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Estimating the effects of the Eurosystem's asset purchase programme at the country level

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Non-technical summary

Research Question

We estimate the effects of the Eurosystem's asset purchase programme (APP) on real GDP, consumer prices and bank loans to non-financial firms in the four largest euro area countries (Germany, France, Italy and Spain) using a Bayesian vector autoregressive (BVAR) multi-country model. We investigate whether the APP affected the four countries differently.

Contribution

We estimate the effects of the APP by comparing a scenario with asset purchases to a scenario without asset purchases. We derive the simulations from a BVAR model in which we identify unconventional monetary policy shocks as shocks to the term structure of interest rates using zero and sign restrictions. We impose these restrictions on euro area financial variables and, as an innovation, on country averages of output and price level responses. Our simulations of the scenario with asset purchases combine unconventional monetary policy shocks with a fixed policy rate for the duration of the purchase programme and accounts for the APP's evolution from 2015 to the end of 2018. Our multi-country model provides a statistically rigorous way to test for cross-country differences of the APP's effects.

Results

We find positive output effects of the APP in all four countries. The estimated effects on the price level and inflation are generally weaker than the effects on real output growth. Our tests for the cross-country differences indicate the APP having the strongest effects on the price level in Spain. Output effects are weakest in France while the effects on the price level are smallest in Italy.

Nichttechnische Zusammenfassung

Fragestellung

Wir schätzen die Wirkungen des erweiterten Ankaufprogramms für Vermögenswerte (asset purchase programme, APP) des Eurosystems auf das reale Bruttoinlandsprodukt, die Verbraucherpreise und die Buchkredite an nichtfinanzielle Unternehmen in den vier größten Mitgliedsländern des Euroraums (Deutschland, Frankreich, Italien und Spanien) in einem Bayesianischen vektorautoregressiven (BVAR) Mehrländer-Modell. Wir untersuchen, ob das Ankaufprogramm unterschiedliche Auswirkungen auf die Länder hatte.

Beitrag

Wir schätzen die Wirkungen des APP durch den Vergleich eines Szenarios mit Wertpapierkäufen mit einem Szenario ohne Käufe. Wir simulieren die Szenarien mit einem BVAR-Modell, in dem wir unkonventionelle geldpolitische Schocks als Schocks auf die Laufzeitstruktur der Zinssätze mit Hilfe von Null- und Vorzeichenrestriktionen identifizieren. Die Restriktionen werden den Finanzvariablen des Euroraums und, als Innovation, den gewichteten Länderdurchschnitten der Output- und Preisniveau-reaktionen auferlegt. Die Simulation des APP-Szenarios kombiniert unkonventionelle geldpolitische Schocks mit einem unveränderten geldpolitischen Zins über die Programmlaufzeit und berücksichtigt die Anpassungen des APP über den Zeitraum von Anfang 2015 bis Ende 2018. Die Mehrländer-Struktur des Modells ermöglicht es uns, in einer statistisch adäquaten Weise auf Unterschiede in den Wirkungen des APP zwischen den Ländern zu testen.

Ergebnisse

Wir schätzen positive Output-Effekte des APP in allen vier Ländern. Die geschätzten Effekte auf das Preisniveau und die Inflation sind geringer als die Effekte auf das reale Output-Wachstum. Unsere Tests auf länderspezifische Unterschiede zeigen, dass das Programm am stärksten auf das Preisniveau in Spanien gewirkt hat. Wir schätzen die geringsten Output-Effekte für Frankreich, während die Wirkung auf das Preisniveau in Italien am schwächsten war.

Estimating the effects of the Eurosystem's asset purchase programme at the country level¹

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Abstract

We assess the macroeconomic effects of the Eurosystem's asset purchases on the four largest euro area economies using simulation exercises that combine unconventional monetary policy shocks with a fixed policy rate for the duration of the purchase programme. We identify unconventional monetary policy shocks in a large Bayesian vector autoregressive (BVAR) model as shocks to the term structure of interest rates using zero and sign restrictions. We propose a multi-country model in which we impose identification assumptions mainly on euro area aggregate financial variables and on country averages of output and price responses. Furthermore, the multi-country structure allows testing for cross-country differences in the effects of the asset purchase programme in a statistically rigorous way using the posterior of the difference between the country-specific effects. We estimate positive output effects in all countries as well as positive effects on bank lending to firms. Effects on HICP inflation, generally, are much weaker. We find substantial cross-country heterogeneity with the largest price level effects in Spain while output effects were smallest in France and inflation effects were smallest in Italy.

Keywords: asset purchase programme, unconventional monetary policy, euro area, Bayesian vector autoregression, regional effects of monetary policy

JEL-Classification: C32, E47, E52, E58

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1 Introduction

In the years following the financial crisis and with short-term interest rates at or close to the lower bound major central banks have resorted to unconventional monetary policies, specifically asset purchase or “quantitative easing” programmes. While the U.S. Federal Reserve and the Bank of England embarked on asset purchase programmes relatively quickly after the crisis hit, the Eurosystem did not start with large scale asset purchases before announcing its “extended asset purchase programme” (APP) in January 2015. The main component of the APP is the “public sector purchase programme” (PSPP) which consists of purchases of euro area government bonds, bonds issued by recognised agencies, international organisations and multilateral development banks located in the euro area. The asset purchase programme has evolved over different stages with extensions to the programme horizon and adjustments in the monthly purchase volumes.² It aims at stimulating the Eurozone economy in order to move the inflation rate back to levels consistent with the Eurosystem’s definition of price stability.³

In this paper we assess the macroeconomic effects of the Eurosystem’s asset purchases on DE, FR, ES and IT. Our analysis includes the original asset purchase programme announced in January 2015 as well as the adjustments announced in December 2015, March 2016, January 2017, October 2017 and June 2018. We obtain our estimates from simulation exercises using identified conventional and unconventional monetary policy shocks in order to account for the policy rate being fixed for the duration of the net asset purchases.

We identify unconventional monetary policy shocks within a large Bayesian vector autoregressive (BVAR) model as shocks to the term structure of interest rates using zero and sign restrictions. These shocks are not restricted to the APP only but reflect all

² In January 2015 purchases of 60bn euros per month were announced from March 2015 “at least until September 2016”. The programme horizon was extended in December 2015 to “at least until March 2017...” together with an announcement of the reinvestment of maturing securities after the end of the net purchases. In March 2016 the Eurosystem announced an increase in the volume of the monthly purchases to 80bn euros from April 2016 “at least until March 2017 ...” The purchase volume was reduced to 60bn euros in January 2017, taking effect from April 2017 but the programme horizon was extended to “at least until December 2017 ...” In October 2017 the Eurosystem announced a reduction in net purchases from January 2018 onwards to 30bn euros per month “at least until September 2018 ...” and, finally, in June 2018 it announced a reduction in net purchases to 15bn euros after September 2018 with no further net purchases after the end of 2018.

³ This is reflected in the ECB Governing Council’s communication concerning the programme’s duration, eg. “[the asset purchases] are intended to run until the end of March 2017, or beyond, if necessary, and in any case until the Governing Council sees a sustained adjustment in the path of inflation consistent with its aim of achieving inflation rates below, but close to, 2% over the medium term.” (Introductory statement to the press conference, 10 March 2016).

exogenous monetary policy interventions which lead to a flattening of the term structure while leaving the actual policy rate unchanged (eg. Baumeister and Benati, 2013; Kapetanios, Stevens and Theodoridis, 2012). We propose a multi-country VAR model which includes macroeconomic time series for the four large euro area countries as well as euro area aggregate financial variables. We impose identification assumptions mainly on the euro area financial variables and, as a methodological contribution, on country *averages* of output and price level responses. This allows us to refrain from imposing strict priors on the effectiveness of QE on the real economy at the country level. As an additional contribution we use the approach developed in Mandler, Scharnagl and Volz (forthcoming) to test for cross-country differences in the effects of the asset purchase programme in a statistically rigorous way.

We find positive output effects in all countries as well as positive effects on bank lending to firms. The effects on HICP inflation, however, are much weaker. Price-level effects of the APP are largest in ES. IT shows the smallest price level effects which are close to zero while we estimate output effects to be smallest in FR. We also show that imposing positive sign restrictions on output and the price level is crucial to find positive effects of the APP on inflation while the output effects remain positive even without this restriction.

A number of studies have been published on the effects of the APP at the euro area level, using DSGE models (eg. Deutsche Bundesbank, 2016; Sahuc, 2017) or VAR models (eg. Boeckx, Dosche and Peersman, 2017; Gambetti and Musso, 2017; Lewis and Roth, 2019; Wieladek and Pascual, 2016). However, there is little evidence on the country-specific effects of the Eurosystem's asset purchases. Lenza and Slacalek (2018) assess the effects of APP (QE) shocks identified via sign restrictions on euro area financial variables (short- and long-term interest rates, stock prices) and country-specific variables (GDP, GDP deflator, unemployment rate, compensation per employee and house prices) for Germany, France, Italy and Spain in a medium-size BVAR. In a second step, they distribute the estimated macro effects from each country's aggregate impulse responses across individual households based on information on the income and portfolio composition and earnings heterogeneity from the Household Finance and Consumption Survey. Burriel and Galesi (2018) analyse the heterogeneity in the effects of the Eurosystem's unconventional monetary policy using a global VAR (GVAR) model, focussing on the impulse responses to an identified unconventional monetary policy shock without explicitly accounting for forward guidance on the policy rate. In contrast, we use a simulation approach that includes the fixing of the policy rate. Our identification of unconventional monetary policy shocks is based on more sign restrictions to sharpen the identification. Furthermore, using our multi-country model we provide a statistically

rigorous assessment of cross-country differences in the effects of the asset purchase programme.

2 Strategies for identifying unconventional monetary policy shocks in VAR models

Vector autoregressive (VAR) models have been widely used for the estimation of the effects of unconventional monetary policy. A number of identification strategies have been employed to disentangle the unconventional monetary policy shock from other structural shocks. One popular approach identifies unconventional monetary policy shocks as innovations to the central bank's balance sheet size or to specific balance sheet components (eg. Burriel and Galesi, 2018; Boeckx, Dossche and Peersman, 2017; Gambacorta, Hofmann and Peersman, 2014; Gambetti and Musso, 2017; Lewis and Roth, 2019). Identification requires disentangling balance sheet innovations that are endogenous to developments in the economy from innovations representing an exogenous shift in the stance of monetary policy. Endogenous balance sheet expansions might be driven by banks increasing their borrowing from the central bank, eg. in periods of financial market stress or impairment of interbank markets. They may be also caused by the central bank responding actively to events in financial markets or in the banking sector with policy measures that imply balance sheet changes, eg. changes to collateral requirements or endogenously triggered asset purchases. The most widely used approach to address this identification problem is to impose sign restrictions on the impulse response of a financial stress or financial market volatility indicator such as the VIX or the CISS.⁴ Since an expansionary *conventional* monetary policy shock could have the same effects on the balance sheet and financial market stress/volatility as an unconventional monetary policy shock these sign restrictions are generally combined with a zero restriction on the monetary policy rate (eg. Gambacorta et al., 2014; Boeckx, Dossche and Peersman, 2017). Lewis and Roth (2019) avoid imposing the sign restriction on financial stress or volatility by including the Eurosystem's total assets together with the sum of balance sheet items related to the main and longer-term refinancing operations and impose the restrictions that total assets rise after an unconventional monetary policy shock while banks' borrowing from the central bank does not increase.

A second identification approach proposed by Weale and Wieladek (2016) and Wieladek and Pascual (2016) focusses on the announcements of asset purchase programmes. They

⁴ The CISS is a composite indicator of systemic stress, see Holló, Kremer and Lo Duca (2012) which aggregates subindices for different segments of the financial system based on time-varying correlations and emphasises episodes in which financial stress affected multiple segments.

construct a QE announcement variable by cumulating the announced size of the asset purchase programmes over time which results in a step function. Their identification scheme to disentangle exogenous asset purchase shocks from endogenous reactions to economic conditions relies on a positive sign restriction on the asset purchase announcement combined with a positive sign restriction on stock prices which are supposed to separate the asset purchase shock from an endogenous change in the announcement variable due to uncertainty or financial stress.

A third strategy for the identification of more general unconventional monetary policy shocks is based on the assumption that the shock leads to a flattening of the term structure of interest rates. Thus, the strategy follows an indirect approach as it does not include a variable directly representing asset purchases or central bank balance sheet policies. Instead it is based on empirical evidence that unconventional monetary policy measures, in particular large scale asset purchases, cause a reduction in long-term government bond yields.⁵ Separation of an expansionary unconventional from a conventional monetary policy shock is achieved by imposing a negative sign restriction on the long-term government bond yield or on the term spread in combination with a zero restriction on the policy rate (see eg. Baumeister and Benati, 2013; Kapetanios et al., 2012; Lenza and Slacalek, 2018). This is the identification strategy we follow in this paper.

Instead of zero and sign restrictions, Rogers, Scotti and Wright (2018) rely on the identification of unconventional monetary policy shocks (expansionary monetary policy shocks at the zero lower bound) through external instruments (eg. Stock and Watson, 2012) which does not require imposing zero or sign restrictions. Their external instrument for the U.S. is constructed from the change in five-year Treasury futures around the time of FOMC announcements (two hour window).⁶

⁵ See, for example, Altavilla, Carboni and Motto (2016) and the references in Baumeister and Benati (2013), p.11, or Kapetanios, Mumtaz, Stevens and Theodoridis (2012), pp. F319.

⁶ For the euro area the external instrument is the change in the spread between German and Italian government bond yields around policy announcements. “The somewhat different treatment of euro area monetary policy surprises is because, over this unusual period [August 2007 to December 2015], accommodative actions of the ECB were clearly aimed at lowering government bond yields such as Italy and other countries whose sovereign bond markets were coming under significant pressure, rather than German bond yields.” (Rogers et al. (2018), p 1843.)

3 Econometric approach and data

3.1 BVAR estimation

Our simulations of the effects of the Eurosystem's APP are based on a Bayesian VAR (BVAR) model. The model is estimated using the approach of Giannone, Lenza and Primiceri (GLP, 2015). They treat the hyperparameters which control the prior distributions not as fixed but as parameters to be estimated and summarise the prior beliefs about these hyperparameters by "hyperpriors".⁷

The VAR model for n variables $y_t = (y_{1,t}, \dots, y_{n,t})'$ can be written as

$$y_t = c + A_1 y_{t-1} + \dots + A_p y_{t-p} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \Sigma) \quad (1)$$

c is a vector of intercepts, A_i is a $n \times n$ matrix of coefficients on lag i , p is the number of lags and ε_t is a vector of serially uncorrelated residuals with mean zero and covariance matrix Σ . For later reference, we collect the A_i matrices and c in the matrix Γ .

The prior in GLP follows the Minnesota approach, where all variables are modelled as independent random walks. The prior means for the coefficients in A_i are

$$E[A_{s,ij} | \Sigma, \gamma] = \begin{cases} 1 & \text{if } i = j \text{ and } s = 1 \\ 0 & \text{otherwise} \end{cases}, \quad (2)$$

conditional on the vector of hyperparameters γ and on the covariance matrix Σ : the coefficient on the first own lag of each variable has a prior mean of one and all other coefficients have a prior mean of zero. The prior covariance of the coefficients in A_i is given by

$$\text{cov}[A_{s,ij}, A_{r,hm} | \Sigma, \lambda, \Psi] = \begin{cases} \lambda^2 \frac{1}{s^2} \frac{\Sigma_{ih}}{\Psi_{jj}} & \text{if } m = j \text{ and } r = s \\ 0 & \text{otherwise} \end{cases}, \quad (3)$$

with the hyperparameters λ and Ψ as elements of the vector γ .

The prior distribution of the covariance matrix is inverse-Wishart:

$$\Sigma \sim IW(\Psi, d) \quad (4)$$

⁷ In the previous literature different approaches have been used to "optimize" the hyperparameters. Litterman (1980) and Doan, Litterman and Sims (1984) choose the hyperparameters as to minimise the forecast errors over a training sample. Bańbura, Giannone and Reichlin (2010) perform a grid search for the values of the hyperparameters in order to match the BVAR in-sample fit to that of a small VAR estimated by OLS.

where $d=n+2$ represents the degrees of freedom. The scale matrix Ψ is diagonal, with the diagonal elements, Ψ_i , being treated as hyperparameters.

GLP decompose the joint prior distribution of the VAR parameters and of the hyperparameters as follows

$$p(\Gamma, \Sigma, \gamma) = p(\Gamma|\Sigma, \gamma)p(\Sigma|\gamma)p(\gamma), \quad (5)$$

$p(\Sigma|\gamma)$ is given by (4) and $p(\Gamma|\Sigma, \gamma)$ is given by (2) and (3). Conditional on the hyperparameters, the prior of the VAR parameters is of the normal-inverse Wishart type, but the posterior distribution takes into account the uncertainty surrounding the hyperparameters. The hyperprior for λ is chosen to be relatively uninformative, i.e. a Gamma distribution with mode equal to 0.2.

