# Online Appendix for "Fear (no more) of Floating: Asset Purchases and Exchange Rate Dynamics"[1]

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**Abstract**

This online appendix describes detailed mathematical derivations of optimality conditions; defines the competitive equilibrium; explains the data sources and targeted empirical moment computations; describes the way system priors are chosen while executing the Bayesian estimation of the baseline model in the main text; and in-cludes a number of robustness exercises regarding the efficacy of asset purchases. It also includes some figures that were left outside the paper for brevity. Section and equation headings with Arabic numerals refer to headings in the main manuscript.

**Keywords:** Asset purchases, exchange rate, conventional monetary policy.
**JEL Classification:** E62, E63, G21

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# A Model derivations

## A.1 Households

Preferences of households over consumption and leisure are defined as

$$E_0 \sum_{t=0}^{\infty} \beta^t \exp(\psi_t^c) U(c_t, h_t), \tag{A.1}$$

where the period utility function $U$ is separable in its arguments and is of CRRA-type in terms of household consumption with

$$U(c_t, h_t) = \left[ (1-h_c) \frac{\left(\frac{c_t - h_c \tilde{c}_{t-1}}{1-h_c}\right)^{1-\sigma} - 1}{1-\sigma} - \frac{\chi}{1+\xi} h_t^{1+\xi} \right]. \tag{A.2}$$

$\psi_t^c$ is a consumption preference shock with

$$\psi_t^c = \rho_c \psi_{t-1}^c + \varepsilon_t^{\psi^c} \tag{A.3}$$

hit by zero mean and constant variance Gaussian innovations $\varepsilon_t^{\psi^c}$. $E_t$ is the mathematical expectation operator conditional on the information set available at $t$, $\beta \in (0,1)$ is the subjective discount factor, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, $h_c \in [0,1)$ governs the degree of external habit formation over aggregate consumption $\tilde{c}_{t-1}$ in the previous period, $\chi$ is the utility weight of labor and $\xi > 0$ determines the Frisch elasticity of labor supply. We abstract from utility of holding real money balances by considering a cashless economy as in Woodford (2003).

Households face the flow budget constraint,

$$c_t + \frac{D_t}{P_t} = \frac{W_t}{P_t} h_t + \frac{(1 + r_{nt-1}) D_{t-1}}{P_t} + \Pi_t - \tau_t. \tag{A.4}$$

On the right hand side are the real wage income $\frac{W_t}{P_t} h_t$ and beginning of period interest bearing deposits $\frac{D_{t-1}}{P_t}$. $\Pi_t$ denotes real profits remitted from firms owned by the households (banks, intermediate home goods producers and capital goods producers). $\tau_t$ stands for the real lump-sum tax collected by the government, mentioned in Section 2.5. On the left hand side are the outlays for consumption expenditures and deposits.

Households choose $c_t, h_t$ and $D_t$ to maximize preferences in (A.2) subject to (A.4) and standard transversality conditions imposed on deposits $D_t$. The first order conditions of the utility maximization problem of the households are given by

$$\varphi_t = \exp(\psi_t^c)\left(\frac{c_t - h_c\tilde{c}_{t-1}}{1-h_c}\right)^{-\sigma}, \tag{A.5}$$

$$\frac{W_t}{P_t} = \frac{\chi h_t^{\xi}}{\varphi_t}, \tag{A.6}$$

$$\varphi_t = \beta E_t\left[\varphi_{t+1}(1+r_{nt})\frac{P_t}{P_{t+1}}\right], \tag{A.7}$$

Equation (A.5) defines the Lagrange multiplier, $\varphi_t$ as the marginal utility of consuming an additional unit of income. Equation (A.6) equates marginal disutility of labor to the shadow value of real wages. Finally, equation (A.7) represent the Euler equation for deposits, that is, the consumption-savings margin. External habit formation implies that $c_t = \tilde{c}_t\ \forall t$.

The CES aggregator for final consumption good reads

$$c_t = \left[\omega_t^{\frac{1}{\gamma}}(c_t^H)^{\frac{\gamma-1}{\gamma}} + (1-\omega_t)^{\frac{1}{\gamma}}(c_t^F)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{A.8}$$

as in Galí and Monacelli (2005) where $\gamma > 0$ is the elasticity of substitution between home and foreign goods, and $0 < \omega_t < 1$ is the time-varying weight of home goods in the consumption basket, which captures the degree of home bias in household preferences and follows the stochastic process

$$\log\omega_t = (1-\rho_\omega)\bar{\omega} + \rho_\omega\log(\omega_{t-1}) + \varepsilon_t^{\omega}. \tag{A.9}$$

$\bar{\omega}$ is the steady state weight of home goods in the consumption basket and $\varepsilon_t^{\omega}$ are Gaussian innovations with zero mean and constant variance.

Let $P_t^H$ and $P_t^F$ represent domestic currency denominated prices of home and foreign goods, which are aggregates of a continuum of differentiated home and foreign good varieties respectively.

