referring to the aggregate of the Euro Area, while "-x" referres to the fact that the variable for all the four countries is inclueded.
Transformation coding is as follows:

- 1 refers to the variable in levels
- 2 refers to the variable in first differences
- 3 refers to the logarith
- 4 refers to the first difference of the logarithm

Identifier	Variable	Source	Transform.
Real Activity			
IP EA	Industrial Production, Intermediate Goods, Volume Index 2015=100, SA	Eurostat	4
IPx	Industrial Production, Intermediate Goods, Volume Index 2015=100, SA	Eurostat	4
IPIG EA	Industrial Production, Intermediate Goods, Volume Index 2010=100, SA	Eurostat	4
IPE EA	Industrial Production, Energy, Volume Index 2010=100, SA	Eurostat	4
IPCG EA	Industrial Production, Capital Goods, Volume Index 2010=100, SA	Eurostat	4
IPCONG EA	Industrial Production, Consumer Goods, Volume Index 2010=100, SA	Eurostat	4
IPDUR EA	Industrial Production, Durable Consumer Goods, Volume Index 2010=100, SA	Eurostat	4
IPNDUR EA	Industrial Production, Non-Durable Consumer Goods, Volume Index 2010=100, SA	Eurostat	4
IPMQ EA	Industrial Production, Mining & Quarrying, Volume Index 2010=100, SA	Eurostat	4
IPM EA	Industrial Production, Manufacturing, Volume Index 2015=100, SA	Eurostat	4
IPIGx	Industrial Production, Intermediate Goods, Volume Index 2010=100, SA	Eurostat	4
IPCGx	Industrial Production, Capital Goods, Volume Index 2010=100, SA	Eurostat	4
IPCONGx	Industrial Production, Consumer Goods, Volume Index 2010=100, SA	Eurostat	4
IPDURx	Industrial Production, Durable Consumer Goods, Volume Index 2010=100, SA	Eurostat	4
IPNDURx	Industrial Production, Non-Durable Consumer Goods, Volume Index 2010=100, SA	Eurostat	4
IPMx	Industrial Production, Manufacturing, Volume Index 2010=100, SA	Eurostat	4
NEWORD INT EA	New Industrial Orders, Intermediate goods, Volume Index 2015=100, SA	ECB SDW	4
NEWORD CAP EA	New Industrial Orders, Capital goods, Volume Index 2015=100, SA	ECB SDW	4
NEWORD DUR EA	New Industrial Orders, Durable goods, Volume Index 2015=100, SA	ECB SDW	4
NEWORD NDUR EA	New Industrial Orders, Non-Durable goods, Volume Index 2015=100, SA	ECB SDW	4
NEWORD MAN EA	New Industrial Orders, Manufacturing, Volume Index 2015=100, SA	ECB SDW	4
BUILD EA	Building permits - Residential Buildings, number of dwellings, Volume Index 2015=100, SA	Eurostat	4
PRCON EA	Production in Construction, Volume Index 2015=100, SA	Eurostat	4
TIG EA	Industrial Turnover, Intermediate Goods, Volume Index 2015=100, SA	Eurostat	4
TE EA	Industrial Turnover, Energy, Volume Index 2015=100, SA	Eurostat	4
TCG EA	Industrial Turnover, Capital Goods, Volume Index 2015=100, SA	Eurostat	4
TIGx	Industrial Turnover, Intermediate Goods, Volume Index 2015=100, SA	Eurostat	4
TEx	Industrial Turnover, Energy, Volume Index 2015=100, SA	Eurostat	4
TCGx	Industrial Turnover, Capital Goods, Volume Index 2015=100, SA	Eurostat	4
IM EA W	Import of Goods and Services from the rest of the World, Volume Index 2015=100, SA	Eurostat	4
RETSAL EA	Retail sales in Manufacturing, Index, 2015=100	Eurostat	4
RETSALx	Retail sales in Manufacturing, Index, 2015=100	Eurostat	4
EX EA W	Export of Goods and Services, Volume Index 2015=100, SA	Eurostat	2

