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DOMESTIC AND INTERNATIONAL MACROECONOMIC EFFECTS OF THE EUROSYSTEM EXPANDED ASSET PURCHASE PROGRAMME

by Pietro Cova*, Patrizio Pagano** and Massimiliano Pisani*

Abstract

This paper evaluates the domestic and international macroeconomic effects of purchases of domestic long-term sovereign bonds by the Eurosystem. To this end, we calibrate a five-country dynamic general equilibrium model of the world economy. According to our results, the sovereign bond purchases would generate an increase in economic activity and in inflation in the euro area of about one percentage point in the first two years by inducing a fall in the long-term interest rates and an increase in liquidity. International spillovers may be nontrivial and expansionary, depending on the monetary policy stance of the partner countries and on the response of international relative prices.

JEL Classification: E43, E44, E52, E58.
Keywords: DSGE models, open-economy macroeconomics, non-standard monetary policy, zero lower bound.

Contents

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1 Introduction[1]

Following persistently weak economic conditions and deflation risks, since September 2014 the euro area (EA) monetary policy rate has been set very close to zero. Such a low rate has nevertheless failed to stimulate the economy to a degree judged consistent with the price stability target. Therefore, in January 2015 the Eurosystem announced the Expanded Asset Purchase Programme (APP). This programme involves purchases of sovereign bonds issued by EA governments, agencies and European institutions in the secondary market against central bank money. Its purpose is to create additional liquidity, in excess of that obtained using the standard channel based on the short-term policy rate, which is now constrained by the zero lower bound. The programme aims at increasing the prices of securities and, thus, at reducing the implied long-term interest rates, thereby stimulating economic activity and favoring the achievement of price stability.[2]

The announcement of the APP has spurred a debate about the domestic and international macroeconomic effects of the programme. The assessment is rather challenging, as it is the first time that this type of "non-standard" monetary policy measure has been implemented in the EA. Thus, there are no precedents that can help in evaluating the APP transmission mechanism. From this perspective, the use of a fully structural model, grounded on sound economic theory and disciplined by an appropriate calibration, can be extremely useful.

This paper contributes to the debate by quantitatively assessing the domestic and international macroeconomic effects of the EA APP by simulating a large-scale multi-country dynamic general equilibrium model of the EA and the world economy, calibrated to the EA, China (CH), Japan (JP), the U.S. (US), and the rest of the world (RW).[3] Building on a recent contribution by Canzoneri, Cumby,

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[2]To be fair, the programme involves the purchases of both public and private securities, as it also encompasses the asset-backed securities purchase programme (ABSPP) and the covered bond purchase programme (CBPP3). We focus on the purchases of sovereign bonds.

[3]In what follows we will interchangeably use the expressions countries or regions when referring

Diba and Lopez-Salido (2013, henceforth CCDLS), we formalize liquidity as an aggregate of "narrow" money and sovereign bonds in an otherwise standard New Keynesian open economy model.[4] Unlike CCDLS, we introduce demand for EA long-term sovereign bonds. In each country households optimally demand liquidity, which facilitates transactions for consumption purposes (thereby providing so called "liquidity services"). "Liquidity" is a combination of domestic narrow money balances (currency in circulation) and short- and long-term government bonds. In this way, we relax the well-known "Wallace neutrality" and make assets imperfect substitutes, as they differ by the liquidity services they provide.[5] This framework allows us to formalize the APP as purchases of long-term sovereign bonds by the EA monetary authority financed via narrow money injection. The model calibration, disciplined by the data, implies that narrow money is a more liquid asset than sovereign bonds, as the related parameter in the liquidity bundle is larger. Thus, the APP generates an increase in overall liquidity, as the monetary authority exchanges a more liquid asset (money) for a less liquid one (long-term sovereign bonds). The implied decrease in long-term rates and the increase in overall liquidity induces households to increase consumption, favoring the increase in aggregate demand and, thus, economic activity. The measure is particularly relevant in a context where the short-term policy rate cannot be further reduced as it is already at the zero level.

Sovereign bonds are denominated in the currency of the issuer. Short-term bonds pay the domestic monetary policy rate. Long-term bonds are formalized as perpetuities paying an exponentially decaying coupon, as in Woodford (2001).

The model allows us to evaluate the international spillovers of the APP, associated with trade and financial linkages. The latter can differ across EA partner countries in terms of their intensities. For this reason, we have decided to consider not only the US, but also CH and JP, which represent the most relevant regions in the world economy and in international financial markets, other than EA and the US, and the RW, which includes the main EA trade partners. To capture their nontrivial role in international liquidity markets, we allow EA and US short-

to the EA, CH, JP, US and RW.

[4] See CCDLS (2008) for a closed-economy analysis.

[5] See Wallace (1981).

and long-term sovereign bonds to be internationally traded and to be a component of liquidity in each country.[6] In contrast, we assume that CH, JP and RW government bonds are not internationally traded.

We simulate the APP as an exogenous increase in the purchases of EA long-term sovereign bonds by the EA monetary authority, financed by injecting narrow money into the economy, lasting 7 quarters (hypothetically from March 2015 to the end of September 2016). Thereafter, from the 8th to 14th quarter, the APP is gradually phased out (7 quarters). Moreover, a sensitivity analysis is performed. Given the uncertainty surrounding the substitutability among assets in the liquidity bundle, we calibrate the related parameters to values larger and, alternatively, lower than the benchmark. We also consider a longer, and fully anticipated, phasing out period (20 instead of 7 quarters). The latter analysis is useful to evaluate the role of the anticipation effect, associated with households being forward looking and taking their optimal decisions on the basis of the whole intertemporal path of interest rates. The anticipation effect can be significant, as the Eurosystem has clearly announced that the APP should be in place until at least September 2016 and in any case until the Governing Council sees a sustained adjustment in the path of inflation towards its medium-term target. Consistent with the current EA monetary policy stance, in all scenarios the EA (short-term) monetary policy rate is kept constant at the baseline level for 8 quarters. All simulations are run under perfect foresight. So there is no uncertainty, policies are fully credible and agents perfectly anticipate the future path of shocks (the only exception is the initial period, as the shock is initially unexpected).

Our main results are as follows.

First, the APP has expansionary effects on the EA economy. As money is more liquid than sovereign bonds, overall liquidity increases. Further, the increased demand of bonds determines an increase in their price and lowers the EA long-term interest rate. Both the higher liquidity and the lower long-term interest rates support consumption and investment demand. Thus, both EA GDP and inflation persistently increase, thanks also to the depreciation of the nominal exchange rate.

[6] See Chinn and Frankel (2008), Devereux and Shi (2013) and Krishnamurthy and Vissing-Jorgensen (2012). We treat the EA as a single country in our model, alongside the CH, JP, US and the RW. Thus, the EA government bonds are meant to denote bonds denominated in euro issued by the (hypothetical) EA government.

The increase in economic activity and in inflation in the EA would be of about one percentage point in the first two years.

Second, other regions' GDPs increase, because of higher exports towards the EA, triggered by the improvement in EA aggregate demand. Specifically, the RW benefits the most, given its relatively large exports to the EA. The increase in foreign GDP can become relatively large if the monetary policy stance in the partner country is "accommodative", i.e. the local monetary authority does not increase the domestic policy rate in correspondence with the APP. In this case, the increase in inflation, associated with the increase in EA demand for exports, would imply a lower real interest rate, which would have an additional expansionary effect on local aggregate demand.

Third, the short-run effects of the APP depend on the degree of nominal exchange rate pass-through into import prices and the elasticity of substitution between traded goods. The latter two features crucially affect the sign of international spillovers. If the pass-through and the elasticity of substitution between traded goods are sufficiently large and if there are no short-run adjustment costs on imports, then EA GDP increases to a larger extent because of the larger increase in net exports. The expenditure-switching effect associated with the euro nominal depreciation dominates; other regions' exports and, thus, GDP, decrease in the short run, while increase in the medium run following the gradual and persistent increase in EA aggregate demand. However, the stance of the foreign monetary policy is crucial. If the policy rate is kept constant at its baseline level, then foreign GDP increases, thanks to the dominant expansionary intertemporal substitution effects associated with persistent high inflation, and, thus, low real interest rates.

Our paper relates to other contributions on unconventional monetary policy. Chen, Curdia, and Ferrero (2012) introduce preferred habitat theory for financial assets to evaluate the impact of US quantitative easing. They assume there is a type of household that can invest only in physical capital or in long-term sovereign bonds. Thus, the reduction in the long-term interest rate induces those households to increase investment in physical capital. Burlon, Gerali, Notarpietro and Pisani (2015) formalize the EA as a monetary union and evaluate the impact of the APP on EA member countries on the basis of a framework as in Chen, Curdia and Ferrero (2012). Unlike them, we assume 1) a representative agent having an explicit demand for liquidity that provides consumption transaction services, and 2) that liquidity is a composite of narrow money and short- and long-term sovereign bonds.[7] The last assumption is more in line with Alpanda and Kabaka (2015), who introduce a composite liquidity bundle similar to ours in the utility function of the representative household. The implied utility associated by liquidity can be justified in terms of the provided transaction services, which are not explicitly formalized in their framework. Both our formalization and the one adopted by Albanda and Kabaka (2015) can be considered as observationally equivalent to an always binding liquidity constraint on households' consumption expenditures, with liquidity being a composite bundle of assets. Alpanda and Kabaka (2015) evaluate the international spillover effects of large-scale asset purchases using a two-country dynamic stochastic general-equilibrium model with nominal and real rigidities, and portfolio balance effects. Unlike them, we evaluate non-standard monetary policy measures on the EA economy and on its main trade and financial partners by explicitly introducing liquidity in a multi-country quantitative dynamic general equilibrium model.

Cova, Pagano and Pisani (2014, 2015) use a framework similar to the one used in this paper to evaluate the international macroeconomic effects of changes in official reserves. Here we introduce long-term sovereign bonds and we focus on non-standard monetary policy measures.

In the literature, to the best of our knowledge, there are no quantitative results available for domestic and international macroeconomic effects of the APP. The only exception is Burlon, Gerali, Notarpietro and Pisani (2015), who report nontrivial expansionary macroeconomic effects of the APP.[8]

The rest of the paper is organized as follows: section 2 reports the main features of the model setup and the calibration, section 3 contains the results and section 4 concludes.

[7] Our setup would be closer to the one in Chen, Curdia and Ferrero (2012) if we would allow for a transactions cost on investment in physical capital.

[8] Cova and Ferrero (2015) find non-negligible expansionary effects of APP on the Italian GDP by simulating the Bank of Italy quarterly model of the Italian economy.

2 Model setup

We build up and simulate a five-region New Keynesian dynamic general equilibrium model of the world economy, calibrated to the EA, CH, JP, US and RW.

Following the theoretical framework of CCDLS, in each country households' liquidity includes not only domestic money, but also domestic and US government bonds. Unlike CCDLS, we distinguish between short- and long-term government bonds, the latter formalized as perpetuities following Woodford (2001). We also assume that EA sovereign bonds are internationally traded and are a component of each region's liquidity.

As usual in dynamic open economy models, financial assets allow households to smooth consumption over time and to share idiosyncratic risk across countries. The novelty of the framework we use is that it allows assets to be part of liquidity. They pay, as usual, an interest rate ("pecuniary" return). Moreover, they allow households to pay for transaction services when buying consumption goods. Thus, their yield embodies a liquidity premium, which reflects the non-pecuniary return of these transactions services.

The transactions technology makes assets imperfect substitutes, because each asset is different from the others for the amount of liquidity services provided. Thus, the households' portfolio problem is nontrivial. The resulting private sector demand interacts with 1) the monetary authority demand for unconventional monetary policy purposes and 2) the supply by the fiscal authority. They jointly determine the equilibrium interest rates and exchange rates in the global markets. In particular, the distinction between EA short- and long-term sovereign bonds allows us to formalize the APP.

Households also trade a private bond at the international level, denominated in US dollars, that pays an interest rate which does not embody the aforementioned liquidity premium, as the bond does not offer any transaction services. The bond allows for a proper calibration of countries' net foreign asset position (NFA) and, hence, a full characterization of the current account dynamics. While admittedly this is only a shortcut in order to account for other asset classes that are riskier than government bonds and that affect countries' financial accounts, by and large US dollar-denominated debt still constitutes the most important component among private international assets and liabilities.

Other features of the model are more standard and in line with other existing New Keynesian multi-country general equilibrium models, based on nominal (price and wage) and real rigidities (habit in consumption, adjustment costs on investment and imports).[9] The model distinguishes between intermediate and final goods. The former include both tradable and non-tradable goods, and are produced by monopolistic competitive firms that set their prices to maximize profits subject to quadratic adjustment costs. Final goods are non-tradable, and are distinguished in private consumption, government consumption and investment goods. They are produced under perfect competition. In each region there is a continuum of households, that maximize lifetime utility subject to the budget constraint. The world economy size is normalized to 1. The size of each country corresponds to the size of households population and to the number of firms operating in each sector. Specifically, n^{EA}, n^{US}, n^{CH}, n^{JP} ($0 < n^{EA}$, n^{US}, n^{CH}, $n^{JP} < 1$) are the sizes of EA, US, CH, JP, respectively. The size of RW is obtained subtracting other regions' sizes from 1.

In what follows we report the key equations that define "international liquidity". As equations are similar across countries, we report only the EA case. Where this is not the case, it will be explicitly stated.[10]

2.1 Households and international liquidity

EA representative household j's intertemporal utility at time 0 is

$$U_0(j) \equiv E_0 \Sigma_{t=0}^{\infty} \beta^t \left\{ \frac{(C_t(j) - \xi C_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t(j)^{1+\chi}}{1+\chi} \right\}, \tag{1}$$

where E is the expectation operator, $0 < \beta < 1$ is the discount rate, C is consumption of the final good and N measures labor effort. The parameter $0 \leq \xi \leq 1$ accounts for external consumption habits. The intertemporal elasticity of substitution is $1/\sigma > 0$, and the inverse of the Frisch labor supply elasticity is $\chi > 0$.

[9]The model is similar to the Euro Area and the Global Economy Model (EAGLE) developed by Gomes, Jacquinot and Pisani (2010) and to the Global Economy Model (GEM) developed at the IMF (see Pesenti, 2008).

[10]See the Appendix "The model" for a description of the other main equations.

The budget constraint is

$$
\begin{aligned}
& M_t(j) - M_{t-1}(j) \\
& + P_t^L B_t^{EA,L}(j) - \left(1 + \kappa P_t^L\right) B_{t-1}^{EA,L}(j) \\
& + B_t^{EA,S}(j) - R_{EA,t-1} B_{t-1}^{EA,S}(j) \\
& + S_t P_t^{US,L} B_t^{US,L}(j) - \left(1 + \kappa^{US} P_t^{US,L}\right) S_t B_{t-1}^{US,L}(j) \\
& + S_t B_t^{US,S}(j) - S_t R_{US,t-1} B_{t-1}^{US,S}(j) \\
& + S_t B_t^{PR}(j) - S_t R_{t-1}^{PR} B_{t-1}^{PR}(j) \\
& = W_t(j) N_t(j) + R_{K,t} K_{t-1}(j) + D_t(j) \\
& - (1 + \tau_t(j)) P_t C_t(j) - P_{I,t} I_t(j) - TAX_t(j) + TR_t(j) - AC_t^W(j),
\end{aligned}
\tag{2}
$$

where M is domestic narrow money holdings and $B^{EA,L}$ is the domestic long-term government bond and P^L its price. The long-term bond is formalized as a perpetuity, paying an exponentially decaying coupon κ $(0 < \kappa < 1)$, in line with Woodford (2001). Its gross yield to maturity (our measure of long-term interest rate) is given by

$$
R_{L,t} = \frac{1}{P_{L,t}} + \kappa. \tag{3}
$$

The term $B^{EA,S}$ represents the short-term government bond, expressed as a one-period bond for the sake of tractability. It pays the domestic (gross) monetary policy rate R_{EA}. The terms $B^{US,L}$ and $B^{US,S}$ represent household's holding of US long- and short-term sovereign bonds, respectively. The term $P^{US,L}$ is the price of the long-term bond in US dollars. The short-term bond pays the US (gross) monetary policy rate, R_{US}. Both bonds are multiplied by the nominal exchange rate S between the euro and the US dollars (number of euros per US dollars). Thus, their value is converted in euro terms. The term B^{PR} is EA household holdings of the internationally traded bond that does not provide liquidity services, denominated in US dollar and paying the gross nominal interest rate R^{PR}.

On the right-hand side W stands for the wage rate, $R_K K$ is the income from renting the stock of physical capital K to domestic firms at the rate R_K, D is dividends from ownership of domestic firms, τ is the transactions cost, P is the consumption price index, I is investment in physical capital and P_I the related price index, TAX is lump-sum taxes, TR is lump-sum transfers associated with money injections. Finally, the term AC^W is the quadratic adjustment cost paid by the household to change its nominal (sticky) wage.

