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THE MACROECONOMIC EFFECTS OF AN OPEN-ENDED ASSET PURCHASE PROGRAMME

by Lorenzo Burlon,* Alessandro Notarpietro* and Massimiliano Pisani*

Abstract

In this paper we evaluate the effectiveness of an open-ended asset purchase programme (APP) for the euro area. To achieve this, we use the large-scale New Keynesian dynamic general equilibrium model calibrated to the euro area and the rest of the world developed by Burlon et al. (2017), but we modify it and assume that the central bank does not announce the end date of the programme, leaving open the possibility of extending it in future periods, conditional on inflation developments. We assume that agents form their expectations about possible additional purchases beyond the horizon of the central bank's announcement according to a rule linking them to the expected inflation gap. It is shown that an open-ended APP is more effective in immediately stimulating macroeconomic conditions than an APP with an ex-ante commitment to an end date. Moreover, the open-ended dimension provides a hedge against the materialization of negative euro-area aggregate demand shocks that push inflation away from its path towards the target. Its effectiveness is further reinforced by forward guidance on monetary policy rates.

JEL Classification: E43, E44, E52, E58.
Keywords: central bank communication, open-ended announcement, non-standard monetary policy, DSGE models, open-economy macroeconomics, euro area.

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* Bank of Italy, Directorate General for Economics, Statistics and Research.

1 Introduction

In January 2015 the Eurosystem extended its asset purchase programme (APP) to euro-denominated investment-grade securities issued by euro-area (EA) governments and institutions in the secondary market. The reason for this decision was the progressive fall of inflation that was leading to a de-anchoring of inflation expectations from levels consistent with price stability and risks of a deflationary spiral. The implementation of these measures contributed to improve EA macroeconomic conditions and favored a substantial progress on the path towards a sustained adjustment in inflation.

In December 2016 the ECB started a recalibration of the non-standard monetary policy measures, and in particular the APP.[1]

The design of this recalibration involved several decisions about its timing, size, and composition, and should be related to decisions about the (current and expected) path of (short-term) monetary policy rates.

Crucially, the recalibration must be accompanied by a careful communication, that allows to appropriately manage agents' (households' and firms') expectations about future monetary and financial conditions and, thus, favor the macroeconomic effectiveness of the implemented measures.

In this respect, a crucial feature of the recalibration is the choice between a programme with an end date for the net purchases that is announced and a programme that remains open-ended. So far, the ECB has chosen to maintain the possibility to extend the flow of future net purchases beyond the horizon of the purchases to which it has made explicit commitment. This has contributed to reaffirm a steadfast commitment to pursue the price stability objective and to maintain the prudent approach that should unavoidably characterize monetary policy under uncertainty about the current and future states of the economy. Moreover, in its announcements, the ECB has connected the end of the Forward Guidance (FG) to the end of the APP by explicitly communicating that monetary policy rates are expected to remain at their present levels for an extended period of time, and, crucially, past the horizon of our net asset purchases.

In this paper we evaluate the macroeconomic effectiveness of the announcement that the APP is open-ended. To this purpose, we build on the large-scale New Keynesian dynamic general equilibrium model calibrated to the EA and the rest of the world (RW) developed in Burlon et al. (2017). The EA is formalized as a monetary union of two regions, Home and rest of the euro area (REA), where Home is of medium size (its GDP being around 20 percent of overall EA GDP). The APP consists of purchases of long-term sovereign bonds by the EA central bank (we consider only the public sector purchase programme leg of the APP for simplicity). Following Chen et al. (2012), we assume that in each EA country some households (labeled "restricted") have access only to long-term sovereign bonds. This feature captures the presence

[1] See Draghi and Constâncio (2017).

of investors who have a demand over specific asset classes and maturities, as formalized in the preferred-habitat framework.[2] The presence of these agents allows for real effects of purchases of long-term sovereign bonds, as those households' decisions depend only on long-term rates. The rest of the households (labeled "unrestricted") have instead access to multiple asset markets and, in particular, their decisions are directly affected by the short-term monetary policy rates. Moreover, we assume FG on the policy rates, i.e., the central bank announces the number of periods the policy rates should be expected to remain at their current (baseline of the model) level.

Different from the theoretical framework in Burlon et al. (2017), we assume that, in the case of an open-ended programme, when there is no explicit commitment by the central bank to close the programme, agents follow an empirical rule to form their expectations about future, not yet announced, asset purchases that the central bank would implement in the quarters past the announced horizon. The rule links the expected purchases to the expected inflation gap, i.e., the distance of expected inflation from the target. If the expected inflation gap is positive, then agents expect additional purchases (that have not been announced). The rule is based on the inference that agents may have drawn from previous APP announcements. Crucially, the rule specification and its parameter values are in line with anecdotal evidence provided by financial analysts.[3] This allows us to discipline the results of our simulations from both a theoretical and a quantitative point of view. Moreover, we use the ECB October 2017 announcement on the pace and amount of future purchases as a case study for our analysis.

The other model features are in line with those of existing large-scale dynamic general equilibrium models of the EA, like Eurosystem's EAGLE (Gomes et al. (2010)) and ECB's New Area Wide Model (Christoffel et al. (2008)). In particular, we distinguish between final (non-tradable) consumption and investment goods and between intermediate tradable and non-tradable goods, produced according to sector-specific technologies exploiting domestic capital and labor. We also include standard nominal (price and wage) and real (consumption habit and investment adjustment costs) frictions.

We consider several scenarios. We simulate future purchases either under a "full" announcement – i.e., an announcement of a purchasing programme that specifies both the overall path of future purchases and their end date – or under an "open-ended" announcement, in which the end date is not specified and the possibility of additional future purchases is communicated. All announcements are accompanied by the FG on the policy rate. Moreover, we assess the effectiveness of the two announcements when a negative demand shock to the EA aggregate demand reduces EA inflation and, thus, widens the gap from the inflation target.

The results are the following ones. First, the announcement of keeping the APP open-ended is more effective in stimulating macroeconomic conditions than an announcement that commits

[2] See Modigliani and Sutch (1966) and Andrés et al. (2004). Recently, Altavilla et al. (2015), Blattner and Joyce (2016), and Ferdinandusse et al. (2017) have provided empirical evidence on the presence of preferred-habitat investors in the EA.

[3] See Skolimowski (2017) and Praet (2018).

to an end date. Given the initial positive inflation gap, agents expect additional purchases in the case of open-ended APP. The long-term interest rate decreases more than in the case of announcing a programme that is not open-ended and EA economic activity and inflation increase more. Second, the effectiveness of the open-ended programme is reinforced by the FG on monetary policy rates. In particular, for a given amount of announced purchases, keeping the monetary policy rate unchanged past the purchases' horizon stimulates economic activity and reduces the expected inflation gap. This induces households to expect a lower amount of additional (unannounced) purchases. Third, the open-ended APP is more effective in stabilizing the economy if negative EA aggregate demand shocks unexpectedly materialize and push down inflation. In this case, the widening of the inflation gap associated with the shocks induces agents to expect a larger amount of additional purchases by the central bank.

The paper builds upon several recent contributions.

Among the recent studies that analyze the effectiveness of the APP, there is a growing consensus that the adoption of the APP has had both financial and real effects, and that the latter are mostly consistent with a portfolio rebalancing channel. See, among others, Breckenfelder et al. (2016). Differently from previous studies, our exercise features two EA-specific characteristics, the monetary union and open-economy dimensions, and attempts a first description of expectations' formation by private agents in presence of an open-ended programme.

Burlon et al. (2017) study the macroeconomic effectiveness of the APP under different assumptions regarding the duration of the purchases and of the FG on the policy rates. One of the main conclusions of that paper is that the more distant in the future the announced closing date of a programme, the larger the (current and future) effectiveness of the programme itself. In this paper, instead, using a similar framework as in Burlon et al. (2017) (the key difference being the rule on expectations about unannounced future purchases) we show that not announcing a closing date when phasing out from the programme can be an effective policy choice. Even if based on a case study (i.e., the ECB October 2017 announcement), our analysis makes clear a rather general point on central bank communication, relevant from both theoretical and quantitative perspectives: (1) the way agents form expectations about future purchases and (2) the extent to which the central bank can shape them through (past and current) announcements are both crucial for designing the phasing out from a programme in an effective way. Moreover, we are the first, to the best of our knowledge, to make this type of analysis in a fully-fledged New Keynesian model.[4] The importance of monetary policy communication in situations where high macroeconomic uncertainty and new policy tools may limit the predictability of policy actions is the focus of Coenen et al. (2017).

The paper is organized as follows. Section 2 describes the main features of the model, in particular the non-standard monetary policy measures (sovereign bond purchases by the central bank) and the formation of agents' expectations on future purchases by the central bank in the case of open-ended APP. Section 3 describes the simulated scenarios. Section 4 reports the main

[4]See also Harrison (2012), Darracq Pariès and Kühl (2016), Woodford (2016), and Reis (2017).

results. Section 5 concludes.

2 The model

The model builds on the one in Burlon et al. (2017) with one crucial departure, i.e., the presence of an empirical rule that, in the case of an open-ended programme, households use to form their expectations about future unannounced asset purchases by the central bank. We first provide an overview of the model. Subsequently, we describe its key features, i.e., the rule used by agents to form expectations about unannounced future purchases, (restricted and unrestricted) households, capital producers, the EA central bank, the regional fiscal authorities, and the definition of general equilibrium. Finally, we show the calibration.

2.1 Overview

The model is New Keynesian and represents a world economy composed of three regions, i.e., Home, REA (Home+REA=EA), and RW. The size of the world economy is normalized to 1. Home, REA, and RW have sizes equal to n, n^*, and $(1-n-n^*)$, with $n > 0$, $n^* > 0$, and $n + n^* < 1$.[5] Home and REA share the currency and the central bank. The latter sets the nominal interest rate according to EA-wide variables (a standard Taylor rule holds) when it does not deliberately enact non-standard monetary policy measures. The presence of the RW outside the EA allows to assess the role of the nominal exchange rate and extra-EA trade for the transmission of the EA shocks.