Identifier	Variable	Source	Transform.
Labor Market			
UNEMP EA	Unemployment rate	Eurostat	2
UNEMPx	Unemployment rate	Eurostat	2
UNEMP VOL EA	Unemployment volume, Thousands people	Eurostat	4
UNEMPx VOL	Unemployment volume, Thousands people	Eurostat	4
Prices			
PPITOT EA	Producer Price Index, Total Output, 2015=100, NA	Eurostat	4
PPITOTx	Producer Price Index, Total Output, 2015=100, NA	Eurostat	4
HCPI EA	Harmonized Consumer Price Index, Total, 2015=100, SA	Eurostat	4
CORE	Harmonized Consumer Price Index, Excluding Energy and Food, 2015=100, SA	Eurostat	4
HCPI01	Harmonized Consumer Price Index, Food and Non-alcholic Beverages, 2015=100, SA	Eurostat	4
HCPI04	Harmonized Consumer Price Index, Housing, water, electricity,		4
	gas and other fuels, 2015=100, SA	Eurostat	
HCPI05	Harmonized Consumer Price Index, Furnishings, household equipment		4
	and routine household maintenance, 2015=100, SA	Eurostat	
HCPIx	Harmonized Consumer Price Index, Total, 2015=100, SA	Eurostat	
COREx	Harmonized Consumer Price Index, Excluding Energy and Food, 2015=100, SA	Eurostat	4
IMPRCTOT EA	Import price index (extra Euro Area), Total industry, 2015=100, SA	ECB SDW	4
CONPRC EA	Import price index (extra Euro Area), Consumer goods industry, 2015=100, SA	ECB SDW	4
ENPRC EA	Import price index (extra Euro Area), Energy, 2015=100, SA	ECB SDW	4
HRENTPRC EA	Harmonized Consumer Price Index, Actual Rentals for Housing, 2015=100, NA	ECB SDW	
HRENTPRCx	Harmonized Consumer Price Index, Actual Rentals for Housing, 2015=100, NA	ECB SDW	4
BRENT	Brent Crude, Price per barrel, USD / EUR to USD exchange rate, NA	World Bank, Eurostat	4
ENERGY WB	Energy Price, Price Index, 2010=100, NA	World Bank	4
COMMPRC	ECB Commodity Price index, use-weighted, 2010=100, NA	ECB SDW	4
Exchange rates			
EURUSD	Exchange rate, Euro to US Dollar, NA	Eurostat	
EURCHF	Exchange rate, Euro to Swiss Franc, NA	Eurostat	4
EURGBP	Exchange rate, Euro to Pound Sterling, NA	Eurostat	4
EURYEN	Exchange rate, Euro to Japanese Yen, NA	Eurostat	4
NEER	Nominal Effective Exchange rate, Euro to 19 commercial partners	Eurostat	4

Identifier	Variable	Source	Transform.
Interest rates & Financial Markets			2
EONIA	Eonia rate - Historical close, average of observations through period	ECB SDW	2
EURIBOR3	Euribor 3-month - Historical close, average of observations through period	ECB SDW	2
EURIBOR6	Euribor 6-month - Historical close, average of observations through period	ECB SDW	2
EURIBOR12	Euribor 1-year - Historical close, average of observations through period	ECB SDW	2
EA1y	1-year government bond yield, EA changing composition,	ECB SDW	2
	All central governments, Euro-Area Yield Curve	Eurostat	2
EA10y	10-year government bond yield, EA changing composition,	ECB SDW	2
	All central governments, Euro-Area Yield Curve	Eurostat	2
2yx	Short-term interest rate - 2 years maturity, denominated in Euro	Datastream	2
10yx	Long-term interest rate - 10 years maturity, denominated in Euro	Datastream	2
LOANHH EA	Lending for house purchase to Households	ECB SDW	4
LOANNFC EA	Loans to Non-Financial Corporations	ECB SDW	4
LOANHHx	Bank interest rates - Lending to Households for house purchase	ECB SDW	4
LOANNFCx	Bank interest rates - Loans to Non-Financial Corporations	ECB SDW	4
STOXX EA	Euro Stoxx 50 - monthly average price	Datastream	4
STOXXx	DAX , CAC 40, FTSE MIB, IBEX 35 - monthly average price	Datastream	4
Expectations & Sentiment			
ESI EA	Economic Sentiment Indicator	Eurostat	2
CCON EA	Consumer Confidence Indicator	Eurostat	2
ICON EA	Confidence in the Industrial Sector Indicator	Eurostat	2
CONSERV EA	Confidence in the Services Sector Indicator	Eurostat	2
ESIx	Economic Sentiment Indicator	Eurostat	2
CCONx	Consumer Confidence Indicator	Eurostat	2
ICONx	Confidence in the Industrial Sector Indicator	Eurostat	2
CONSERVx	Confidence in the Services Sector Indicator	Eurostat	2