As in Schmitt-Grohé and Uribe (2004) and CCDLS, the transactions cost is proportional to consumption, with a factor of proportionality that is an increasing function of velocity:

$$\tau_t(j) = \begin{cases} \left(\frac{A}{v_t(j)}\right)(v_t(j) - \bar{v})^2 & \text{for} \quad v_t(j) > \bar{v} \\ 0 & \text{for} \quad v_t(j) \leq \bar{v} \end{cases}, \tag{4}$$

where $\bar{v}$ is the satiation level of velocity and $A > 0$ is a cost parameter. Velocity depends in turn on consumption C and overall liquidity $\tilde{M}$ holdings according to the relation

$$v_t(j) = \frac{C_t(j)}{\tilde{M}_t(j)}. \tag{5}$$

The overall liquidity $\tilde{M}_t$ is a nested CES bundle, which includes not only holdings of domestic narrow money M, but also domestic government bonds B^{EA} (composed of domestic short- and long-term bonds, $B^{EA,S}$ and $B^{EA,L}$ respectively) and US government bonds (B^{US}, composed of short- and long-term bonds, $B^{US,S}$ and $B^{US,L}$respectively):

$$\tilde{M}_t(j) = \left(\zeta_1^{\frac{1}{\lambda_1}} M_t(j)^{\frac{\lambda_1-1}{\lambda_1}} + \zeta_2^{\frac{1}{\lambda_1}} B_t^{EA}(j)^{\frac{\lambda_1-1}{\lambda_1}} + (1-\zeta_1-\zeta_2)^{\frac{1}{\lambda_1}} \left(S_t B_t^{US}(j)\right)^{\frac{\lambda_1-1}{\lambda_1}}\right)^{\frac{\lambda_1}{\lambda_1-1}} \tag{6}$$

$$B_t^{EA}(j) = \left(\theta^{\frac{1}{\lambda_2}} B_t^{EA,S}(j)^{\frac{\lambda_2-1}{\lambda_2}} + (1-\theta)^{\frac{1}{\lambda_2}} \left(P_t^L B_t^{EA,L}(j)\right)^{\frac{\lambda_2-1}{\lambda_2}}\right)^{\frac{\lambda_2}{\lambda_2-1}}, \tag{7}$$

$$B_t^{US}(j) = \left(\omega^{\frac{1}{\lambda_3}} B_t^{US,S}(j) + (1-\omega)^{\frac{1}{\lambda_3}} \left(P_t^{US,L} B_t^{US,L}(j)\right)^{\frac{\lambda_3-1}{\lambda_3}}\right)^{\frac{\lambda_3}{\lambda_3-1}}, \tag{8}$$

where US government bonds, denominated in US dollars, are appropriately converted in euro terms by the bilateral nominal exchange rate S. The parameters $\zeta_1, \zeta_2 \in [0, 1]$ measure the relevance of, respectively, EA money and domestic government bonds in facilitating transactions. Parameters $\lambda_1, \lambda_2, \lambda_3 > 0$ represent elasticities of substitution among assets in the corresponding bundle. The US government bond characterizes the international component of the EA liquidity holdings. Similarly, the parameters $\theta, \omega \in [0,1]$ measure the relevance of EA and US short-term bonds, respectively ($1-\theta$ and $1-\omega$ measure the relevance of EA and US long-term bonds, respectively). As reported in section 2.4, our calibration implies that narrow money is a more liquid asset than sovereign bonds, as the related parameter in the liquidity bundle is relatively large. Thus, the APP generates an increase in overall liquidity, as the monetary authority exchanges a more liquid asset (money) for a less liquid one (long-term sovereign bonds).

The transactions cost allows sovereign bonds to directly affect the intertemporal cost of consumption. *Ceteris paribus*, a higher amount of sovereign bonds' holdings today reduces the transaction cost today and favors current relative to future consumption. Thus, the transaction cost is observationally equivalent to an always binding liquidity constraint, where in each period consumption has to be equal to the amount of overall available liquidity, including the sovereign bonds.

The representative household optimality conditions with respect to consumption C, domestic narrow money M, domestic (EA) short- and long-term government bonds, $B^{EA,S}$ and $B^{EA,L}$ respectively, and US short- and long-term government bond, $B^{S,US}$ and $B^{L,US}$ respectively, are given by the following equations:

$$\left(C_t(j) - \xi C_{t-1}\right)^{-\sigma} = \Lambda_t(j)\left[1 + 2A\left(v_t(j) - \bar{v}\right)\right], \tag{9}$$

$$1 - A\left[\left(v_t(j)\right)^2 - (\bar{v})^2\right]\zeta_1^{\frac{1}{\lambda_1}}\left(\frac{\tilde{M}_t(j)}{M_t(j)}\right)^{\frac{1}{\lambda_1}} = E_t\left[\beta\frac{\Lambda_{t+1}(j)}{\Lambda_t(j)}\frac{P_t}{P_{t+1}}\right], \tag{10}$$

$$\begin{aligned} 1 - A\left[\left(v_t(j)\right)^2 - (\bar{v})^2\right]\zeta_2^{\frac{1}{\lambda_1}}\theta^{\frac{1}{\lambda_2}}\left(\frac{\tilde{M}_t(j)}{B_t^{EA}(j)}\right)^{\frac{1}{\lambda_1}}\left(\frac{B_t^{EA}(j)}{B_t^{EA,S}(j)}\right)^{\frac{1}{\lambda_2}} &= \\ = R_t E_t\left[\beta\frac{\Lambda_{t+1}(j)}{\Lambda_t(j)}\frac{P_t}{P_{t+1}}\right], \end{aligned} \tag{11}$$

$$
\begin{aligned}
1 - A\left[\left(v_t(j)\right)^2 - (\bar{v})^2\right]\zeta_2^{\frac{1}{\lambda_1}}(1-\theta)^{\frac{1}{\lambda_2}}\left(\frac{\tilde{M}_t(j)}{B_t^{EA}(j)}\right)^{\frac{1}{\lambda_1}}\left(\frac{B_t^{EA}(j)}{P_t^L B_t^{EA,L}(j)}\right)^{\frac{1}{\lambda_2}} &= \\
= E_t\left[\beta\frac{\Lambda_{t+1}(j)}{\Lambda_t(j)}\frac{1+\kappa P_{t+1}^L}{P_t^L}\frac{P_t}{P_{t+1}}\right], \quad (12)
\end{aligned}
$$

$$
\begin{aligned}
1 - A\left[\left(v_t(j)\right)^2 - (\bar{v})^2\right] \times \\
\times(1-\zeta_1-\zeta_2)^{\frac{1}{\lambda_1}}\omega^{\frac{1}{\lambda_3}}\left(\frac{\tilde{M}_t(j)}{S_t B_t^{US}(j)}\right)^{\frac{1}{\lambda_1}}\left(\frac{B_t^{US}(j)}{B_t^{S,US}(j)}\right)^{\frac{1}{\lambda_2}} &= \\
= R_t^{US}E_t\left[\beta\frac{\Lambda_{t+1}(j)}{\Lambda_t(j)}\frac{P_t}{P_{t+1}}\frac{S_{t+1}}{S_t}\right], \quad (13)
\end{aligned}
$$

$$
\begin{aligned}
1 - A\left[\left(v_t(j)\right)^2 - (\bar{v})^2\right] \times \\
\times(1-\zeta_1-\zeta_2)^{\frac{1}{\lambda_1}}(1-\omega)^{\frac{1}{\lambda_3}}\left(\frac{\tilde{M}_t(j)}{S_t B_t^{US}(j)}\right)^{\frac{1}{\lambda_1}}\left(\frac{B_t^{US}(j)}{P_t^{US,L}B_t^{US,L}(j)}\right)^{\frac{1}{\lambda_2}} &= \\
= E_t\left[\beta\frac{\Lambda_{t+1}(j)}{\Lambda_t(j)}\frac{1+\kappa P_{t+1}^{US,L}}{P_t^{US,L}}\frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}\right], \quad (14)
\end{aligned}
$$

where Λ is the marginal value of wealth.[11] Eq. (9) states that the marginal value of wealth is lowered by the transactions costs. Eq. (10) states that in equilibrium the current value of money holdings, which yield zero pecuniary returns, but provide transaction services (the left-hand side of the equation), should be equal to the present value of the return on saving (the right-hand side of the equation) – the stochastic discount factor. Similarly, eq. (11) shows that the presence of a liquidity premium, decreasing in the stock of government bonds outstanding (left-hand side), determines the spread between the interest rate on short-term government bonds and that on a risky asset (right-hand side), as measured by the stochastic discount factor. A similar intuition applies to the other above reported first order conditions. Thus, the latter show that, due to the presence of transactions services, interest rates differ from a standard model in which assets are perfect substitutes. These liquidity premia are affected by the size of the asset stocks outstanding in each period. Given demand for overall liquidity, demand for a specific liquid asset is directly proportional to the asset's capability of facilitating transaction costs (measured by its weight in the transaction technology) and its "pecuniary"

[11] The remaining first order conditions are not shown for brevity and are available upon request.

return. At the margin, expected returns of different assets are equated, taking into account the transaction services provided by each asset. The transaction cost is necessary for multiple assets to have a nontrivial role in households' choices. Without the transaction cost, indeed, assets would be perfectly substitutable, and the increase in bonds purchases would not have real effects. For the nominal exchange rate determination, combining the linearized versions of the optimality conditions with respect to domestic and US government bonds shows that there is a departure from the standard uncovered interest parity condition (UIP), due to the imperfect substitutability between domestic and foreign bonds.[12]

Similar expressions for budget constraints, transaction costs and liquidity hold for households in regions other than the EA. Liquidity holdings of US households include domestic money, government bonds and, as an international component, EA government bonds. The liquidity holdings of CH, JP, and RW households include not only domestic money and government bonds, but also, as international components, both US and EA government bonds. For example, in the case of the RW household j, overall liquidity $\tilde{M}$ is defined as

$$\tilde{M}_t(j) = \left(\begin{array}{c} \zeta_1^{\frac{1}{\lambda_1}} M_t(j)^{\frac{\lambda_1-1}{\lambda_1}} + \zeta_2^{\frac{1}{\lambda_1}} B_t(j)^{\frac{\lambda_1-1}{\lambda_1}} + \zeta_3^{\frac{1}{\lambda_1}} \left(S_t^{RW} B_t^{US}(j) \right)^{\frac{\lambda_1-1}{\lambda_1}} \\ + (1-\zeta_1-\zeta_2-\zeta_3)^{\frac{1}{\lambda_1}} \left(\frac{S_t^{RW}}{S_t} B_t^{EA}(j) \right)^{\frac{\lambda_1-1}{\lambda_1}} \end{array} \right)^{\frac{\lambda_1}{\lambda_1-1}} \tag{15}$$

where the term S^{RW} is the nominal exchange rate of the RW currency against the US dollar (units of RW currency per US dollar). A similar bundle holds for CH and JP households.

Our "representative" country-specific liquidity portfolio can be thought of as a synthesis of different strategies of liquidity management, followed by investors that are rather different in terms of preferences and available financial technologies. We choose not to model this type of heterogeneity to keep the model parsimonious. To partially fix this issue, we run sensitivity analysis on the elasticity of substitution among assets (Section 3.5.1), considering values of those parameters larger and lower than in the benchmark calibration.

[12] See also Canzoneri, Cumby and Diba (2013).

2.2 Public sector supply and demand of (international) liquidity

In each region a standard Taylor rule holds for the gross (short-term) monetary policy rate:

$$\log\left(R_t/\bar{R}\right) = \rho_R \log\left(R_{t-1}/\bar{R}\right) + (1-\rho_R)\,\varphi_\pi \log\left(\Pi_t/\bar{\Pi}\right) + (1-\rho_R)\varphi_{GDP}\log(GDP_t/GDP_{t-1}), \tag{16}$$

where an upper-bar "$^-$" denotes steady-state values of variables, $\rho_R > 0$ is a parameter capturing inertia in the monetary policy conduct, while φ_π and φ_{GDP} are the parameters measuring respectively the response of the policy rate to deviations of the (gross) domestic inflation rate Π from its target $\bar{\Pi}$ and to the GDP growth rate. As in standard New Keynesian models, the central bank sets the short-term interest rate on domestic (short-term) government bonds by appropriately changing the amount of money supply.

The EA monetary authority implements the APP by buying EA long-term sovereign bonds in the secondary market. In each period, the amount of purchased sovereign bonds by the central bank, $B^L_{CB,t}$, is exogenously set through an appropriate shock.

The consolidated budget constraint of monetary and fiscal authorities is

$$M^S_t + B^{G,S}_t + P^L_t B^{G,L}_t = M^S_{t-1} + R_{t-1}B^{G,S}_{t-1} + \left(1+\kappa P^L_t\right) B^{G,L}_{t-1} + P_t G_t - TAX_t + TR_t, \tag{17}$$

where M^S_t is the supply of money, $B^{G,S}$ is the supply of domestic short-term government bonds, $B^{G,L}_t$ is the supply of long-term government bonds ($B^{G,S}_t$, $B^{G,L}_t > 0$ represent short- and long-term public debt, respectively). The term G_t denotes public consumption, TAX_t is lump-sum taxes and TR_t lump-sum transfers. Public consumption is assumed to be exogenous and is kept constant at its initial steady-state level.

Lump-sum taxes guarantee fiscal solvency according to the fiscal rule

$$TAX_t - \overline{TAX} = \varphi_b \left(B^{G,S}_{t-1} - \bar{B}^{G,S}\right), \tag{18}$$

where $\overline{TAX}$ is the tax steady-state level, φ_b is a parameter that determines the tightness of the fiscal policy rule, i.e. the speed at which the short-term debt is returned to the target (steady-state) level, $\bar{B}^{G,S}$. Similarly, in CCDLS the parameter φ_b is assumed to be larger than the steady-state value of the real interest rate paid by the short-term government bond, to guarantee that the primary surpluses move to stabilize the debt. The supply of long-term sovereign bonds is exogenously set.

2.3 Bond market clearing conditions

For the EA short-term government bond, the (world-wide) market clearing condition is

$$\begin{aligned}
& \int_0^{n^{EA}} B_t^{EA,S}(j)\, dj + \int_{n^{EA}}^{n^{US}} B_t^{EA,S}(j)\, dj + \\
& \int_{n^{US}}^{n^{CH}} B_t^{EA,S}(j)\, dj + \int_{n^{CH}}^{n^{JP}} B_t^{EA,S}(j)\, dj + \int_{n^{JP}}^{1} B_t^{EA,S}(j)\, dj \\
= \; & B_t^{S,G}. \qquad (19)
\end{aligned}$$

Correspondingly, the market clearing of the EA long-term government bond is

$$\begin{aligned}
& \int_0^{n^{EA}} B_t^{EA,L}(j)\, dj + \int_{n^{EA}}^{n^{US}} B_t^{EA,L}(j)\, dj + \\
& \int_{n^{US}}^{n^{CH}} B_t^{EA,L}(j)\, dj + \int_{n^{CH}}^{n^{JP}} B_t^{EA,L}(j)\, dj + \int_{n^{JP}}^{1} B_t^{EA,L}(j)\, dj \\
& + B_{CB,t}^{L} \\
= \; & B_t^{L,G}, \qquad (20)
\end{aligned}$$

where B_{CB}^{L} represents the purchases of EA long-term sovereign bonds by the EA monetary authority. Similar conditions hold for US short- and long-term sovereign bonds.

CH, JP and RW governments issue short-term and long-term government bonds to domestic households. The corresponding market clearing conditions for CH are

$$B^{S,G}_{CH,t} = \int_{n^{US}}^{n^{CH}} B^{S}_{CH,t}(j)\,dj, \tag{21}$$

$$B^{L,G}_{CH,t} = \int_{n^{US}}^{n^{CH}} B^{L}_{CH,t}(j)\,dj. \tag{22}$$

Similar conditions hold for JP and RW sovereign bonds.

Finally, the market clearing condition for the bond denominated in US dollars that does not provide liquidity services, which is traded internationally by households, is

$$\begin{aligned} & \int_{0}^{n^{EA}} B^{PR}_{EA,t}(j)\,dj + \int_{n^{EA}}^{n^{US}} B^{PR}_{US,t}(j)\,dj \\ & + \int_{n^{US}}^{n^{CH}} B^{PR}_{CH,t}(j)\,dj + \int_{n^{CH}}^{n^{JP}} B^{PR}_{JP,t}(j)\,dj + \int_{n^{JP}}^{1} B^{PR}_{RW,t}(j)\,dj \\ = \ & 0. \end{aligned} \tag{23}$$

The conditions make clear the interaction between the central bank, the fiscal authority and households when the APP is implemented. EA central banks' purchases of domestic long-term sovereign bonds is an asset demand shock. For a given supply of EA government bonds, the shock affects the long-term interest rate and hence the (optimal) demand of households for each asset. As a result a new market equilibrium, characterized by new equilibrium interest rates, exchange rates and, hence, real allocations is achieved.

2.4 Calibration

We fully match all reported empirical ratios by appropriately adjusting parameters of the model. Parameters in the production functions, consumption and investment baskets are set to exactly match the observed "great ratios" (2012 averages) and trade flows. Moreover, similarly to CCDLS, we calibrate the parameters of transactions costs and the transactions technology to match key monetary and fiscal ratios. Remaining parameters are set to values in line with theoretical and quantitative contributions of a fully estimated version of the ECB New Area Wide Model (NAWM, see Christoffel, Coenen and Warne 2008), the IMF Global Economy Model (GEM, see Laxton 2008 and Pesenti 2008) and the Eurosystem Euro Area and Global Economy Model (EAGLE, see Gomes, Jacquinot and Pisani 2010).