Crucial features of the model are two: the rule-based formation of households' expectations about future (unannounced) APP purchases in the open-ended scenario and financial market segmentation.

The first key, and novel, feature is that, in scenarios featuring the open-ended programme, when the central bank does not commit to an end date and keeps the possibility to continue purchases past the announcement horizon, agents follow a rule to form their expectations about future unannounced purchases, that the central bank will implement in the quarters past the horizon of the announced asset purchases. The rule links the expected purchases to the expected inflation gap, i.e., the distance of expected inflation from the target. The rule is based on the inference that agents may have drawn from previous APP announcements.

The second crucial feature of the model is financial market segmentation à la Chen et al. (2012), which allows us to relax the well-known "Wallace neutrality" and make financial assets imperfect substitute so that sovereign bonds' purchases by the central bank have real effects in our model.[6] In each EA region there are two types of households, "restricted" and "unrestricted."

[5] For each region, size refers to the overall population, to the number of firms operating in each sector and, in the case of each EA region, the number of capital producers.

[6] See Wallace (1981).

Restricted households can invest only in domestic long-term sovereign bond market and, because they are owner of domestic capital producers (joint with domestic unrestricted households), in domestic private physical capital. The increase in the purchases of long-term government bonds by the monetary authority reduces long-term interest rates (their term premium component) and therefore induces restricted households to increase consumption and investment via the standard intertemporal substitution effect. To the opposite, unrestricted households (1) have access to the domestic short-term private bond and long-term sovereign bond markets, (2) trade a riskless private bond with RW households, and (3) invest in physical capital because they own domestic capital producers. The consumption/saving decisions of the unrestricted households depend not only on long-term interest rates, but also on short-term ones. Thus, the FG on short-term (monetary policy) rate directly affects optimal choices of those households, in particular consumption and investment in physical capital through the capital producers. Finally, there are capital producers that accumulate private physical capital by demanding final investment goods subject to quadratic adjustment costs on investment change. They rent out capital to the domestic firms producing intermediate goods. They maximize profits with respect to capital and investment taking prices as given, and evaluate returns according to a weighted average of restricted and unrestricted households' stochastic discount factors (where the weights reflect the corresponding population shares). The (net) revenues are rebated in a lump-sum way to domestic restricted and unrestricted households according to their corresponding shares.

Remaining features of the model are standard.

Households consume a final non-tradable good which is a composite of intermediate non-tradable and tradable goods. The latter are domestically produced or imported. All households supply differentiated labor services to domestic firms and act as wage setters in monopolistically competitive labor markets by charging a mark-up over their marginal rate of substitution between consumption and leisure.

On the production side, there are perfectly competitive firms that produce two final goods (consumption and investment goods) and monopolistic firms that produce intermediate goods (firms are owned by domestic unrestricted households). The two final goods are sold domestically and are produced combining all available intermediate goods using a constant-elasticity-of-substitution (CES) production function. The two resulting bundles can have different compositions. Intermediate tradable and non-tradable goods are produced combining private capital and labor. The two factors are assumed to be mobile across sectors. Intermediate tradable goods can be sold domestically and abroad. Since intermediate goods are differentiated, firms have market power and restrict output to create excess profits. We also assume that markets for tradable goods are segmented, so that firms can set a different price for each of the three markets. As in Gomes et al. (2010), adjustment costs ensure that main variables react smoothly to a shock. Specifically, on the real side, habits and quadratic costs prolong the adjustment of consumption and investment, respectively. On the nominal side, quadratic costs make wages and

prices sticky.[7]

2.2 Expectations about future bond purchases in the open-ended APP

Even if the size, pace, and timing of the APP changed from one announcement to the other, the official communication by the ECB has always aimed these announcements to the achievement of a sustained adjustment in the path of inflation, "that is consistent with its aim of achieving inflation rates below, but close to, 2% over the medium term."

Thus, it is plausible that market participants and private analysts have strived to map the features of each announcement into some possible form of ECB's "reaction function," that connects the expected adjustment in inflation to the expected amount of sovereign bonds' purchases.[8]

Consistent with the evidence on the inference by market participants reported by Skolimowski (2017), in the "open-ended" scenarios we assume that agents (households and firms) in both EA regions form their expectations about future central bank purchases according to a rule. The rule dictates that in correspondence of positive expected inflation gaps in the quarters past the end of announced purchases, agents form their expectations about additional unannounced future central bank purchases in those quarters according to the size of the (positive) inflation gap. Thus, we assume that in both EA regions expectations over future unannounced purchases evolve as follows:

$$\mathbb{E}_t \left[B^L_{APP,t+h} - B^L_{APP,t+h-1} \right] = \phi_{APP} \left(\pi^{target} - \mathbb{E}_t \left[\pi_{t+h} \right] \right), \tag{1}$$

where $\mathbb{E}_t$ is the expectation operator, $B^L_{APP,t}$ are the central bank purchases, π^{target} is the (annualized) inflation target of the central bank, $\mathbb{E}_t \left[\pi_{t+h} \right]$ is the expected (annualized) inflation rate in quarter $t+h$ with $h = 1, 2, 3, \ldots$, and $\phi_{APP} > 0$ is a parameter regulating the amount of additional expected net central bank purchases corresponding to each percentage-point deviation of expected inflation from the central bank target.

The above rule should not be interpreted as describing a central bank's systematic feedback rule regarding asset purchases that is perfectly known by agents.[9] Our rule wants to describe, in a stylized way, the formation of agents' expectations over unannounced future purchases, and does neither imply nor intend to model a complete control of the central bank over long-term interest rate developments.

[7] See Rotemberg (1982).

[8] In several speeches the ECB President Mario Draghi had suggested that the communication would have been aimed at clarifying its own reaction function. See, for example, Draghi (2014a) and Draghi (2014b). According to Praet (2018), "the convergence of market expectations towards the ECB's indications about the size and horizon of net asset purchases has proceeded in tandem with the gradual rise of inflation expectations towards our medium-term policy aim. Likewise, there is a strong co-movement between markets views of the convergence of inflation towards the ECBs aim on the one hand and, on the other, the length of the interval between the end of net asset purchases and the first rate rise fully priced into market rates. This suggests that our monetary policy reaction function is well understood."

[9] This corresponds to actual recent policy experience by the Bank of Japan and its yield-curve control policy. See Jones and Kulish (2013) and Amamiya (2017).

2.3 Restricted households

There exists a continuum of restricted households j', with $j' \epsilon (0, n\lambda_R]$, where $0 \leq \lambda_R \leq 1$. Their preferences are additively separable in consumption and labor effort. The generic restricted household j' receives utility from consumption $C_R(j')$ and disutility from labor $L_R(j')$. The household's expected lifetime utility is

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta_R^t \left[\frac{\left(C_{R,t}\left(j'\right) - hC_{R,t-1}\right)^{1-\sigma}}{(1-\sigma)} - \frac{L_{R,t}\left(j'\right)^{1+\tau}}{1+\tau} \right] \right\}, \tag{2}$$

where E_0 denotes the expectation conditional on information set at date 0, β_R is the discount factor ($0 < \beta_R < 1$), $1/\sigma$ is the elasticity of intertemporal substitution ($\sigma > 0$), and $1/\tau$ is the labor Frisch elasticity ($\tau > 0$). The parameter h ($0 < h < 1$) represents external habit formation in consumption.[10]

Restricted households have access only to the market of long-term sovereign bonds. The budget constraint is

$$\begin{aligned} & P_t^L B_{R,t}^L\left(j'\right) - \sum_{s=1}^{\infty} \kappa^{s-1} B_{R,t-s}^L\left(j'\right) \\ = \; & \Pi_t^{prof}\left(j'\right) + W_{R,t}\left(j'\right) L_{R,t}\left(j'\right) \\ & -P_t C_{R,t}\left(j'\right) - AC_{R,t}^W\left(j'\right), \end{aligned} \tag{3}$$

where $B_{R,t}^L$ is the amount of long-term sovereign bonds, Π_t^{prof} is profit from ownership of the Home capital producers. The long-term sovereign bonds have price $P_{L,t}$ and are formalized as perpetuities paying an exponentially decaying coupon $\kappa \in (0, 1]$, following Woodford (2001). The implied gross yield to maturity at time t on the long-term bond is defined as

$$R_t^L = \frac{1}{P_t^L} + \kappa. \tag{4}$$

Finally, households act as wage setters in a monopolistic competitive labor market. Each household j' supplies one particular type of labor services which is an imperfect substitute to services supplied by other households. It sets its nominal wage $W_{R,t}\left(j'\right)$ taking into account of the labor demand and quadratic adjustment costs AC_R^W à la Rotemberg:

$$AC_{R,t}^W\left(j'\right) \equiv \frac{\kappa_W}{2} \left(\frac{W_{R,t}\left(j'\right)/W_{R,t-1}\left(j'\right)}{\Pi_{t-1}^{\alpha_W} \bar{\Pi}_{EA}^{1-\alpha_W}} - 1 \right)^2 W_{R,t} L_{R,t}, \tag{5}$$

where $\kappa_W > 0$ and $0 \leq \alpha_W \leq 1$ are parameters regulating wage stickiness, the variable $\Pi_t \equiv P_{C,t}/P_{C,t-1}$ is the consumer price inflation rate, and $\bar{\Pi}_{EA}$ is the long-run inflation target of

[10] Following common practice in the New Keynesian literature, the assumption of cashless economy holds in the model.

the EA central bank (assumed to be constant). The adjustment costs are proportional to the per-capita (average) wage bill of restricted households, $W_{R,t}L_{R,t}$.[11]

Restricted households are crucial for the APP to have real effects in our model. As they cannot arbitrage between short-term and long-term bonds, their consumption decisions depend only upon the long-term interest rate (they do not directly depend upon the short-term rate). Therefore, the monetary policy authority can affect their consumption and saving decisions by directly intervening in the secondary long-term sovereign bond market.

2.4 Unrestricted households

There exists a continuum of unrestricted households, indexed by j, with $j \in (n\lambda_R, n]$. These households have the same preferences as restricted households described in (2), thus they consume and supply labor. The only difference is the discount factor, β_U, which can be different from that of restricted households (this allows a well defined steady-state of the model).