The expenditure minimization problem of households

$$\min_{c_t^H, c_t^F} P_t c_t - P_t^H c_t^H - P_t^F c_t^F$$

subject to (A.37) yields the domestic consumer price index (CPI),

$$P_t = \left[\omega_t(P_t^H)^{1-\gamma} + (1-\omega_t)(P_t^F)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{A.10}$$

and the optimal demand frontier between home and foreign goods,

$$\frac{c_t^H}{c_t^F} = \frac{\omega_t}{1-\omega_t}\left(\frac{P_t^H}{P_t^F}\right)^{-\gamma}. \tag{A.11}$$

The final demand for home consumption good $c_t^H$, is an aggregate of a continuum of varieties of intermediate home goods along the [0,1] interval. That is, $c_t^H = \left[\int_0^1 (c_{it}^H)^{1-\frac{1}{\epsilon_t}} di\right]^{\frac{1}{1-\frac{1}{\epsilon}}}$, where each variety is indexed by $i$, and $\epsilon_t$ is the time-varying elasticity of substitution between these varieties. To introduce cost-push shocks, we assume that $\epsilon_t$ follows the process

$$\log \epsilon_t = (1-\rho_\epsilon)\bar{\epsilon} + \rho_\epsilon \log(\epsilon_{t-1}) + \varepsilon_t^\epsilon. \tag{A.12}$$

$\bar{\epsilon}$ is the steady state elasticity of substitution and $\varepsilon_t^\epsilon$ are Gaussian innovations with zero mean and constant variance.

For any given level of demand for the composite home good $c_t^H$, the demand for each variety $i$ solves the problem of minimising total home goods expenditures, $\int_0^1 P_{it}^H c_{it}^H di$ subject to the aggregation constraint, where $P_{it}^H$ is the nominal price of variety $i$. The solution to this problem yields the optimal demand for $c_{it}^H$, which satisfies

$$c_{it}^H = \left(\frac{P_{it}^H}{P_t^H}\right)^{-\epsilon_t} c_t^H,$$

with the aggregate home good price index $P_t^H = \left[\int_0^1 (P_{it}^H)^{1-\epsilon_t} di\right]^{\frac{1}{1-\epsilon_t}}$. The demand for foreign consumption goods follows an analogous logic to that of home goods leading to the optimal demand for foreign goods of

$$c_{it}^F = \left(\frac{P_{it}^F}{P_t^F}\right)^{-\epsilon_t} c_t^F,$$

where $P_t^F$ satisfies $P_t^F = \left[\int_0^1 (P_{it}^F)^{1-\epsilon_t} di\right]^{\frac{1}{1-\epsilon_t}}$. For simplicity, the elasticity of substitution between imported consumption good varieties $\epsilon_t$ is taken to be equal to those between home good varieties.

## A.2 Banks' net worth maximization

Banks' net worth growth with their profits that are created by making loans to nonfinancial firms and the government, while funding themselves from domestic depositors and foreign lenders,

$$n_{jt+1} = R_{kt+1} q_t l_{jt} + R_{t+1}^g q_t^g b_{jt}^g - R_{t+1} d_{jt} - R_{t+1}^* b_{jt}^*, \tag{A.13}$$

The gross real per-period return from holding government bonds satisfies

$$R^g_{t+1} = \frac{\kappa_{gt} + (1-\delta_g)q^g_{t+1}}{q^g_t}. \tag{A.14}$$

with the natural logarithm of coupon payments following the stochastic process

$$\log \kappa_{gt} = (1-\rho_{\kappa_g}) \log \bar{\kappa_g} + \rho_{\kappa_g} \log \kappa_{gt-1} + \varepsilon^{\kappa_g}_t \tag{A.15}$$

with the steady state coupon payment of $\bar{\kappa_g}$ and zero mean and constant variance Gaussian innovations, $\varepsilon^{\kappa_g}_t$.

The cost of foreign borrowing is defined as

$$R^*_{t+1} = \Psi_t R^*_{nt} \frac{S_{t+1}}{S_t} \frac{P_t}{P_{t+1}} \quad \forall t, \tag{A.16}$$

with US interest rates following the stochastic process

$$\log(R^*_{nt}) = (1-\rho_{R^*_n}) \log(\bar{R^*_n}) + \rho_{R^*_n} \log(R^*_{nt-1}) + \varepsilon^{R^*_n}_t \tag{A.17}$$

with zero mean and constant variance Gaussian innovations, $\varepsilon^{R^*_n}_t$ and the steady state level of world interest rates $\bar{R^*_n}$. An orthogonal shock $\psi^{rp}_t$ following the process

$$\psi^{rp}_t = \rho_{rp}\psi^{rp}_{t-1} + \varepsilon^{rp}_t \tag{A.18}$$

with zero mean and constant variance Gaussian innovations $\varepsilon^{rp}_t$ also hits the country risk premium $\Psi_t$ to capture sovereign spread fluctuations that originate from country risk. Combining equations (1) and (A.13) and re-arranging terms produce bank's net worth evolution condition (2) in the main text. Using this transition function for net worth, bankers solve the value maximization problem,