Table 1 reports the model implied great ratios for the five regions.

Table 2 shows the preference and technology parameters. Preferences are the same across households of different regions. The habit parameter is set to 0.85, the intertemporal elasticity of substitution to 1.0 and the Frisch elasticity to 0.50. We further assume a quarterly depreciation rate of capital to 0.02, consistently with an annual depreciation rate of 8%.

As for the final goods, the degree of substitutability between domestic and imported tradables is higher than that between tradables and non-tradables, consistently with the existing literature. We set the (long-run) elasticity of substitution between tradables and non-tradables to 0.5 and the long-run elasticity between domestic and imported tradables to 2.5.

Table 3 reports real and nominal rigidities. For real rigidities, parameters of the adjustment costs on investment changes are set to 3.5 in all countries. For nominal rigidities, we set the Rotemberg (1982) price and wage adjustment parameters in the tradable and non-tradable sectors to 400. This value for quadratic adjustment costs in prices is roughly equivalent to a four-quarter contract length under Calvo-style pricing, as highlighted, among others, by Faruqee, Laxton and Muir (2007).

Table 4 reports the values of the elasticity of substitution among assets in the liquidity bundle, the elasticity of substitution among imported goods and the steady-state international trade linkages. Parameters λ_1, λ_2 and λ_3 in eqs. (6)-(8) are set to 1 in every region, in line with CCDLS ("Cobb-Douglas" calibration). Given the high uncertainty surrounding the elasticity parameters, we perform sensitivity analysis. Results are reported in Section 3.5.1.

The weight of domestic tradable goods in the consumption and investment tradable baskets is different across countries, to match multilateral import-to-GDP ratios. In particular, we rely on the United Nations' Commodity Trade Statistics (COMTRADE) data on each region's imports of consumer and capital goods, to derive a disaggregated steady-state matrix delineating the pattern and composition of trade for all regions' exports and imports. We then set the weights of bilateral imports to match this trade matrix, reported in Table 4. It is interesting to highlight that trade with the RW region clearly dominates trade patterns for all the other countries, and in particular for EA.

Table 5 contains price and wage markup values. We identify the non-tradable and tradable intermediate sectors in the model with the services and manufacturing sectors in the data, respectively. In each region the markup in the non-tradable sector is higher than that in the tradable sector and labor market, which we instead assume to be equal. Our values are in line with other existing similar studies, such as Bayoumi, Laxton and Pesenti (2004), Faruqee, Laxton and Muir (2007). Many, if not all, of these studies refer to Jean and Nicoletti (2002) and Oliveira Martins and Scarpetta (1999) for estimates of markups.

Table 6 reports the parameters of the policy rules. For monetary policy rules, the interest rate reacts to the its lagged value (inertial component of the monetary policy), gross inflation and output growth (see eq. 16). For fiscal policy, the parameter governing the speed of adjustment of short-run public debt is assumed equal across countries and allows for a stabilization of the short-run debt in the long run (long-run debt is exogenous and kept constant at its steady-state level in every region).

Table 7 shows the ratios (% of GDP) for the different asset stocks that enter into the model: currency in circulation, total general government debt levels and, in the case of the US and the EA, foreign private holdings of government debt issued in US dollars and in euros. The ratios are matched by calibrating the parameters affecting the transactions technology, which involves money and government bonds held by private agents. Following CCDLS we first compute the asset ratios using the data available on currency in circulation, total general government debt levels and, for the United States and the EA, on foreign private holdings of government debt issued in US dollars and in euros. The specific data sources used to compute these stocks are reported in the Appendix "Data". Second, we use these asset ratios, together with the steady-state level of transactions costs (τ in eq. 4), which we set as in CCDLS to 0.8% of consumption, and with our choice of the liquidity premium, to jointly pin down the parameters entering the transactions costs and transactions technology (i.e. the cost parameters A, the satiation levels of velocity v, and the shares of the various assets – denoted above by ζ and ω – in the definition of the liquidity balances, $\tilde{M}$). We match asset shares by maturity distribution. We consider as "short-term" ("long-term") those outstanding bonds having residual maturity up to (greater than) 1 year.

In our model the yield curve on sovereign bonds is composed by two "points", one representing the short-term sovereign bond and its return, the other the long-term sovereign bonds and its return. Short- and long-term interest rates are endogenously determined by market clearing conditions, given the calibrated values for bond holdings. The short-term interest rate is around 3% in every region, the long-term interest rate is around 4%. The duration of the long-term bonds is set to 6.5 years.

3 Results

In what follows we simulate the model to assess the macroeconomic implications of the APP, formalized as an exogenous increase in the purchases of long-term sovereign bonds by the EA monetary authority. The shock is calibrated so that it corresponds to monthly purchases of 60 billion euros of long-term bonds that last for 7 quarters (from March 2015 to September 2016). The phasing-out, i.e. the return of the Eurosystem balance sheet to the pre-APP level, is assumed to be gradual over 7 quarters, starting from October 2016. During the first 8 quarters, the short-term monetary policy rate is assumed to be constant at its baseline level $\bar{R}$ (see Taylor rule, eq. 16), reflecting the commitment of the central bank to maintain an accommodative stance for a prolonged period. Thus, the constant monetary policy rate is not the outcome of the zero lower bound constraint, but should be interpreted as a deliberate policy choice. From quarter 9, the monetary policy rate is set according to a Taylor rule. Finally, the supply of long-term public debt is kept constant at its steady-state level. It is crucial that fiscal policy not offset the effect of the unconventional monetary policy. The Government may, in fact, increase the maturity of its outstanding debt by issuing long-term bonds while redeeming short-term ones. In that case, the net effect on long-term interest rate of the long-term asset purchase programme by the Central Bank, if any, may be considerably blurred. According to Hamilton and Wu (2012) this is what happened in the US between November 2009 and November 2010, during the so-called QE2.

All simulations are run under perfect foresight. Therefore, there is no uncertainty, policies are fully credible and households and firms perfectly anticipate the future.[13]

3.1 Benchmark simulation: domestic (EA) effects

Fig. 1 reports the responses of the main EA financial variables. The EA long-term interest rate – measured by the yield-to-maturity – declines following the increase in long-term bond purchases (see eq. 3). The decline is rather persistent, as the interest rate returns to nearly its baseline level after 5 years.

The low long-term interest rate provides an incentive to substitute the most liquid asset – domestic narrow money – and the EA short-term sovereign bond, whose pecuniary relative return has increased, for EA long-term sovereign bonds. The holdings of US sovereign bond fall because of the rather limited increase in their returns denominated in US dollars and the expected appreciation (from quarter 2 on) of the euro versus the US currency. For the same reasons, the EA representative household increases its borrowing in the US-dollar denominated bond that does not provide liquidity services (the percentage increase reported in the chart represents higher borrowing, as the initial position is negative). Overall liquidity $\tilde{M}$ increases, in a rather persistent way. Due to lower EA interest rates and higher US ones, the euro depreciates on impact both in nominal and real terms. The US monetary authority raises the interest rates to stabilize domestic inflation and economic activity, following expansionary spillovers associated with higher EA aggregate demand.

Fig. 2 reports the responses of the main EA macroeconomic variables. Both EA GDP and inflation increase, by 1.4% of the baseline level and 0.8 percentage points, respectively. The reduction in the transaction cost – associated with the increase in liquidity – and the simultaneous reduction in long-term interest rates induce households to increase their consumption. Firms augment labor to produce more and satisfy the higher demand. The implied higher marginal productivity of capital favors the increase in investment. Higher aggregate demand induces

[13]In particular, there is no premium associated with inflation risk.

higher inflation. Provided that the central bank does not hike the short-term term interest rate and that the long-term rate decreases, persistently higher inflation will determine a reduction in the real interest rates, which will further spur aggregate demand. Higher activity encourages imports, while higher prices have a negative effect on international competitiveness, partially compensated in the short-run by the nominal (and real) exchange rate depreciation. Overall, exports do not change significantly.

To further explain the transmission mechanism, we also present the results of a simulation in which we relax the assumption of constant (short-term) monetary policy rate, held in the benchmark scenario. In this alternative scenario, when the APP is implemented, the EA monetary policy rate is set according to the Taylor rule (see eq. 16) since the beginning of the simulation.

Fig. 3 compares the results for the main financial variables. The APP has a stimulating effect on the EA economy. Thus, the short-term policy rate increases to stabilize inflation and GDP. The increase in the short-term interest rate is an incentive for households to substitute short-term domestic bonds for domestic long-term bonds. The monetary authority increases money supply by a smaller amount when raising the policy rate. Thus, liquidity increases to a lower extent than in the benchmark case. The long-term bond price increases less than in the benchmark scenario, and thus the fall in long-term interest rate is smaller. The EA household reduces its holdings of US sovereign bonds to a lower extent because of the lower expected euro appreciation (the increase in the EA short-term rate limits the depreciation of the euro exchange rate against the US dollar). For the same reasons, households increase their borrowing in US private bonds by a smaller amount. With respect to the benchmark case, the allocation across different bonds is not substantially different, as the pecuniary returns are similar in both scenarios.

Fig. 4 reports the results for the main macroeconomic variables. Not surprisingly, the stimulating effects of the APP on GDP and its main components are smaller if the short-term interest rate is raised rather than held constant at its baseline value while the non-standard monetary policy measures are implemented. It is nonetheless interesting to note that the macroeconomic effects are positive and not trivial. This suggests that APP provides a non-negligible expansionary contribution to the response of the macroeconomic variables in the benchmark scenario.

3.2 Benchmark simulation: international spillovers

One relevant issue of the APP is the assessment of its international spillovers. The largest cross-country spillover effects of the APP are those on the RW region and are reported in Fig. 5. Spillovers to the other regions are qualitatively similar but smaller.[14] In the benchmark scenario, RW GDP and inflation slightly increase, driven by the higher exports towards the EA. The RW monetary authority raises its policy rate to stabilize the economy. Households substitute domestic short-term bonds, euro-denominated short-term bonds and US dollar-denominated bonds, whose (relative) returns have increased, for euro-denominated long-term bonds and domestic money. Overall liquidity falls. The implied increase in the transactions cost, domestic and US interest rates, induces households to reduce consumption and investment in physical capital. Imports decrease, following the decrease in aggregate demand. Finally, and consistent with the relatively large increase in the RW interest rate, the RW exchange rate appreciates against the US dollar and the euro; the appreciation partially counterbalances the positive effect of higher EA aggregate demand on RW exports.

We have evaluated whether the spillovers are transmitted mainly through trade or financial variables. To that purpose, we have simulated the APP under the assumption that the EA is an almost "closed" economy by markedly increasing the home bias in consumption and investment baskets. The resulting EA import-to-GDP ratio is 5% (24% in the benchmark calibration). We do not report results to save space. The RW GDP increases to a much lower extent than in the benchmark scenario, less than 0.1% (in the benchmark scenario it is 0.2%). The reason is that in the new scenario RW exports towards the EA increase relatively less, given the lower weight of EA imported goods in EA aggregate demand. The result suggests that the trade channel is the more relevant than the financial channel. This is not extremely surprising, given the calibration of the model. The modest amount of EA sovereign bonds held in foreign portfolios implies that the reduction in the EA long-term interest rate should have a rather limited direct effect on foreign

[14] They are available upon request.

households' financial allocations and, hence, on their consumption and investment choices.

3.3 International spillovers and foreign monetary policy stance

As shown in Fig. 5, spillovers to the RW economy are expansionary but not extremely large. They are about 12% of the EA GDP expansion, thanks to the increase in RW exports towards the EA.

We further explore spillovers by evaluating their interaction with the stance of RW monetary policy. It is assumed that the RW monetary authority promises, in a fully credible way, to keep the (short-term) monetary policy rate constant at its baseline level for 8 quarters, even if the policy rate is increased in correspondence with the expansionary spillovers of the EA APP to stabilize domestic inflation. We posit that the Taylor rule becomes active only from quarter 9 on.

Fig. 6 reports the results of the APP for the main RW macroeconomic variables. Compared to the benchmark scenario, the RW GDP increases relatively more when the RW policy rate is kept constant, by around 0.4% of the baseline level. Thus, the spillover is now equal to 25% of the EA GDP expansion. The RW household rebalances its portfolio in favor of EA short-term sovereign bonds, as in the benchmark scenario (results are not reported to save space). Unlike the benchmark scenario, the monetary conditions are now expansionary. The RW household's holdings of domestic money and overall liquidity increase, favoring demand for consumption. The latter stimulates production, capital accumulation, and, thus, demand for investment.

Overall, APP spillovers are widely amplified by the RW policy rate held constant at its baseline level.

The results suggest that a full assessment of the APP spillovers should take into account the particular monetary policy stance of the EA partners. On the one hand, households in partner countries can anticipate rather large deflationary effects associated with the exchange rate appreciation against the euro. On the other hand, they can also anticipate large reflationary effects of the APP if expansionary spillovers, associated with higher exports towards the EA, are dominant and amplified by the country-specific monetary policy stance.

3.4 High nominal exchange rate pass-through

Fig. 7 shows results under the assumption that the short-run pass-through of the nominal exchange rate into import prices is larger than in the benchmark simulation. Nominal price stickiness of imported goods is reduced, so that the exchange rate movement is almost fully passed through into the price of imports in the first two quarters after the shock (the degree of pass-through is around 0.5 after the first two quarters in the benchmark scenario). Moreover, we increase the elasticity of substitution between tradables, from 2.5 to 5.5, and set the short-run adjustment costs on imports to zero. The euro depreciation is quickly passed through into export and import prices. The implied expenditure-switching effect positively affects demand of EA goods (exports increase relatively more than in the benchmark scenario). EA production increases more than in the benchmark scenario, driving up firms' demand for domestic capital and labor. Thus, investment and consumption increase at a faster rate as well. The larger increase in consumption favors a larger increase in demand for liquidity. EA households are more willing to sell domestic long-term sovereign bonds. Thus, in equilibrium the price of long-term bonds increases at a lower rate and, correspondingly, the interest rate decreases to a lower extent. EA inflation is faster as well, because of the larger increase in the euro price of imported goods. The exchange rate depreciates at a faster pace, to support the absorption of the larger excess supply of EA goods in the world market.

Fig. 8 shows the spillovers to the RW. Unlike the benchmark scenario, now RW GDP decreases in the short run, following the initial drop in RW exports, due to the negative and large expenditure-switching effect, as the real exchange rate appreciation is now quickly passed through into import prices. For the same reason the inflation rate slightly falls in the short run, but peaks in the medium run, inducing the monetary authority to lower the policy rate on impact (not reported), limiting the reduction in consumption and investment.

Fig. 9 reports results when the RW policy rate is kept constant at its baseline level during the first 8 quarters. Thus, unlike the benchmark scenario (and the scenario reported in Fig. 8), the policy rate does not increase after the first quarters to stabilize inflation as in the benchmark scenario. Now GDP increases in the short run, following the increase in consumption and investment, associated with the relatively low intertemporal path of nominal and real interest rates. Thus, the RW monetary policy stance is crucial for the spillovers also when the short-run impact of international relative prices is relatively large, because the expansionary effects associated with a persistently low real interest rate can more than counterbalance the recessionary ones associated with the short-run exchange rate appreciation.

3.5 Sensitivity analysis

We modify the benchmark scenario in two alternative ways. First, we modify the elasticity of substitution among assets. In particular, we simulate the model with an elasticity both higher and lower than in the benchmark case. Second, we posit that the phasing-out of the APP is more gradual, and lasts 20 rather than 7 quarters. The sensitivity on the elasticity of substitution is necessary as there is no clear consensus about its calibration. The sensitivity on the phasing-out allows us to evaluate the role of the anticipation effect, as in our simulations the perfect foresight assumption holds, so that households take their decisions on the basis of the intertemporal path of interest rates. Moreover, the latter exercise sheds some light on the macroeconomic implications of the APP design, as it has been announced by the Eurosystem that the APP is intended to remain in place until at least September 2016 and in any case until the Governing Council sees 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.

3.5.1 Elasticity of substitution among assets

Fig. 10 reports the effects of APP when the elasticity of substitution among assets is set to 2.5 (instead of 1 as in the benchmark scenarios). Domestic macroeconomic effects are smaller than in the benchmark case. Given the APP, the long-term interest rate now decreases to a smaller extent. Thus, the increase in EA households consumption is lower. Given the transaction cost, the same happens to liquidity demand. The increase in GDP, investment and imports is more muted as well (see

Fig. 11). The moderate increase in EA aggregate demand implies lower cross-country spillovers. Fig. 12 shows that RW GDP increases to a lower extent, as exports towards the EA augment to a lower extent.

Fig. 13 reports results under the assumption that the elasticity of substitution among assets is set to 0.8. The macroeconomic effects of the APP are now larger than in the benchmark scenario. It is now more difficult for households to substitute one asset for the other. Thus, the increase in central bank demand induces a larger increase in the price of EA long-term sovereign bonds, and consequently a larger decrease in the long-term interest rate. Households have a stronger incentive to increase consumption. The larger expansion in transactions motivates a larger rise in overall liquidity. As reported in Fig. 14, EA GDP and investment increase at a faster rate. The larger increase in EA aggregate demand prompts larger imports. The latter benefit RW GDP, which grows more than in the benchmark scenario (Fig. 15).