Home unrestricted households have access to multiple financial assets (all denominated in euro terms): the short-term (one-period) sovereign bond B^G, exchanged with the domestic government; the short-term private bond B^P, exchanged with REA unrestricted and RW households and paying the (gross) interest rate R^P; the long-term sovereign bond B^L_U, exchanged with the domestic restricted households, domestic government and, because of the APP, the EA central bank. Thus, they have several opportunities to smooth consumption when facing a shock. The budget constraint of the generic unrestricted household j is

$$\begin{aligned}
&B^G_t(j) - B^G_{t-1}(j) R_{t-1} \\
&+B^P_t(j) - B^P_{t-1}(j) R^P_{t-1}(1-\phi_{t-1}) \\
&+P^L_t B^L_{U,t}(j) - \sum_{s=1}^{\infty} \kappa^{s-1} B^L_{U,t-s}(j) = \\
&W_{U,t}(j) L_{U,t}(j) + \Pi^P_t(j) + \Pi^{prof}_t(j) - P_t C_{U,t}(j) \\
&-TAX_t(j) - AC^W_{U,t}(j) - AC^B_{U,t}(j),
\end{aligned} \tag{6}$$

where the short-term government bond B^G_t pays the EA (gross) monetary policy rate R_t. The dividends $\Pi^P_t(j)$ are from ownership of domestic monopolistic firms (claims to firms' profits are not internationally tradable). The term ϕ_t represents an exponential adjustment costs, needed to stabilize the position in the internationally traded bond.[12] The variable Π^{prof}_t is

[11] As the implied first order conditions are rather standard we do not report them to save on space. They are available upon request.

[12] The adjustment cost is defined as

$$\phi_{B,t} \equiv \phi_{b1} \frac{\exp\left(\phi_{b2}\left(B^P_t - \bar{B}^P\right)\right) - 1}{\exp\left(\phi_{b2}\left(B^P_t - \bar{B}^P\right)\right) + 1}, \text{ with } \phi_{b1}, \phi_{b2} > 0$$

where B^P_t and $\bar{B}^P$ are the period t and steady-state positions of the representative Home unrestricted household, respectively. Both are taken as given in the maximization problem. A similar cost holds for the RW household.

profit from ownership of the Home capital producers. The term TAX_t represents lump-sum taxes. Unrestricted households supply labor services under monopolistic competition and face quadratic adjustment costs $AC^W_{U,t}$ when setting nominal wages (the cost is similar to the one paid by restricted households, see eq. 5). They also pay adjustment costs $AC^B_{U,t}$ on long-term sovereign bond holdings.[13]

First order conditions imply no-arbitrage conditions for the unrestricted households.[14] Thus, in equilibrium the interest rates paid by the different bonds are equal to the monetary policy rate R_t, net of the spreads induced by the longer maturity and the adjustment costs.[15]

2.5 Capital goods producers

There exists a continuum of mass $0 \leq n \leq 1$ of firms e that produce private physical capital. They optimally choose capital K_t and investment I_t to maximize profits subject to the law of capital accumulation, the adjustment costs on investment, and taking prices as given. The law of motion of capital accumulation is

$$K_t(e) = (1-\delta) K_{t-1}(e) + \left(1 - AC^I_t(e)\right) I_t(e),$$

where $0 < \delta < 1$ is the depreciation rate. The adjustment cost on investment AC^I_t is

$$AC^I_t(e) \equiv \frac{\phi_I}{2}\left(\frac{I_t(e)}{I_{t-1}(e)} - 1\right)^2, \text{ with } \phi_I > 0.$$

Capital producers rent existing physical capital stock $K_{t-1}(e)$ at the nominal rate R^K_t to domestic firms producing intermediate tradable and non-tradable goods. Investment is a final non-tradable good, composed of intermediate tradable (domestic and imported) and non-tradable intermediate goods. Capital producers buy it in the corresponding market at price P_I.[16] Because of the adjustment costs on investment, a "Tobin's Q" holds.

When maximizing profits with respect to capital and investment, capital producers discount profits using the stochastic discount rates of restricted and unrestricted households, aggregated according to the corresponding population shares.

[13] We assume a standard quadratic form for the adjustment cost, that is,

$$AC^B_{U,t}(j) \equiv \frac{\phi_{b^L}}{2}\left(P^L_t B^L_{U,t}(j) - \bar{P}^L \bar{B}^L_U\right)^2, \text{ with } \phi_{b^L} > 0,$$

where $\bar{P}^L \bar{B}^L_U$ is the (symmetric) steady-state value of the long-term sovereign bond. The adjustment cost guarantees that the bond holdings follow a stationary process and that the economy converges to the steady state.

[14] As the implied first order conditions are rather standard we do not report them to save on space. They are available upon request.

[15] See Chen et al. (2012) for the details. Our calibration implies that households can modify their financial positions without facing relevant adjustment costs.

[16] As for the consumption basket, the investment bundle is a composite of tradable and non-tradable goods. The composition of consumption and investment goods can be different.

2.6 The central bank

The EA central bank sets the (short-term) policy rate R_t according to a Taylor rule of the form

$$\left(\frac{R_t}{\bar{R}}\right)^4 = \left(\frac{R_{t-1}}{\bar{R}}\right)^{4\rho_R} \left(\frac{\Pi_{EA,t,t-3}}{\bar{\Pi}^4_{EA}}\right)^{(1-\rho_R)\rho_\pi} \left(\frac{GDP_{EA,t}}{GDP_{EA,t-1}}\right)^{(1-\rho_R)\rho_{GDP}}. \tag{7}$$

The parameter ρ_R ($0 < \rho_R < 1$) captures inertia in interest-rate setting, while the term $\bar{R}$ represents the steady-state gross nominal policy rate. The parameters ρ_π and ρ_{GDP} are respectively the weights of yearly EA CPI inflation rate $\Pi_{EA,t,t-3} \equiv P_{C,t}/P_{C,t-4}$ (in deviation from the long-run steady-state target $\bar{\Pi}^4_{EA}$) and the GDP gross growth rate ($GDP_{EA,t}/GDP_{EA,t-1}$). The CPI inflation rate is a geometric average of Home and REA inflation rates, with weights equal to the corresponding (steady-state) regional GDP (as a share of the steady-state EA GDP). EA GDP is the sum of Home and REA GDP. A similar equation describes monetary policy in the RW region.

In the simulated scenarios the central bank resorts to non-standard measures, namely the sovereign bond purchases and FG.

Sovereign bond purchases imply that the central bank purchases long-term (domestic) sovereign bonds in the secondary markets to affect the long-term interest rates and hence the real side of the economy.

Thus, the market clearing condition for the long-term sovereign bonds of the Home region is

$$\int_0^{n\lambda_R} B^L_{R,t}(j')dj' + \int_{n\lambda_R}^{n} B^L_{U,t}(j)dj + B^L_{APP,t} = B^L_{G,t}, \tag{8}$$

where $B^L_{APP,t}$ are the central bank purchases. A similar condition holds for the REA region.

The other non-standard measure that we consider is FG. The central bank commits to keep the policy rate constant at its baseline (steady-state) level for a prolonged period of time and to follow the Taylor rule (7) thereafter. Households and firms, that are forward-looking, anticipate this future change in the monetary policy regime when taking consumption and investment decisions.

2.7 Fiscal authorities

Fiscal policy is set at the regional level. The government budget constraint is

$$B^S_{G,t} - B^S_{G,t-1}R_{t-1} + P_{L,t}B^L_{G,t} - \sum_{s=1}^{\infty} \kappa^{s-1} B^L_{G,t-s} \leq P_{N,t}C_G - TAX_t, \tag{9}$$

where $B^S_{G,t}$, $B^L_{G,t}$ are short-term and long-term nominal sovereign bonds, respectively ($B^S_{G,t}, B^L_{G,t} > 0$ is public debt). The short-term bond is a one-period nominal bond issued in the domestic bond

market that pays the (gross) monetary policy interest rate R_t. The variable C_G represents government purchases of goods and services, which is assumed to be constant at its steady-state level. Consistent with the empirical evidence, C_G is fully biased towards the intermediate non-tradable good. Therefore, it is multiplied by the corresponding price index $P_{N,t}$.[17] The variable $TAX_t > 0$ are lump-sum taxes paid by households.

The government follows a fiscal rule defined on lump-sum taxes to bring the short-term public debt as a percentage of domestic GDP, $b^s_{G,t} > 0$, in line with its long-run (steady-state) target $\bar{b}^s_G$.[18] The rule is

$$\frac{tax_t}{tax_{t-1}} = \left(\frac{b^s_{G,t}}{\bar{b}^s_G}\right)^{\phi_1} \left(\frac{b^s_{G,t}}{\bar{b}^s_{G,t-1}}\right)^{\phi_2}, \tag{11}$$

where the parameters $\phi_1, \phi_2 > 0$ respectively call for a increase (reduction) in lump-sum taxes as a ratio to GDP (tax_t) whenever the current-period short-term public debt (as a ratio to GDP) is above (below) the target and increasing over time. We choose lump-sum taxes to stabilize public finance as they are non-distortionary. Lump-sum taxes are paid by unrestricted households only. In this way we are able to isolate the response of restricted households to the APP from the indirect fiscal adjustments implied by the program. However, as the Ricardian equivalence does not hold because restricted households hold long-term sovereign bonds but are not subject to lump-sum taxes, our assumption on the distribution of lump-sum taxes or, equivalently, on the initial distribution of public debt implies that sovereign bond holdings are net wealth.

We assume that the long-term sovereign bond $B^L_{G,t}$ is kept constant at its steady-state level, so that changes in the long-term interest rate are entirely due to the non-standard monetary policy measures.[19] A similar rule holds in the REA. In the RW the rule holds for the overall public debt, as there is no distinction between short- and long-term domestic sovereign bonds.