$$\begin{aligned} V_{jt} &= \max_{l_{jt+i}, b^g_{jt+i}, d_{jt+i}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i}\, n_{jt+1+i} \\ &= \max_{l_{jt+i}, b^g_{jt+i}, d_{jt+i}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i} \Big( \left[R_{kt+1+i} - R^*_{t+1+i}\right] q_{t+i} l_{jt+i} \\ &+ \left[R^g_{t+1+i} - R^*_{t+1+i}\right] q^g_{t+i} b^g_{jt+i} - \left[R_{t+1+i} - R^*_{t+1+i}\right] d_{jt+i} + R^*_{t+1+i} n_{jt+i} \Big). \end{aligned}$$

subject to the constraint (5) in the main text. Since,

$$V_{jt} = \max_{l_{jt+i}, b^g_{jt+i}, d_{jt+i}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i}\, n_{jt+1+i}$$

$$= \max_{l_{jt+i}, b^g_{jt+i}, d_{jt+i}} E_t \left[ (1-\theta)\Lambda_{t,t+1} n_{jt+1} + \sum_{i=1}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i}\, n_{jt+1+i} \right],$$

we have

$$V_{jt} = \max_{l_{jt}, b^g_{jt}, d_{jt}} E_t \Big\{ \Lambda_{t,t+1} [(1-\theta) n_{jt+1} + \theta V_{jt+1}] \Big\}.$$

producing the recursive formulation of the net worth maximization problem.

Using our linear conjecture (6) in the main text on this value function, the Lagrangian which solves the bankers' profit maximization problem becomes,

$$\max_{l_{jt}, b^g_{jt}, d_{jt}} L = \nu^l_t q_t l_{jt} + \nu^g_t q^g_t b^g_t - \nu^*_t d_{jt} + \nu_t n_{jt} \tag{A.19}$$

$$+\mu_t \left[ \nu^l_t q_t l_{jt} + \nu^g_t q^g_t b^g_t - \nu^*_t d_{jt} + \nu_t n_{jt} - \lambda \left( q_t l_{jt} + \omega_g q^g_t b^g_{jt} - \omega_d d_{jt} \right) \right],$$

where the term in square brackets incorporates the incentive compatibility constraint, (5).

### A.3 Capital producers

The investment adjustment cost function is given by the following quadratic function of the investment growth

$$\Phi\left(\frac{i_t}{i_{t-1}}\right) = \frac{\phi}{2}\left[\frac{i_t}{i_{t-1}} - 1\right]^2.$$

Capital producers use an investment good that is composed of home and foreign final goods in order to repair the depreciated capital and to produce new capital goods

$$i_t = \left[ \omega_i^{\frac{1}{\gamma_i}} (i^H_t)^{\frac{\gamma_i - 1}{\gamma_i}} + (1-\omega_i)^{\frac{1}{\gamma_i}} (i^F_t)^{\frac{\gamma_i - 1}{\gamma_i}} \right]^{\frac{\gamma_i}{\gamma_i - 1}},$$

where $\omega_i$ governs the relative weight of home input in the investment composite good and $\gamma_i$ measures the elasticity of substitution between home and foreign inputs. Capital producers choose the optimal mix of home and foreign inputs according to the intratemporal first order condition

$$\frac{i^H_t}{i^F_t} = \frac{\omega_i}{1-\omega_i} \left(\frac{P^H_t}{P^F_t}\right)^{-\gamma_i}.$$

The resulting aggregate investment price index $P^I_t$, is given by

$$P^I_t = \left[ \omega_i (P^H_t)^{1-\gamma_i} + (1-\omega_i)(P^F_t)^{1-\gamma_i} \right]^{\frac{1}{1-\gamma_i}}.$$

Capital producers require $i_t$ units of investment good at a unit price of $\frac{P_t^I}{P_t}$ and incur investment adjustment costs $\Phi\left(\frac{i_t}{i_{t-1}}\right)$ per unit of investment to produce new capital goods $i_t$ and repair the depreciated capital, which will be sold at the price $q_t$. Therefore, a capital producer makes an investment decision to maximize its discounted profits represented by

$$\max_{i_{t+i}} \sum_{i=0}^{\infty} E_0 \left[ \Lambda_{t,t+1+i} \left( q_{t+i} i_{t+i} - \Phi\left(\frac{i_{t+i}}{i_{t+i-1}}\right) q_{t+i} i_{t+i} - \frac{P_{t+i}^I}{P_{t+i}} i_{t+i} \right) \right]. \tag{A.20}$$

The optimality condition with respect to $i_t$ produces the following Q-investment relation for capital goods

$$\frac{P_t^I}{P_t} = q_t \left[ 1 - \Phi\left(\frac{i_t}{i_{t-1}}\right) - \Phi'\left(\frac{i_t}{i_{t-1}}\right)\frac{i_t}{i_{t-1}} \right] + E_t \left[ \Lambda_{t,t+1} q_{t+1} \Phi'\left(\frac{i_{t+1}}{i_t}\right)\left(\frac{i_{t+1}}{i_t}\right)^2 \right].$$

Finally, the aggregate physical capital stock of the economy evolves according to

$$k_{t+1} = (1-\delta_t)k_t + \exp(\psi_t^i)\left[1 - \Phi\left(\frac{i_t}{i_{t-1}}\right)\right] i_t, \tag{A.21}$$

with $\delta_t$ being the endogenous depreciation rate of capital determined by the utilization choice of intermediate goods producers. $\psi_t^i$ is a marginal-efficiency-of-investment shock that follows the stochastic process

$$\psi_t^i = \rho_{\psi^i} \psi_{t-1}^i + \varepsilon_t^{\psi^i} \tag{A.22}$$

with zero mean and constant variance Gaussian innovations, $\varepsilon_t^{\psi^i}$.