The joint posterior distribution of the VAR parameters in Γ and Σ can, conditional on the hyperparameters, be estimated by means of the Gibbs sampler, as in standard BVAR models.

The posterior of the hyperparameters is given by

$$p(\gamma|y) \propto p(y|\gamma)p(\gamma), \quad (6)$$

with y representing the data. Since the hyperprior $p(\gamma)$ is known, the only unknown element in (6) is the marginal likelihood $p(y|\gamma)$. GLP derive a closed form solution for the marginal likelihood from which draws can be obtained using a Metropolis-Hastings algorithm. The MCMC algorithm then combines a Metropolis-Hastings step for drawing the hyperparameters with a Gibbs sampler for drawing the VAR coefficients and covariances conditional on the drawn hyperparameters.⁸

For the simulation of the APP effects we require identification of a conventional and an unconventional monetary policy shock. These shocks are identified using zero and sign restrictions and the algorithm of Arias, Rubio-Ramirez and Waggoner (2018) with the unconventional monetary policy shock identified via the term structure of interest rates (see section 3.3).

⁸ Estimations of the VAR was carried out in MATLAB using a modified and extended version of the code from Primiceri's website <http://faculty.wcas.northwestern.edu/~gcp575/GLPreplicationWeb.zip>. For models of the size used in this paper's application the algorithm converges only very slowly. The results presented in this paper are based on a simplified algorithm which fixes the hyperparameters at their values maximizing the marginal likelihood but does not draw from their posterior distribution.

3.2 Data

Our model combines a block of euro area variables with blocks of country-specific variables for the four largest euro area countries (DE, ES, FR or IT). The country blocks are similar to the model used for the analysis of the OMT in Altavilla, Giannone and Lenza (2017) and for the analysis of the transmission of conventional monetary policy in the euro area in Mandler et al. (2016). The euro-area block consists of financial variables which are used for the identification of the unconventional monetary policy shock.

The country-specific variables includes for all four countries real GDP, the harmonised index of consumer prices (HICP) or, alternatively, the GDP deflator, bank loans to non-financial corporations⁹, the lending rate on bank loans to non-financial corporations and the yield on five-year government bonds.

The euro area block consists of financial variables which are used for the identification of the unconventional monetary policy shock. We include the EONIA as indicator for conventional monetary policy, a stock price index, the nominal effective exchange rate of the euro, the composite indicator of systemic stress (CISS, Holló, Kremer and Lo Duca, 2012), the euro area average yields on government bonds with maturity of five- and ten years, the excess bond premium as the spread between the euro area average yield on corporate bonds and the yield on German government bonds from Gilchrist and Mojon (2018)¹⁰, and the spread between the euro area average yield on five-year government bonds and five-year German government bonds. As additional variables we add the oil price to control for external inflationary or deflationary pressure and the yield on U.S. treasury bonds with maturity of five years to control for possible spillover from U.S. long-term interest rates which, otherwise, might cause shocks to euro area long-term bond yields related to developments in the U.S. as being interpreted as unconventional monetary policy shocks.

All variables except for interest rates, CISS and spreads enter in log-levels. The models are estimated on quarterly data from 2000Q1 to 2017Q4 with four lags.

While the multi-country structure of the model comes at the cost of a substantial increase in the model dimension it has two distinct advantages: (i) it allows directly for possible

⁹ Bank loans are notional stocks constructed from data on loan flows, which have been adjusted for non-transaction related changes in stocks, such as statistical reclassifications or securitisations.

¹⁰ Caldara and Herbst (2019) show for the U.S. credit spreads, such as the excess bond premium being important in modelling the monetary policy reaction function in a VAR model. Although corporate bonds account for less than 10% of overall external financing of non-financial corporations in the Euro area (see Mandler and Schornagl, 2019) we include this variable as it might contain important information about macroeconomic risk.

cross-country interactions and spill-overs and (ii) it allows testing for the importance of cross-country differences in the effectiveness of asset purchases.

3.3 Identification

We identify a conventional and an unconventional monetary policy shock using zero and sign restrictions based on the algorithm in Arias et al. (2018). The identification restrictions are summarized in Table 1. The identification of the unconventional monetary policy shock is based on the assumption that it leads to a compression in the term structure of interest rates while the policy rate remains unchanged as, eg. in Baumeister and Benati (2013) and Kapetanios et al. (2012). Thus, the unconventional monetary policy shocks are not restricted to the APP only but also reflect other policy interventions which lead to a reduction in the term spread while leaving the policy rate unchanged.

Most of the identification restrictions on the unconventional monetary policy shock apply to the financial variables: we impose an increase in the stock market index, a nominal exchange rate depreciation, a reduction in financial stress as measured by CISS, a reduction in the excess bond premium and a compression in the euro area average government bond yield spread relative to DE. The exchange rate restriction is important to separate the unconventional monetary policy shock from an increase in international investors' risk appetite, which would lead to an appreciation in the exchange rate but have the same effects on the other variables. For the country-specific block we assume that the asset purchase programme leads to a reduction in the government bond yields. The restrictions on the financial variables can be derived from theoretical models or have been established in event studies.¹¹

Concerning the effects of an unconventional monetary policy shock on the real economy we consider two alternative approaches. In the baseline model we require that an expansionary unconventional monetary policy shock results in positive average impulse responses of output and prices across countries where we weight the individual country impulse responses by real GDP. Thus, we do not enforce output and price level to increase in each country after an expansionary monetary policy shock but only require positive responses on average. Since the Eurosystem's monetary policy responds to aggregate developments in the euro area not including euro area output and price level in the model might result in a misspecified monetary policy reaction function. However, the four

¹¹ See, eg. Altavilla et al. (2016), Andrade, Breckenfelder, De Fiore, Karadi and Tristani (2016), De Santis (2019) and Deutsche Bundesbank (2017). Rogers et al. (2018) construct their instrument for unconventional policy shocks in the euro area from changes in the spread between Italian and German government bond yields.

countries account for the vast majority of euro area aggregate GDP¹² and, thus, the estimation of the monetary policy reaction function should work reasonably well without the euro area aggregates for these variables. As a robustness check, we add euro area aggregate output and price level to the model and impose the sign restrictions on these aggregate variables.

For the conventional monetary policy shock we assume that a reduction in the policy rate leads to a decline in government-bond yields in all countries and a positive average impulse response in real GDP and in the GDP price level across countries. In the robustness test we impose the latter two restrictions on euro area aggregate output and prices. All sign and zero restrictions are imposed only on impact and are summarized in Table 1.¹³

Assuming positive effects of asset purchases on euro area output and price level might be controversial. However, theoretical models strongly suggest that central bank asset purchases have a stimulating effect on the real economy¹⁴ and following Paustian (2007) identification will be more precise if these restrictions are included. Furthermore, we only restrict the average responses in output and in the price level across countries and do not assume that the APP causes output and prices to rise in each country.¹⁵ However, as a robustness check we drop the sign restrictions on output and the price level (“weak” restrictions) and report the results for this identification scheme, as well.

¹² Over the sample period the four countries on average account for more than 75% of euro area aggregate output.

¹³ The sign restrictions for the model including euro area aggregate output and prices, which is used for the robustness check are shown in the appendix.

¹⁴ See, eg. the survey in Deutsche Bundesbank (2016).

¹⁵ Concerning the sign restrictions on euro area aggregate output and price level in the second model version there is, potentially, some “spillover” from the sign restrictions on the euro area variables into the country-specific variables, as well, since the four countries considered here carry substantial weight in the euro area variables.

Table 1: Sign and zero restrictions for multi-country (MC) model

monetary policy shock variable	unconventional		conventional
	“strong” restrictions	“weak” restrictions	
<u>euro area block</u>			
EONIA	0	0	-
stock price index	+	+	
NEER	-	-	
CISS	-	-	
5- and 10-year government bond yield	-	-	-
excess bond premium	-	-	
spread between 5-year euro area average and German government bond yields	-	-	
<u>country block (DE, FR, IT, IS)</u>			
real GDP (average response)	+		+
HICP or GDP deflator (average response)	+		+
Loans to NFCs			
Lending rate			
5-year government bond yield	-	-	-
Sign restrictions imposed in impact period.			

3.4 Simulation design for estimating the effects of the APP

Our estimates of the effects of the macroeconomic effects of output and inflation in the four countries are based on a simulation approach which accounts for both the asset purchases as well as for the sequencing of the exit from the APP assuming that the Eurosystem will not raise the policy rate while it is still conducting net asset purchases in the APP.¹⁶ This simulation uses identified unconventional (APP) and conventional monetary policy shocks and is similar to the approach in Kapetanios et al. (2012).

The posterior distribution of the APP effects is obtained from as differences between two scenarios with the difference being computed for each draw of our BVAR model. The reference scenario is an unconditional forecast of the model from 2015Q1 to 2018Q4. Thus, we choose a four-year horizon for the simulation. The simulation under the APP shifts the ten-year euro area average government bond yield down by 60bp in 2015Q1 using an identified unconventional policy shock to compute the effects on all the other model variables.¹⁷ Based on the values resulting from this policy intervention we simulate the model from 2015Q2 onwards allowing the long-term government bond yields to evolve endogenously according to the model but imposing the condition that from 2015Q2 onwards the policy rate follows the same path as under the reference scenario, i.e. under the unconditional forecast. This removes the endogenous response of the policy rate to the asset purchases which generally implies a tightening of monetary policy in response to the expansionary effects of the asset purchases on output and prices, which, in turn, reduces the expansionary effects of the asset purchases relative to a scenario in which the policy rate did not change.¹⁸ We assume that the Eurosystem does not counteract the expansionary effect of the APP and tries, at least partially, to account for the effects of forward guidance; the simulation approach assumes that the Eurosystem does not counteract the expansionary effects of the APP by raising interest rates. This does not account for the commitment to low interest rates on expectations. Instead, the conventional monetary policy shocks that keep the policy rate fixed are unexpected in each period. In that sense, our model will tend to underestimate the effects that result from the combination of the APP and forward guidance.

¹⁶ This is stated in the introductory statements to the press conference following the ECB Governing Council Meetings, eg. “We continue to expect them [the policy rates] to remain at present or lower levels for an extended period of time, and well past the horizon of our net asset purchases.” Introductory statement to the press conference on 27 April 2017

¹⁷ Note, that this will have no impact effect on the policy rate since the identification restrictions impose a zero response of the policy rate to an unconventional monetary policy shock.

¹⁸ See the impulse responses in the appendix for the endogenous response of policy rates to the expansionary effects of unconventional monetary policy.

Technically, this amounts to a conditional forecast of the model using an identified shock, in our case a conventional monetary policy shock, to conform to the conditioning assumption while all other variables, including the ten-year bond yield from 2015Q2 onwards, are allowed to evolve according to the model dynamics and the effects of the conventional monetary policy shocks required to keep the policy rate at its baseline path.¹⁹ Because of the linearity of the model the difference between the conditional simulation and the unconditional forecast is equivalent to an impulse response function to a -60bp shock to the ten-year government bond yield assuming conventional policy shocks to keep the policy rate fixed.

Repeating this procedure for each draw of the VAR model yields the posterior distribution of these impulse responses. We add to these the effects of the APP adjustments in 2015Q4, 2016Q1, 2017Q1, 2017Q4 and 2018Q2 from similar simulations based on shocks to the ten-year government bond yield of -20bp, -30bp +10bp, -20bp and zero for 2018Q2.²⁰ Because of this more realistic simulation approach, our results are not directly comparable to those in Burriel and Galesi (2018) for individual countries or those in Gambetti and Musso (2017) for the euro area since their analyses do not account for the fixing of the policy rate.

The size of the unconventional monetary policy shocks, i.e. the size of the shocks to the long-term government bond yield, which enter the simulation is based on the changes in long-term interest rates in the technical assumptions of the Eurosystem's macroeconomic projections, the (B)MPE.²¹ In the projections, these technical assumptions are used as conditioning variables and are derived from futures rates, see ECB (2014). The size of the original 2015Q1 APP shock also corresponds roughly to the estimate in the event study by Altavilla, Carboni and Motto (2015) of around -50bp for ten-year government bond yields. DeSantis (2016) estimates an effect of -63bp using an

¹⁹ This is implemented using a MATLAB procedure based on the Dynare procedure *mcforecast3*, see Adjemian, Bastani, Juillard, Karamé, Mihoubi, Perendia, Pfeifer, Ratto and Villemot (2011).

²⁰ Because of the linearity of the model this can be carried out easily by, for each draw of the model, scaling the dynamic effects of the original APP programme, shifting their time path along the time axis as required and adding up the resulting paths.

²¹ The -60bp shock for 2015Q1 is equal to the revision in the expected level of long-term government bond yields in 2015 from the December 2014 projections to the March 2015 projections, see ECB (2014, 2015a). The -20bp for the APP shock in 2015Q4 represents the revision between the December 2015 projections (for which the cut-off point was before the Governing Council meeting on which the APP was extended) and the March 2016 projections (see ECB 2015b, 2016a), the -30bp APP shock is equal to the revision between the March 2016 projections (again, with cut-off point before the Governing Council meeting) and the June 2016 projections (see ECB 2016a, 2016b), the +10bp shock in 2017Q1 is derived from the revision between the December 2016 and the March 2017 projections (see ECB 2016c, 2017a) and the -20bp shock in 2017Q4 follows from the revision between the September 2017 and the December 2017 BMPE (see ECB 2017b,c). For the decision in June 2018 on the phasing out of APP net purchases we do not include a shock, since it was widely anticipated.

error correction model. Our simulations do not account for the uncertainty around these estimates which results in underestimation of the uncertainty surrounding the APP effects.

In implementing this simulation algorithm, we discard all draws from the identified BVAR model for which a two-standard deviation conventional monetary policy shock does not move the policy rate by at least 10bp. The reason for this is that the sign restriction algorithm yields a number of draws for which the effects of a structural conventional monetary policy shock on the policy rate are extremely small. Because of the small effects these draws would require very large structural monetary policy shocks in order to keep the policy rate at the unconditional forecast in our simulations of the APP. Subjecting the dynamic system for these draws to the large required conventional policy shocks results in a strong divergence of the simulations.²²

4 Results

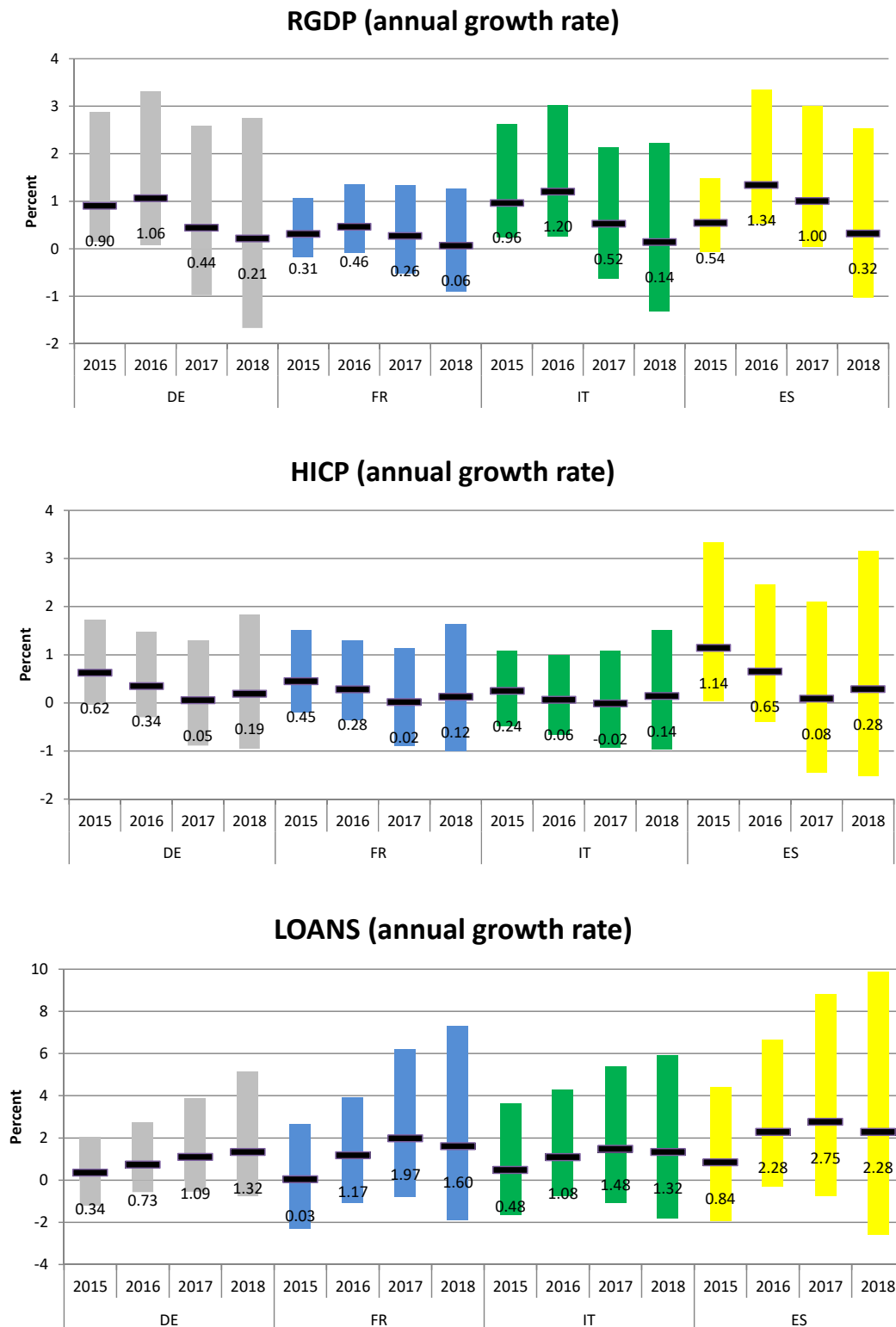
Figure 1 shows the estimated effects of the APP on real GDP, HICP and bank loans to non-financial corporations for the four countries using the baseline multi-country (MC) model.²³ The results are shown as difference in the average annual growth rates of the respective variable over each year under the APP compared to the no-APP scenario. The black vertical bars indicate the median estimate (given by the numbers below) and the coloured bar diagrams the range between the 16th and the 84th percentile of the posterior distribution.