Overall, the analysis shows that the sign of the APP effects on EA and RW economies does not change in correspondence with the considered values of the elasticity of substitution. APP has expansionary domestic and cross-country effects on GDP and inflation. The size of the effects can be rather large if the elasticity is low, because of the large drop in the EA long-term interest rate. The effects on the EA economy are small, but not negligible, when the elasticity is relatively large.

3.5.2 APP: long phasing-out

Fig. 16 shows results under the assumption that the phasing-out of the APP lasts for 20 quarters (rather than 7). The expansionary macroeconomic effects of the APP are larger than in the benchmark scenario. In the new scenario the EA long-term interest rate falls more and remains below its baseline for a longer period, as the non-standard monetary policy measure is more prolonged than in the benchmark scenario. EA households anticipate that the interest rate would be relatively low for longer. Thus, with respect to the benchmark scenario, there is a stronger stimulus to aggregate demand for consumption and investment. In turn, this stimulates inflation and imports as well. In the medium run, because of the larger increase in EA prices, which implies a bigger loss in international price competitiveness, exports decrease to a larger extent.

Cross-country spillovers (not reported to save space) in correspondence with the long-lasting phasing out are larger. Foreign GDP increases, triggered by the larger increase in exports towards the EA.

Overall, the effects of the APP are expansionary on both EA and RW GDP. They are larger when the APP is anticipated to last for a longer amount of time by households. To increase the macroeconomic effect of the APP, this suggests the importance of announcing not only the size of the purchases, but also their duration.

4 Conclusions

We have evaluated the domestic and cross-country macroeconomic effects of the EA APP by simulating a multi-country dynamic general equilibrium model. According to our results, the APP has nontrivial expansionary effects on the EA economy, because it stimulates EA aggregate demand by reducing the long-term interest rate. Cross-country spillovers can be quite significant, dependending on the response of international relative prices and on the foreign monetary policy stance. The latter aspect can be further evaluated by simulating non-standard monetary policy measures, or their phasing-out, in regions other than the EA, for example in CH, JP or in the US. The macroeconomic effects on selected countries and the global economy can be assessed. We leave these interesting issues for future research.

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Appendix: Data sources

We rely on several data sources in order to compute the different asset holdings that characterize the model. In particular, money balances held by households are computed as 2001-2012 averages using the variable "Currency in circulation" from the IMF's *International Financial Statistics* database. Data on foreign private and official holdings of US government bonds is taken from the April 2013 issue on *Foreign Portfolio Holdings of US Securities*.[15] The outstanding holdings refer to June 2012. We include both short- and long-term debt issued both by the Treasury and by the Government-sponsored Agencies. The latter have been taken over or placed into conservatorship by the U.S. Treasury in September 2008, and as such should command a liquidity premium equal or, at least, very close to that on U.S. Treasury bonds. As the information provided for China only refers to the aggregate holdings, with no distinction between private and official holdings being available, we assume that the entire holdings are official, except for a small part which we arbitrarily assume is being held by private households: alternatively, we would have needed to modify the model in order to set private Chinese household holdings of US bonds equal to zero, but this would have added some complications to our calibration procedure. Foreign holdings of euro denominated government bonds are computed from Tables A1 and A2 in *The International Role of the Euro*, July 2013, ECB. To compute private versus official holdings of euro denominated government bonds we rely the information provided in Andritzky (2012). Finally, data on domestic holdings of government bonds for the remaining countries are computed by combining the IMF's *Fiscal Monitor* database and the information on the different types of holders (private vs. official) reported in Andritzky (2012).

[15] See Department of the Treasury, the Federal Reserve Bank of New York, and the Board of Governors of the Federal Reserve System (2013).

Appendix: The Model

In this Appendix we report a detailed description of the model except for fiscal and monetary policies and households' optimization problems, which are reported in the main text.[16]

There are five blocs, Home, US (*), CH (China, **), JP (Japan, ***), and RW (rest of the world, ****). In what follows we illustrate the Home economy. The structure of each of the other four regions is similar and to save space we do not report it.

Final consumption and investment goods

There is a continuum of symmetric Home firms producing nontradable final consumption under perfect competition. Each firm producing the consumption good is indexed by $x \in (0, n]$, where the parameter $0 < n < 1$ measures the size of Home economy. Firms in the other regions are similarly indexed (the size of the world economy is normalized to 1, so $n + n^{*} + n^{**} + n^{***} + n^{****} = 1$). The CES production technology used by the generic firm x producing the consumption good is

$$A_t(x) \equiv \left(\begin{array}{l} a_{TA}^{\frac{1}{\phi_A}} \left(\begin{array}{l} a_{HA}^{\frac{1}{\rho_A}} Q_{HA,t}(x)^{\frac{\rho_A - 1}{\rho_A}} \\ + (1 - a_{HA})^{\frac{1}{\rho_A}} \times \\ \left(\left(\sum_{i=1}^{4} a_{IMPA,i}^{\frac{1}{\rho_{IMPA}}} Q_{IMPA,i,t}(x)^{\frac{\rho_{IMPA}-1}{\rho_{IMPA}}} \right)^{\frac{\rho_{IMPA}}{\rho_{IMPA}-1}} \right)^{\frac{\rho_A - 1}{\rho_A}} \end{array} \right)^{\frac{\rho_A}{\rho_A - 1} \frac{\phi_A - 1}{\phi_A}} \\ + (1 - a_{TA})^{\frac{1}{\phi_A}} Q_{NA,t}(x)^{\frac{\phi_A - 1}{\phi_A}} \end{array} \right)^{\frac{\phi_A}{\phi_A - 1}},$$

where Q_{HA}, Q_{IMPA}, and Q_{NA} are bundles of respectively tradable intermediate goods produced in the Home country, tradable intermediate goods produced in one among the other four regions and imported by Home, and nontradable intermediate goods produced in the Home country. The parameter $\rho_{IMPA} > 0$ is the elasticity of substitution among imported consumption goods. The parameter $\rho_A > 0$ is

[16] For a detailed description of the main features of the model see also Pesenti (2008).

the elasticity of substitution among tradable goods and $\phi_A > 0$ is the elasticity of substitution between tradable and nontradable goods. The parameter a_{HA} ($0 < a_{HA} < 1$) is the weight of the Home tradable, the parameter $a_{IMP,i}$ ($0 < a_{IMP,i} < 1$, $\sum_{i=1}^{4} a_{IMPA,i} = 1$) the weight of the generic imported tradable from country i, and the parameter a_{TA} ($0 < a_{TA} < 1$) the weight of tradable goods.

The production of investment good is similar. There are symmetric Home firms under perfect competition indexed by $y \in (0, n]$. Output of the generic Home firm y is

$$E_t(x) \equiv \left(\begin{array}{l} a_{TE}^{\frac{1}{\phi_E}} \left(\begin{array}{l} a_{HE}^{\frac{1}{\rho_E}} Q_{HE,t}(x)^{\frac{\rho_E - 1}{\rho_A}} \\ + (1 - a_{HE})^{\frac{1}{\rho_E}} \times \\ \left(\left(\sum_{i=1}^{4} a_{IMPE,i}^{\frac{1}{\rho_{IMPE}}} Q_{IMPE,i,t}(x)^{\frac{\rho_{IMPE}-1}{\rho_{IMPE}}} \right)^{\frac{\rho_{IMPE}}{\rho_{IMPE}-1}} \right)^{\frac{\rho_E - 1}{\rho_E}} \end{array} \right)^{\frac{\rho_E}{\rho_E - 1} \frac{\phi_E - 1}{\phi_E}} \\ + (1 - a_{TE})^{\frac{1}{\phi_E}} Q_{NE,t}(x)^{\frac{\phi_E - 1}{\phi_E}} \end{array} \right)^{\frac{\phi_E}{\phi_E - 1}}.$$

Finally, we assume that public expenditure C_N^G is composed of nontradable intermediate goods only, produced by firms $g \in (0, n]$.

Intermediate goods

Demand

Bundles used to produce the final consumption goods are CES indexes of differentiated intermediate goods, each produced by a single firm under conditions of monopolistic competition:

$$
\begin{aligned}
Q_{HA}(x) &\equiv \left[\left(\frac{1}{n}\right)^{\theta_T}\int_0^n Q(h,x)^{\frac{\theta_T-1}{\theta_T}}\,dh\right]^{\frac{\theta_T}{\theta_T-1}}, && (24)\\
Q_{NA}(x) &\equiv \left[\left(\frac{1}{n}\right)^{\theta_N}\int_0^n Q(i,x)^{\frac{\theta_N-1}{\theta_N}}\,di\right]^{\frac{\theta_N}{\theta_T-1}}, && (25)\\
Q_{IMPA,US,t}(x) &\equiv \left[\left(\frac{1}{n^*}\right)^{\theta_T}\int_n^{n+n^*} Q(g,x)^{\frac{\theta_T-1}{\theta_T}}\,dg\right]^{\frac{\theta_T}{\theta_T-1}}, && (26)
\end{aligned}
$$

where firms in the Home tradable and nontradable sectors are respectively indexed by $h \in (0,n]$ and $x \in (0,n]$, while Home firms in the sector importing US goods are indexed by g. A similar indexation holds for firms in sectors importing from CH, JP, RW. Parameters θ_T, $\theta_N > 1$ are the elasticity of substitution across brands in the tradable and nontradable sectors, respectively. The prices of the nontradable intermediate goods are denoted by $p(i)$. Each firm x takes these prices as given when minimizing production costs of the final good. The resulting demand for nontradable intermediate input i is

$$
Q_{A,t}(i,x) = \left(\frac{1}{n}\right)\left(\frac{P_t(i)}{P_{N,t}}\right)^{-\theta_N} Q_{NA,t}(x), \tag{27}
$$

where $P_{N,t}$ is the cost-minimizing price of one basket of local intermediates:

$$
P_{N,t} = \left[\int_0^n P_t(i)^{1-\theta_N}\,di\right]^{\frac{1}{1-\theta_N}}. \tag{28}
$$

We can derive $Q_A(h,x)$, $Q_A(f,x)$, $C_N^G(g,x)$ in a similar way. Firms y and g that respectively produce the final investment and public consumption goods have similar demand curves. Aggregating over x, y, and g it can be shown that total demand for nontradable intermediate good i is

$$
\begin{aligned}
&\int_0^n Q_{A,t}(i,x)\,dx + \int_0^n Q_{E,t}(i,y)\,dy + \int_0^n C_{N,t}^G(i,g)\,dg \\
= &\left(\frac{P_t(i)}{P_{N,t}}\right)^{-\theta_N}\left(Q_{NA,t} + Q_{NE,t} + C_{N,t}^G\right),
\end{aligned}
$$

where C_N^g is public sector consumption. Home demands for (intermediate) domestic and imported tradable goods can be derived in a similar way.

Supply

The supply of each Home nontradable intermediate good i is denoted by $N^S(i)$:

$$N_t^S(i) = \left((1-\alpha_N)^{\frac{1}{\xi_N}} L_{N,t}(i)^{\frac{\xi_N - 1}{\xi_N}} + \alpha^{\frac{1}{\xi_N}} K_{N,t}(i)^{\frac{\xi_N - 1}{\xi_N}} \right)^{\frac{\xi_N}{\xi_N - 1}}. \tag{29}$$

Firm i uses labor $L_{N,t}^p(i)$ and capital $K_{N,t}(i)$ with constant elasticity of input substitution $\xi_N > 0$ and capital weight $0 < \alpha_N < 1$. Firms producing intermediate goods take the prices of labor inputs and capital as given. Denoting W_t the nominal wage index and R_t^K the nominal rental price of capital, cost minimization implies that

$$L_{N,t}(i) = (1-\alpha_N) \left(\frac{W_t}{MC_{N,t}(i)} \right)^{-\xi_N} N_t^S(i), \tag{30}$$

and

$$K_{N,t}(i) = \alpha \left(\frac{R_t^K}{MC_{N,t}(i)} \right)^{-\xi_N} N_t^S(i),$$

where $MC_{N,t}(n)$ is the nominal marginal cost:

$$MC_{N,t}(i) = \left((1-\alpha) W_t^{1-\xi_N} + \alpha \left(R_t^K\right)^{1-\xi_N} \right)^{\frac{1}{1-\xi_N}}. \tag{31}$$

The productions of each Home tradable good, $T^S(h)$, is similarly characterized.

Price setting in the intermediate sector

Consider now profit maximization in the Home nontradable intemediate sector. Each firm i sets the price $p_t(i)$ by maximizing the present discounted value of profits subject to the demand constraint and the quadratic adjustment costs,

$$AC_{N,t}^p(i) \equiv \frac{\kappa_N^p}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} - 1 \right)^2 Q_{N,t},$$

which is paid in units of sectorial product $Q_{N,t}$ and where $\kappa_N^p \geq 0$ measures the degree of price stickiness. The resulting first-order condition, expressed in terms of domestic consumption, is

$$p_t(i) = \frac{\theta_N}{\theta_N - 1} mc_t(i) - \frac{A_t(i)}{\theta_N - 1}, \tag{32}$$

where $mc_t(i)$ is the real marginal cost and $A_t(i)$ contains terms related to the presence of price adjustment costs:

$$\begin{aligned} A_t(i) \quad \approx \quad & \kappa_N^p \frac{P_t(i)}{P_{t-1}(i)} \left(\frac{P_t(i)}{P_{t-1}(i)} - 1 \right) \\ & -\beta \kappa_N^p \frac{P_{t+1}(i)}{P_t(i)} \left(\frac{P_{t+1}(i)}{P_t(i)} - 1 \right) \frac{Q_{N,t+1}}{Q_{N,t}}. \end{aligned}$$

The above equations clarify the link between imperfect competition and nominal rigidities. When the elasticity of substitution θ_N is very large and hence the competition in the sector is high, prices closely follow marginal costs, even though adjustment costs are large. To the contrary, it may be optimal to maintain stable prices and accommodate changes in demand through supply adjustments when the average markup over marginal costs is relatively high. If prices were flexible, optimal pricing would collapse to the standard pricing rule of constant markup over marginal costs (expressed in units of domestic consumption):

$$p_t(i) = \frac{\theta_N}{\theta_N - 1} mc_{N,t}(i). \tag{33}$$

Firms operating in the intermediate tradable sector solve a similar problem. We assume that there is market segmentation. Hence the firm producing the brand h chooses $p_t(h)$ in the Home market, and a price in each of the other 4 regions ($p_t^*(h)$, $p_t^{**}(h)$, $p_t^{***}(h)$, $p_t^{****}(h)$) to maximize the expected flow of profits (in terms of domestic consumption units),

$$E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left[\begin{array}{c} p_\tau(h) y_\tau(h) + \frac{p_\tau^*(h)}{rer^*} y_\tau^*(h) + \frac{p_\tau^{**}}{rer^{**}}(h) y_\tau^{**}(h) \\ + \frac{p_\tau^{***}}{rer^{***}}(h) y_\tau^{***}(h) + \frac{p_\tau^{****}}{rer^{****}}(h) y_\tau^{****}(h) \\ -mc_{H,\tau}(h) \left(y_\tau(h) + y_\tau^*(h) + y_\tau^{**}(h) + y_\tau^{***}(h) + y_\tau^{****}(h) \right) \end{array} \right],$$

subject to quadratic price adjustment costs similar to those considered for non-tradable goods and standard demand constraints. Each term "rer" represents the bilateral exchange rate between the Home currency and the currency of the considered importing country. The term E_t denotes the expectation operator conditional on the information set at time t, $\Lambda_{t,\tau}$ is the appropriate discount rate, and $mc_{H,t}(h)$ is the real marginal cost. The first order conditions with respect to $p_t(h)$, $p_t^*(h)$, $p_t^{**}(h)$,$p_t^{***}(h)$, and $p_t^{****}(h)$ are respectively

$$\begin{aligned} p_t(h) &= \frac{\theta_T}{\theta_T - 1} mc_t(h) - \frac{A_t(h)}{\theta_T - 1}, && (34) \\ p_t^*(h) &= \frac{\theta_T}{\theta_T - 1} \frac{mc_t(h)}{rer^*} - \frac{A_t^*(h)}{\theta_T - 1}, && (35) \\ p_t^{**}(h) &= \frac{\theta_T}{\theta_T - 1} \frac{mc_t(h)}{rer^{**}} - \frac{A_t^{**}(h)}{\theta_T - 1}, && (36) \\ p_t^{***}(h) &= \frac{\theta_T}{\theta_T - 1} \frac{mc_t(h)}{rer^{***}} - \frac{A_t^{***}(h)}{\theta_T - 1}, && (37) \\ p_t^{****}(h) &= \frac{\theta_T}{\theta_T - 1} \frac{mc_t(h)}{rer^{****}} - \frac{A_t^{****}(h)}{\theta_T - 1}, && (38) \end{aligned}$$

where θ_T is the elasticity of substitution of intermediate tradable goods, while $A(h)$ and $A^*(h)$ involve terms related to the presence of price adjustment costs:

$$\begin{aligned} A_t(h) &\approx \theta_T - 1 + \kappa_H^p \frac{P_t(h)}{P_{t-1}(h)} \left(\frac{P_t(h)}{P_{t-1}(h)} - 1 \right) \\ &\quad - \beta \kappa_H^p \frac{P_{t+1}(h)}{P_t(h)} \left(\frac{P_{t+1}(h)}{P_t(h)} - 1 \right) \frac{Q_{H,t+1}}{Q_{H,t}}, \\ A_t^*(h) &\approx \theta_T - 1 + \kappa_H^{p*} \frac{P_t^*(h)}{P_{t-1}^*(h)} \left(\frac{P_t^*(h)}{P_{t-1}^*(h)} - 1 \right) \\ &\quad - \beta \kappa_H^{p*} \frac{P_{t+1}^*(h)}{P_t^*(h)} \left(\frac{P_{t+1}^*(h)}{P_t^*(h)} - 1 \right) \frac{Q_{H,t+1}^*}{Q_{H,t}^*}, \end{aligned}$$

where κ_H^p, κ_H^{p*} respectively measure the degree of Home tradable nominal price rigidity in the Home country and in the US. Similar equations hold for prices of the Home traded goods sold in CH, JP, RW.