## A.4 Final goods producers

Final goods producers transform intermediate good varieties $y_t(i)$, that sell at the monopolistically determined price $P_t^H(i)$, into a final good that sell at the competitive price $P_t^H$, using the constant returns-to-scale technology,

$$y_t^H = \left[ \int_0^1 y_t^H(i)^{1-\frac{1}{\epsilon_t}} di \right]^{\frac{1}{1-\frac{1}{\epsilon_t}}}.$$

The profit maximization problem of final goods producers

$$\max_{y_t^H(i)} \; P_t^H \left[ \int_0^1 y_t^H(i)^{1-\frac{1}{\epsilon_t}} di \right]^{\frac{1}{1-\frac{1}{\epsilon_t}}} - \left[ \int_0^1 P_t^H(i) y_t^H(i) di \right]. \tag{A.23}$$

solved at the zero profit condition implies that the optimal intermediate good demand becomes,

$$y_t^H(i) = \left(\frac{P_t^H(i)}{P_t^H}\right)^{-\epsilon_t} y_t^H,$$

with, $P_t^H(i)$ and $P_t^H$ satisfying the price index aggregator,

$$P_t^H = \left[\int_0^1 P_t^H(i)^{1-\epsilon_t} di\right]^{\frac{1}{1-\epsilon_t}}.$$

Imported intermediate good varieties are transformed via a similar technology with the same elasticity of substitution between varieties as in home final goods production. Therefore, $y_t^F(i) = \left(\frac{P_t^F(i)}{P_t^F}\right)^{-\epsilon_t} y_t^F$ and $P_t^F = \left[\int_0^1 P_t^F(i)^{1-\epsilon_t} di\right]^{\frac{1}{1-\epsilon_t}}$ hold for imported intermediate goods.

### A.5 Intermediate goods producers

There is a large number of home-based intermediate goods producers indexed by $i$, who produce variety $y_t^H(i)$ using the constant returns-to-scale production technology,

$$y_t^H(i) = \exp(z_t)\Big(u_t(i)k_t(i)\Big)^{\alpha} h_t(i)^{1-\alpha}.$$

As shown in the production function, firms choose the level of capital and labor used in production, as well as the utilization rate of the capital stock. $\exp(z_t)$ is the stochastic aggregate productivity level, following the autoregressive process

$$z_t = \rho^z z_{t-1} + \varepsilon_t^z,$$

with zero mean and constant variance Gaussian innovations $\varepsilon_t^z$.

Producer $i$ who operates as a monopolistically competitor sells intermediate good $y_t^H(i)$ to final good producers in the domestic market. Consequently, it sets the nominal sales price $P_t^H(i)$ optimally to meet the domestic demand for its variety,

$$y_t^H(i) = \left(\frac{P_t^H(i)}{P_t^H}\right)^{-\epsilon_t} y_t^H,$$

which depends on the aggregate home output $y_t^H$ produced by final goods producers. These firms face both the nominal marginal costs of production $MC_t$ as well as a Rotemberg (1982)-type quadratic menu cost of price adjustment

$$P_t y_t^D \frac{\varphi^H}{2}\left[\frac{P_t^H(i)/P_{t-1}^H(i)}{P_{t-1}^H/P_{t-2}^H} - 1\right]^2,$$

These costs are denoted in nominal terms as a function of domestic, aggregate intermediate goods demand $y_t^D$ scaled by the parameter $\varphi^H$ capturing the degree of price rigidity in the economy.

Domestic intermediate goods producers maximize present discounted real profits by choosing their nominal price level:

$$\max_{P_t^H(i)} E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left[ \frac{D_{t+j}^H(i)}{P_{t+j}} \right] \tag{A.24}$$

subject to the nominal profit function

$$D_{t+j}^H(i) = P_{t+j}^H(i) y_{t+j}^D(i) + S_{t+j} P_{t+j}^{H*} c_{t+j}^{H*}(i) - MC_{t+j} y_{t+j}^D(i) - P_{t+j} y_{t+j}^D \frac{\varphi^H}{2} \left[ \frac{P_{t+j}^H(i)/P_{t+j-1}^H(i)}{P_{t+j-1}^H/P_{t+j-2}^H} - 1 \right]^2, \tag{A.25}$$