For real GDP growth the majority of the probability mass of the posterior distribution lies in the positive domain at least for the first two years. The distributions also tend to be positively skewed, i.e. large positive realizations relative to the median are more likely than large negative deviations. In DE and FR the bulk of the effects occur in the first two years. For ES and IT substantial median output effects are also estimated for 2017. The effects on inflation are generally weaker than on output growth and there is little evidence of positive inflation effects after the second year. Concerning the time profiles the inflation effects are largest in the first year while the output growth effects show a hump-shaped pattern and are largest in the second year of the programme.

²² Without this adjustment the probability bands around the estimates for some variables turn out to be about ten times as wide as shown in this paper.

²³ The impulse responses to the unconventional monetary policy shock are shown in the appendix. They indicate that the reduction in the long-term government bond yield persists for about two years and that the unconventional monetary policy shock leads to a delayed positive response in bank lending to firms. The results show that the policy rate would rise for about two years after an expansionary unconventional monetary policy shock, which, to some extent, counteracts the original expansionary effects of the asset purchases.

Figure 1: Estimated APP effects from multi-country (MC) model

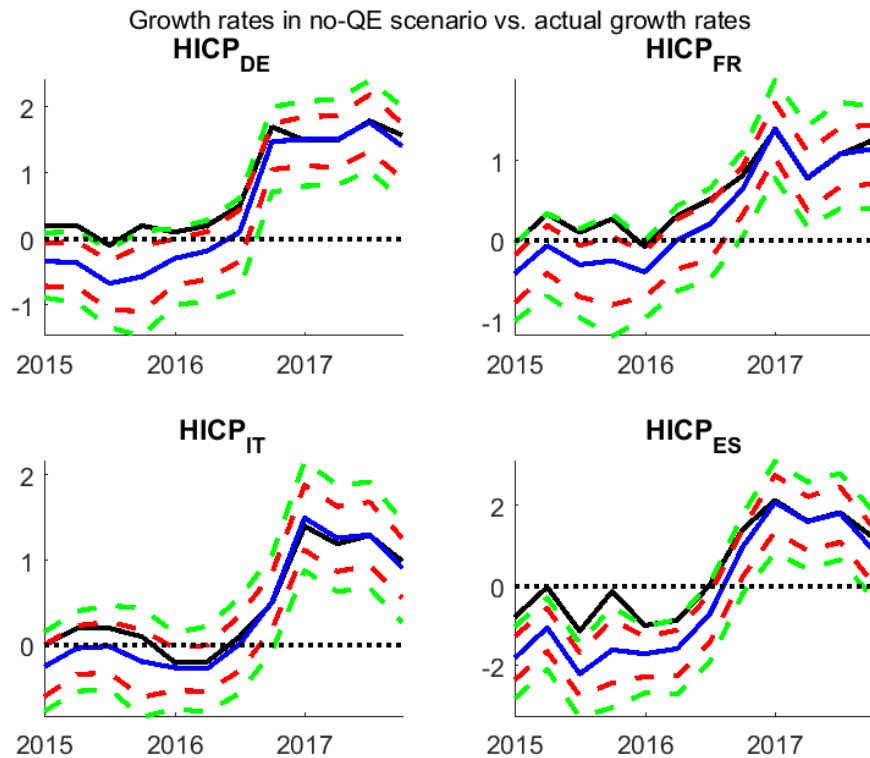


Deviation from annual growth rates from unconditional forecast (annual averages). Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Sign restrictions on country averages of real GDP and price level.

The time pattern of the effects on loans to NFCs is qualitatively different from those on output and prices and presents a more persistent increase but with little effect in the first year. The delayed pick-up in bank lending is consistent with the well documented lag in bank lending to real activity in the euro area (eg. Scharnagl and Mandler, 2019 and Deutsche Bundesbank, 2015). Furthermore, the estimation uncertainty about the effects on bank lending is substantially higher than for the other variables.

Figure 2 shows results from a counterfactual analysis. It shows for the time period between 2015Q1 and 2017Q4 the posterior distribution of the annual HICP inflation rate in all countries after removing the estimated effects of the APP.²⁴ The upper green (red) line below zero indicates a posterior-probability ratio of 3:1 (2:1) for a negative inflation rate in the quarter.²⁵

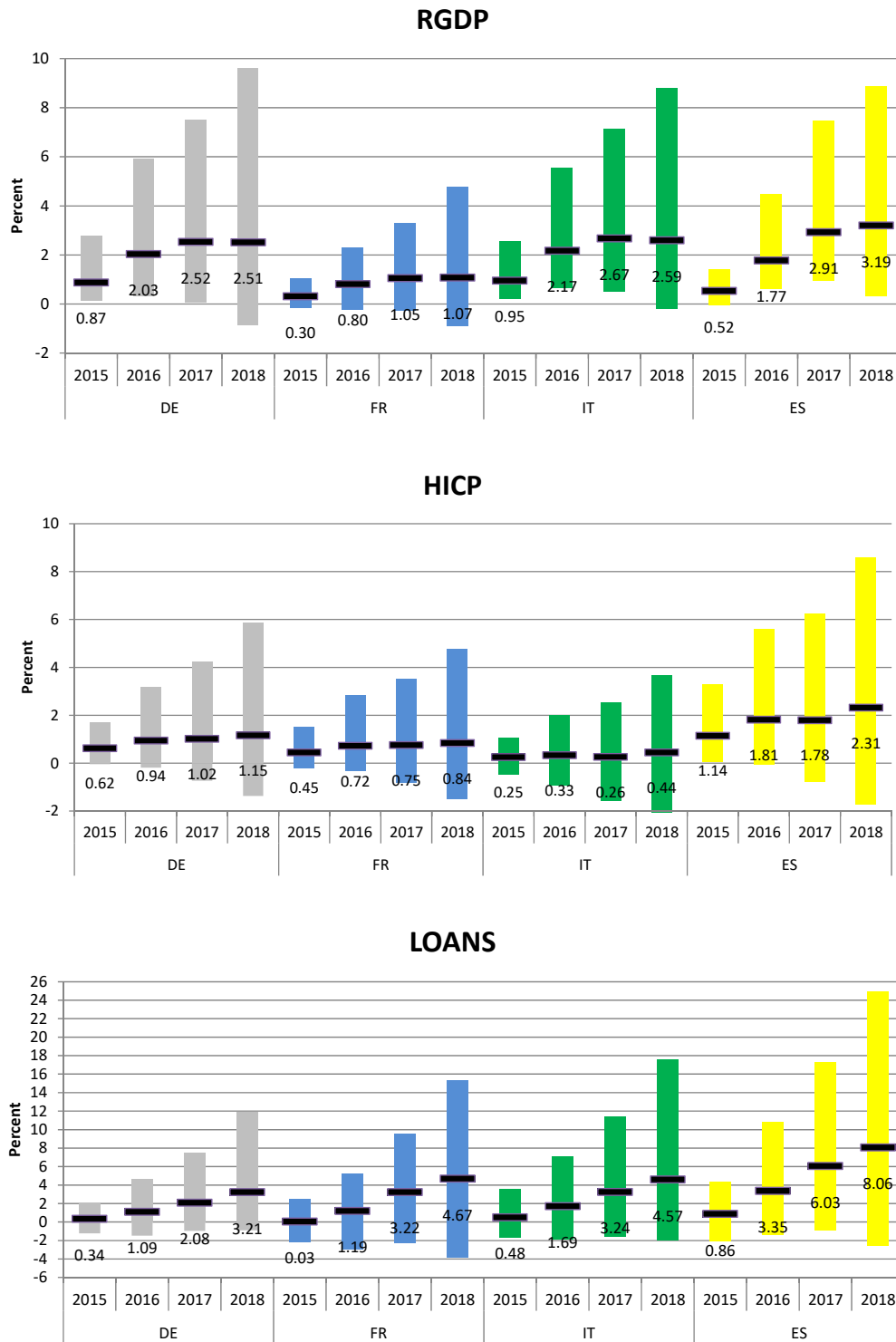
Figure 2: Actual (black) and counterfactual inflation rate without APP, MC model (median of counterfactual in blue, 33th and 66th percentiles in red, 25th and 75th percentiles in green)



²⁴ These distributions are computed by subtracting from the observed inflation rate the simulated APP effects for each draw from the model.

²⁵ If the 66th percentile is below zero the posterior-probability ratio of negative inflation is at least 66:34 \approx 2:1. If the 75th percentile is below zero the posterior-probability ratio of negative inflation is at least 75:25 \approx 3:1.

Figure 3: Estimated APP effects from MC model (cumulative effects)



100 times log-difference between conditional and unconditional forecasts, average per year. Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Sign restrictions on country averages of real GDP and price level.

Figure 3 shows for each year the average difference in the levels of the variables between the APP and the no-APP scenario which can be interpreted as the cumulative effects of the purchase programme. The cumulative nature of the estimates is reflected in higher estimation uncertainty than for the annual growth rates, particularly for bank lending. The estimates show positive output effects in all countries with the largest effect (about 3.2% output gain after four years) in ES followed by DE and IT with output gains of around 2.5%. The effects on the HICP are also biggest in ES with around two percent after four years followed by DE and FR with around one percent while the price level effects in IT are essentially zero. The APP effects on bank lending to NFCs are estimated with much more uncertainty than for the other two variables.

One important advantage of the multi-country model is that we can analyse possible cross-country differences in the effects of the asset purchases in a statistically rigorous way (Mandler et al., 2016). While it is not possible to compare impulse responses from single-country models because the comparison does not account for the correlation between the impulse responses that results from using (partly) identical or correlated data computing the *difference* in the impulse responses to a shock in the multi-country model for each draw of the BVAR yields an estimate of the posterior distribution of the cross-country difference in the shock effects which can be interpreted in the usual Bayesian fashion. In this paper, we adapt this approach to our simulations of the APP effects. For each draw of the model, we obtain the simulated APP effects as the difference between a forecast conditional on APP and the unconditional forecast as described in Section 3.4. For each draw, we compute the difference of the estimated APP effects between each possible country pair which gives us the posterior distributions of the cross-country differences. Figure 4 shows the results from this exercise for the differences across countries in the simulated cumulative effects of the APP, i.e. it compares the results in Figure 3 across countries but without the annual averaging. The graphs show from the posterior distributions of the differences between the first and the second country the median and the ranges between the 33th and the 66th percentiles and between the 25th and the 75th percentiles. These percentiles correspond to posterior-probability ratios of 2:1 or 3:1 for positive or negative differences in the APP effects between the two countries in question.²⁶

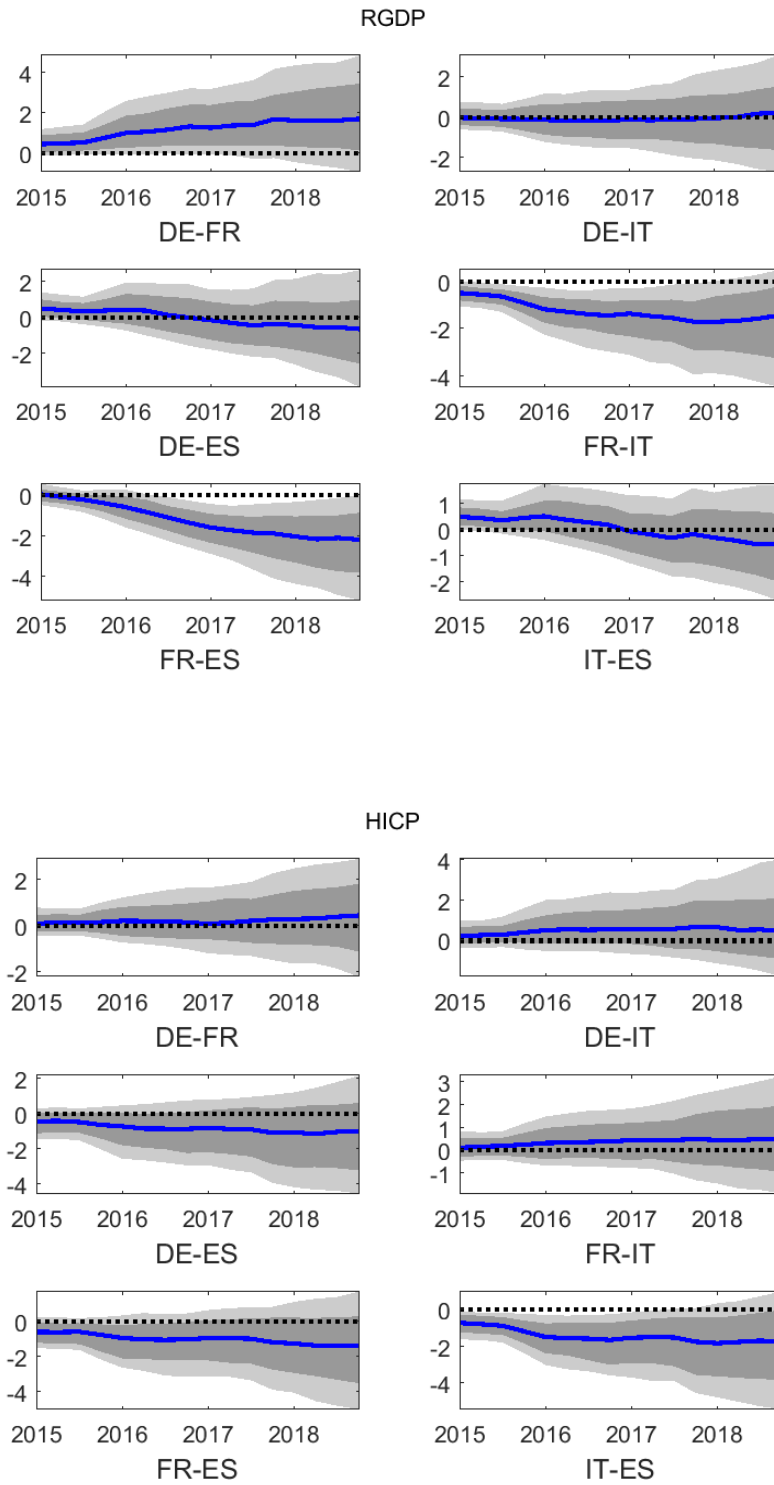
For example, the top left panel for real GDP suggests a positive difference between the APP effects in DE and FR with a posterior-probability ratio of 3:1. This shows the effects

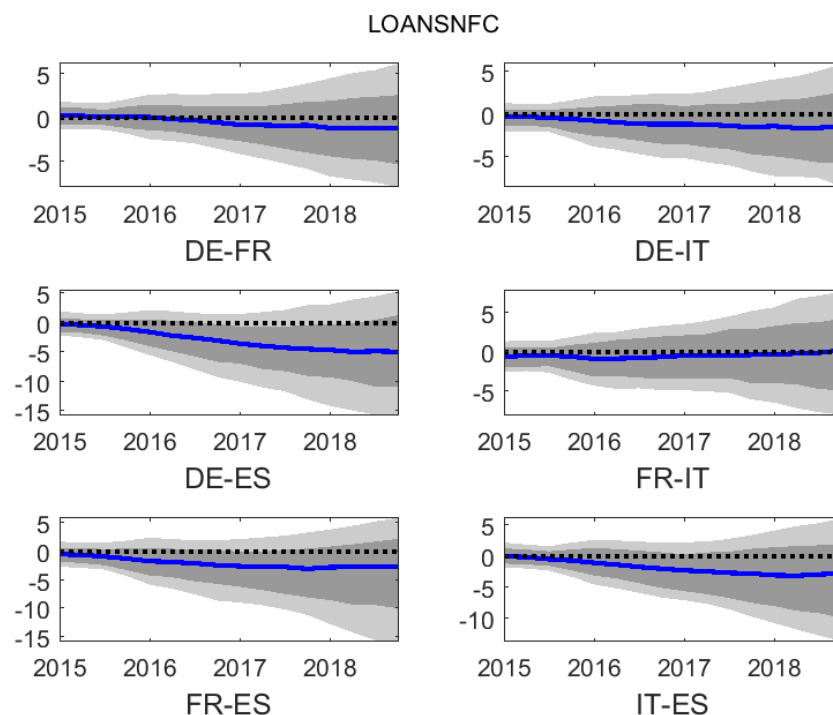
²⁶ If the 25th (33th) percentile is above zero this indicates a posterior-probability ratio of more than 3:1 (2:1) for the cross-country difference being positive. Correspondingly, if the 75th (66th) percentile is below zero this indicates a posterior-probability ratio of more than 3:1 (2:1) for the cross-country difference being negative.

of the asset purchase programme on output to be larger in DE than in FR. The mid-right panel for real GDP shows a negative difference between FR and IT with a posterior-probability ratio of 3:1 up to about three years, indicating more positive effects of the APP on output in IT than in FR. Similarly the bottom-left panel shows a negative difference between FR and ES, i.e. a more positive output effect in ES than in FR with a posterior-probability ratio of 3:1. Overall, the results from the comparison of the output effects suggest broadly similar effects in DE, ES and IT with weaker effects in FR (DE, ES, IT > FR). For the HICP the differences are somewhat less pronounced but, at a posterior-probability ratio of 2:1, the ranking that emerges implies the most positive effects in ES followed by DE and FR with little difference between the two and the weakest effects on prices in IT (ES > DE, FR > IT). Finally, for loans to firms the lower part of Figure 4 does not point to marked differences between DE, FR and IT but again suggests the APP effects to be larger in ES.²⁷ Our country ranking for the output effects is in contrast to the results from the Global VAR in Burriel and Galesi (2018) who compare the peak impulse responses to an unconventional monetary policy shock across euro area countries. Their output growth ranking is DE > FR > IT > ES (from strongest to weakest effects) with considerable overlap in the interquartile ranges. Their ranking for inflation is ES > DE > IT > FR.