2.8 Equilibrium

In each country the initial asset positions, preferences, technologies, and budget constraints are the same for households belonging to the same type and firms belonging to the same sector. Moreover, profits from ownership of domestic monopolistically competitive firms are equally shared among unrestricted households. Profits from ownership of domestic capital producers are

[17] See Corsetti and Mueller (2006).

[18] The definition of nominal GDP is

$$GDP_t = P_t C_t + P^I_t I_t + P_{N,t} C_G + P^{EXP}_t EXP_t - P^{IMP}_t IMP_t, \tag{10}$$

where P_t, P^I_t, $P_{N,t}$, P^{EXP}_t, P^{IMP}_t are prices of private consumption, private investment, public consumption (given the assumption of fully biased composition towards intermediate non-tradable goods), exports, and imports, respectively.

[19] We include only the short-term debt in the fiscal rule for two reasons. First, we hold the supply of long-term government bonds fixed, B^L_G, so as to isolate the direct demand effects of the APP. Second, we need the fiscal rule to stabilize the short-term debt and, given that the long-term component is exogenous, the overall public debt. We take into account this distinction when we calibrate the model and more specifically the fiscal target $\bar{b}^s_G$, as reported in Table 5.

distributed to restricted and unrestricted households according to the corresponding population shares, and are equally shared within each type. Thus, we consider the representative household for each type (restricted and unrestricted). Moreover, we consider the representative firm for each sector (final non-tradable, intermediate tradable, and intermediate non-tradable) and the representative capital producer. The implied symmetric equilibrium is a sequence of allocations and prices such that, given initial conditions and considered shocks, households and firms satisfy their corresponding first order conditions, the monetary rules, the fiscal rules, and the government budget constraints hold, and all markets clear.

2.9 Calibration

The model is calibrated at quarterly frequency. We set some parameter values so that steady-state ratios are consistent with EA national account data. For remaining parameters we resort to previous studies and estimates available in the literature.[20]

Table 1 contains parameters for preferences and technology. Parameters with "$*$" and "$**$" are related to the REA and the RW, respectively. We assume perfect symmetry between the REA and the RW unless differently specified. The discount factor of EA unrestricted and RW households is set to 0.9994, so that the steady-state short-term interest rate is equal to 0.24% on an annual basis. The discount factor of restricted households determines the steady-state value of the long-term interest rate and is set to 0.991, so that in steady state the spread between short- and long-term bond is equal to 1.7 percentage points. The value for the intertemporal elasticity of substitution is 1. The Frisch labor elasticity is set to 1/3. Habit is set to 0.7. The depreciation rate of capital is set to 0.025.

In each EA region the share of restricted households is set to 0.10 and, thus, the share of unrestricted households to 0.90. Concerning the share of restricted households, recent estimates by Ferdinandusse et al. (2017) show that the average share of total government debt securities issued by EA countries and held by preferred-habitat investors (including central banks and general government outside the Euro area, insurance companies, and pension funds both in and outside the Euro area) is around 0.3. In our framework, restricted households can only hold domestic long-term sovereign bonds. Hence, the estimate by Ferdinandusse et al. (2017) provides an upper bound for the calibration of the share of restricted households. The (resulting) share of capital producers owned by restricted households is set to 0.10, which is equal to the share of restricted households in the population. The chosen shares allow, in correspondence of a standard monetary policy shock and taking the calibration of other parameters as given, to (i) obtain impulse responses in line with estimates prevailing in the literature, especially with respect to the relative response of investment and total consumption and (ii) align the responses of consumption of restricted households with those of unrestricted households.[21]

[20] See the New Area Wide Model (NAWM, Christoffel et al. (2008), the Global Economy Model (GEM, Pesenti (2008), and the Euro Area and Global Economy Model (EAGLE, Gomes et al. (2010).

[21] The resulting share of consumption by unrestricted households is around 0.93 of total consumption and the

The parameters ϕ_{APP} and ϕ^*_{APP} in agents' rule for the formation of expectations over future purchases by the central bank are set so as to correspond to a quarterly flow of additional net purchases equal to €360 billions, or 10% of quarterly EA GDP, for each percentage point deviation of EA annualized inflation from the target. This amount is in line with the rule as reported in Skolimowski (2017).[22]

In the production functions of both tradables and non-tradables, the elasticity of substitution between labor and capital is set to 0.95. To match investment-to-GDP ratios, the bias towards capital in the production function of tradables is set to 0.5 in all regions. The corresponding value in the production function of non-tradables is set to 0.4 in all regions. The share of labor income that accrues to the three types of households is proportional to their shares in the population. In the final consumption and investment goods the elasticity of substitution between domestic and imported tradables is set to 1.5, while the elasticity of substitution between tradables and non-tradables is set to 0.5, as empirical evidence suggests that it is harder to substitute tradables for non-tradables than to substitute across tradables. The biases towards the domestically produced good and composite tradable good are chosen to match the Home and REA import-to-GDP ratios. In the consumption bundle the bias towards the domestic tradable is 0.45 in Home, 0.55 in the REA, and 0.90 in the RW. The bias towards the composite tradable is set to 0.70 in Home and to 0.60 in the REA and the RW. For the investment basket, the bias towards the domestic tradable is 0.45 in Home, 0.55 in the REA, and 0.90 in the RW. The bias towards the composite tradable is 0.80 in Home and 0.70 in the REA and in the RW.

Table 2 reports gross mark-up values. The mark-up in the tradable and non-tradable sectors and in the labor market is set symmetrically across regions to 1.20, 1.50, and 1.30, respectively (the corresponding elasticities of substitution across varieties are set to 6, 3, and 4.3).

Table 3 contains parameters that regulate the dynamics. Adjustment costs on investment change are set to 4.00. Nominal wage quadratic adjustment costs are set to 400. In the tradable sector, we set the nominal adjustment cost parameter to 300 for Home tradable goods sold domestically and in the REA; for Home goods sold in the RW the corresponding parameter is set to 60. The same parameterization is adopted for the REA, while for the RW we set the adjustment cost on goods exported to Home and the REA to 60. Nominal price adjustment costs are set to 600 in the non-tradable sector. The indexation of prices and wages is set to 0.5.

The parameter regulating the adjustment costs paid by the unrestricted household on deviations of long-term sovereign bond positions from steady-state levels is set to 0.0005 in both Home and REA. The parameters regulating the adjustment cost on the internationally traded private bond position paid by Home unrestricted households and RW households are set to 0.0055. These parameters have been calibrated following two criteria. First, they should not greatly affect the model dynamics and yet help to stabilize it. Second, the response of the interest rate on long-

share by restricted households is 0.07, in both EA countries.

[22] The amounts of purchases of Home and REA long-term sovereign bonds are proportional to the corresponding EA GDP share.

term sovereign bonds to the benchmark APP should be in line with existing evidence for the EA. (see, e.g., Altavilla et al. (2015)).

Table 4 reports the parameterization of the systematic feedback rules followed by the fiscal and monetary authorities. In the fiscal policy rule (11) we set $\phi_1 = \phi_2 = 1.01$ in all regions. It is always lump-sum transfers to adjust. The central bank of the EA uses the policy rate to target the contemporaneous EA-wide consumer price inflation (the corresponding parameter is set to 1.7) and the output growth (the parameter is set to 0.1). Interest rate is set in an inertial way and hence its previous-period value enters the rule with a weight equal to 0.87. The values are identical for the corresponding parameters of the Taylor rule in the RW.

Table 5 reports the great ratios, which are matched by the model steady state under our baseline calibration. We assume a nil steady-state net foreign asset position of each region. The sizes of Home and REA GDPs as shares of world GDP are set to 3% and to 15%, respectively, so that Home GDP is around 17% of EA GDP.

Short-term public debt (ratio to yearly GDP) is set to 8% for both Home and REA. Long-term public debt is set to 93.3% of GDP for both Home and REA. Thus, total public debt as a share of GDP is 101% in both Home and REA. Such figure is slightly larger than the average ratio for the EA, which has settled around 90% since 2012.[23] The parameter κ is calibrated to match the duration of this bond, given by $R_{L,t}/\left(R_{L,t}-\kappa\right)$, to the average duration of the EA long-term sovereign bond (8 years).

We assume that in each country long-term sovereign bond holdings are equally shared between unrestricted and restricted households.

The chosen calibration yields impulse response functions to a standard monetary policy shock (+0.25 basis points) for GDP and inflation in each EA region that are in line with those of the workhorse estimated models of the EA in the literature.[24]

3 Simulated scenarios

We consider four scenarios. They are deterministic, i.e., there is no uncertainty around the expected future values of the model variables. In constructing the economic environment at the beginning of our simulations we mimic the situation before the ECB announcement of October 2017. So we assume that the inflation rate before the announcement includes an initial gap of 0.1 pp between the inflation target and actual annualized inflation. The value of 0.1 aims at representing a macroeconomic outlook characterized by an inflation rate that is still not aligned with the target of the central bank in the foreseeable future, at least not in absence of the monetary policy stimulus. A gap of 0.1 pp mirrors the size of the gap between 1.5% and the average year-on-year core inflation expected over 2018 and 2019 by the ECB September 2017

[23] Source: Eurostat (2017).
[24] See, for example, the NAWM and EAGLE models.

projections (see European Central Bank (2017)). In the fourth scenario, we assume that an unexpected negative EA aggregate demand shock affects the EA economy and pushes the EA inflation down after the APP announcement. In all scenarios the central bank announcements are fully credible.

In the first scenario, labeled "Full announcement," we assume that the central bank makes an announcement of future purchases over a fully specified period of time and, in particular, it announces the end date of the programme. Moreover, the FG keeps the policy rate unchanged until the end of the purchases.[25] We calibrate the size of the announced future purchases to mimic the October 2017 announcement by the ECB of future additional purchases between January and September 2018.[26] This consists of €30 billion per month worth of additional purchases for three quarters (from 2018Q1 to 2018Q3), with no additional purchases in the first period after the announcement (2017Q4). Moreover, we assume that the FG keeps the policy rate at the level prevailing before the announcement until the end of the purchases, that is, for 4 quarters (until 2018Q3). Thereafter, the monetary policy rate follows the Taylor rule (see 7).