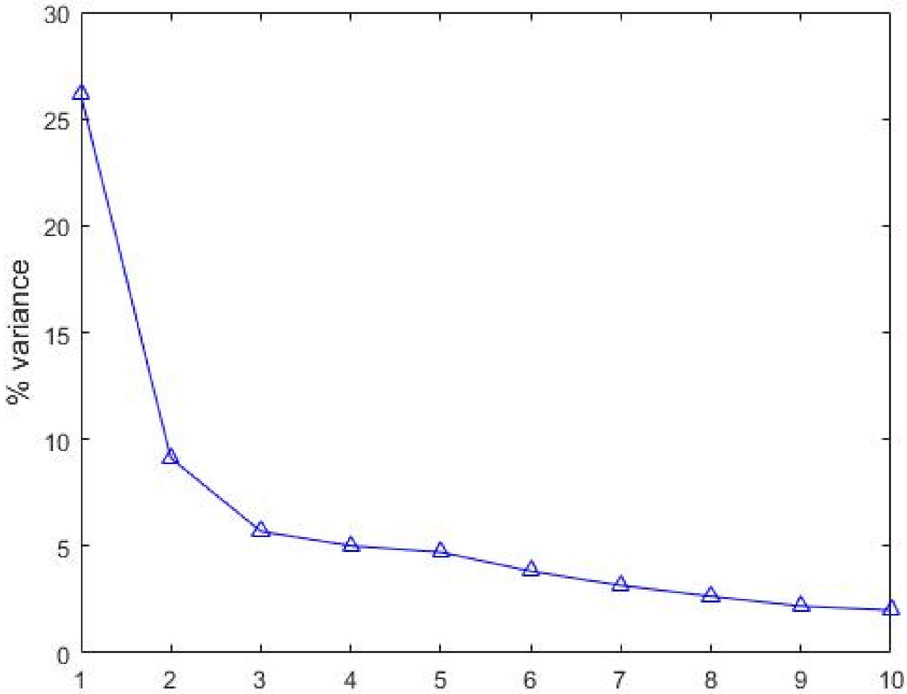

Figure 15: Percentage of the variance explained as a function of the number of factors

C Priors and Estimation Procedure

Priors for parameters of Λ_f and Λ_y and diagonal elements of $\Sigma_\eta$in equation (2) are Normal Inverse-Gamma.

$$\lambda_{i,0}|\sigma^2_{\eta,i,0} \sim N(0, I_r) \quad i = 1, ...n$$

$$\sigma^2_{\eta,i,0} \sim iGamma(\alpha, \gamma) \quad i = 1, ...n$$

I choose α and γ to be 0.01, a standard value in the literature.
Priors on β_0 and $\Sigma_{\nu,0}$ are normal and inverse wishart:

$$\beta_0 \sim N(\beta_{OLS}, (V_{\beta_{OLS}})$$

$$\Sigma_{\nu,0} \sim IW(\Sigma_0, \rho)$$

where $\hat{\beta_{OLS}}$, $\hat{V}_{B_{OLS}}$ and $\hat{\Sigma}_0$ come from OLS estimates over the whole sample. Priors on α_0, ζ_0, W, Ψ, Q are:

$$log\sigma_{\nu,0} \sim N(log(\hat{\sigma_0}), I)$$
$$\alpha_0 \sim N(\hat{\alpha_0}, \hat{V}_\alpha)$$
$$\Psi \sim IW(\Psi_0, \rho_1)$$
$$W \sim IW(W_0, \rho_2)$$
$$Q \sim IW(Q_0, \rho_3)$$

I choose $\hat{\alpha_0}$ and $log(\hat{\sigma_0})$ to be zero, $\Psi_0 = \rho_1\delta_1\hat{V}_\alpha$, $W_0 = \rho_2\delta_2$ and $Q_0 = \rho_3\delta_3\hat{V}_{\beta_{OLS}}$, where $\delta_1 = 0.05$, $\delta_2 = 0.05$,$\delta_2 = 0.001$, $\rho_1 = dim(\Psi) + 1$, $\rho_2 = dim(W) + 1$, $\rho_3 = dim(Q) + 1$.