²⁷ The analysis of the cross-country differences shows that the reduction in government bond yields due to the APP was biggest in IT, followed by ES and FR and smallest in DE. See Figure A3 in the appendix.

Figure 4: Cross-country differences between simulated APP effects from MC model (cumulative effects, percentage points, median, 25th, 33th, 66th and 75th percentiles)





As a first robustness check, we carry out the same analysis using a BVAR model that also includes euro area real GDP and HICP and impose the sign restrictions for the output and price level effects of monetary policy shocks on these two variables instead of on the country averages (multi-country + euro area model, MCEA model). The results are presented in Figures A4 to A6 in the appendix. Results for the cumulative output and price level effects are broadly similar to those from the baseline model. The baseline model tends to yield somewhat larger output effects for DE and somewhat larger price level effects for ES and IT. The changes in the price level effects for DE and in the output effects for IT affect mostly the first three years while the cumulative effects after four years are close to ones from the first model.²⁸ Overall, the results from the MCEA model again indicate positive effects of the APP on real GDP in all countries and somewhat smaller effects on the price level with the effects on the price level in IT being not markedly different from zero. Figure A6 repeats the analysis of the cross-country differences of the APP effects from Figure 4 and yields almost the same ranking as the first model.

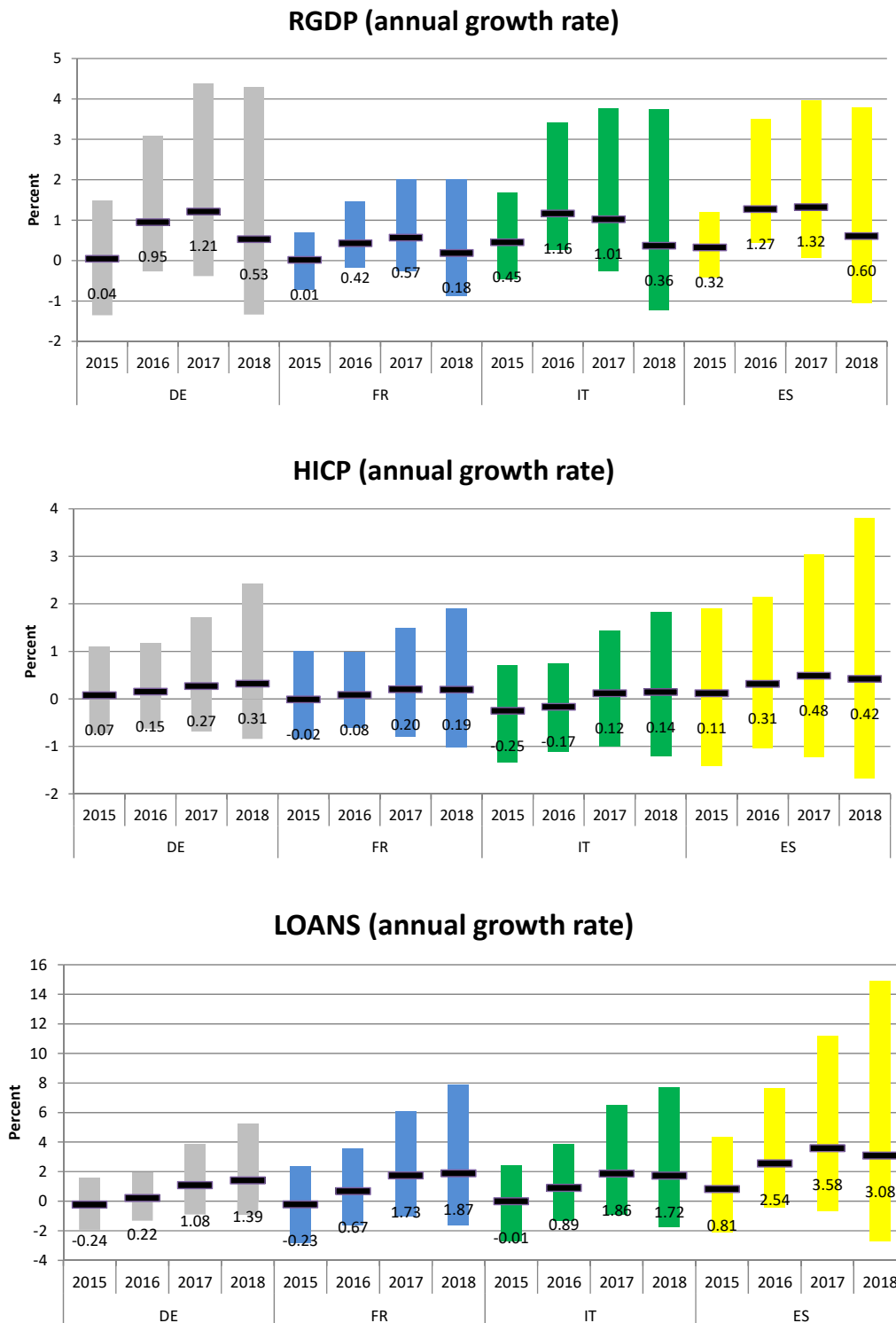
²⁸ One possible explanation for the changes in the estimates for DE is that due to the sign restrictions on output and price level being imposed on the GDP-weighted country averages in the baseline model, a draw for the rotation matrix which implies a large positive response for DE is more likely to be accepted as a draw implying a large positive response for, say, ES since DE carries more weight in the averaging.

As another robustness test, we replace the HICP by the GDP deflator.²⁹ The resulting estimates for the MC model are similar to those from the benchmark model for output and bank lending. The effects on the GDP deflator are somewhat smaller than those on the HICP in DE and ES but larger in IT and we find no longer a clear cross-country ranking for the price level effects. Replacing the HICP by the GDP deflator in the MCEA model has similar effects.

Figures 5 to 7 investigate how strongly our results are affected by the assumption that (average) output and price level rise after an expansionary unconventional monetary policy shock. They show the estimated APP effects (in annual growth rates or as cumulative effects) and the estimates for the cross-country differences obtained after dropping the sign restrictions on the GDP weighted cross-country averages of output and price level in the identification of the unconventional monetary policy shock. Figure 6 shows that this modification results in a slight increase in the estimated effects of the APP on real GDP growth at the four-year horizon and that most of the probability mass of the APP's output effects' posterior distribution remains in positive territory. In contrast, the effects on the inflation rate decline and turn out to be not markedly different from zero anymore. The cross-country comparisons in Figure 7 remain close to those in Figure 4.

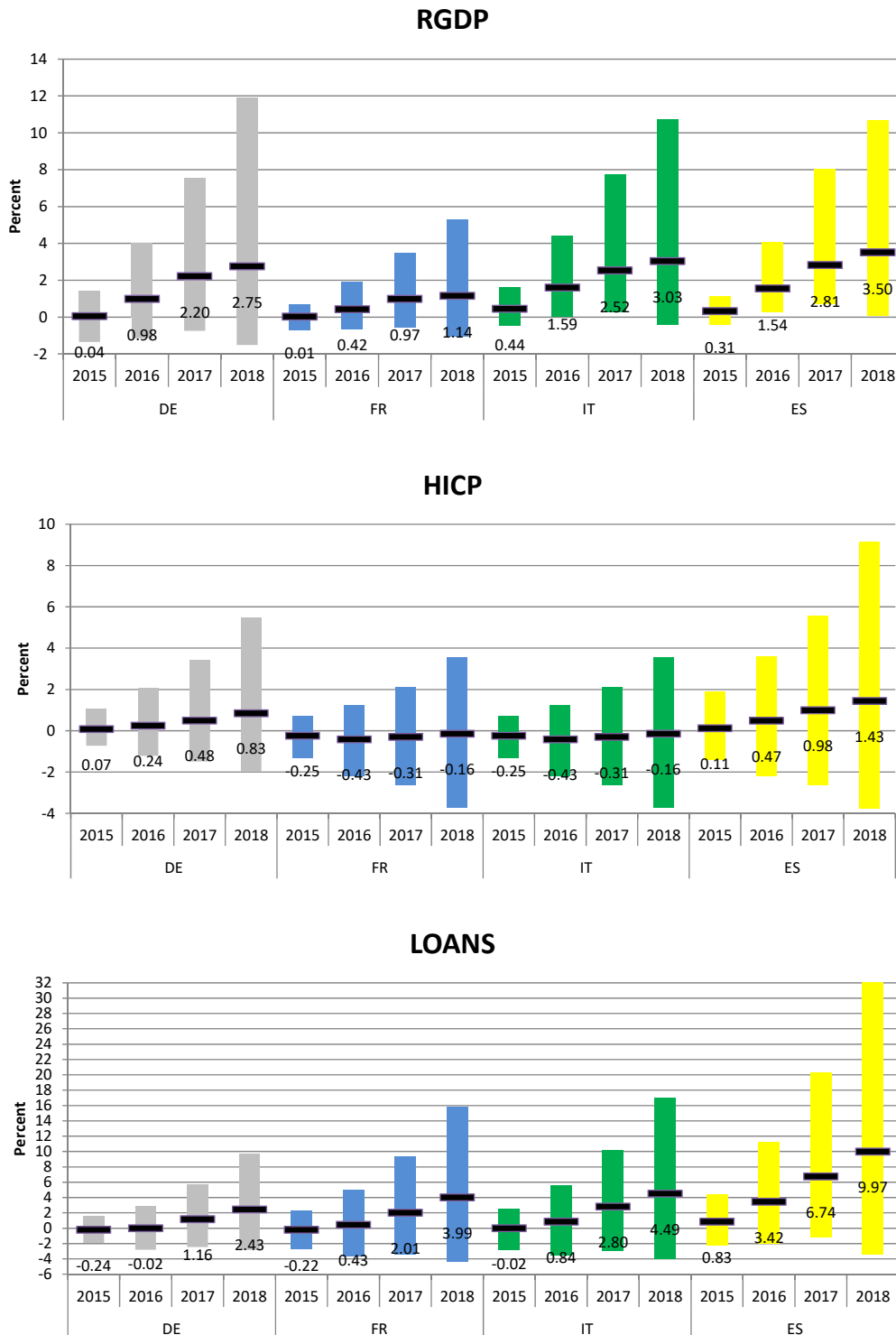
²⁹ Results are shown in the appendix.

Figure 5: Estimated APP effects from MC model (growth rates, no sign restrictions on output and price level)



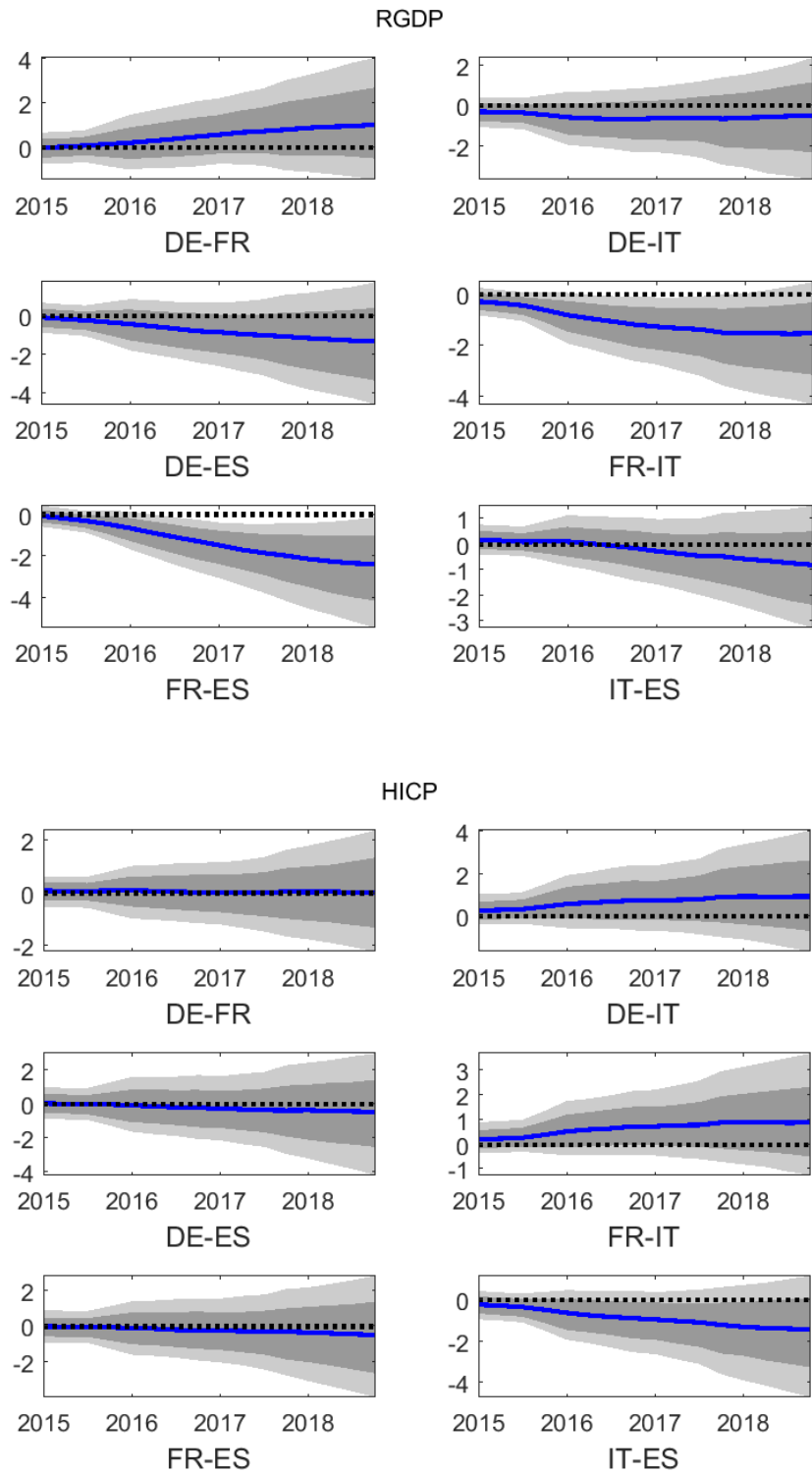
Deviation from annual growth rates from unconditional forecast (annual averages). Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles.