In the second scenario, labeled "Open-ended announcement," the ECB does not announce an end date of the APP and, moreover, announces that it keeps the possibility to further prolong the purchases beyond 2018Q3. In this case, agents, as in previous scenario, fully believe the announced purchases (from 2018Q1 to 2018Q3) and, moreover, form expectations about additional unannounced future purchases according to the empirical rule (1), which links expected purchases to the inflation gap. We assume, in a deliberately conservative way, that the rule is active for two quarters (2018Q4 and 2019Q1). Expectations on the FG on the policy rate are the same as in the first scenario.

In the third scenario, labeled "Open-ended announcement with prolonged FG," we assume the same conditions of the second scenario hold but the FG on the policy rate, which keeps the policy rate unchanged also in the two additional periods of expected net purchases induced by the open-ended announcement, that is, in 2018Q4 and 2019Q1. This assumption on the FG is consistent with the current wording of ECB official communication, for which the first rate hike occurs only "well past the horizon" of net asset purchases (see Draghi and Constâncio (2017)).

In the fourth scenario, labeled "Negative demand shock," we simulate a negative EA-wide aggregate demand shock, that induces a reduction in EA consumption and investment, calibrated to induce a drop in EA annualized inflation of around 0.1 pp in the average of the first year of simulation, so to double the size of the inflation gap. The shock hits the EA economy after the (full or open-ended) announcement.

[25] For simplicity, in all simulations the decay of the outstanding amounts is expected to start immediately after the end of the purchases. Thus, we abstract from the effects of the announcement on the reinvestment policy, which is an additional instrument in the APP toolbox.

[26] See European Central Bank (2017a) for reference.

4 Results

4.1 Full announcement

Figure 1 reports the quarterly response of key EA-wide variables in the case of full announcement, i.e., when the central bank announces the amounts and pace of future purchases and, more crucially for the purposes of this paper, the end date of the programme. The announcement consists of €30 billion per month worth of additional purchases for three quarters (from 2018Q1 to 2018Q3), with no additional purchases in the first period after the announcement (2017Q4). The overall announced purchases amount to roughly 2.5% of annual EA GDP. Moreover, we assume FG, i.e., the central bank announces to keep the policy rate at the level prevailing before the announcement (the baseline, steady-state level in our model) until the end of the purchases (i.e., that for 4 quarters, until 2018Q3). Thereafter, the monetary policy rate follows the Taylor rule (see eq. 7).

As a result of the announced purchases, the interest rate on long-term sovereign bonds decreases by 8 bp on impact and, thereafter, gradually returns to its baseline level (the size of the initial decrease is in line with the range of estimates of the existing literature once we rescale the size of the shock). The policy rate is constant at its baseline (steady-state) level during the first year, and increases starting from the fifth quarter. The nominal exchange rate of the euro slightly depreciates on impact, consistent with the uncovered interest parity condition, that holds in the model, and the implemented expansionary monetary policy measures.

The lower long-term interest rate induces restricted households to increase consumption and investment in physical capital (not reported to save on space). The FG on short-term interest rates favors unrestricted households' aggregate demand. Following the higher domestic aggregate demand, the EA GDP persistently increases above its baseline level (by 0.06% at the peak). Similarly, the CPI inflation rate increases (3 bp at the peak). The dynamics of international trade (not reported to save on space) is characterized by the increase in imports, driven mostly by the relatively large increase in investment in physical capital, which has a large imported component (this effect on imports dominates the negative one associated with the depreciation of the exchange rate). Exports slightly increase in the medium run.

Overall, the announced measures are expansionary, as agents make consumption and investment decisions on the basis of their expectations about the expansion of the central bank's balance sheet and the duration of the FG. In other terms, agents' expectations about the future path of interest rates reflects the (credible) announcement of the central bank about the intended accommodative stance of monetary policy.

4.2 Open-ended announcement

In this scenario the central bank does not announce an end date of the APP. Instead, it announces that it keeps the possibility to further prolong the purchases beyond 2018Q3 conditionally on inflation developments. Agents, as in the scenario reported in the previous section, fully believe the announced purchases (implemented from 2018Q1 to 2018Q3). Expectations on the FG are the same as in the first scenario (i.e., the monetary policy rate is kept constant during the initial 4 quarters, until 2018Q3, and, thereafter, it follows the Taylor rule).

Crucially, and differently from the "Full announcement" scenario, it is now assumed that agents form their expectations about additional unannounced future purchases according to the empirical rule (1), which links expected purchases to the inflation gap. We assume, in a deliberately conservative way, that the rule is active for two quarters, 2018Q4 and 2019Q1 (we investigate the effects of the rule being active for more periods in the next sections).

Figure 2 reports the results and compare them to those of the "Full announcement" scenario. Households and firms now expect more purchases than in the "Full announcement" scenario. The endogenous profile of expected unannounced future purchases proceeds beyond September 2018 at roughly the same pace as the one fully announced up to that date (around €30 billion per month), bringing the central bank's balance sheet at almost 4% of annual EA GDP by the end of 2019Q1. The reason for the larger expected purchases relies on the rule (1) (which is estimated on the basis of data on Eurosystem APP purchases and inflation gaps). Purchases announced by the central bank, that feed the model simulation, are not large enough to close the initial inflation gap. Thus, agents expect additional future purchases, in 2018Q4 and 2019Q1, to further reduce the inflation gap, even if they were not announced.

Relative to the "Full announcement" scenario, the macroeconomic impact is rescaled upwards, because of the additional future (expected) purchases. Following the larger increase in the expected central bank's demand of sovereign bonds, long-term rates decrease by an additional 6 bp. Consistent with the more expansionary stance, the exchange rate depreciates to a larger extent. The additional decrease in the long-term interest rates favors a larger increase in aggregate demand for consumption and investment. The EA GDP reaches 0.1% above the baseline level by the end of 2018, and the inflation rate closes half the initial gap, at 5 bp above the baseline level by the end of 2018.[27] The FG effectiveness is also indirectly enhanced by the additional expected purchases, because the short-term real interest rates decrease to a larger extent, consistent with the larger increase in inflation and the expectations of constant nominal rates in the initial quarters. As a result, the policy rate increases to a larger extent in the subsequent quarters, consistent with the Taylor rule that has to stabilize a larger initial increase in inflation and GDP.

Overall, the additional expansionary effects of the open-ended announcement are rather small,

[27] We do not report the details by country as in the first scenario because the impacts are rather symmetric and similar to what reported in Figure 1. They are available upon request.

because the additional purchases are relatively small (around €25 billion per month) and the rule is active for two quarters only (six months).

Even though the additional effects are small, the simulations lead to a conclusion that is relevant from a policy perspective. Specifically, our results suggest that agents' expectations can be relevant for the relative macroeconomic effectiveness of closed- vs open-ended announcements. The latter are more expansionary than the former if agents expect that the central bank will implement further measures if the ones announced are not sufficient to achieve the target. In this respect, not only the central bank's past actions are important, but a crucial element is the central bank's confirmation that the duration of the programme and inflation dynamics are intertwined.

Moreover, as we show in the next section, the effects are larger if the rule is active for more periods, implying not only more additional expected purchases but also a longer duration of the FG on the monetary policy rate (so called "signalling" effect of the purchases programme).

4.3 Open-ended announcement with prolonged FG

In this Section we evaluate the interaction between the open-ended and FG announcements. In particular, we focus on announced references to continue to expect key policy rates to remain at their present levels for an extended period of time, and well past the horizon of our net asset purchases.[28] In this case, agents expect a longer FG to accompany the additional purchases commanded by the empirical rule.

For expected purchases, the same conditions of the open-ended scenario reported in the previous section hold.

For the FG on the policy rate, the central bank announces that it will keep the policy rate unchanged also in the two additional periods of expected purchases induced by the open-ended announcement, that is, in 2018Q4 and 2019Q1.

Figure 3 shows the results. The expected extension of the FG induces lower real short-term interest rates, that favor aggregate demand of consumption and investment in physical capital by restricted households. There is a larger increase in GDP and its components (see Figure 3). As the announcement with the prolonged FG proves to be more expansionary, the impact on inflation is larger (around 7 bp). Thus, the inflation gap at the onset of the open-ended programme is smaller and, consistently, the endogenous rule-based determination of the additional future purchases by the central bank leads to an expected profile of future holdings that is actually lower than the profile that is expected in absence of a prolonged FG. The expected peak holdings reach at most 3.5% of annual EA GDP instead of the 4%, which is reached when agents do not associate an extension of the FG to the extension of the APP. Consistent with the lower expected stock of central bank's purchases, the long-term interest rates decrease by a slightly lower amount.

[28] See Draghi and Constâncio (2017).

We further investigate the quantitative effects of the open-ended programme by assuming that the agents expect not only a longer FG, but also that unannounced purchases will last for more periods than those considered in the previous simulations. Specifically, it is assumed that agents expect three additional quarters of unannounced purchases (instead of two as in previous simulations) and three additional quarters of FG (seven quarters, from 2017Q4 to 2019Q2).

We report the results in Figure 4. Once we extend the open-ended periods from two to three, the front-loading of the macroeconomic impact leads to an inflation rate that reaches 0.1 pp above the baseline, thus closing the initial gap in the first year. The higher resulting inflation rate implies that the holdings in 2019Q1 are lower than in the case with only two open-ended periods. The GDP increases more than in the previous cases, as the larger expected purchases and the longer expected duration of FG induce a further expansion in private expenditure. Similarly, the macroeconomic effectiveness of FG is enhanced by the additional expected purchases, because the implied higher (expected) inflation reduces the short-term real interest rates, given that their nominal counterparts are kept constant.

We take the Overall, the reported results suggest that the macroeconomic effectiveness of the open-ended announcements can be enhanced if those announcements are able to systematically and credibly link agents' expectations on future purchases to expectations on the duration of FG. Moreover, the FG effectiveness in stimulating the economy can also be enhanced by the expected future purchases, as long as the latter are large enough to stimulate expected inflation in a non-negligible way.[29]

4.4 Negative demand shock

A negative demand shock can bring inflation further away from the monetary policy target. In what follows we compare the effectiveness of the full- and open-ended announcement in counteracting the recessionary effects of the demand shock, that materializes immediately after the (alternative) announcements.[30]

We present the results of these simulations in Figure 5.