the domestic demand function $y_t^D(i) = \left( \frac{P_t^H(i)}{P_t^H} \right)^{-\epsilon_t} y_t^D$ and the external demand function $c_{t+j}^{H*}(i)$. Since households own these firms, any profits are remitted to consumers and future streams of real profits are discounted by the stochastic discount factor of consumers, accordingly. The sequences of nominal exchange rate of the foreign currency in domestic currency units $S_t$ and export prices in foreign currency $\{S_{t+j}, P_{t+j}^{H*}\}_{j=0}^{\infty}$ are taken exogenously by the firm, since the intermediate goods producer is a price taker in the export markets. The first-order condition to this problem becomes,

$$(\epsilon_t - 1) \left( \frac{P_t^H(i)}{P_t^H} \right)^{-\epsilon_t} \frac{y_t^D}{P_t} = \epsilon_t \left( \frac{P_t^H(i)}{P_t^H} \right)^{-\epsilon_t - 1} MC_t \frac{y_t^D}{P_t P_t^H} - y_t^D \varphi^H \left[ \frac{P_{t+j}^H(i)/P_{t+j-1}^H(i)}{P_{t+j-1}^H/P_{t+j-2}^H} - 1 \right] \left[ \frac{1/P_{t+j-1}^H(i)}{P_{t+j-1}^H/P_{t+j-2}^H} \right]$$

$$+ \varphi^H E_t \left\{ \Lambda_{t,t+1} y_{t+1}^D \left[ \frac{P_{t+j+1}^H(i)/P_{t+j}^H(i)}{P_{t+j}^H/P_{t+j-1}^H} - 1 \right] \frac{P_{t+1}^H(i)}{P_t^H(i)^2 P_{t+j}^H/P_{t+j-1}^H} \right\}. \tag{A.26}$$

We focus on symmetric equilibrium, in which all intermediate producers choose the same price level with, $P_t^H(i) = P_t^H \ \ \forall i$. Imposing this condition to the first order condition of the profit maximization problem and using the definitions $rmc_t = \frac{MC_t}{P_t}$, $\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$, and $p_t^H = \frac{P_t^H}{P_t}$ yield

$$p_t^H = \frac{\epsilon_t}{\epsilon_t - 1} rmc_t - \frac{\varphi^H}{\epsilon_t - 1} \left[ \frac{\pi_t^H}{\pi_{t-1}^H} - 1 \right] \frac{\pi_t^H}{\pi_{t-1}^H} + \frac{\varphi^H}{\epsilon_t - 1} E_t \left\{ \Lambda_{t,t+1} \frac{y_{t+1}^D}{y_t^D} \left[ \frac{\pi_{t+1}^H}{\pi_t^H} - 1 \right] \frac{\pi_{t+1}^H}{\pi_t^H} \right\}. \tag{A.27}$$

Monopolistic pricing implies that even under flexible prices with $\varphi^H = 0$, the optimal sales price reflects a markup over the marginal cost that is, $P_t^H = \frac{\epsilon_t}{\epsilon_t - 1} MC_t$. Menu costs make this pass through from marginal costs imperfect.

The intermediate goods producer exports the rest of its production $c_t^{H*}(i)$ in the foreign market, in which it is a price taker. We posit an autoregressive exogenous export demand function as in Gertler et al. (2007) and assume that

$$c_t^{H*} = \left[ \left( \frac{S_t P_t^{H*}}{P_t} \right)^{-\Gamma} \exp(y_t^*) \right]^{\nu^H} (c_{t-1}^{H*})^{1-\nu^H},$$

which positively depends on the exogenous foreign output process,

$$y_t^* = \rho^{y^*} y_{t-1}^* + \varepsilon_t^{y^*}$$

with zero mean and constant variance Gaussian innovations, which can be interpreted as export demand shocks. For tractability, we assume that the small open economy takes export prices $P_t^{H*} = P_t^* = 1$ as given so that exports are fundamentally pinned down by the real exchange rate $s_t = \frac{S_t P_t^*}{P_t}$ and foreign demand.

Determination of local currency import prices follow an analogous logic to that of domestic intermediate goods price setting. In particular, we assume that the law of one price holds at the intermediate goods level $MC_t^F = S_t P_t^{F*}$ and foreign currency import prices obey $P_t^{F*} = 1 \; \forall t$, which is taken as given by the small open economy. Then, the local currency prices of imported intermediate goods are determined by

$$p_t^F = \frac{\epsilon_t}{\epsilon_t - 1} s_t - \frac{\varphi^F}{\epsilon_t - 1} \left[ \frac{\pi_t^F}{\pi_{t-1}^F} - 1 \right] \frac{\pi_t^F}{\pi_{t-1}^F} + \frac{\varphi^F}{\epsilon_t - 1} E_t \left\{ \Lambda_{t,t+1} \frac{y_{t+1}^F}{y_t^F} \left[ \frac{\pi_{t+1}^F}{\pi_t^F} - 1 \right] \frac{\pi_{t+1}^F}{\pi_t^F} \right\} \tag{A.28}$$

with $\frac{S_t P_t^{F*}}{P_t} = s_t$ and $p_t^F = \frac{P_t^F}{P_t}$.