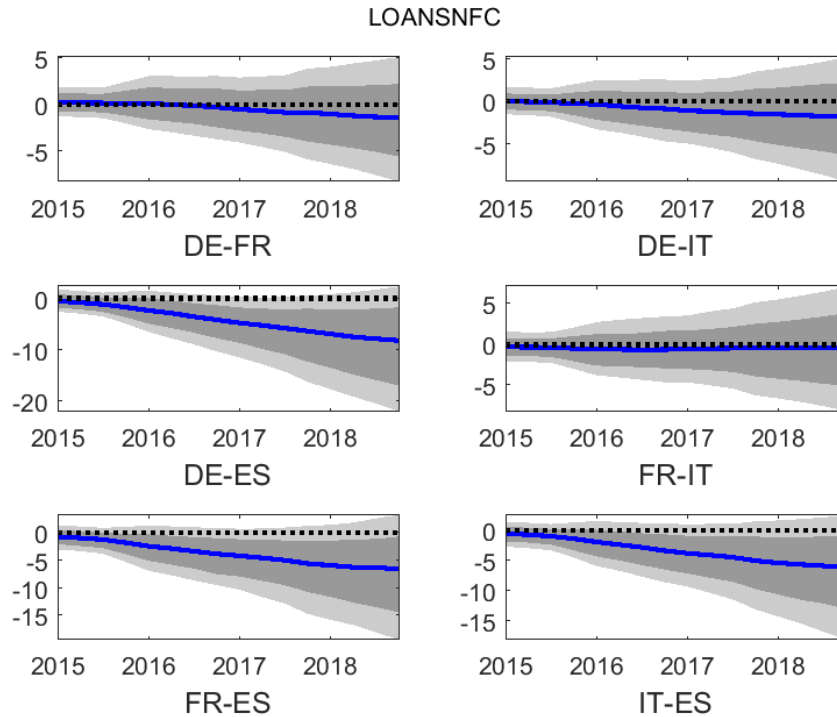
Figure 6: Estimated APP effects from MC model (cumulative effects, no sign restrictions on output and price level)



100 times log-difference between conditional and unconditional forecasts, average per year. Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles.

Figure 7: Cross-country differences between simulated APP effects from MC model (no sign restrictions on output and price level, cumulative effects, percentage points, median, 25th, 33th, 66th and 75th percentiles)





5 Discussion and conclusions

We present a cross-country comparison of the macroeconomic effect of the Eurosystem's asset purchase programme over the time period from 2015 to 2018 using a simulation approach based on identified unconventional and conventional monetary policy shocks. Our results strongly indicate positive output effects of the APP in DE, FR, ES and IT. The estimated effects on the price level and inflation are generally weaker than the effects on real output growth. The models, thus, suggest that the expansionary output effects of QE translate into consumer price inflation only to a limited extent. Based on the posterior distribution of the cross-country differences we conclude that the APP had the strongest positive effects on the price level in ES. Output effects were weakest in FR while the effects on the price level were smallest in IT. The overall size of these differences is economically relevant with median differences generally between one and two percentage points. We also estimate substantial positive effects of the APP on bank lending to non-financial corporations, again with the largest effects in ES, but estimation uncertainty for this variable turns out to be particularly pronounced.

Concerning identification assumptions, the assumption of positive output and price level effects of the APP at the euro area level turns out to influence the estimated country-specific effects on the price level and on inflation: the cumulative output effects are not strongly affected by dropping this assumption and the posterior distributions still show positive effects in all countries and across all models. However, the effect on the HICP in all countries shifts towards zero if one does not assume an increase in output and price level.

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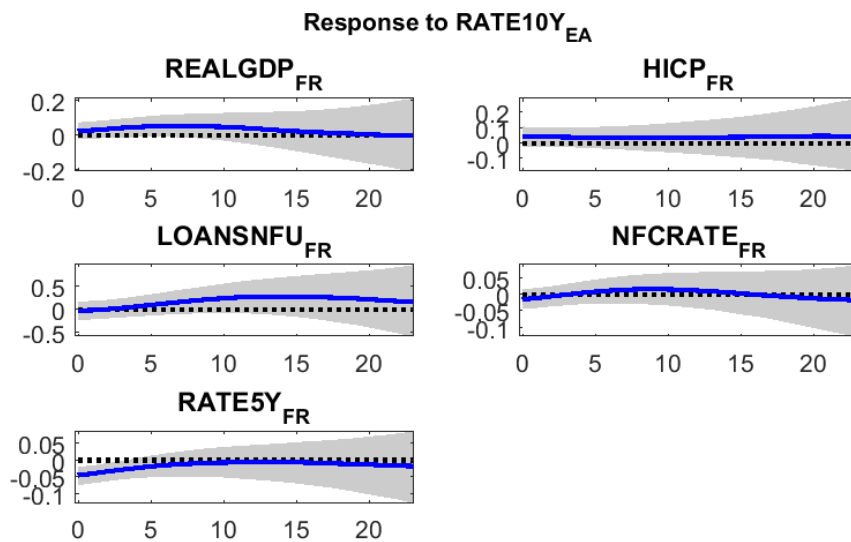
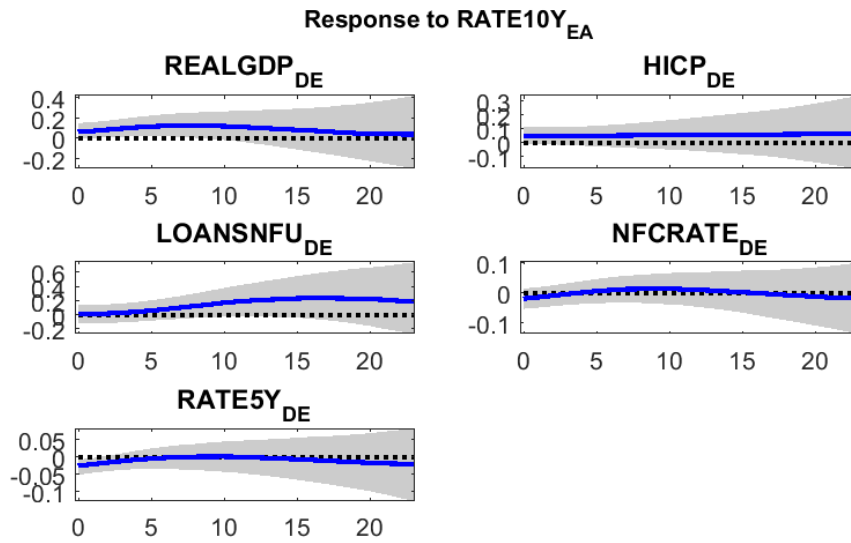
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Appendix

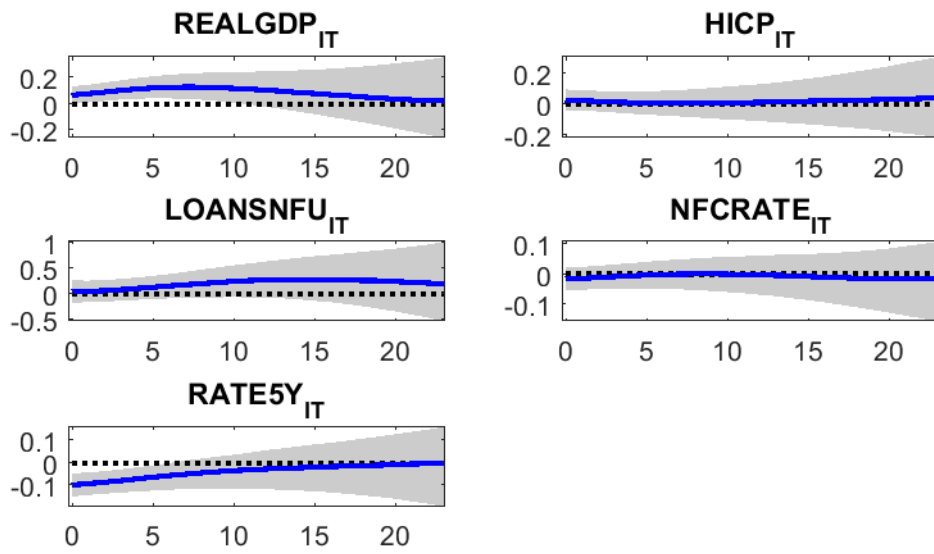
Table A1: Sign and zero restrictions for model with euro area output and price level (multi-country + euro area, MCEA model)

monetary policy shock variable	unconventional	conventional
<u>euro area block</u>		
real GDP	+	+
HICP or GDP deflator	+	+
EONIA	0	-
stock price index	+	
NEER	-	
CISS	-	
5- and 10-year government bond yield	-	-
excess bond premium	-	
spread between 5-year euro area average and German government bond yields	-	
<u>country block (DE, FR, IT, IS)</u>		
real GDP		
HICP or GDP deflator		
Loans to NFCs		
Lending rate		
5-year government bond yield	-	-
Sign restrictions imposed in impact period.		

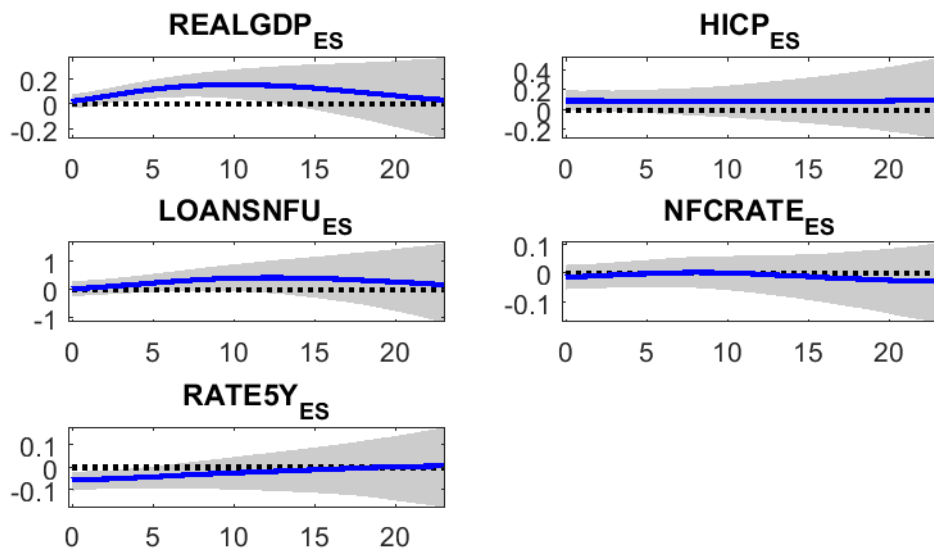
Figure A1: Impulse responses to an expansionary one-standard deviation unconventional monetary policy shock in the MC model (percentage points, median and 16th and 84th percentiles)



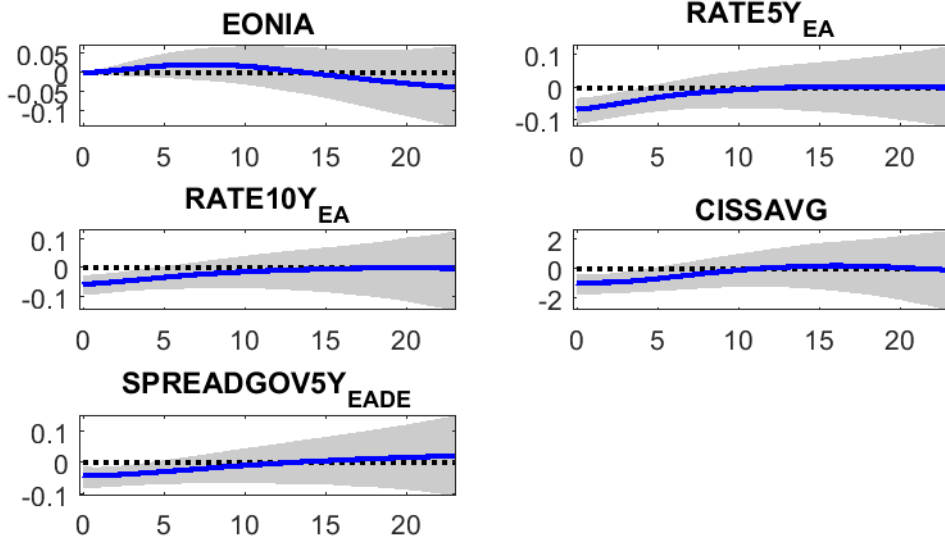
Response to $RATE10Y_{EA}$



Response to $RATE10Y_{EA}$



Response to $RATE10Y_{EA}$



Response to $RATE10Y_{EA}$

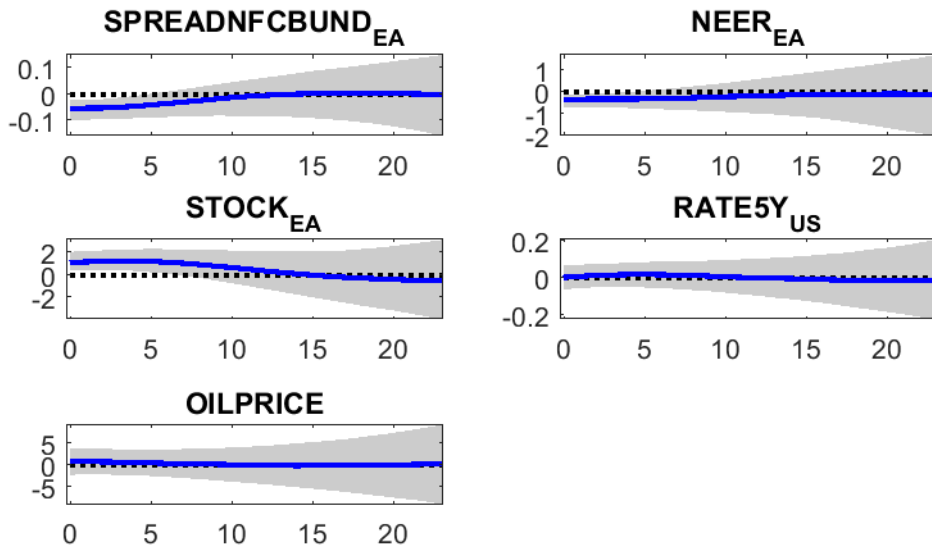
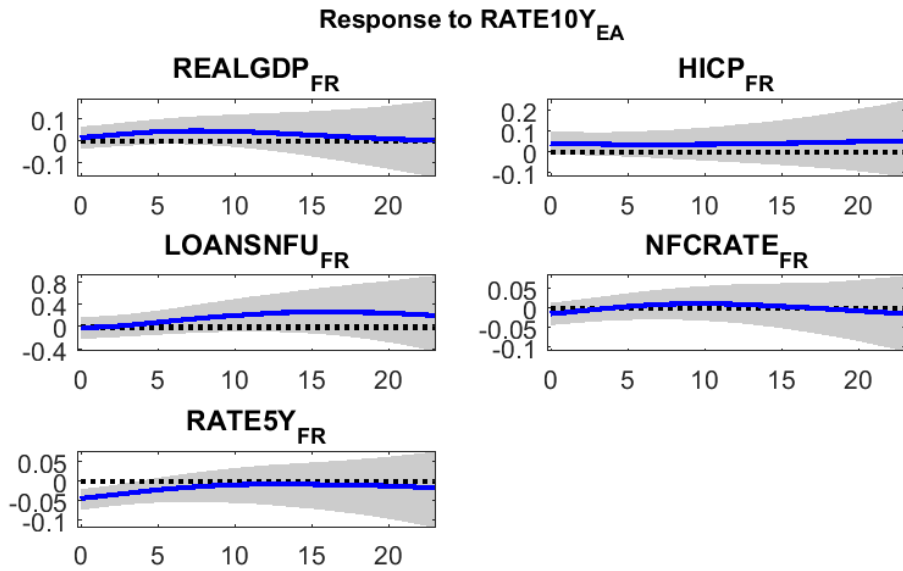
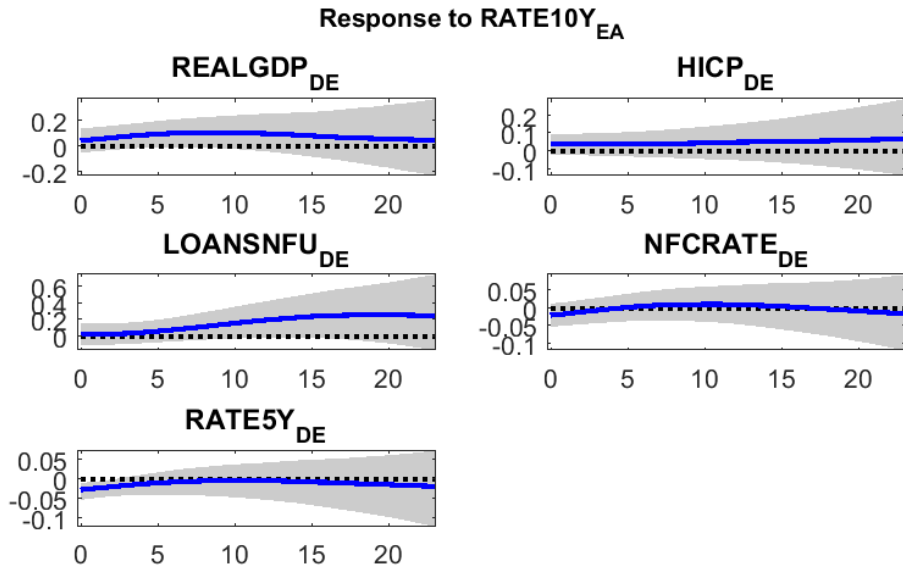
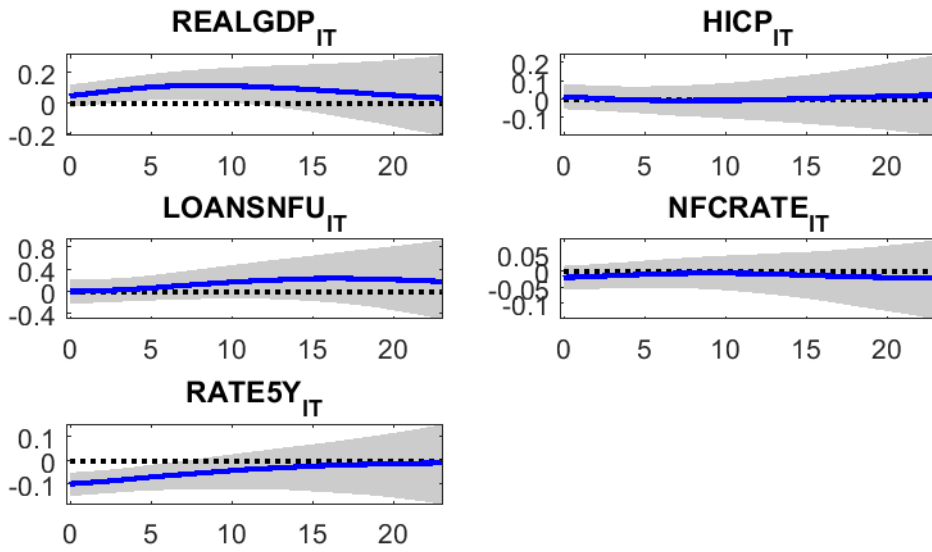