Labor Market

In the case of firms in the nontradable intermediate sector, the labor input $L_N(i)$ is a CES combination of differentiated labor inputs supplied by domestic agents and defined over a continuum of mass equal to the country size ($j \in [0, n]$):

$$L_{N,t}(i) \equiv \left(\frac{1}{n}\right)^{\frac{1}{\psi}} \left[\int_0^n L_t(i,j)^{\frac{\psi-1}{\psi}} dj\right]^{\frac{\psi}{\psi-1}}, \tag{39}$$

where $L(i,j)$ is the demand of the labor input of type j by the producer of good i and $\psi > 1$ is the elasticity of substitution among labor inputs. Cost minimization implies that

$$L_t(i,j) = \left(\frac{1}{n}\right)\left(\frac{W_t(j)}{W_t}\right)^{-\psi} L_{N,t}(j), \tag{40}$$

where $W(j)$ is the nominal wage of labor input j and the wage index W is

$$W_t = \left[\left(\frac{1}{n}\right)\int_0^n W_t(h)^{1-\psi} dj\right]^{\frac{1}{1-\psi}}. \tag{41}$$

Similar equations hold for firms producing tradable intermediate goods. Each household is the monopolistic supplier of a labor input j and sets the nominal wage facing a downward-sloping demand obtained by aggregating demand across Home firms. The wage adjustment is sluggish because of quadratic costs paid in terms of the total wage bill,

$$AC_t^W = \frac{\kappa_W}{2}\left(\frac{W_t}{W_{t-1}} - 1\right)^2 W_t L_t, \tag{42}$$

where the parameter $\kappa_W > 0$ measures the degree of nominal wage rigidity and L_t is the total amount of labor in the Home economy.

Table 1: Steady state national accounts (% of GDP)

	EA	US	CH	JP	RW
Private consumption	54.3	58.5	38.8	55.1	56.7
Investment	20.0	15.0	40.0	20.0	20.0
Public consumption	20.0	20.0	20.0	20.0	20.0
Imports	23.8	14.3	22.2	14.8	19.2
Consumption goods	13.1	7.8	10.3	8.2	11.1
Investment goods	10.7	6.5	11.9	6.6	8.1
Share of world GDP	14.1	21.1	14.9	9.2	40.7

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 2: Households and Firms Behavior

	EA	US	CH	JP	RW
Households					
Subjective discount factor	0.995	0.995	0.995	0.995	0.995
Depreciation rate	0.02	0.02	0.02	0.02	0.02
Intertemporal elasticity of substitution	1.00	1.00	1.00	1.00	1.00
Habit persistence	0.85	0.85	0.85	0.85	0.85
Inverse of the Frisch elasticity of labor	2.00	2.00	2.00	2.00	2.00
Tradable Intermediate Goods					
Bias toward capital	0.40	0.40	0.50	0.40	0.40
Non-tradable Intermediate Goods					
Bias toward capital	0.35	0.35	0.45	0.35	0.35
Final consumption goods					
Substitution btw domestic and imp. goods	2.50	2.50	2.50	2.50	2.50
Bias toward domestic goods	0.52	0.83	0.34	0.67	0.77
Substitution btw tradables and non-trad.	0.50	0.50	0.50	0.50	0.50
Bias toward tradable goods	0.50	0.50	0.60	0.50	0.50
Final investment goods					
Substitution btw domestic and imp. goods	2.50	2.50	2.50	2.50	2.50
Bias toward domestic goods	0.28	0.59	0.24	0.47	0.60
Substitution btw tradables and nontr.	0.50	0.50	0.50	0.50	0.50
Bias toward tradable goods	0.50	0.50	0.70	0.50	0.50

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 3: Real and nominal rigidities

	EA	US	CH	JP	RW
Real Rigidities					
Investment adjustment	3.50	3.50	3.50	3.50	3.50
Nominal Rigidities					
Households					
Wage stickiness	400	400	400	400	400
Manufacturing					
Price stickiness (domestically produced goods)	400	400	400	400	400
Price stickiness (imported goods)	400	400	400	400	400
Services					
Price stickiness	400	400	400	400	400

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 4: International linkages (% GDP)

	EA	US	CH	JP	RW
Substitution between assets in the liquidity bundle	1.00	1.00	1.00	1.00	1.00
Substitution between consumption imports	2.50	2.50	2.50	2.50	2.50
Imported consumption goods from					
EA	...	1.1	1.0	0.8	3.4
US	0.9	...	0.8	0.7	4.3
CH	1.3	1.4	...	1.8	2.5
JP	0.3	0.5	0.9	...	0.9
RW	10.5	4.9	7.6	5.9	...
Substitution between investment imports	2.50	2.50	2.50	2.50	2.50
Imported investment goods from					
EA	...	0.8	1.1	0.4	2.9
US	0.9	...	0.9	0.6	1.7
CH	1.2	1.3	...	1.4	2.7
JP	0.3	0.4	1.3	...	0.9
RW	8.4	4.0	8.6	4.3	...
Net foreign assets (%yearly GDP)	−17.6	−27.4	21.0	57.3	5.3
Net foreign assets (%yearly GDP) (1)	−0.4	13.3	−6.5	23.0	−9.9
Financial intermediation cost function (ϕ_1)	0.15	...	0.15	0.15	0.15
Financial intermediation cost function (ϕ_2)	0.3	...	0.3	0.3	0.3

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world. (1) net of private and official holdings of USD and EUR government bonds

Table 5: (Gross) Price and wage markups

	EA	US	CH	JP	RW
Manufacturing (tradables) price markup	1.20	1.20	1.20	1.20	1.20
Services (non-tradables) price markup	1.30	1.30	1.30	1.30	1.30
Wage markup	1.20	1.20	1.20	1.20	1.20

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 6: Monetary and fiscal policy

	EA	US	CH	JP	RW
Inflation target	1.02	1.02	1.02	1.02	1.02
Interest rate inertia	0.87	0.87	0.87	0.87	0.87
Interest rate sensitivity to inflation gap	1.70	1.70	1.70	1.70	1.70
Interest rate sensitivity to output growth	0.10	0.10	0.10	0.10	0.10
Lump-sum tax sensitivity to debt gap	0.60	0.60	0.60	0.60	0.60

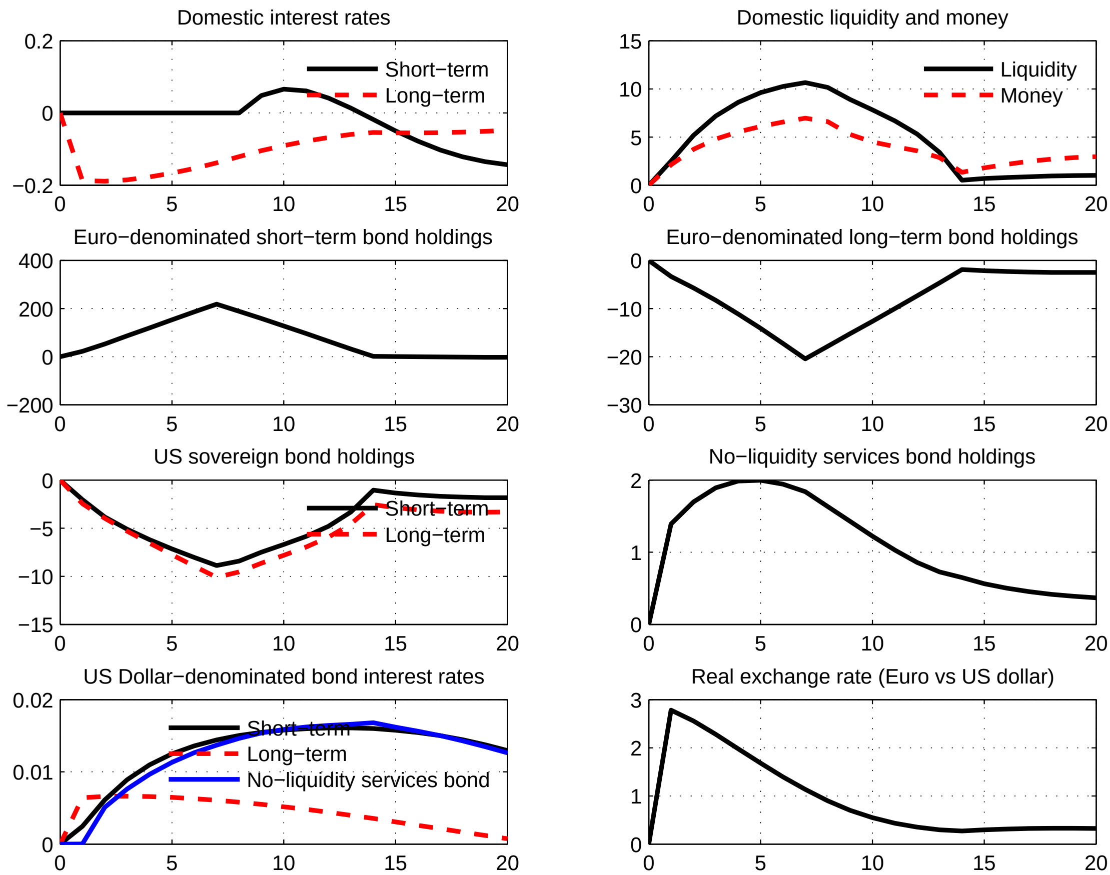
Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 7: Asset ratios (% of annualized GDP)

	EA	US	CH	JP	RW
Private agents					
Currency in circulation	8	6	12	15	8
USD govt bond holdings	2	23	5	7	3
EUR govt bond holdings	67	1	4	6	2
Total govt. debt	93	75	26	201	81
Share of long-term govt. debt, % of total debt	85	69	83	94	83

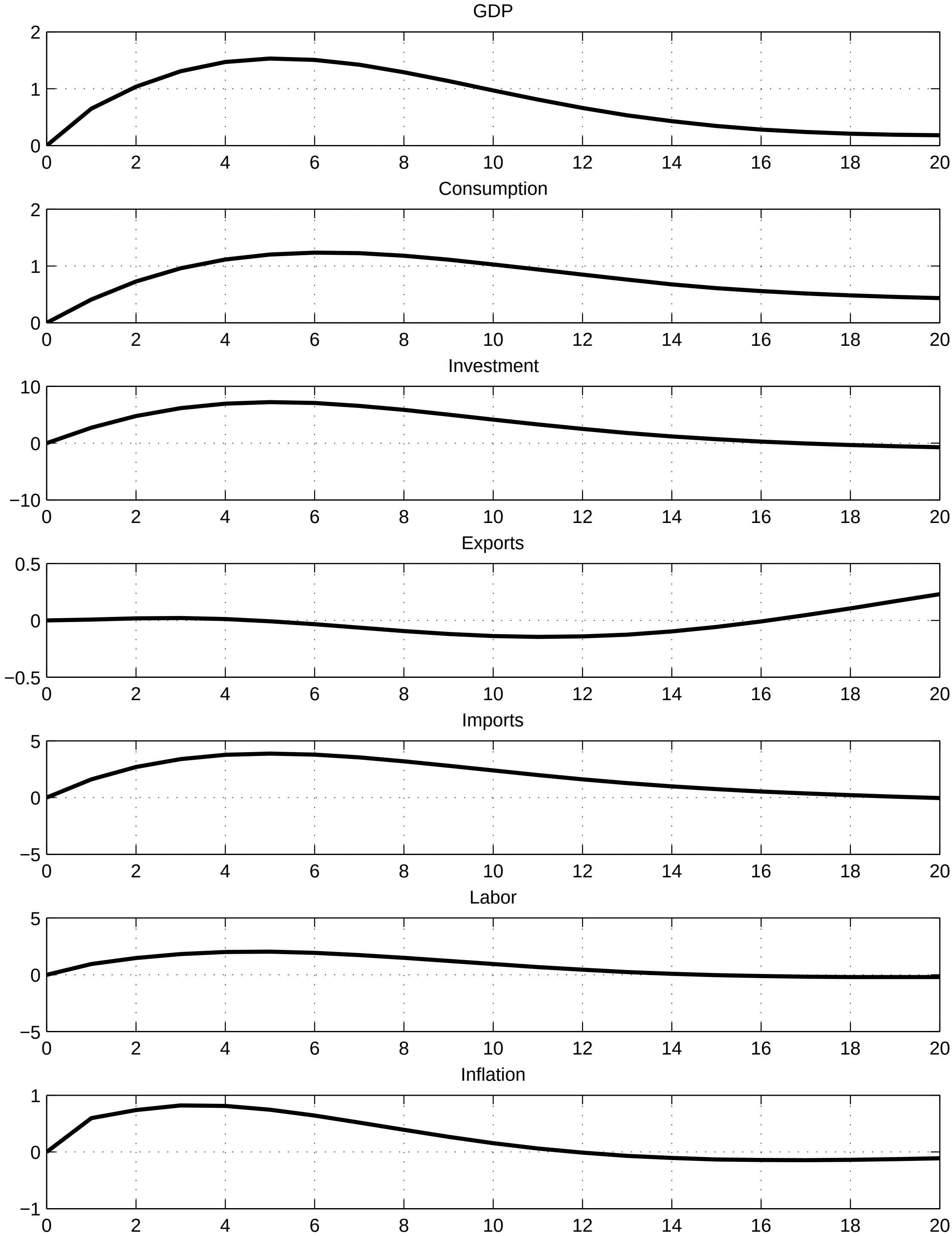
Notes: EA=euro area; US=United States; CH=China; RW=Rest of the world. Private holdings of US government bonds for CH are set as the average of private holdings for JP and RW. Long-term bonds are those with maturities greater than 1 year. For CH and RW, shares of long-term bonds are set to the average of EA, US and JP. Sources: Department of the Treasury, Federal Reserve Bank of New York, Board of Governors of Federal Reserve System Foreign Portfolio Holdings of US Securities (April 2013), ECB The International Role of the Euro (July 2013), IMF Fiscal Monitor (October 2014), IMF International Financial Statistics (October 2014).