C.1 MCMC

Estimation is based on 30.000 burn-in draws and 30.000 draws of the Gibbs sampler of the following MCMC:

1. Draw $\{1 : f_t\}$ from the posterior $p(1 : f_t|\beta_t, \Sigma_{\nu,t}, \Sigma_\eta, \lambda_i)$
2. Draw λ_i from $p(\lambda_i|\sigma^2_{i,\eta})$. Since Σ_η is assumed to be diagonal, I draw coefficients λ_i separately for each variable in x_t.

3. Draw $\sigma^2_{i,\eta}$ from $p(\sigma^2_{i,\eta}|\lambda_i)$

4. Draw $\{1:\beta_t\}$ from $p(\{1:\beta_t\}|\Omega_{\nu,t}, A_t, \{1:f_t\})$ using the Carter-Khon algorithm.

5. Draw elements of A_t from $p(A_t|\{1:\beta_t\}, \Omega_{\nu,t})$ and $\Omega_{\nu,t}$ from $p(\Omega_{\nu,t}|\{1:\beta_t\}, A_t)$

D Responses to a Covid shock

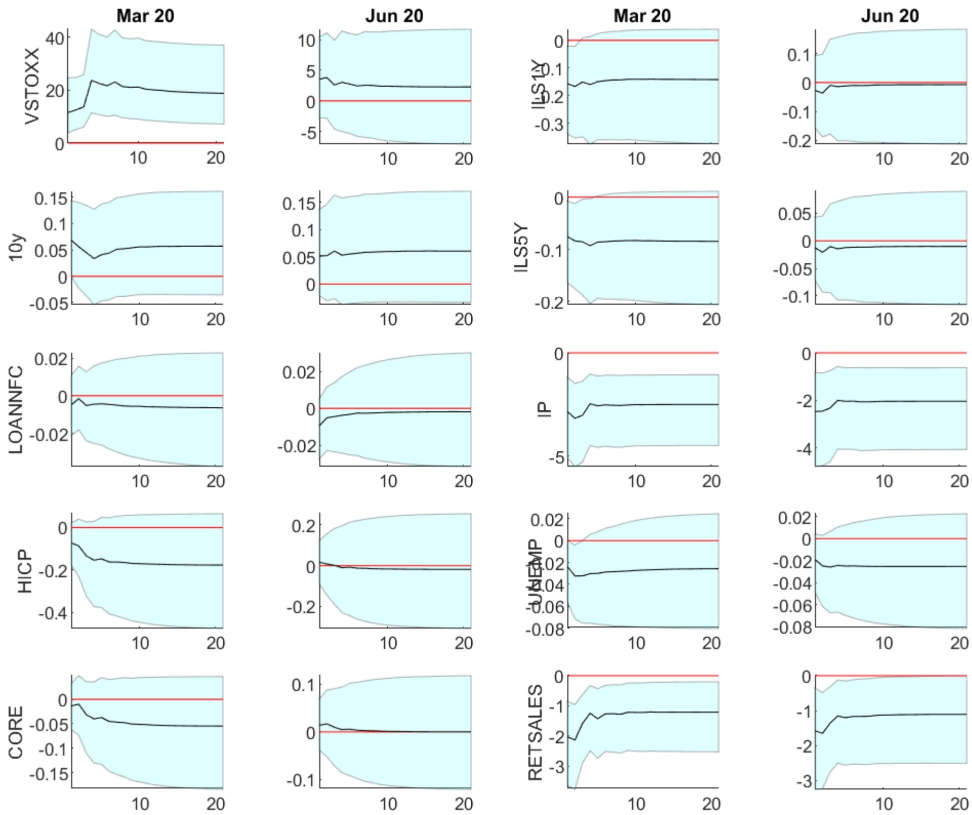

Figure 16: IRFs to a Covid shock. Euro Area. Mean and 16-84 percentiles of posterior distribution.