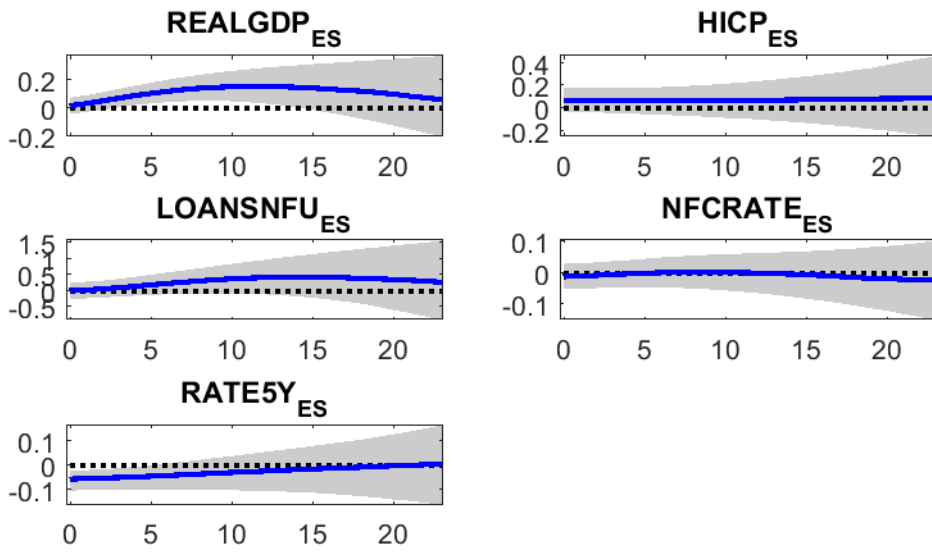
Figure A2: Impulse responses to an expansionary one-standard deviation unconventional monetary policy shock in the multi-country + euro area (MCEA) model (percentage points, median and 16th and 84th percentiles)



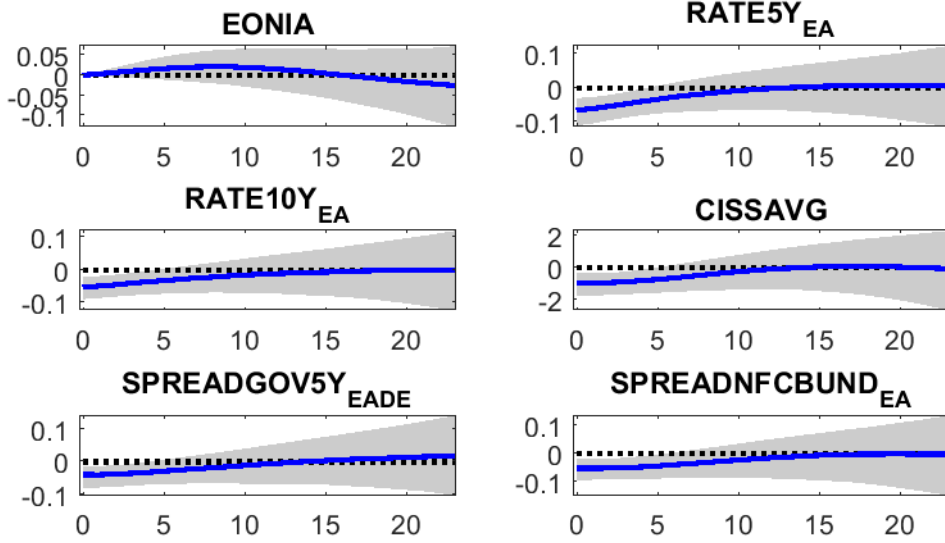
Response to $RATE10Y_{EA}$



Response to $RATE10Y_{EA}$



Response to $RATE10Y_{EA}$



Response to $RATE10Y_{EA}$

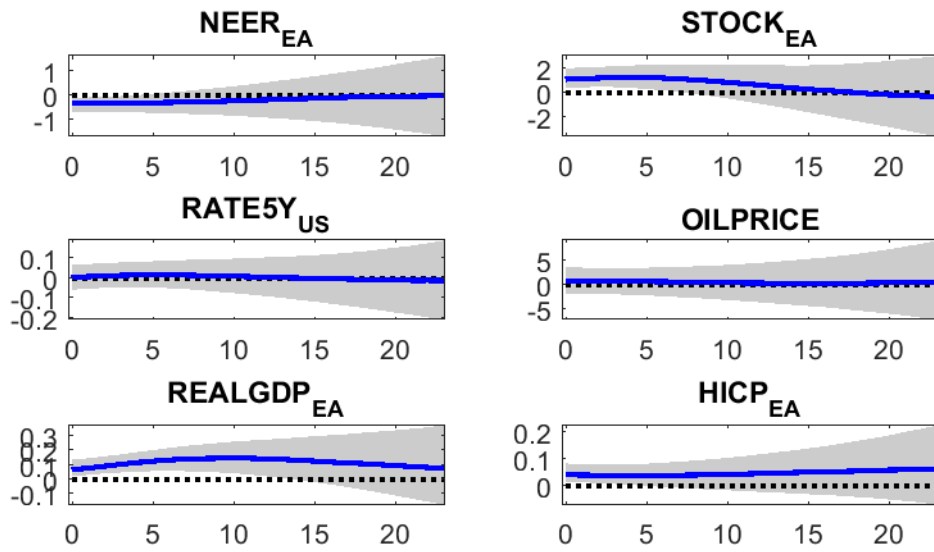


Figure A3: Cross-country differences between simulated APP effects from MC model
 – bond yields percentage points, median, 25th, 33th, 66th and 75th percentiles)

RATE5Y

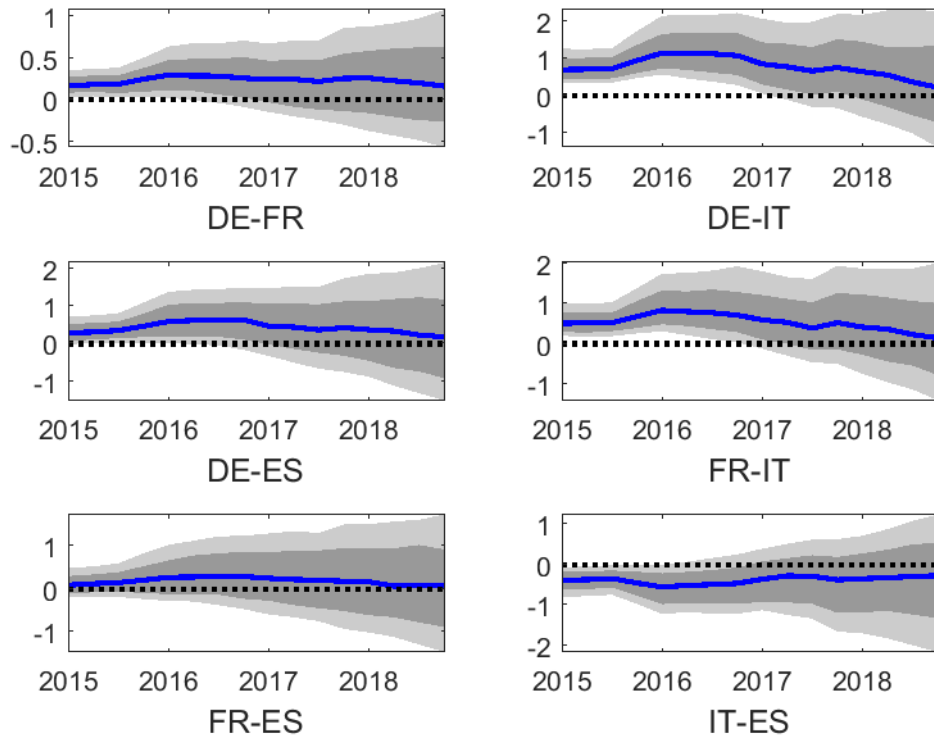
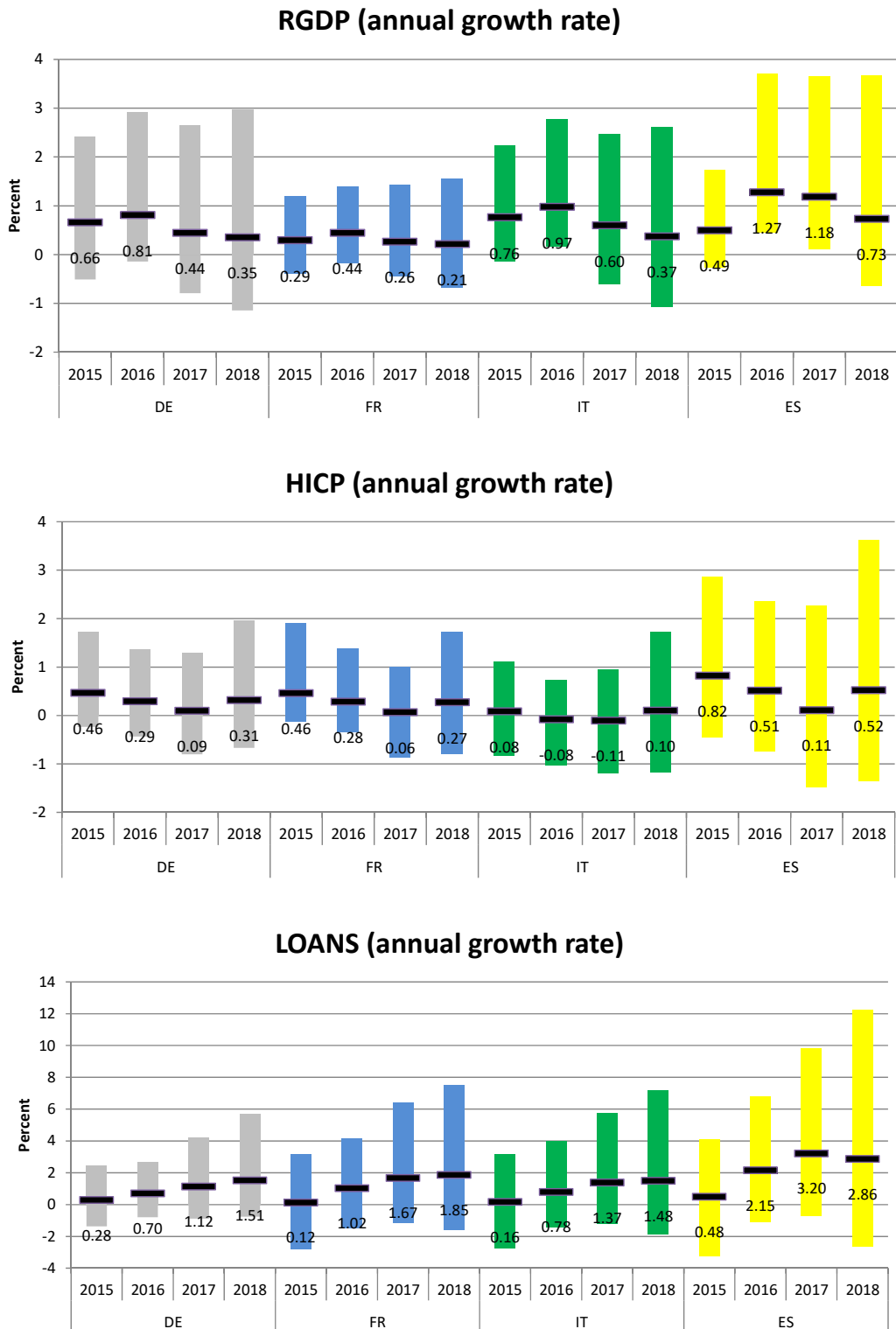
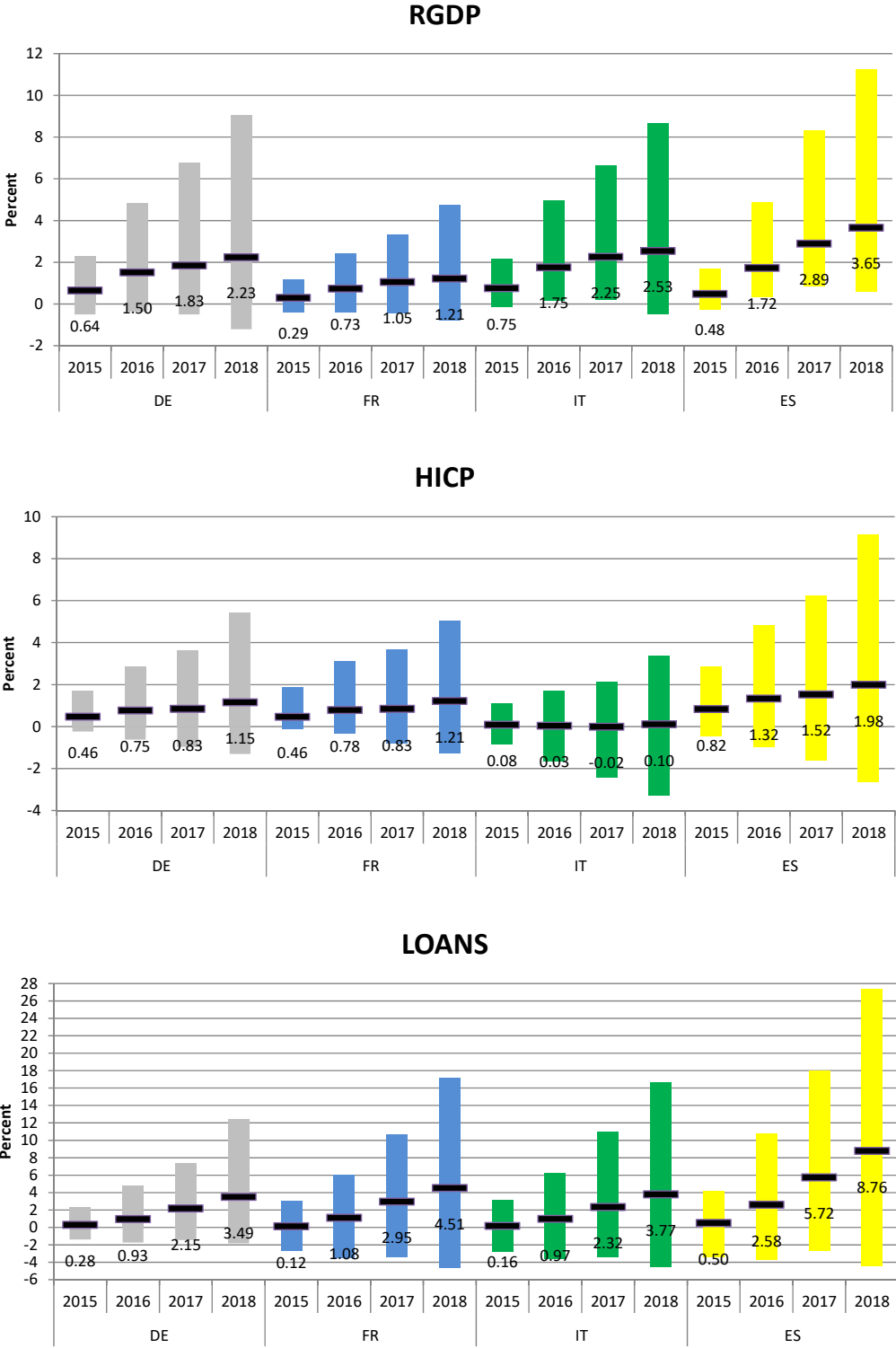


Figure A4: Estimated APP effects from multi-country + euro area (MCEA) model (growth rates)