Figure 1: APP. EA financial variables



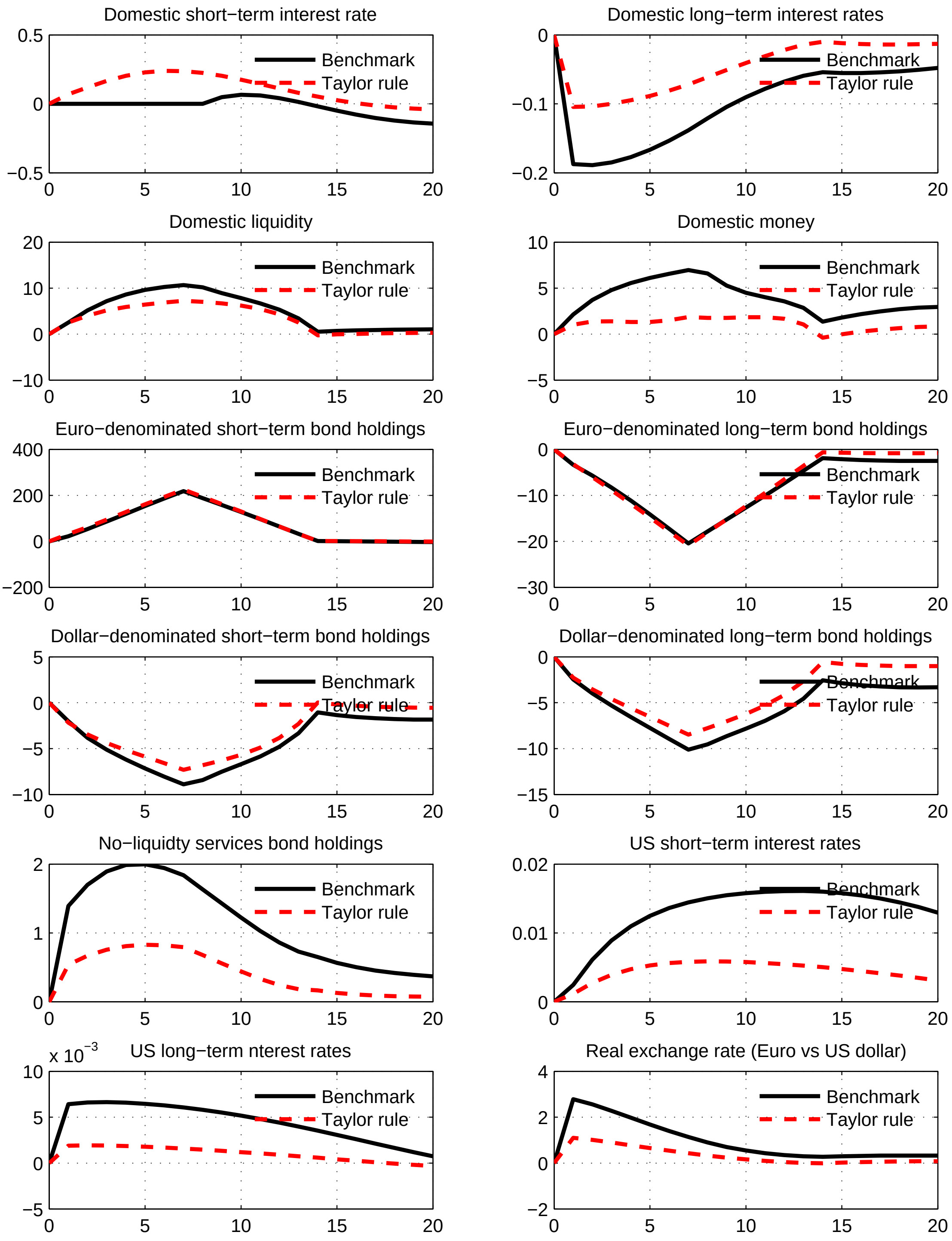
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline, for interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 2: APP. EA real variables



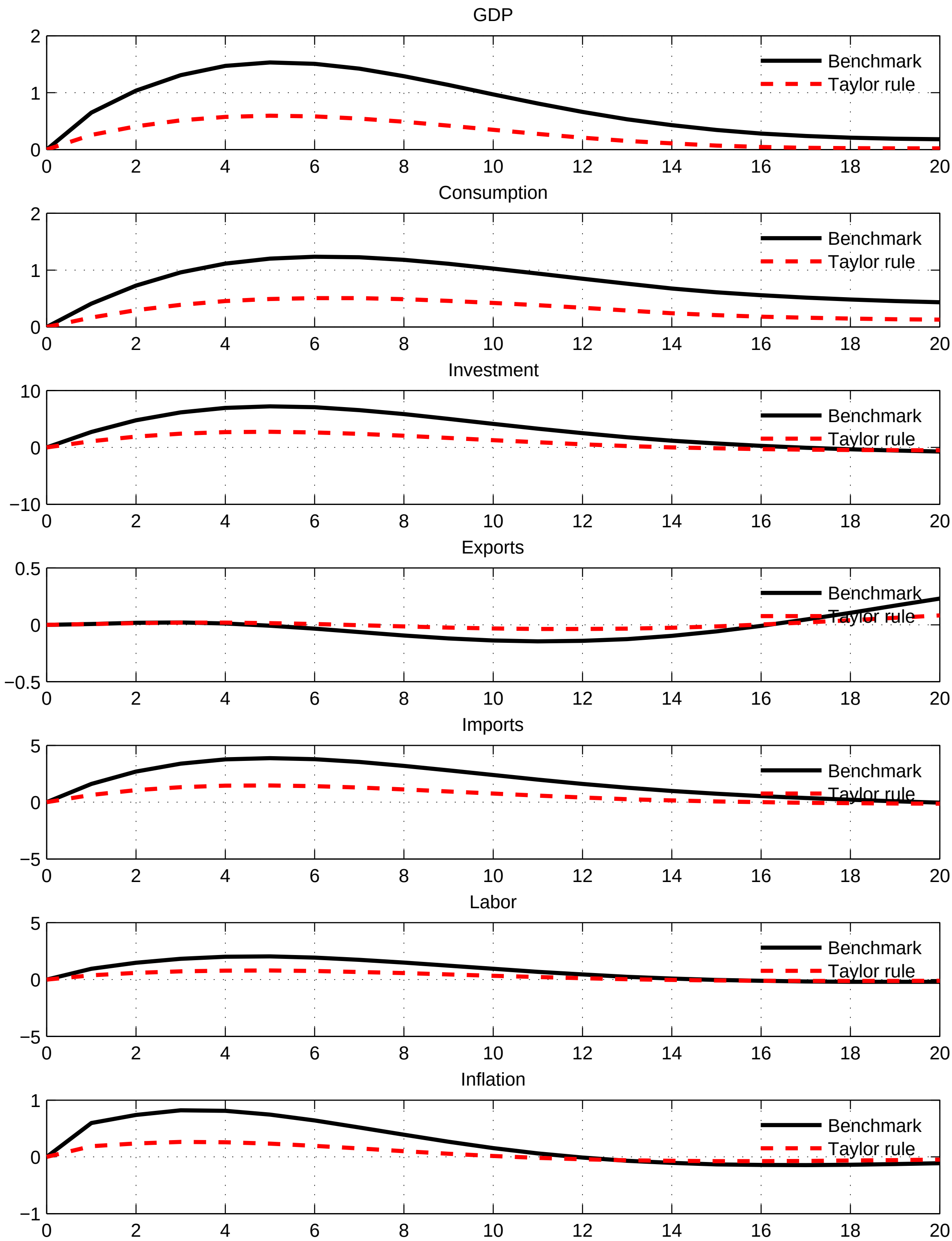
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline, for inflation annualized percentage point deviation.

Figure 3: APP and standard Taylor rule. EA financial variables



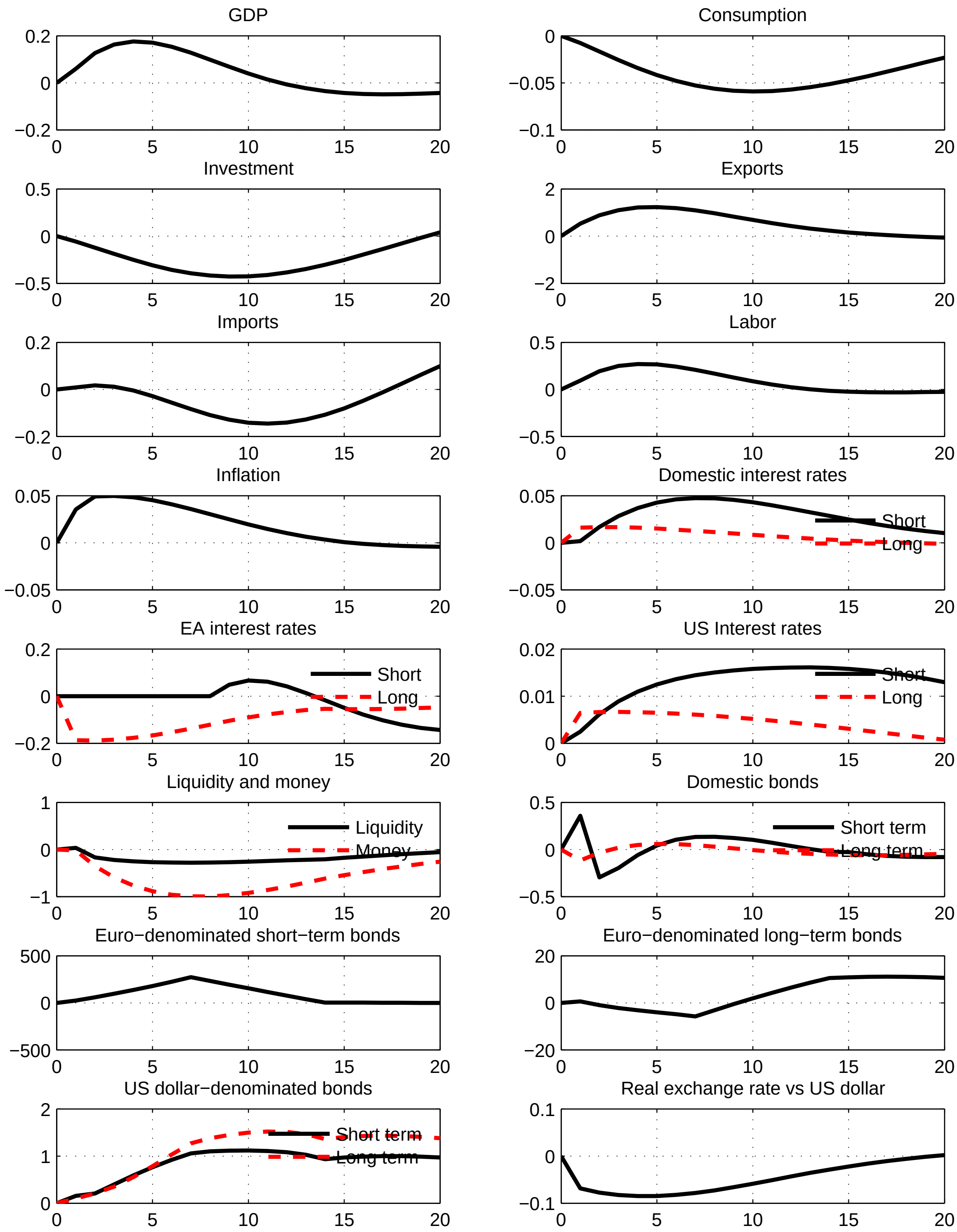
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 4: APP and standard Taylor rule. EA real variables



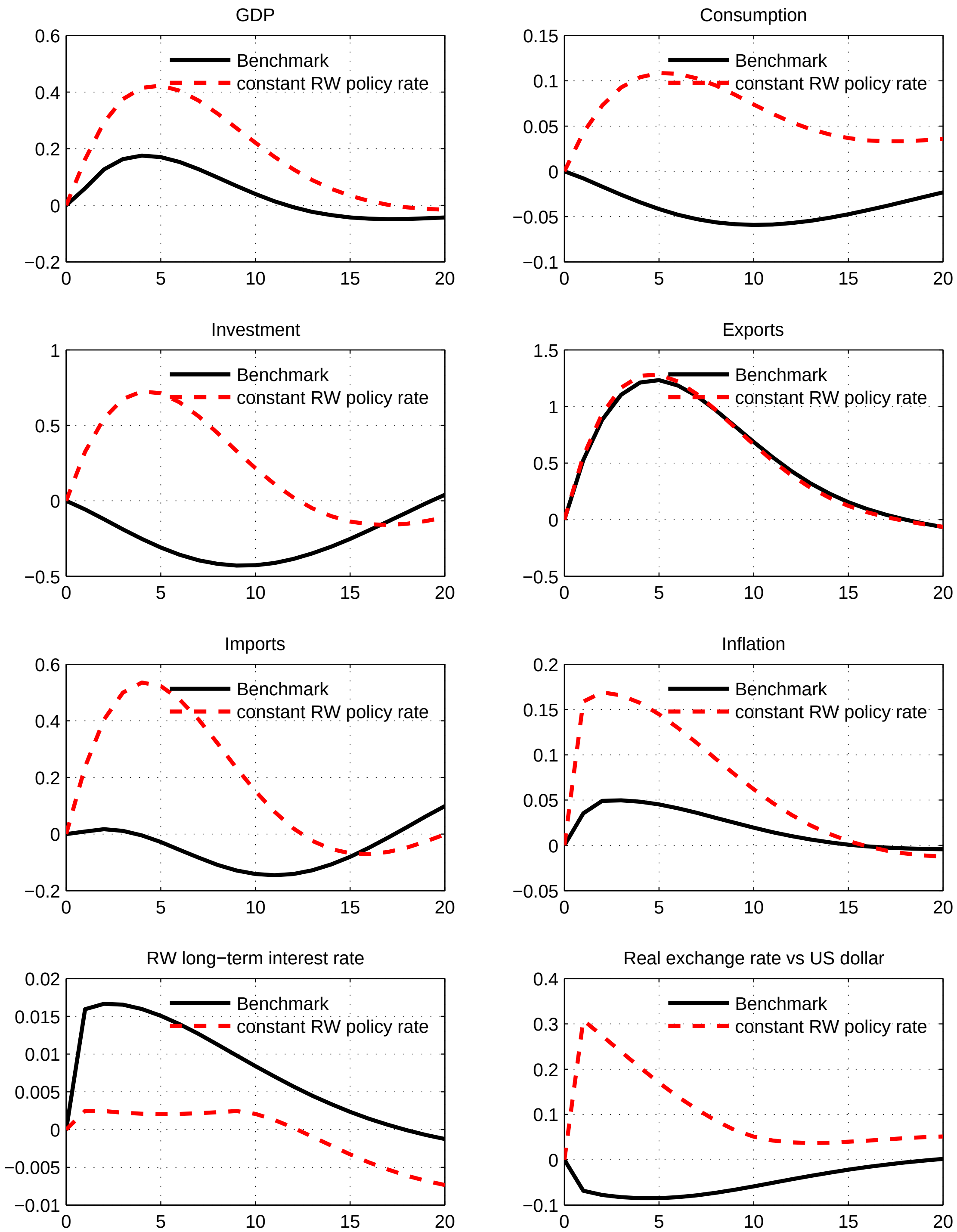
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline, for inflation and interest rates, annualized percentage point deviation.

Figure 5: APP. RW variables



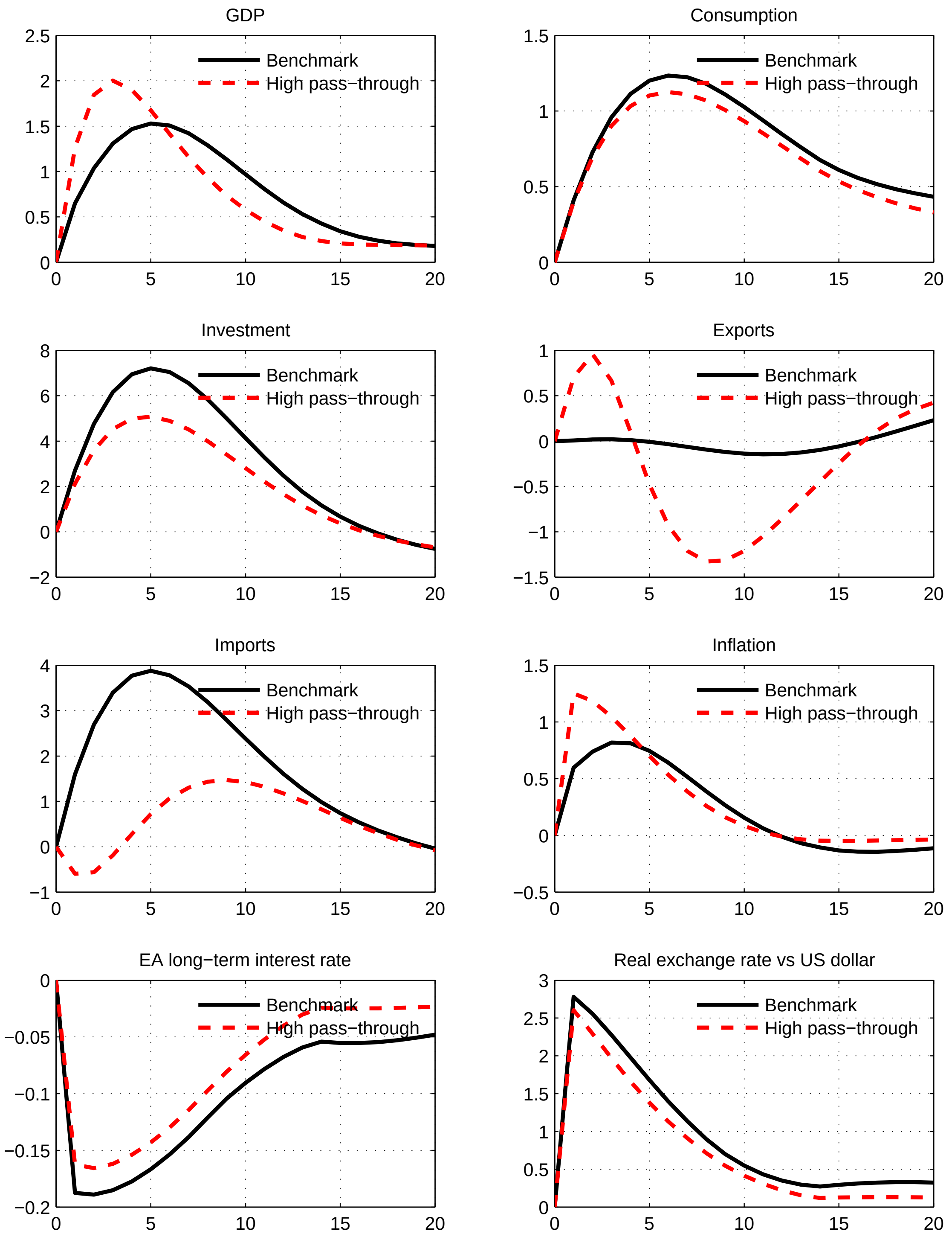
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 6: APP and constant monetary policy rate in the RW. RW variables