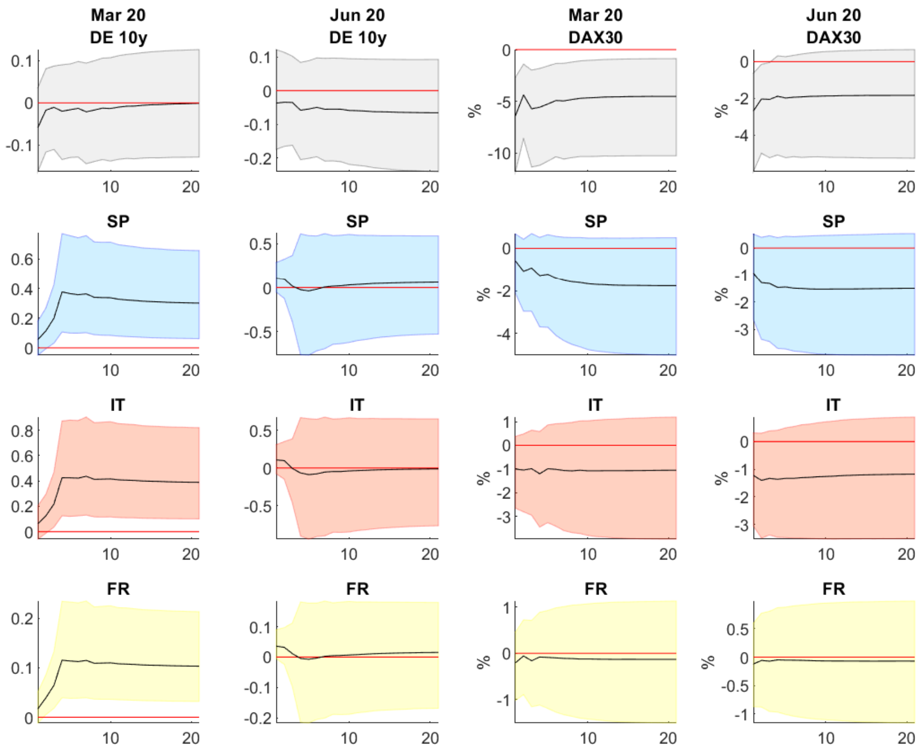

Figure 17: IRFs to a Covid shock. Germany and countries differences with respect to Germany - Retail Sales. Mean and 16-84 percentiles of posterior distribution. Mean and 16-84 percentiles of posterior distribution.

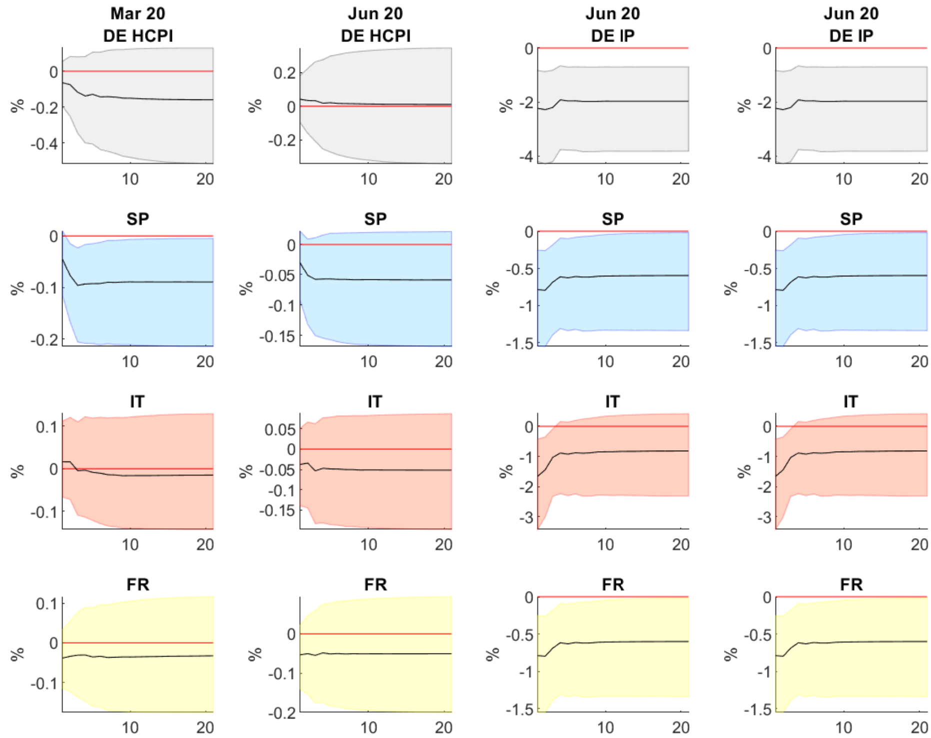

Figure 18: IRFs to a Covid shock. Germany and countries differences with respect to Germany - Retail Sales. Mean and 16-84 percentiles of posterior distribution. Mean and 16-84 percentiles of posterior distribution.