For a given sales price, intermediate good producers determine their optimal factor demands and utilization of capital by solving a symmetric, intra-temporal cost minimization problem. The cost function reflects the capital gains from market valuation of firm capital (which is interchangeable with securities issued by intermediate good producers) and outlays spared for repairing its worn out portion. Consequently, firms minimize

$$\min_{u_t, k_t, h_t} q_{t-1}(R_{kt} - 1)k_t - (q_t - q_{t-1})k_t + p_t^I \delta(u_t) k_t + w_t h_t + rmc_t \left[ y_t^H - \exp(z_t) \left( u_t k_t \right)^{\alpha} h_t^{1-\alpha} \right] \tag{A.29}$$

subject to the endogenous depreciation rate function,

$$\delta_t = \delta + \frac{d}{1+\varrho} u_t^{1+\varrho}, \tag{A.30}$$

with $\delta, d, \varrho > 0$. The first order conditions to this problem determine optimal factor demands and the utilization choice are

$$p_t^I \delta_t' k_t = \alpha \left( \frac{y_t^H}{u_t} \right) rmc_t, \tag{A.31}$$

$$R_{kt} = \frac{\alpha \left( \frac{y_t^H}{k_t} \right) rmc_t - p_t^I \delta_t + q_t}{q_{t-1}}, \tag{A.32}$$

$$w_t = (1-\alpha) \left( \frac{y_t^H}{h_t} \right) rmc_t. \tag{A.33}$$

### A.6 De-anchored inflation expectations

When running the experiment of assessing the efficacy of asset purchases under de-anchored inflation expectations, we resolve the price setting problem of intermediate goods producers, which produces the following modified the New Keynesian Phillips curves

$$p_t^H = \frac{\epsilon_t}{\epsilon_t - 1} rmc_t - \frac{\varphi^H}{\epsilon_t - 1} \left[ \frac{\pi_t^H}{\left(\pi_{t-1}^H\right)^{\alpha_H} \left(\pi^H\right)^{1-\alpha_H}} - 1 \right] \frac{\pi_t^H}{\left(\pi_{t-1}^H\right)^{\alpha_H} \left(\pi^H\right)^{1-\alpha_H}}$$

$$+ \frac{\varphi^H}{\epsilon_t - 1} E_t \left\{ \Lambda_{t,t+1} \frac{y_{t+1}^D}{y_t^D} \left[ \frac{\pi_{t+1}^H}{\left(\pi_t^H\right)^{\alpha_H} \left(\pi^H\right)^{1-\alpha_H}} - 1 \right] \frac{\pi_{t+1}^H}{\left(\pi_t^H\right)^{\alpha_H} \left(\pi^H\right)^{1-\alpha_H}} \right\} \tag{A.34}$$

$$p_t^F = \frac{\epsilon_t}{\epsilon_t - 1} s_t - \frac{\varphi^F}{\epsilon_t - 1} \left[ \frac{\pi_t^F}{\left(\pi_{t-1}^F\right)^{\alpha_F} \left(\pi^F\right)^{1-\alpha_F}} - 1 \right] \frac{\pi_t^F}{\left(\pi_{t-1}^F\right)^{\alpha_F} \left(\pi^F\right)^{1-\alpha_F}}$$

$$+ \frac{\varphi^F}{\epsilon_t - 1} E_t \left\{ \Lambda_{t,t+1} \frac{y_{t+1}^F}{y_t^F} \left[ \frac{\pi_{t+1}^F}{\left(\pi_t^F\right)^{\alpha_F} \left(\pi^F\right)^{1-\alpha_F}} - 1 \right] \frac{\pi_{t+1}^F}{\left(\pi_t^F\right)^{\alpha_F} \left(\pi^F\right)^{1-\alpha_F}} \right\} \tag{A.35}$$

instead of (A.27) and (A.28) in the baseline analysis. In this formulation, $\pi^H$ and $\pi^F$ are steady-state (target) home-goods and foreign-goods inflation rates, and $\alpha^H$ and $\alpha^F$ are home-goods and foreign-goods inflation indexation parameters, respectively.

### A.7 Government

Government expenditures follow the exogenous process

$$\log(g_t) = (1-\rho_g) \log \bar{g} + \rho_g \log(g_{t-1}) + \varepsilon_t^g, \tag{A.36}$$

where $\varepsilon_t^g$ are innovations drawn from a Gaussian distribution with zero mean and constant variance. This exogenous sum of government demand falls on home and foreign goods via a CES aggregator similar to private consumption spending. That is,

$$g_t = \left[\omega_t^{\frac{1}{\gamma}} (g_t^H)^{\frac{\gamma-1}{\gamma}} + (1-\omega_t)^{\frac{1}{\gamma}} (g_t^F)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}} \tag{A.37}$$

$$\frac{g_t^H}{g_t^F} = \frac{\omega_t}{1-\omega_t}\left(\frac{P_t^H}{P_t^F}\right)^{-\gamma}. \tag{A.38}$$