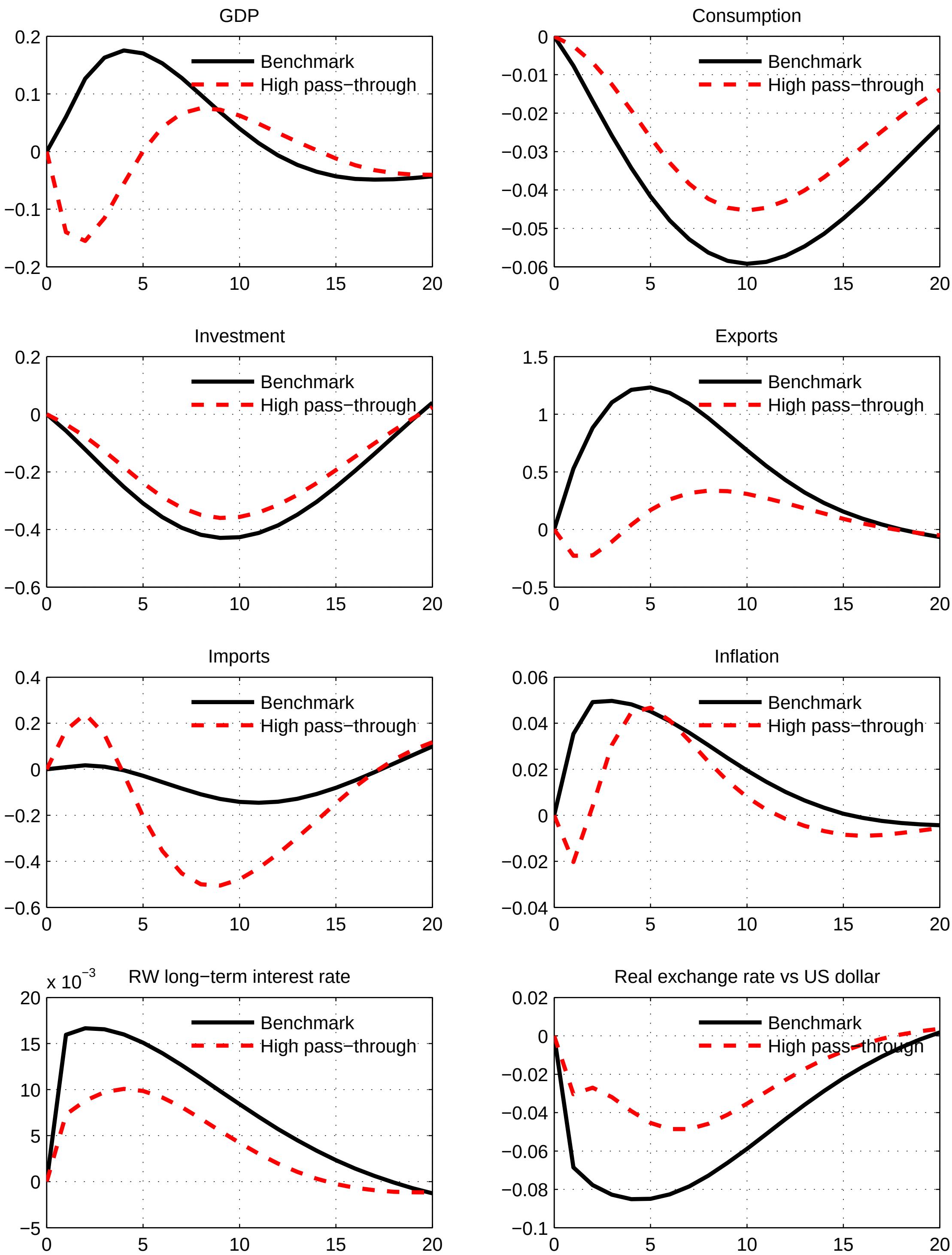
Notes: horizontal axis, quarters; vertical axis, % deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 7: APP and high pass-through. EA variables



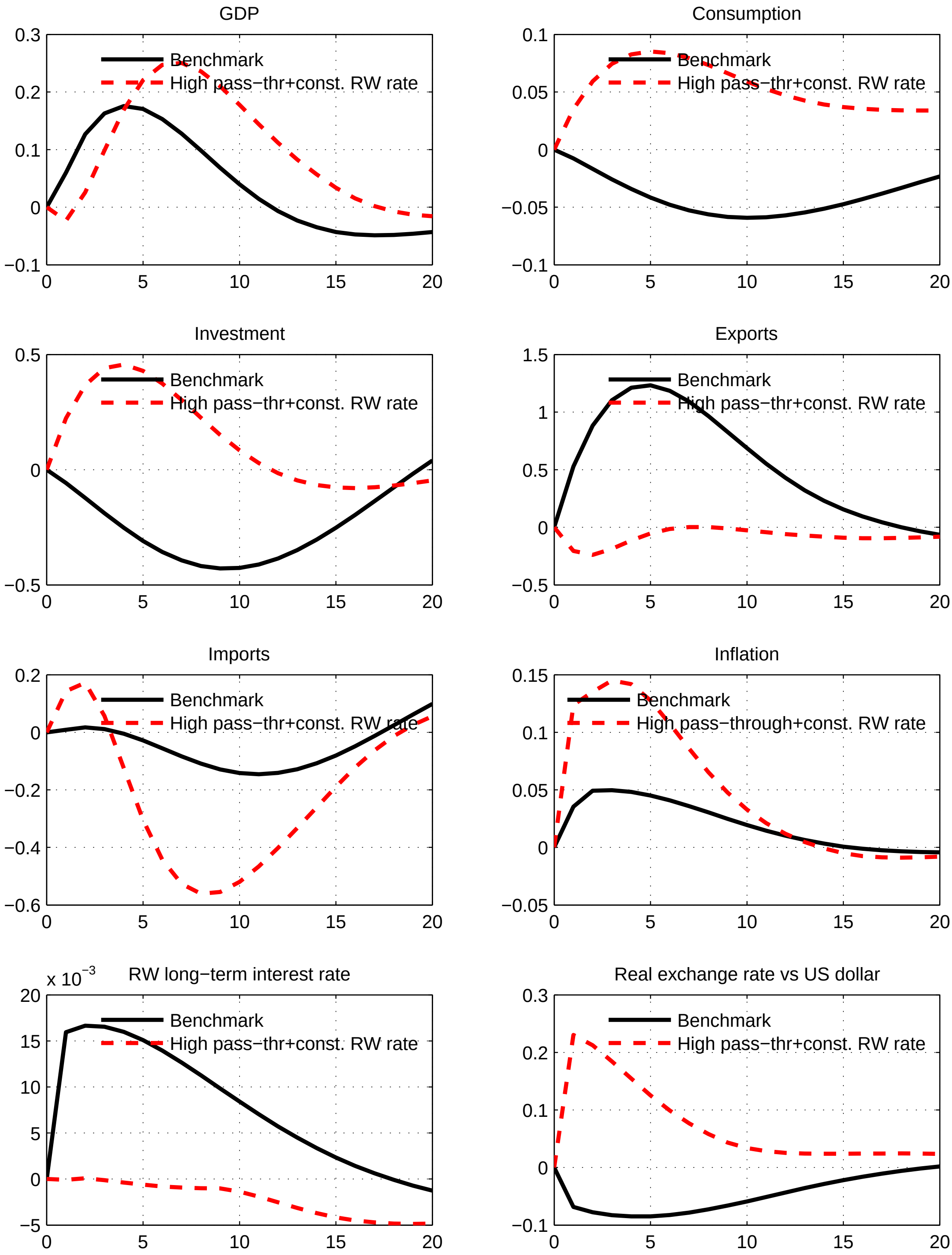
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 8: APP and high pass-through. RW variables



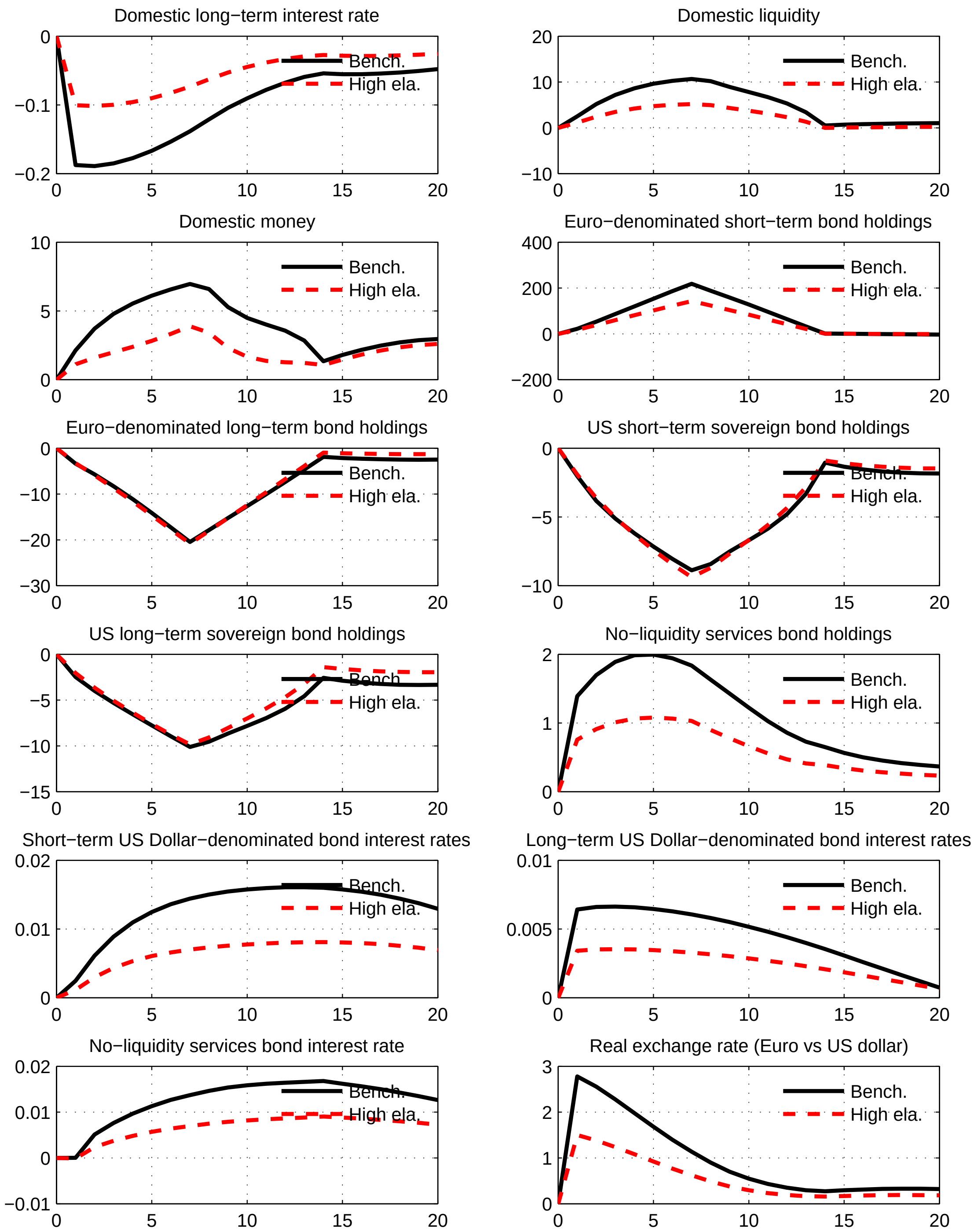
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 9: APP, high pass-through and constant monetary policy rate in the RW. RW variables



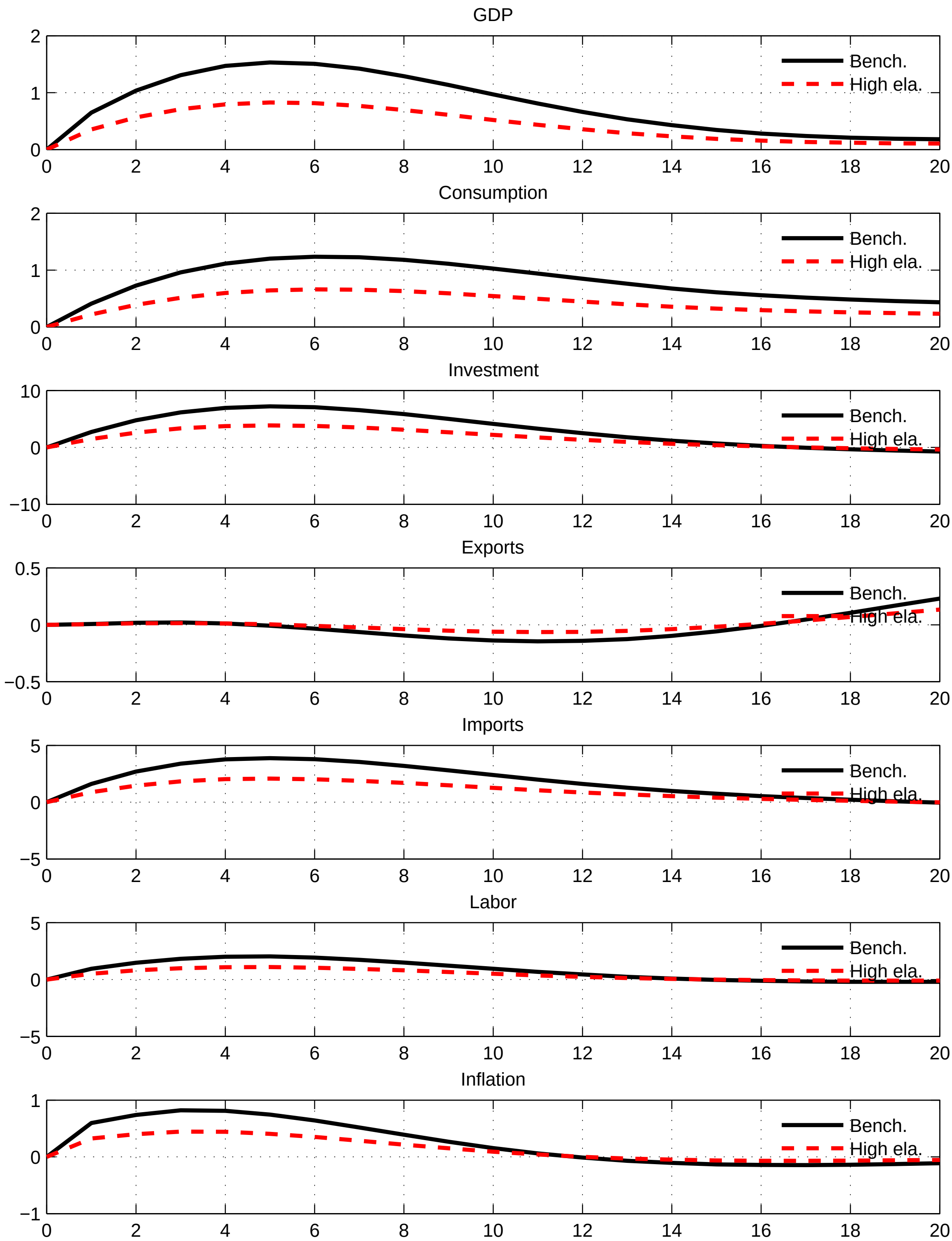
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 10: APP, high asset elasticity of substitution. EA variables



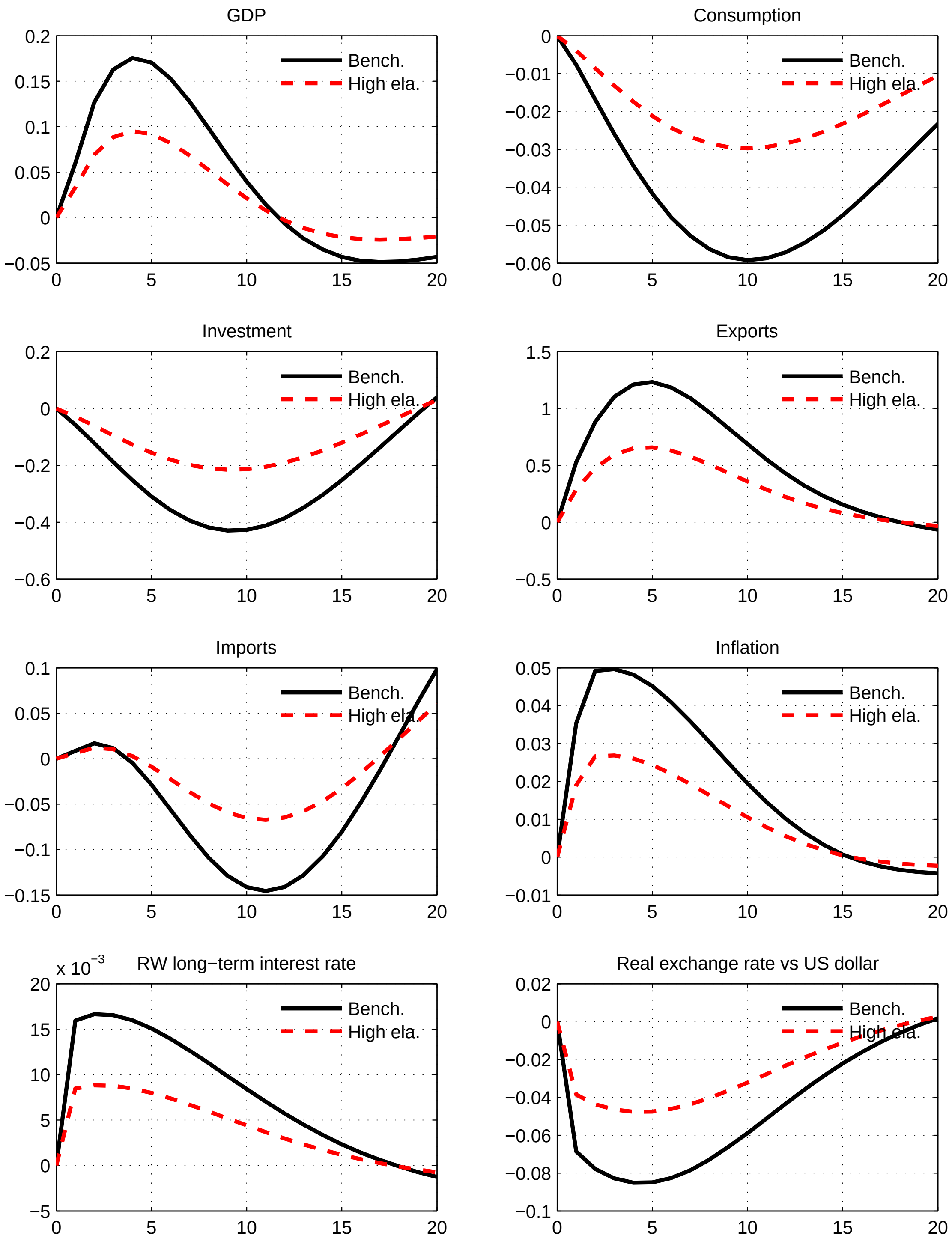
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 11: APP, high asset elasticity of substitution. EA variables