In the first simulation (labelled as "Shock," dash-dotted black line in the charts), a negative EA demand shock decreases EA GDP by almost 0.5% and the EA inflation rate by 0.1 annualized pp at the trough. We consider the following alternative scenarios on top of the previous one: in the second ("Shock+full announcement," solid black line), the full announcement of the additional APP purchases until September 2018; in the third, the open-ended announcement with prolonged FG until 2019Q1 ("Shock+open-ended (2q)," dashed red line) and, finally, in the fourth the the open-ended announcement with prolonged FG until 2019Q3 ("Shock+open-ended

[29] The size of additional expansionary effects in the case of prolonged FG is consistent with recent contributions on the macroeconomic effectiveness of FG. See Del Negro et al. (2012). In our model the decisions of restricted households are not directly affected by the short-term interest rates. Thus, it is likely that the effectiveness of FG is, in our model, lower than in the standard representative agent New Keynesian model.

[30] The negative demand shock is a combination of negative consumption preference and investment specific shocks in the two EA regions and in the RW that feed the model in the initial three quarters.

(4q)," green line).

All announcements help contain the worsening of macroeconomic conditions and, at the same time, limit the fall in the short-term policy rate.

The open-ended announcement with FG until 2019Q1 is more accommodative than the full announcement, as agents expect higher purchases also in the two quarters of the open-ended leg of the programme. Specifically, the negative effects on inflation of the negative demand shock widen the initial inflation gap. Given the rule, agents expect the central bank to further increase the bond purchases beyond the announced ones. Thus, long-term interest rates decrease to a larger extent, further stimulating the economic conditions. The improvements in inflation and economic activity (i.e., the faster economic recovery) imply a steeper subsequent rise in the short-term monetary policy rate.[31]

The macroeconomic effectiveness of the open-ended announcement with FG in counterbalancing the recessionary shock is further enhanced if agents expect the additional purchases and FG to last for longer.

Overall, our results clearly show that open-ended is more effective than the full-announcement to stabilize macroeconomic conditions in the face of unexpected shocks that drive inflation down. This suggest that an open-ended announcement is particularly desirable if economic conditions are uncertain, because, as long as that type of communication induces agents to believe in a reaction of the central bank, it helps to stabilize expectations about future macroeconomic outcomes.

5 Conclusion

We have used a large-scale New Keynesian DSGE model for the EA to estimate the benefits of keeping the APP open-ended when the inflation rate is not yet aligned with the monetary policy target over the medium term. We find that an open-ended APP helps maintaining an accommodative stance of the monetary policy. Eschewing a full announcement of the future path of purchases increases the effectiveness of the committed future purchases by managing expectations over future purchases. Moreover, the effectiveness increases even further if the central bank induces in agents' expectations a correlation between the continuation of net future purchases and that of the FG on policy rates. Finally, an open-ended APP may prove all the more adequate if additional, unforeseen negative shocks stave off even further the achievement of the inflation target over the medium term.

In this paper we have not assessed the role of announcing a reinvestment policy, which in principle could enhance the effectiveness of the open-ended APP, as long as agents anticipate a

[31] We do not consider the zero lower bound (ZLB) constraint on the monetary policy, but the steeper rise in the policy rate we get under the open-ended programme suggests that the latter should favor an earlier exit from the ZLB. This further corroborates the greater effectiveness of the open-ended programme in stimulating macroeconomic conditions. We leave the analysis of the ZLB for future research.

larger size of the central bank balance sheet. We leave this issue for future research.

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Tables and Figures

Table 1: Parameterisation

Parameter	H	REA	RW
Discount factor $\beta_U, \beta_U^*, \beta^{**}$	0.9994	0.9994	0.9994
Discount factor β_R, β_R^*	0.991	0.991	–
Discount factor β_D, β_D^*	0.99	0.99	–
Intertemporal elasticity of substitution $1/\sigma$	1.0	1.0	1.0
Inverse of Frisch Elasticity of Labor Supply τ	3.0	3.0	3.0
Habit ς	0.7	0.7	0.7
Depreciation rate of capital δ	0.025	0.025	0.025
Share of restricted households λ_R	0.10	0.10	–
Share of cap. producers held by restr. households ω, ω^*	0.10	0.10	–
Open-ended rule on agents' expectations ϕ_{APP}, ϕ_{APP}^*	10	10	–
Tradable Intermediate Goods			
Subst. between factors of production $\xi_T, \xi_T^*, \xi_T^{**}$	0.95	0.95	0.95
Bias towards capital $\alpha_T, \alpha_T^*, \alpha_T^{**}$	0.5	0.5	0.5
Non-tradable Intermediate Goods			
Subst. between factors of production $\xi_N, \xi_N^*, \xi_N^{**}$	0.95	0.95	0.95
Bias towards capital $\alpha_N, \alpha_N^*, \alpha_N^{**}$	0.4	0.4	0.4
Final consumption goods			
Subst. between domestic and imported goods $\phi_A, \phi_A^*, \phi_A^{**}$	1.50	1.50	1.50
Bias towards domestic tradable goods a_H, a_G^*, a_F^{**}	0.45	0.55	0.90
Subst. between tradables and non tradables $\rho_A, \rho_A^*, \rho_A^{**}$	0.50	0.50	0.50
Bias towards tradable goods a_T, a_T^*, a_T^{**}	0.70	0.60	0.60
Final investment goods			
Subst. between domestic and imported goods $\phi_E, \phi_E^*, \phi_E^{**}$	1.50	1.50	1.50
Bias towards domestic tradable goods $\upsilon_H, \upsilon_G^*, \upsilon_F^{**}$	0.45	0.55	0.90
Subst. between tradables and non tradables $\rho_E, \rho_E^*, \rho_E^{**}$	0.50	0.50	0.50
Bias towards tradable goods $\upsilon_T, \upsilon_T^*, \upsilon_T^{**}$	0.80	0.70	0.70

Note: H=Home; REA=rest of the euro area; RW= rest of the world. "*" refers to REA, "**" to RW.

Table 2: Gross Mark-ups

	Mark-ups and Elasticities of Substitution		
	Tradables	Non-tradables	Wages
H	1.2 ($\theta_T = 6$)	1.5 ($\theta_N = 3$)	1.30 ($\psi = 4.3$)
REA	1.2 ($\theta_T^* = 6$)	1.5 ($\theta_N^* = 3$)	1.30 ($\psi^* = 4.3$)
RW	1.2 ($\theta_T^{**} = 6$)	1.5 ($\theta_N^{**} = 3$)	1.30 ($\psi^{**} = 4.3$)

Note: H = Home; REA = rest of the euro area; RW = rest of the world. "*" refers to REA, "**" to RW.

Table 3: Real and Nominal Adjustment Costs

Parameter	H	REA	RW
Real Adjustment Costs			
Investment ϕ_I, ϕ_I^*, ϕ_I^{**}	4.00	4.00	4.00
Adjustment Costs on Bonds			
Households' long-term bond positions ϕ_{b^L}, $\phi_{b^L}^*$	0.0005	0.0005	–
Households' private bond positions			
ϕ_{b1}, ϕ_{b1}^{**}	0.005	–	0.005
ϕ_{b2}, ϕ_{b2}^{**}	0.005	–	0.005
Nominal Adjustment Costs			
Wages κ_W, κ_W^*, κ_W^{**}	400	400	400
H produced tradables κ_H, κ_H^* κ_H^{**}	300	300	60
REA produced tradables κ_G, κ_G^* κ_G^{**}	300	300	60
RW produced tradables κ_F, κ_F^* κ_F^{**}	60	60	300
Non-tradables κ_N, κ_N^*, κ_N^{**}	600	600	600
Indexation			
Wages α_W, α_W^*, α_W^{**}	0.5	0.5	0.5
Prices α_P, α_P^*, α_P^{**}	0.5	0.5	0.5

Note: H = Home; REA = rest of the euro area; RW = rest of the world. "* " refers to REA, "** " to RW.

Table 4: Fiscal and Monetary Policy Rules

Parameter	H	REA	EA	RW
Fiscal policy rule				
$\phi_1, \phi_1^*, \phi_1^{**}$	1.01	1.01	-	1.01
$\phi_2, \phi_2^*, \phi_2^{**}$	1.01	1.01	-	1.01
Common monetary policy rule	-	-		
Lagged interest rate ρ_R, ρ_R^{**}	-	-	0.87	0.87
Inflation ρ_Π, ρ_Π^{**}	-	-	1.70	1.70
GDP growth $\rho_{GDP}, \rho_{GDP}^{**}$	-	-	0.10	0.10