## A.8 Resource constraints

The resource constraint for home goods equates total output to the sum of domestic absorption, external demand and real domestic price adjustment costs, with

$$y_t^H = c_t^H + c_t^{H*} + i_t^H + g_t^H + \frac{\varphi^H}{2} y_t^D \left[\frac{\pi_t^H}{\pi_{t-1}^H} - 1\right]^2 \tag{A.39}$$

and $y_t^D = y_t^H - c_t^{H*}$. A similar condition holds for total imported goods, that is,

$$y_t^F = c_t^F + i_t^F + g_t^F + \frac{\varphi^F}{2} y_t^F \left[\frac{\pi_t^F}{\pi_{t-1}^F} - 1\right]^2. \tag{A.40}$$

GDP of this economy in final goods terms will then be defined as

$$y_t = c_t + i_t + g_t + p_t^H c_t^{H*} - p_t^F y_t^F. \tag{A.41}$$

Finally, the balance of payments vis-à-vis the rest of the world relates net foreign assets to the economy's trade balance

$$-(b_t^* + b_t^{g^*}) + R_t^* b_{t-1}^* + R_t^g b_{t-1}^{g^*} = p_t^H c_t^{H*} - p_t^F y_t^F. \tag{A.42}$$

## A.9 Definition of competitive equilibrium

A competitive equilibrium is defined by sequences of prices $\{p_t^H, p_t^F, p_t^I, \pi_t, w_t, q_t, q_t^g, s_t, R_{kt+1}, R_{t+1}^g, R_{t+1}, R_{t+1}^*\}_{t=0}^{\infty}$, government policies $\{r_{nt}, g_t^H, g_t^F, b_t^{gCB}, l_t^{CB}, \varphi_t^g, \varphi_t^l, \tau_t\}_{t=0}^{\infty}$, allocations $\{c_t^H, c_t^F, c_t, h_t, \varphi_t, d_t, b_t^g, b_t^*, b_t^{g^*}\ l_t, n_t, \kappa_t, v_t^l, v_t^g, v_t, v_t^*, i_t, i_t^H, i_t^F, k_{t+1}, y_t^H, y_t^D, y_t^F, y_t, u_t, rmc_t, c_t^{H*}, D_t^H, \Pi_t, \delta_t\}_{t=0}^{\infty}$, initial conditions, $\{d_-, b_-^g, b_-^*, b_-^{g^*}, k_0, l_0, n_0\}$ and exogenous processes $\{\psi_t^c, \omega_t, \psi_t^{rp}, \kappa_{gt}, b_t^{g^*}, R_{nt}^*, z_t, g_t, \varepsilon_t^{r_n}, \psi_t^i, \epsilon_t, y_t^*\}_{t=0}^{\infty}$ such that;

i) Given exogenous processes, initial conditions, government policies, and prices; the allocations solve the utility maximization problem of households (A.2)-(A.4), the net worth maximization problem of bankers (12)-(13), and the profit maximization problems of capital producers (A.20), final goods producers (A.23), and intermediate goods producers (A.24)-(A.25) and (A.29)-(A.30).

ii) Home and foreign goods, physical capital, security claims, government bonds, domestic deposits, and labor markets clear. Short-term assets issued by the central bank adjust by Walras' Law to finance asset purchases. Resource constraints for home and foreign goods, (A.39) and (A.40) and GDP and balance of payments identities (A.41) and (A.42) hold.

# B Model calibration and estimation

## B.1 Data sources and targeted moment definitions

**Real deposit rate.** Nominal rates are collected from World Development Indicators of the World Bank and are deflated by the CPI index taken from the OECD. For countries with missing nominal deposit rates, we use short-term interest rates data provided by the OECD.

**National accounts.** GDP and its expenditure side components are collected from the Economic Outlook 108 database of the OECD.

**Loan-deposit intermediation margin.** Collected from the World Development Indicators of the World Bank. For Poland and Turkey, data are collected from national central banks.

**Bank leverage.** Inverse of the regulatory capital-to-risk weighted assets ratio collected from the IMF Financial Soundness Indicators.

**Foreign debt share of banks.** Average of 2004, 2009 and 2013 vintages of non-core financing share of banks reported by Ehlers and Víllar (2015).

**Long-term, local-currency government bond yield.** 10-year local-currency sovereign bond yields are collected from the OECD. Data for Philippines are collected from Refinitiv.

**Private credit-to-GDP ratio.** Series on non-financial corporate debt, loans and debt securities as a percent of GDP collected from the IMF Global Debt database.

**U.S. short-term real interest rate.** Series on short-term interest rates provided by the OECD deflated by the CPI index. We take the average of the pre-Global Financial Crisis as our reference period to avoid negative steady-state world interest rates in the model.

**Local-currency government bonds.** Quarterly series of domestic-currency central government debt securities are collected from the Arslanalp and Tsuda (2014) dataset, which is regularly updated as the IMF Sovereign Debt Investor Base for Emerging Markets database. The database also explicitly differentiates between resident and non-resident holders of local-currency securities.

**Asset purchases.** We use the IMF (2020) (second chapter) dataset as our reference in matching the average size of government bond purchases in EMEs during the pandemic.