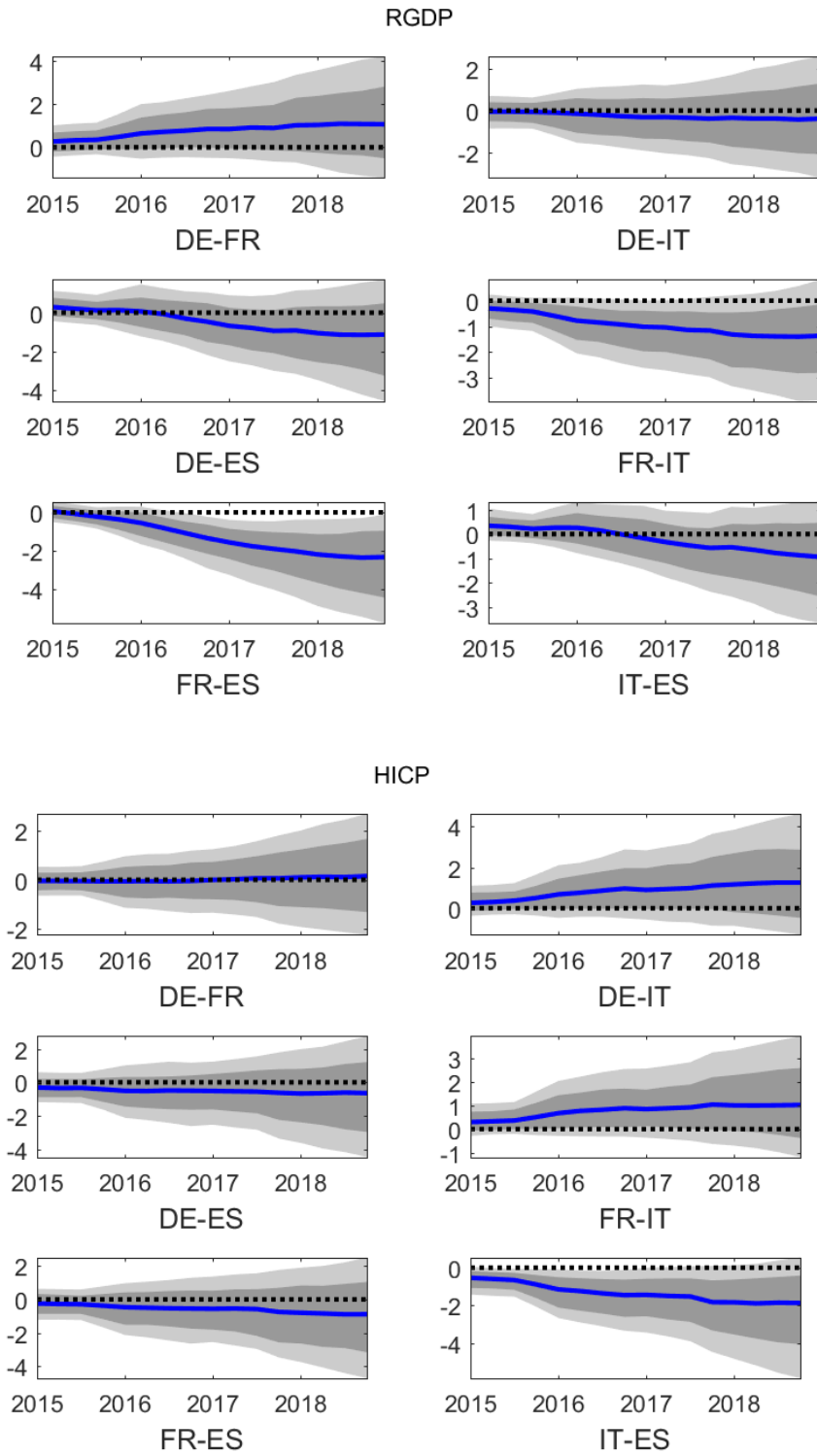
Deviation from annual growth rates from unconditional forecast (annual averages). Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Model includes euro area aggregate real GDP and price level.

Figure A5: Estimated APP effects from MCEA model (cumulative effects)



100 times log-difference between conditional and unconditional forecasts, average per year. Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Model includes euro area aggregate real GDP and price level.

Figure A6: Cross-country differences between simulated APP effects from MCEA model (cumulative effects, percentage points, median, 25th, 33th, 66th and 75th percentiles)



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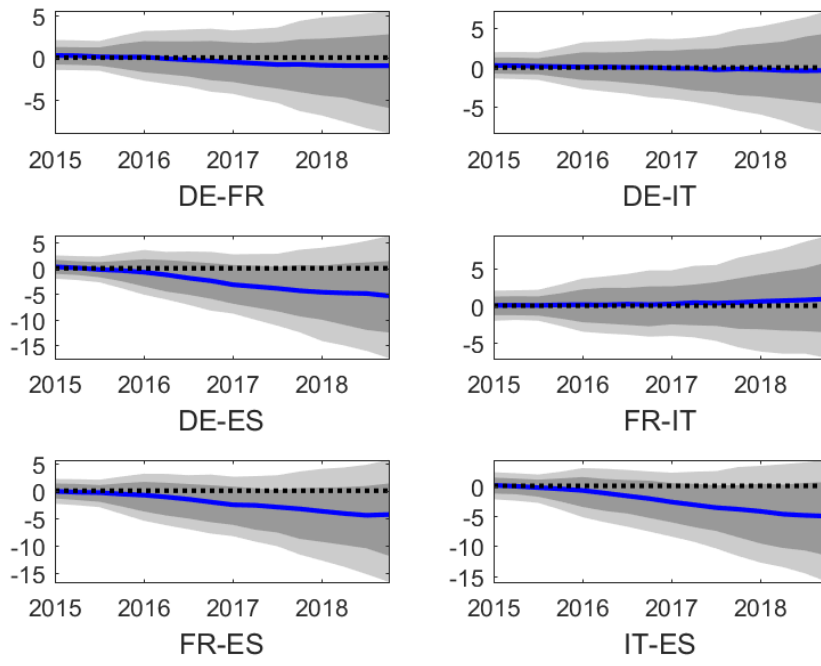
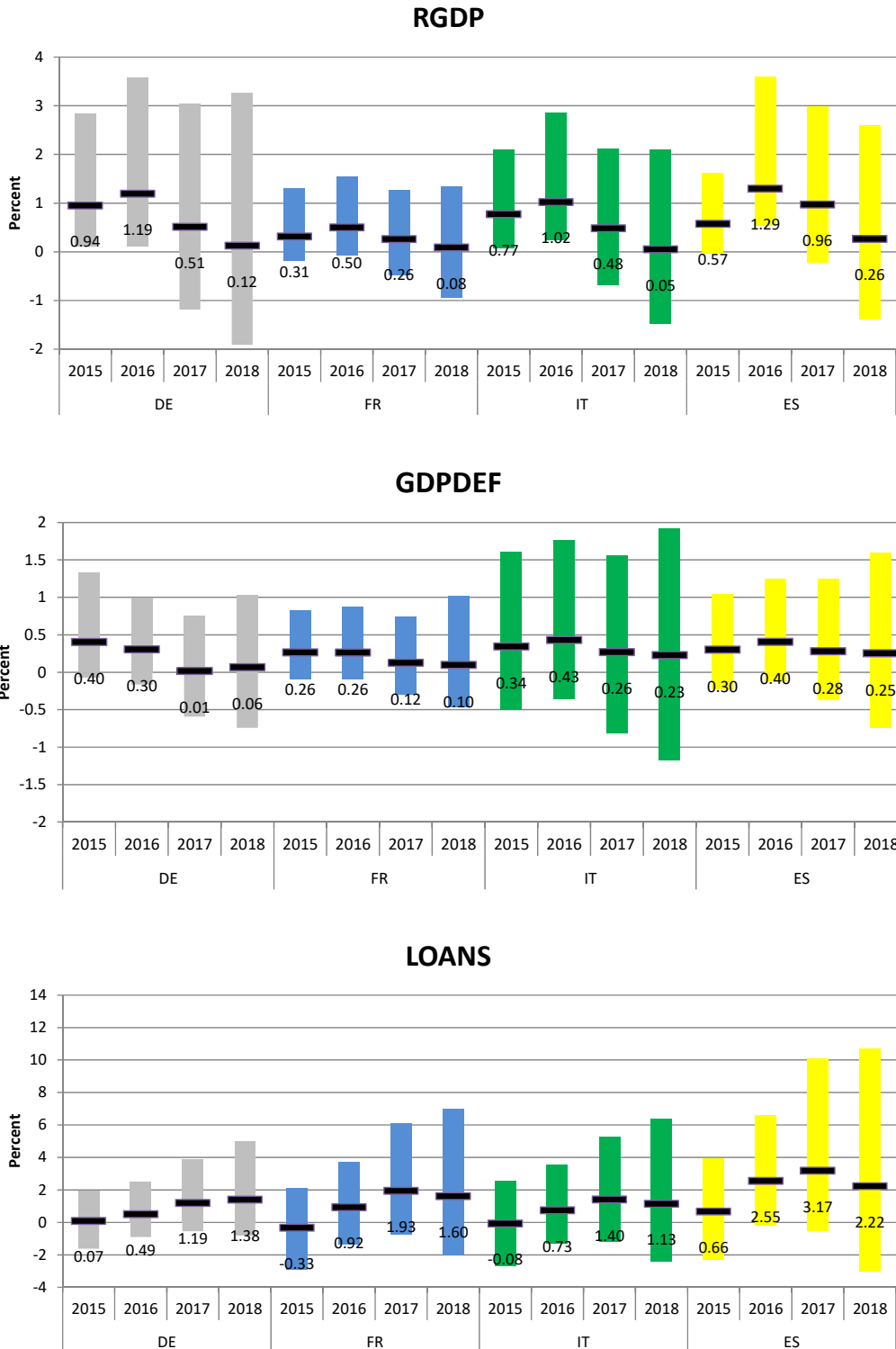
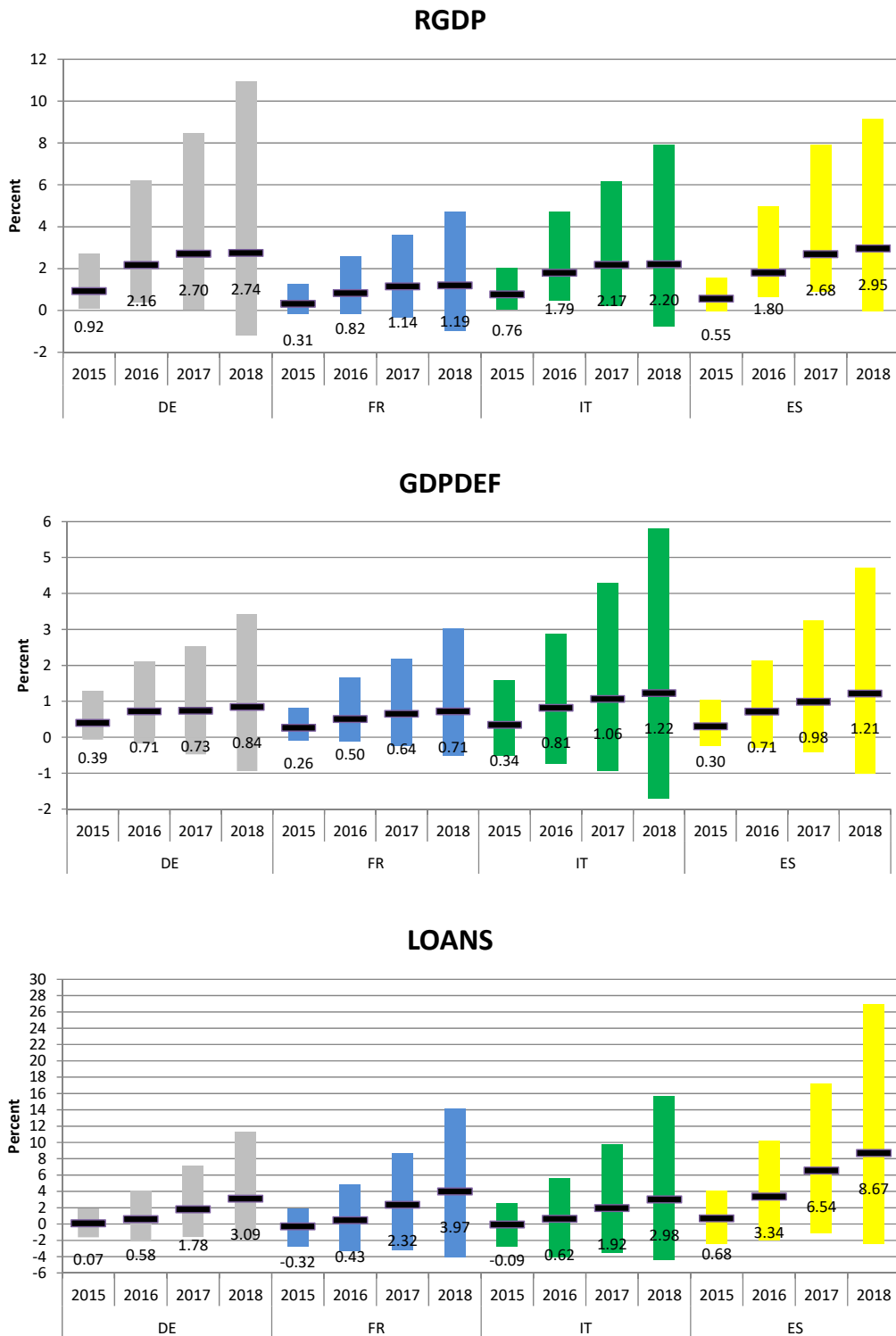


Figure A7: Estimated APP effects from MC model with GDP deflator (growth rates)



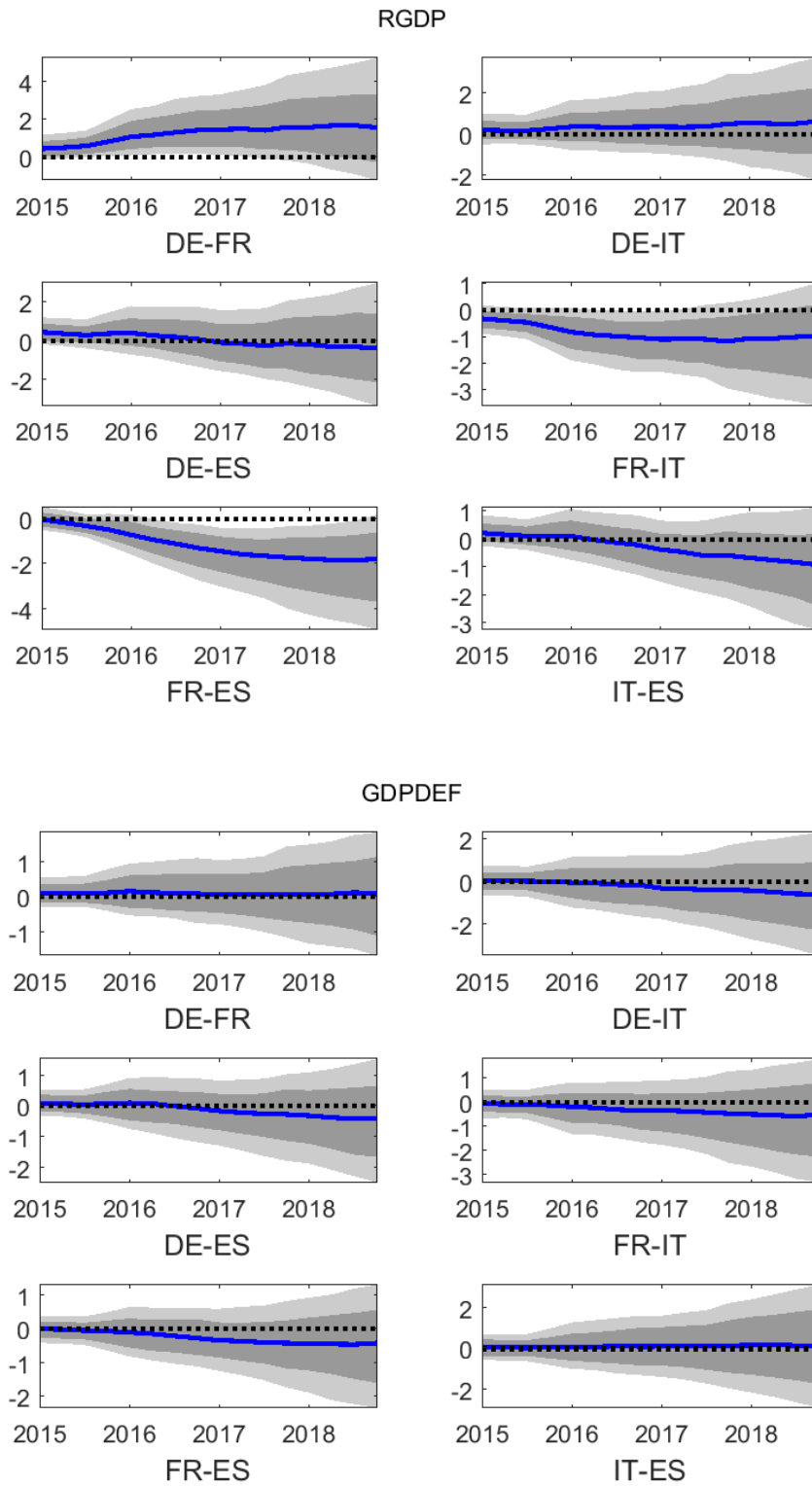
Deviation from annual growth rates from unconditional forecast (annual averages). Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Sign restrictions on country averages of real GDP and price level.