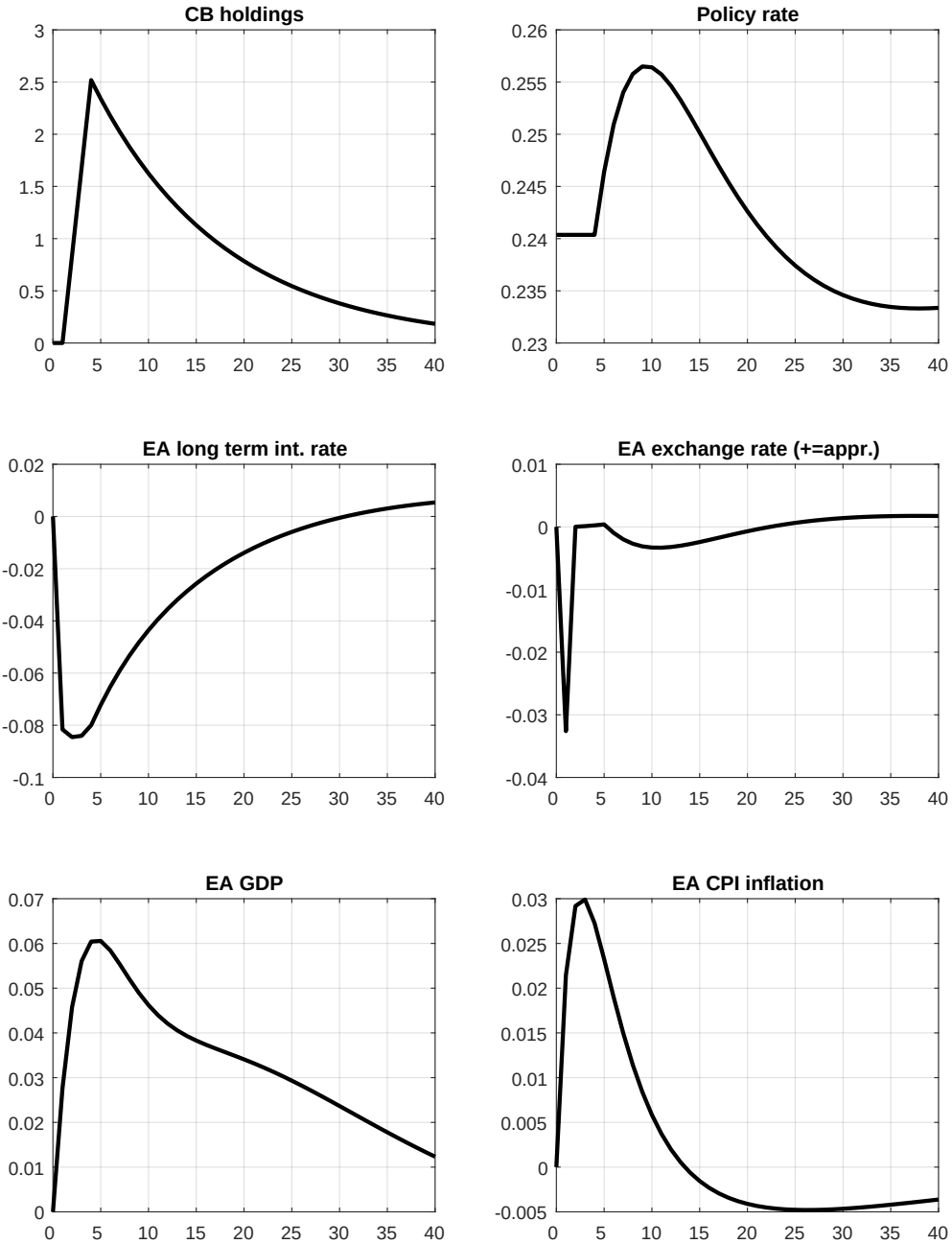
Note: H = Home; REA = rest of the euro area; EA = euro area; RW = rest of the world. "* " refers to REA, "** " to RW.

Table 5: Main macroeconomic variables (% of GDP)

	H	REA	RW
Private consumption	58.3	59.7	58.8
Public consumption	18.0	18.0	18.0
Investment	21.1	19.7	20.6
Imports	27.4	20.7	4.0
Home Imports from	–	6.7	20.7
REA Imports from	2.7	–	18.0
Net Foreign Asset Position	0.0	0.0	0.0
GDP (share of world GDP)	3.1	15.0	81.9
Short-term public debt (ratio to annual GDP)	8.0	8.0	–
Long-term public debt (ratio to annual GDP)	93.3	93.3	–

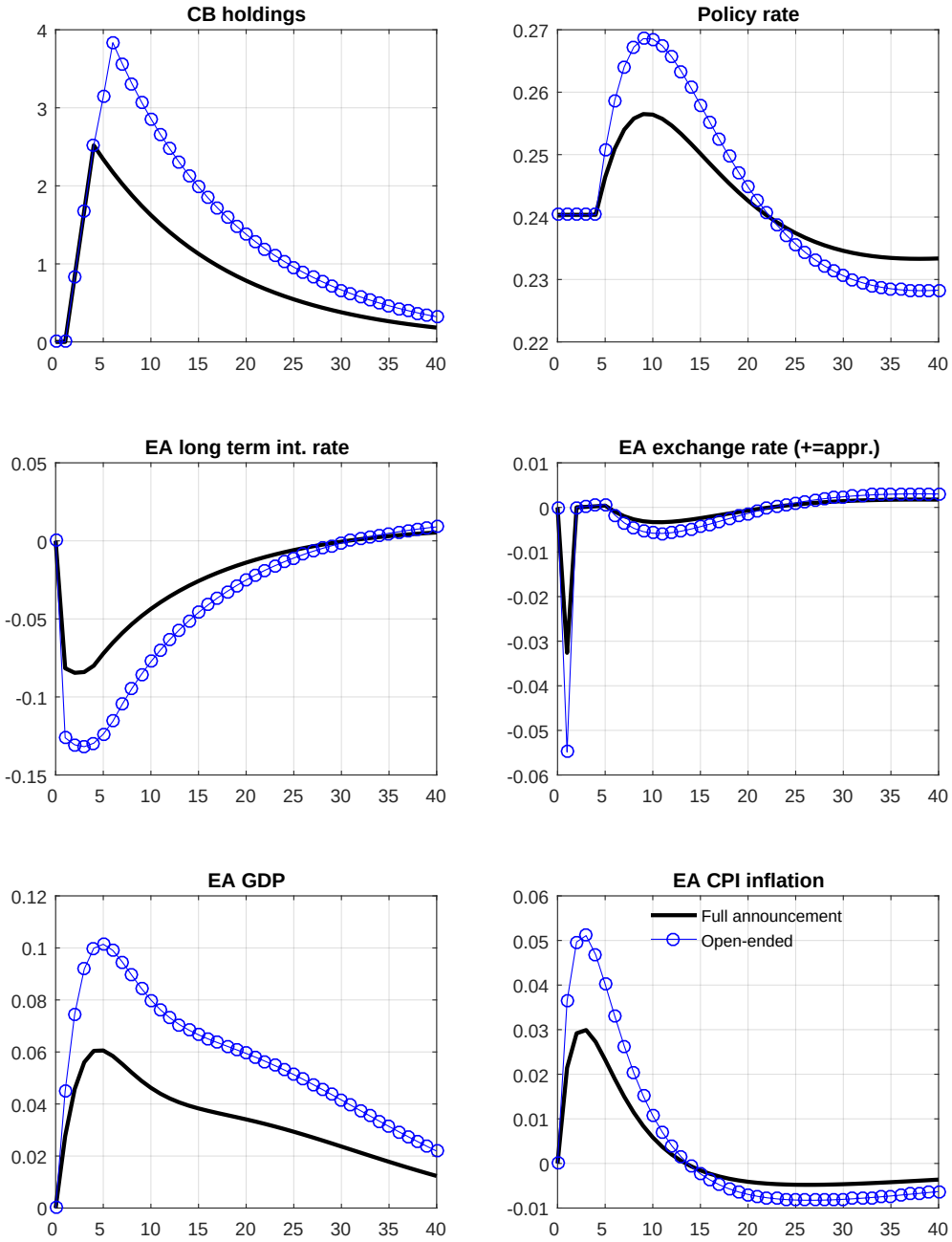
Note: H = Home; REA = rest of the euro area; RW = rest of the world.

Figure 1: Full announcement. EA variables.



Notes: Quarters on the horizontal axis. On the vertical axis, % deviations from the baseline for GDP and exchange rate (positive values correspond to an appreciation of the euro); annualized percentage point deviations from the baseline for inflation and long-term interest rate; levels for the policy rate; percentage point deviations from the baseline for the central bank (CB) holdings measured as percentage of EA annual GDP.

Figure 2: Open-ended announcement. EA variables.



Notes: Quarters on the horizontal axis. On the vertical axis, % deviations from the baseline for GDP and exchange rate (positive values correspond to an appreciation of the euro); annualized percentage point deviations from the baseline for inflation and long-term interest rate; levels for the policy rate; percentage point deviations from the baseline for the central bank (CB) holdings measured as percentage of EA annual GDP.

Figure 3: Open-ended announcement with prolonged FG. EA variables.