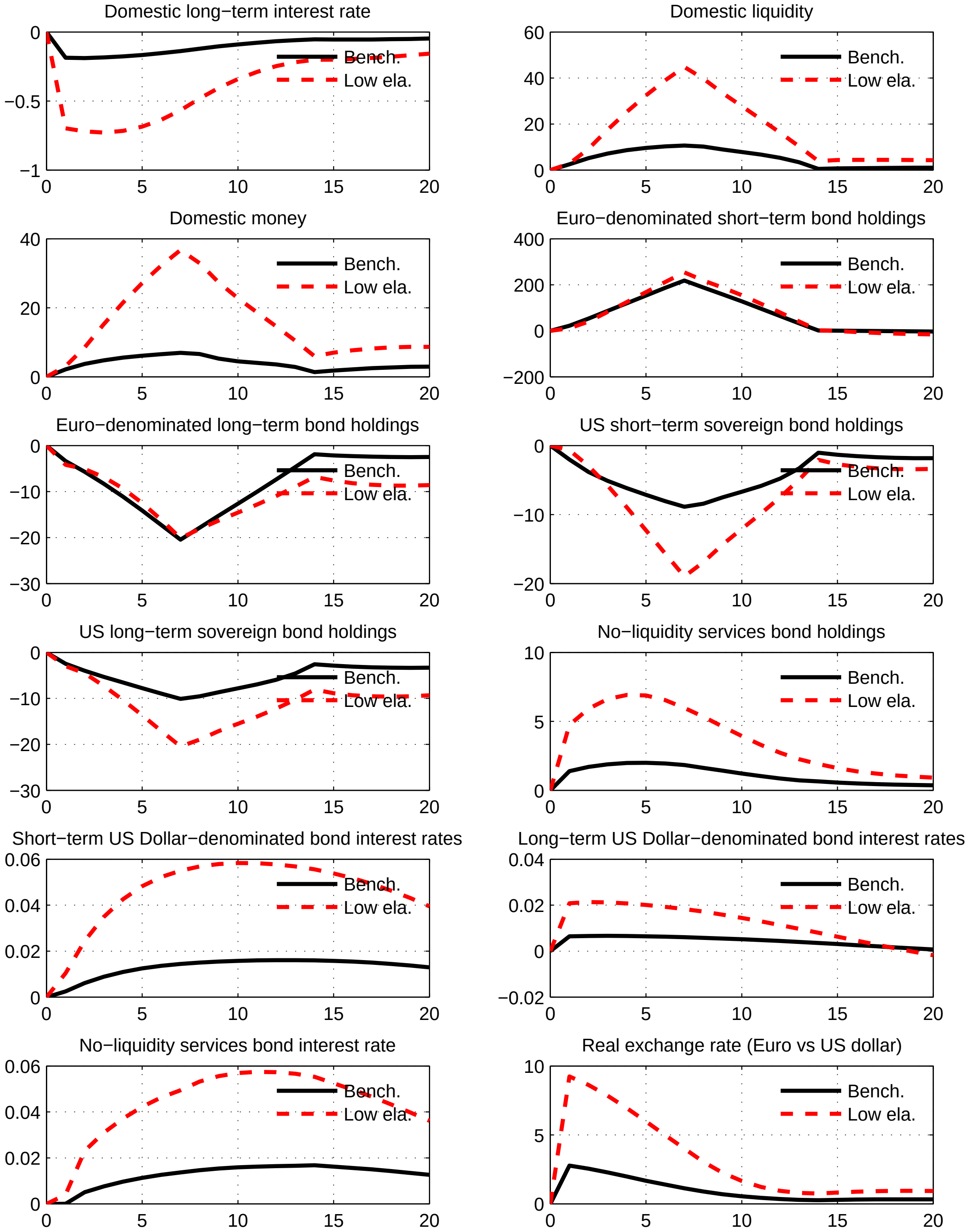
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 12: APP, high asset elasticity of substitution. RW variables



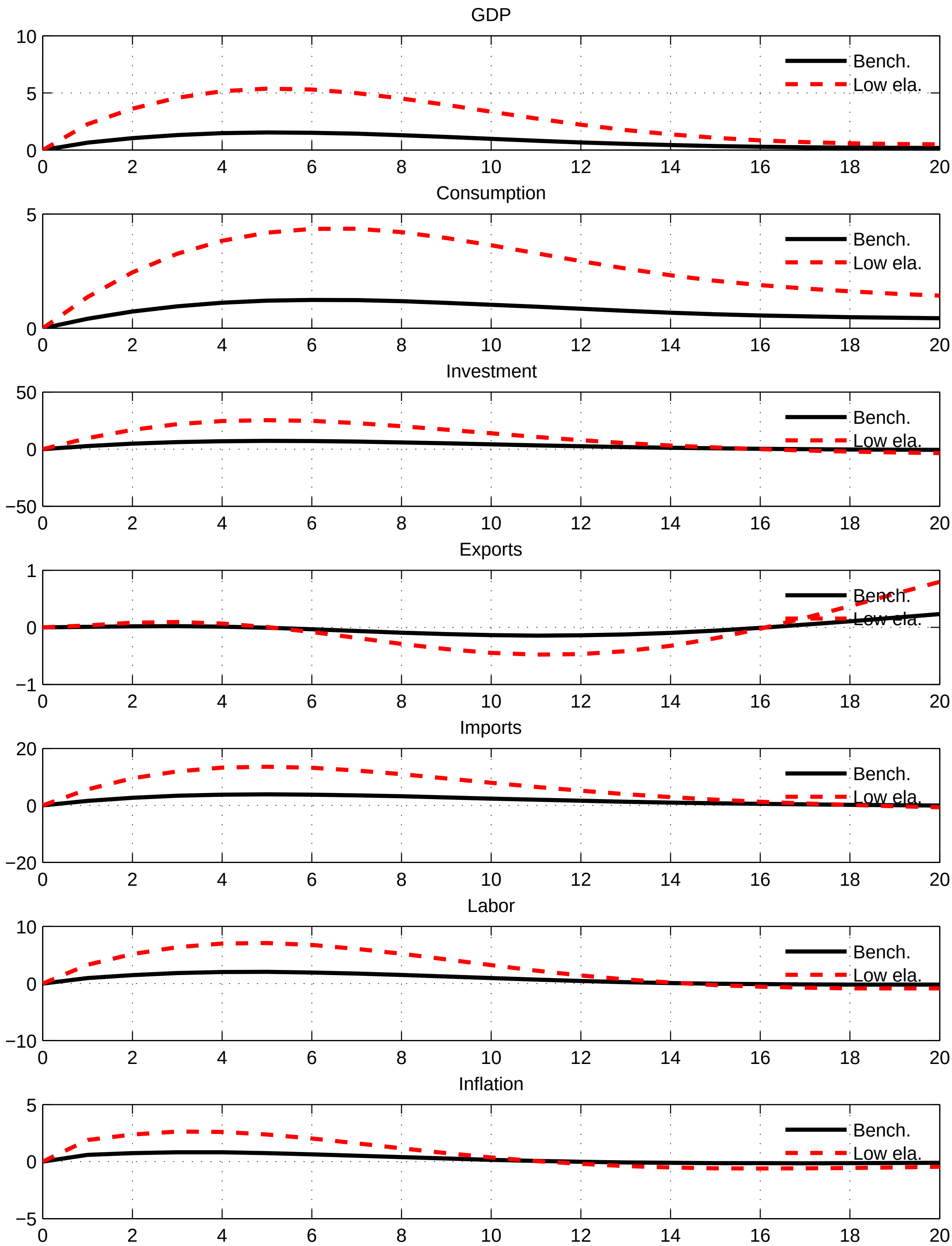
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 13: APP, low asset elasticity of substitution. EA variables



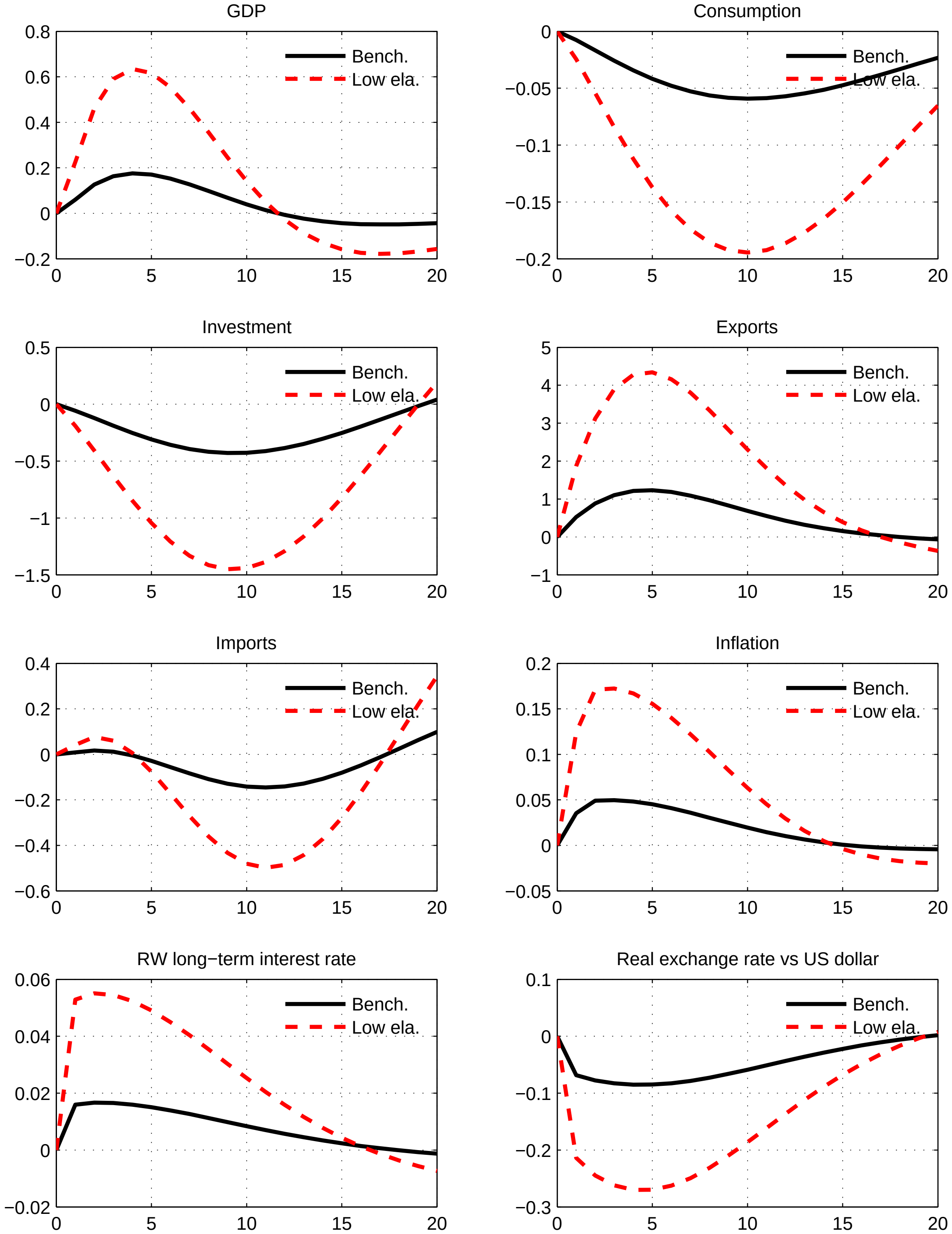
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 14: APP, low asset elasticity of substitution. EA variables



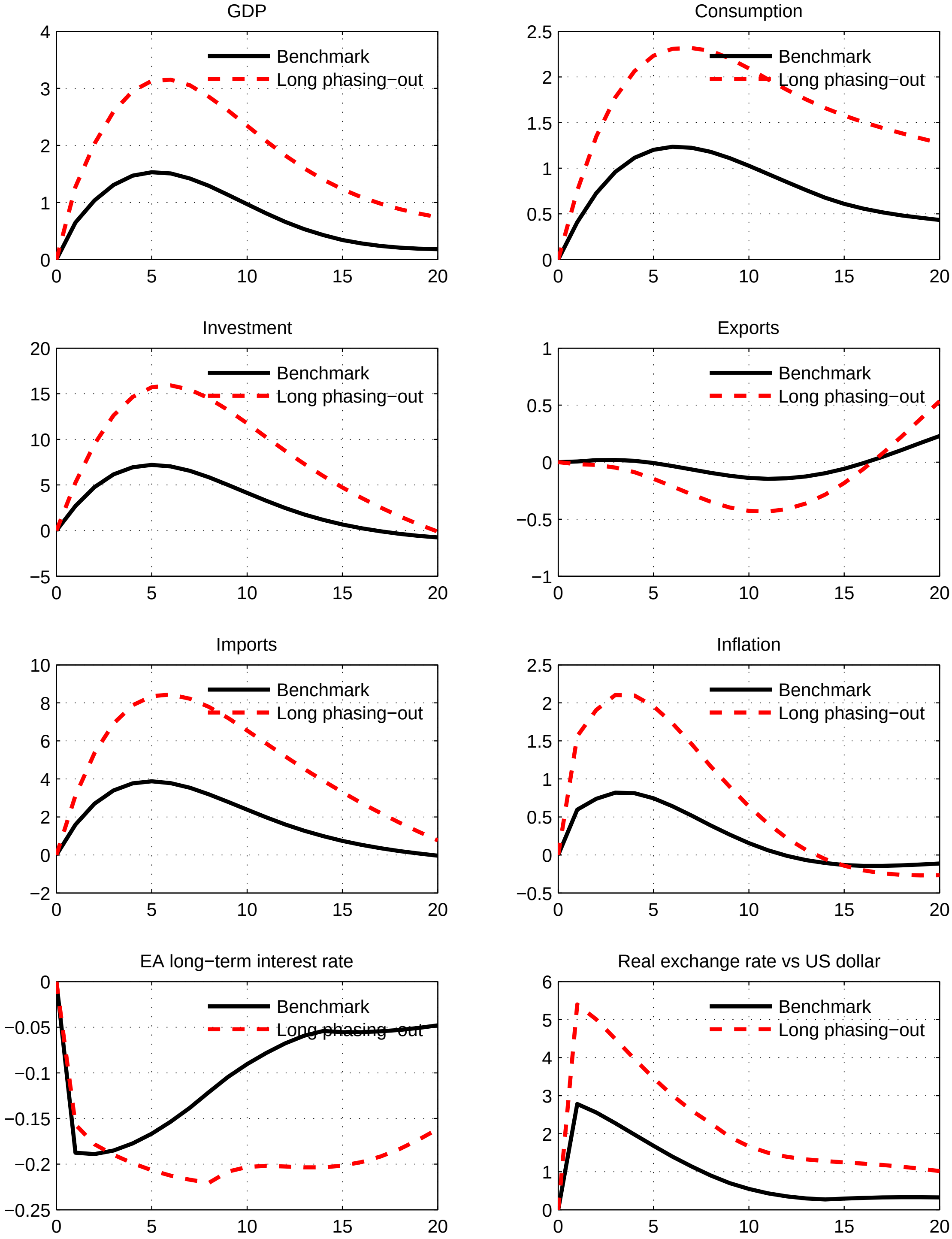
Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 15: APP, low asset elasticity of substitution. RW variables



Notes: horizontal axis, quarters; vertical axis, percent deviations from the baseline, for inflation and interest rates, annualized percentage point deviation; for real exch. rate, +=depreciation.

Figure 16: APP, long phasing-out. EA variables



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