**Figure A8: Estimated APP effects from MC model with GDP deflator
(cumulative effects)**



100 times log-difference between conditional and unconditional forecasts, average per year. Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Sign restrictions on country averages of real GDP and price level.

Figure A9: Cross-country differences between simulated APP effects from MC model with GDP deflator (cumulative effects, percentage points, median, 25th, 33th, 66th and 75th percentiles)



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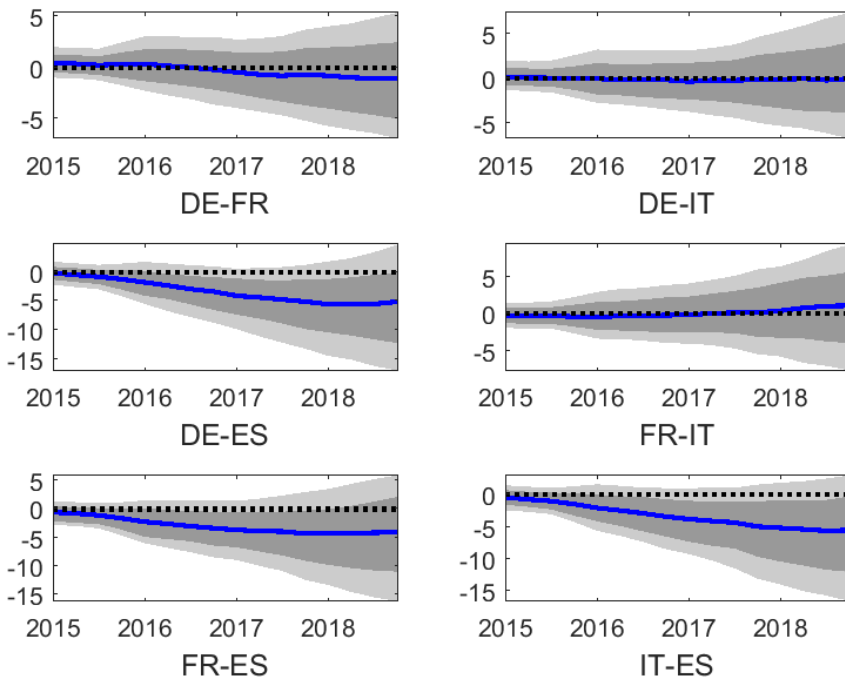
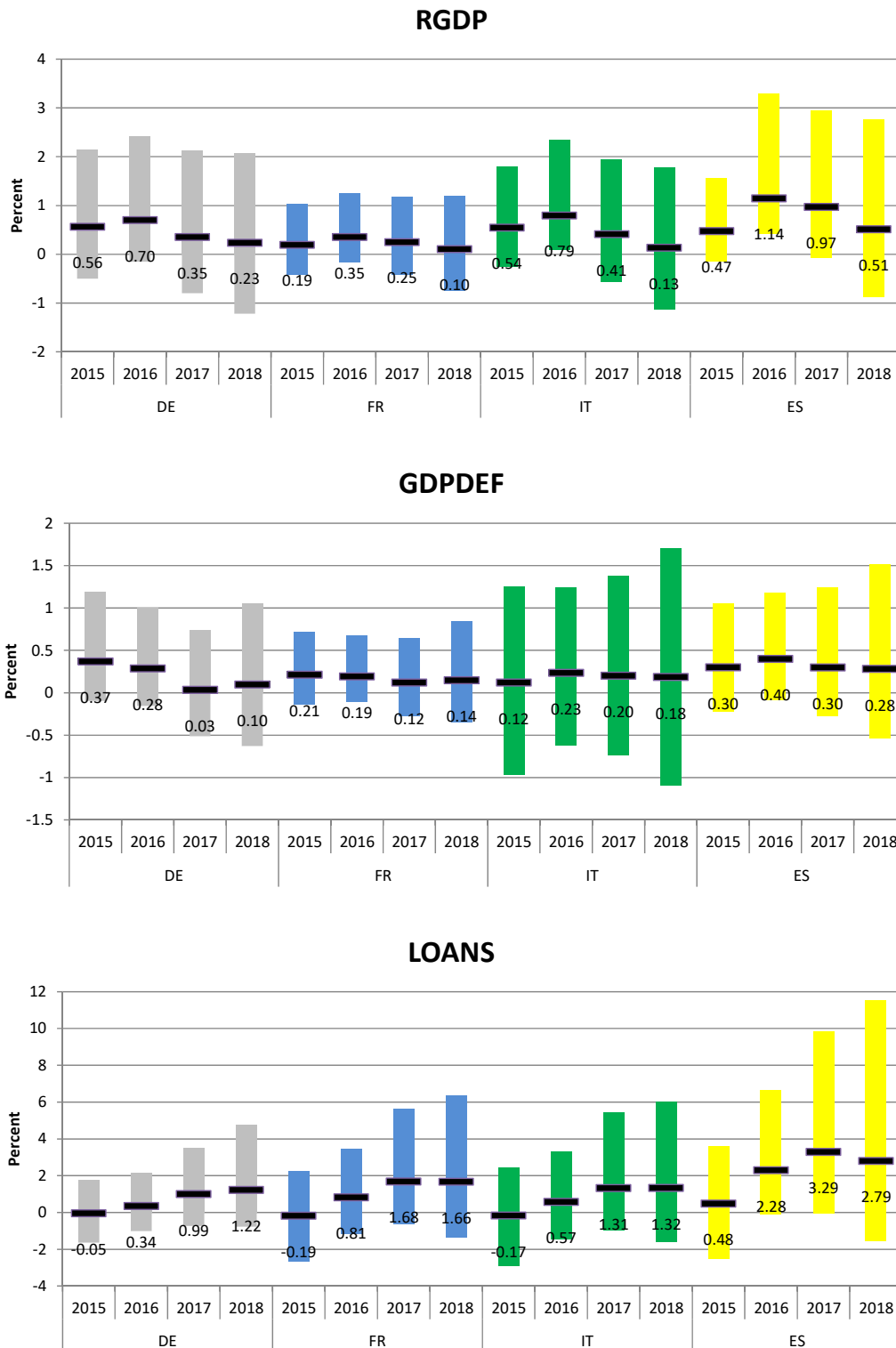
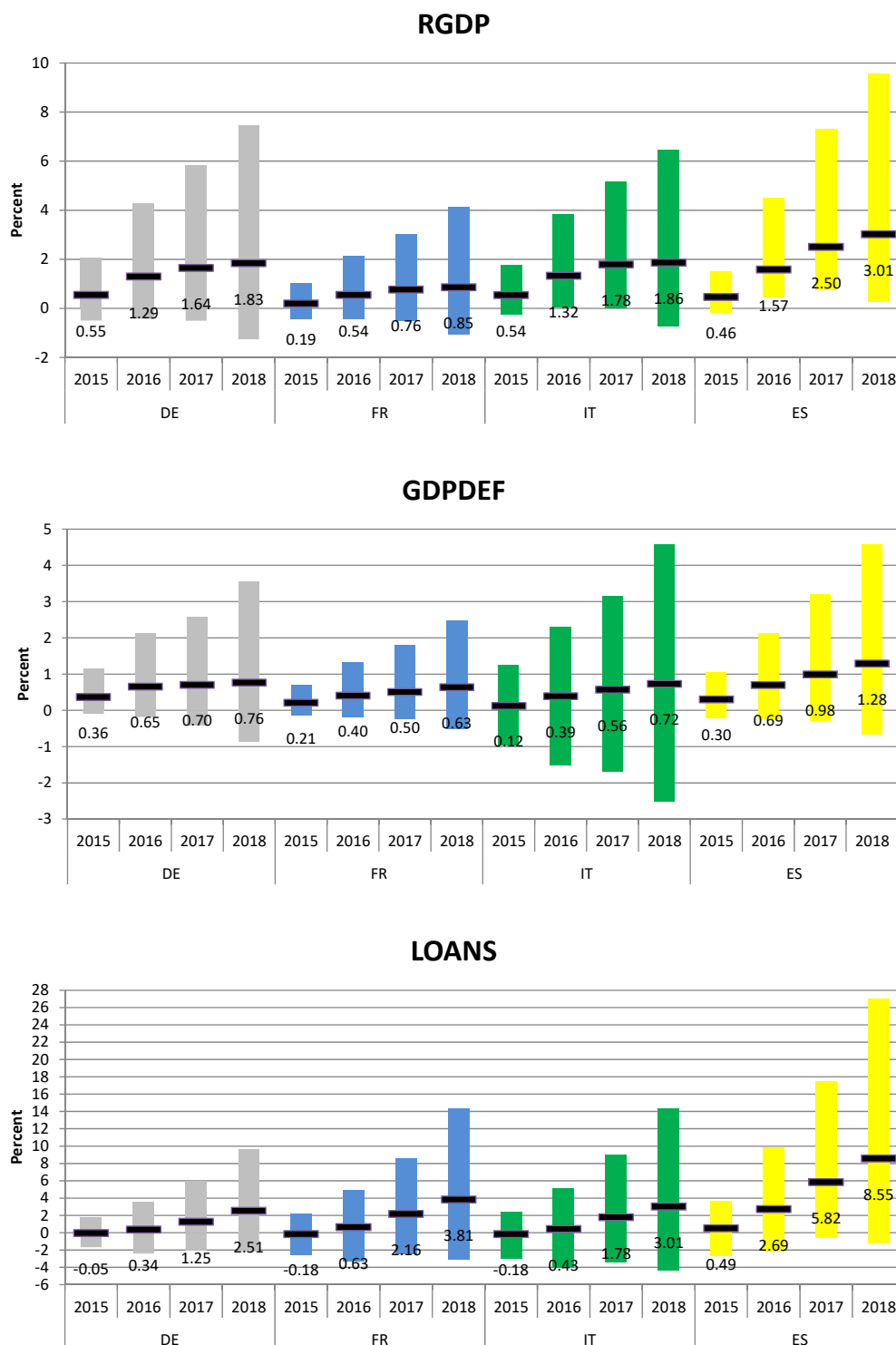


Figure A10: Estimated APP effects from MCEA model with GDP deflator (growth rates)



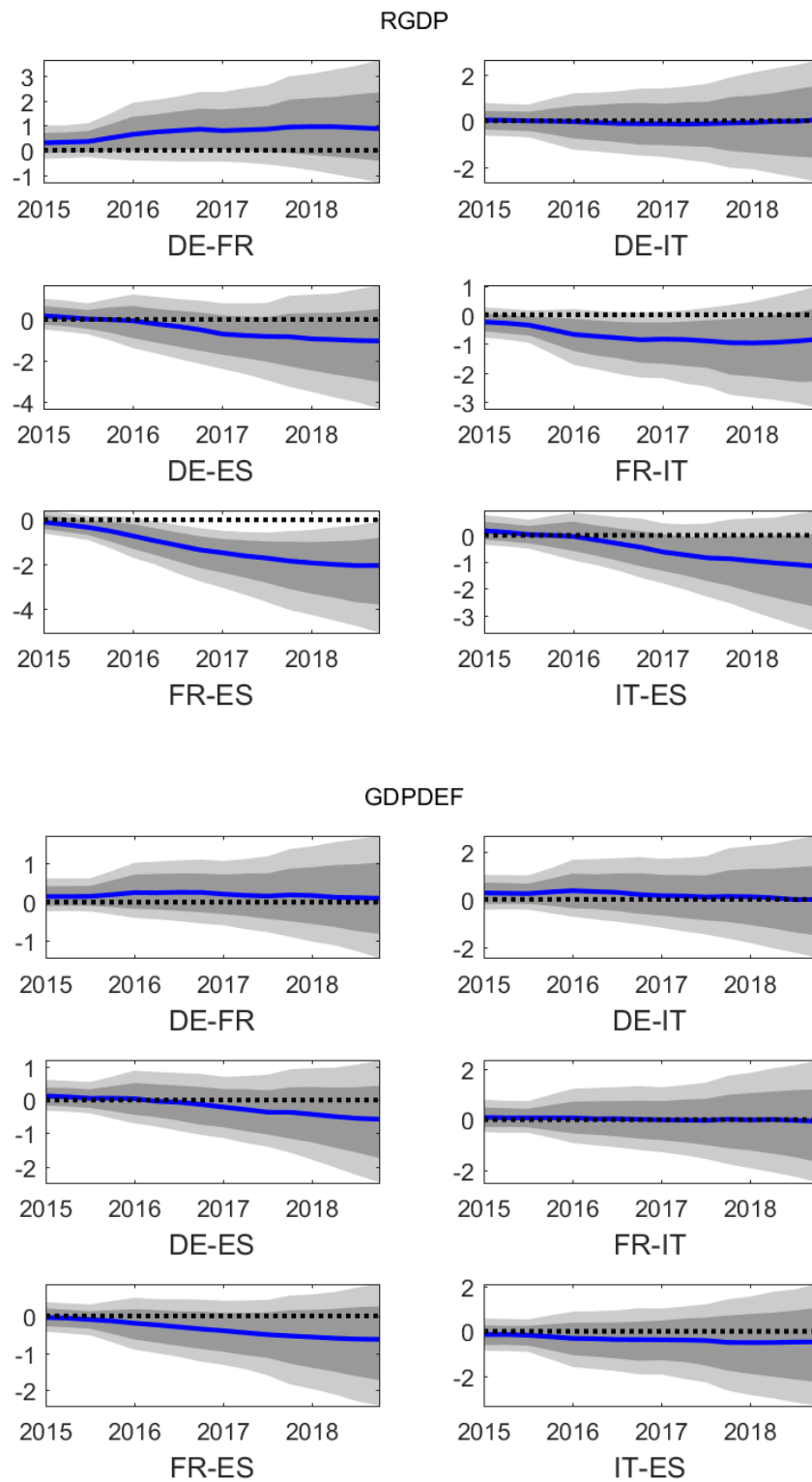
Deviation from annual growth rates from unconditional forecast (annual averages). Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Model includes euro area aggregate real GDP and price level.

Figure A11: Estimated APP effects from MCEA model with GDP deflator (cumulative effects)



100 times log-difference between conditional and unconditional forecast, average per year. Black lines and numbers indicate median estimate. Bars represent area between 16th and 84th percentiles. Model includes euro area aggregate real GDP and price level.

Figure A12: Cross-country differences between simulated APP effects from MCEA model with GDP deflator (cumulative effects, percentage points, median, 25th, 33th, 66th and 75th percentiles)



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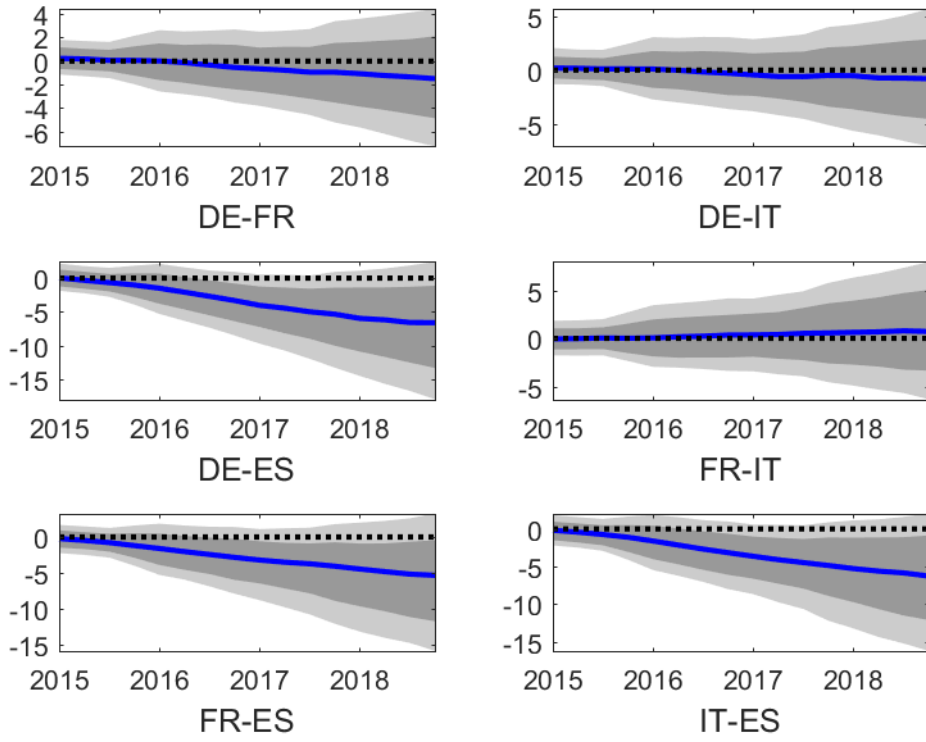


Figure A13: Actual (black) and counterfactual inflation rate without APP, MCEA model (median of counterfactual in blue, 33th and 66th percentiles in red, 25th and 75th percentiles in green)