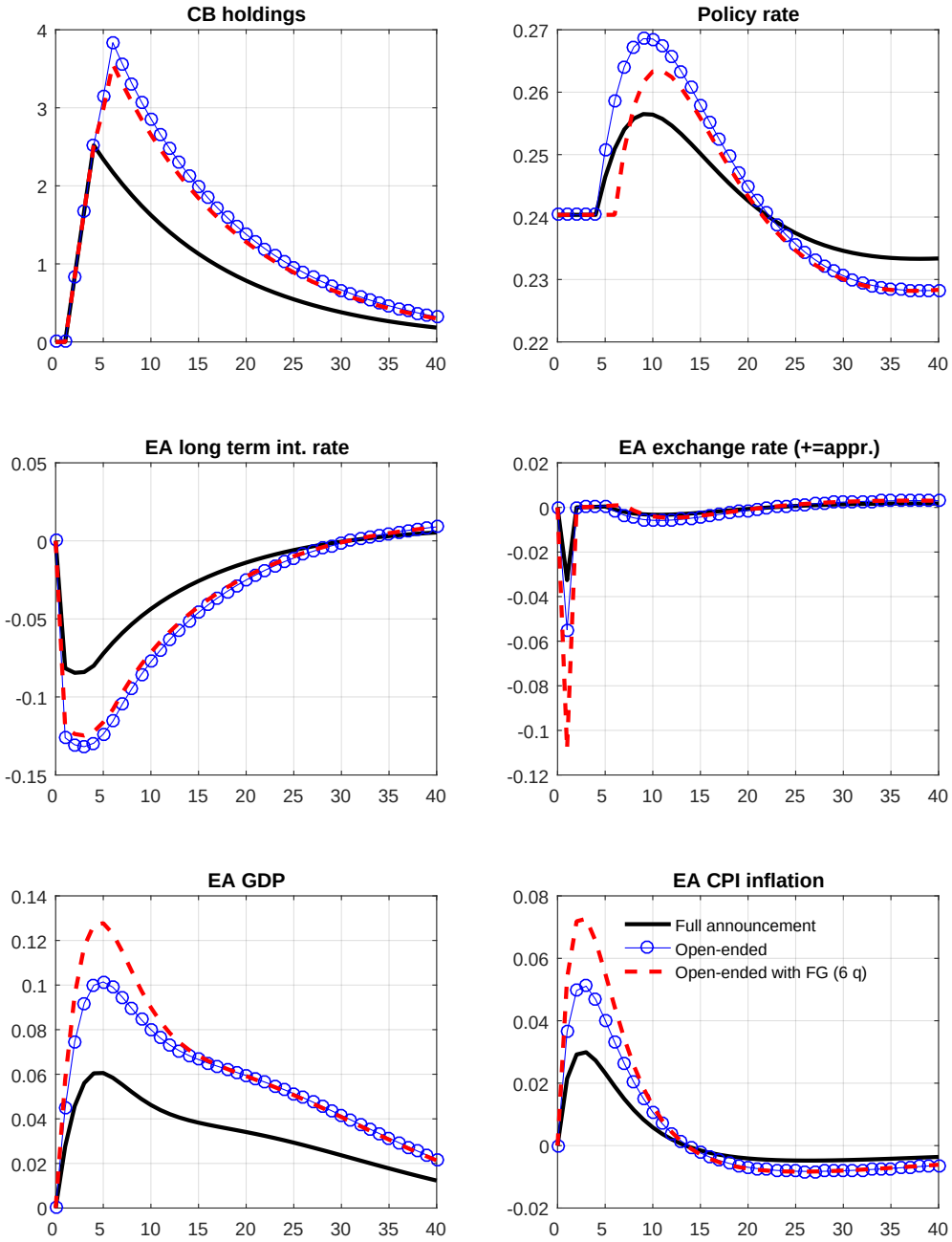


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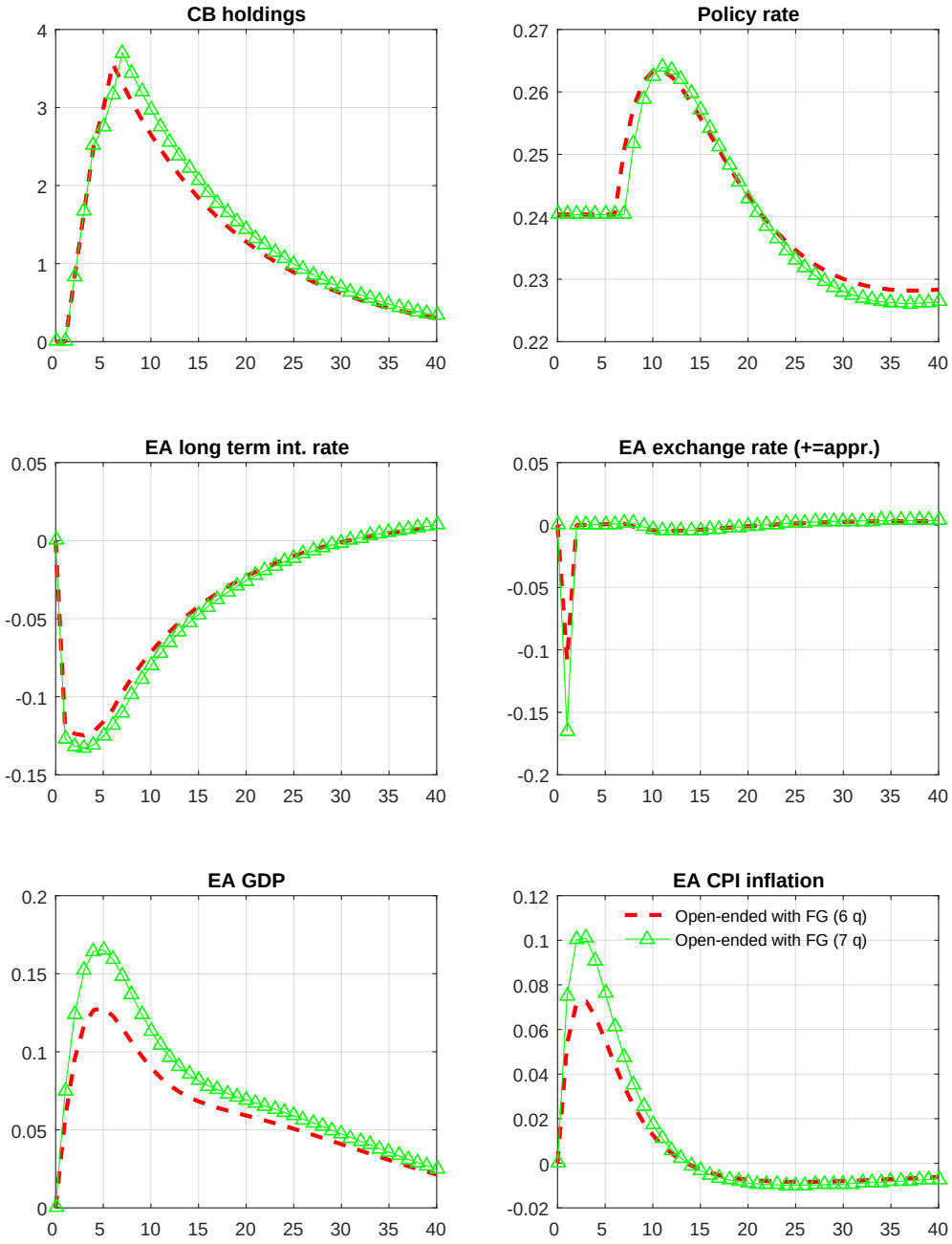
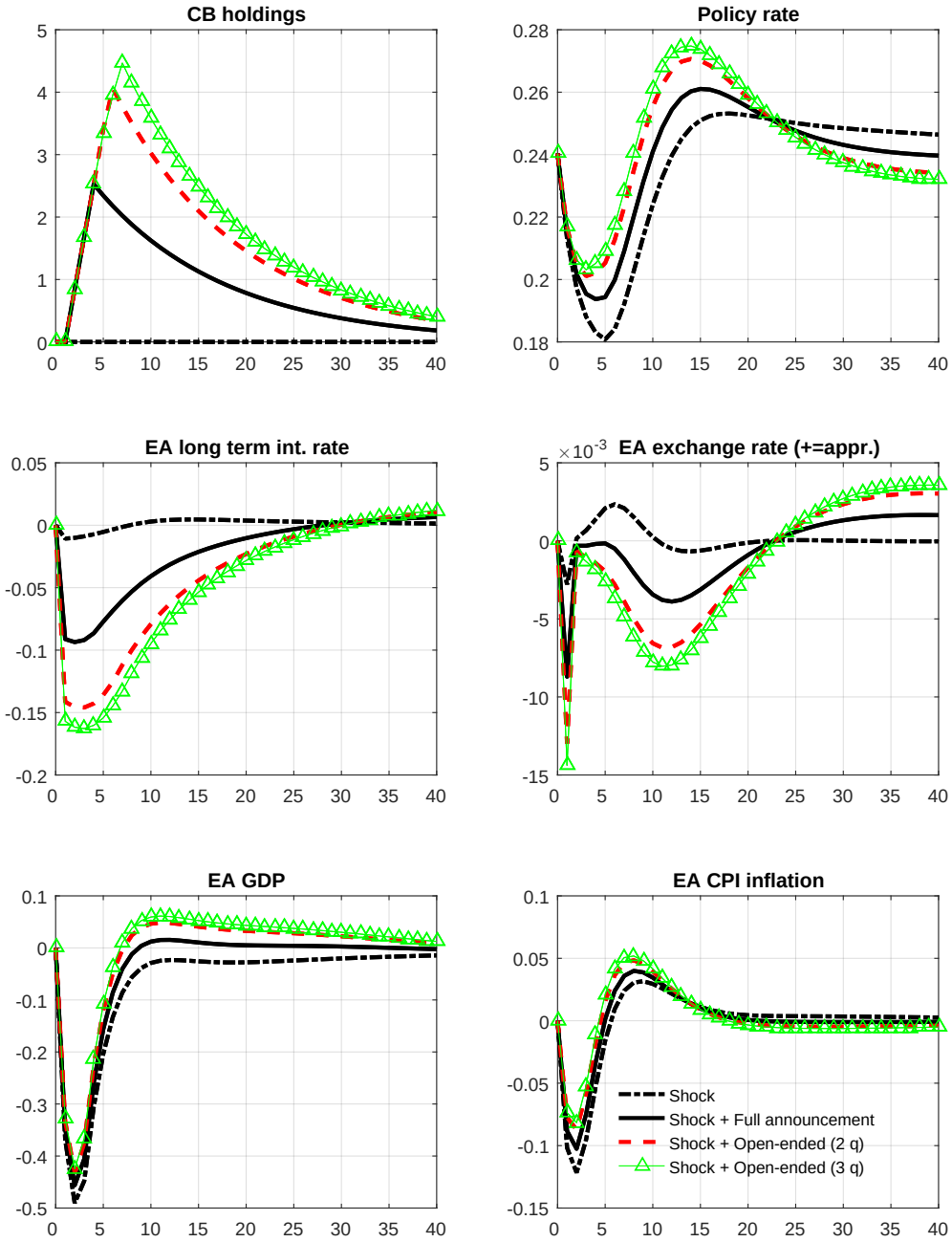
Figure 4: Open-ended announcement: additional periods of purchases and forward guidance. EA variables.



Notes: Quarters on the horizontal axis. On the vertical axis, % deviations from the baseline for GDP and exchange rate (positive values correspond to an appreciation of the euro); annualized percentage point deviations from the baseline for inflation and long-term interest rate; levels for the policy rate; percentage point deviations from the baseline for the central bank (CB) holdings measured as percentage of EA annual GDP.

Figure 5: Negative EA aggregate demand shock. EA variables.



Notes: Quarters on the horizontal axis. On the vertical axis, % deviations from the baseline for GDP and exchange rate (positive values correspond to an appreciation of the euro); annualized percentage point deviations from the baseline for inflation and long-term interest rate; levels for the policy rate; percentage point deviations from the baseline for the central bank (CB) holdings measured as percentage of EA annual GDP.

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