### B.2 System priors used in the Bayesian estimation

The *RISE* toolbox allows for augmenting marginal priors (below) with *system priors*.[1] In contrast to marginal priors that deal with parameters independently, system priors are priors about the model's features and behavior as a system and are modelled with a density function conditional on the model parameters. In theory, the system priors can either substitute or be combined with marginal priors. In our estimation setup, we choose to augment our marginal priors with specific beliefs about the variances of the observed variables. Specifically, we specify our system priors as inverse gamma distributions over the variances of the observed variables, $\Gamma^{-1}(\mu, \sigma)$, where we set $\mu$ equal to the second-order moment from the data set that is used in the estimation, and a not too restrictive standard deviation (given the magnitude of the variances of the observed variables), $\sigma$, equal to 10 percent of the mean. We did not set prior beliefs about co-variances. Table B.1 provides a forecast error variance decomposition exercise for selected macroeconomic and financial variables.

[1] This is somewhat similar to the framework laid out in Andrle and Benes (2013) and Del Negro and Schorfheide (2008). See the *RISE* website (`https://github.com/jmaih/RISE_toolbox`) for the particular codes.

**Table B.1:** Forecast error variance decomposition

| Variable | Shock<br>Total factor productivity | Domestic monetary policy | US monetary policy | Markup | Government expenditure | Bond coupon rate | Import demand | Consumption preference | Investment efficiency | External risk premium | Foreign demand | Bond sell-off |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **One quarter ahead (%)** | | | | | | | | | | | | |
| GDP | 1 | 0 | 0 | 1 | 1 | 0 | 35 | 3 | 11 | 0 | 48 | 0 |
| Consumption | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 99 | 0 | 0 | 0 | 0 |
| Investment | 43 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 |
| Current account balance | 5 | 0 | 1 | 3 | 1 | 0 | 33 | 3 | 1 | 1 | 53 | 0 |
| Government bonds held by banks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 88 |
| Private credit to non-financials | 49 | 0 | 0 | 42 | 0 | 0 | 0 | 0 | 7 | 0 | 1 | 0 |
| Real exchange rate | 51 | 2 | 7 | 13 | 0 | 0 | 1 | 1 | 15 | 8 | 2 | 0 |
| Policy rate | 3 | 39 | 4 | 31 | 0 | 0 | 9 | 0 | 11 | 4 | 0 | 0 |
| Inflation rate | 9 | 0 | 1 | 47 | 0 | 0 | 40 | 0 | 2 | 1 | 1 | 0 |
| Domestic credit spreads | 66 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 13 | 0 | 1 | 0 |
| Excess yield of government bonds | 4 | 0 | 0 | 3 | 0 | 88 | 0 | 0 | 4 | 1 | 0 | 0 |
| **1 year ahead (%)** | | | | | | | | | | | | |
| GDP | 3 | 1 | 0 | 5 | 0 | 0 | 27 | 5 | 5 | 0 | 54 | 0 |
| Consumption | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 98 | 0 | 0 | 0 | 0 |
| Investment | 52 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Current account balance | 17 | 0 | 1 | 8 | 0 | 0 | 18 | 4 | 4 | 1 | 45 | 0 |
| Government bonds held by banks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 0 | 56 |
| Private credit to non-financials | 50 | 0 | 0 | 43 | 0 | 0 | 1 | 0 | 5 | 1 | 1 | 0 |
| Real exchange rate | 49 | 2 | 6 | 15 | 0 | 0 | 1 | 1 | 15 | 8 | 3 | 0 |
| Policy rate | 2 | 39 | 4 | 24 | 0 | 0 | 6 | 0 | 15 | 6 | 4 | 0 |
| Inflation rate | 9 | 0 | 1 | 46 | 0 | 0 | 38 | 0 | 3 | 1 | 2 | 0 |
| Domestic credit spreads | 54 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 18 | 0 | 1 | 0 |
| Excess yield of government bonds | 4 | 0 | 16 | 2 | 0 | 71 | 0 | 0 | 5 | 1 | 0 | 0 |
| **5 years ahead (%)** | | | | | | | | | | | | |
| GDP | 6 | 2 | 1 | 7 | 0 | 0 | 27 | 5 | 8 | 1 | 45 | 0 |
| Consumption | 4 | 1 | 0 | 2 | 0 | 0 | 1 | 90 | 1 | 0 | 1 | 0 |
| Investment | 47 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 |
| Current account balance | 21 | 0 | 1 | 12 | 0 | 0 | 17 | 5 | 6 | 2 | 36 | 0 |
| Government bonds held by banks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | 0 | 29 |
| Private credit to non-financials | 50 | 0 | 0 | 43 | 0 | 0 | 1 | 0 | 4 | 1 | 0 | 0 |
| Real exchange rate | 46 | 2 | 6 | 16 | 0 | 0 | 5 | 1 | 14 | 8 | 4 | 0 |
| Policy rate | 20 | 20 | 2 | 26 | 0 | 0 | 10 | 2 | 9 | 3 | 8 | 0 |
| Inflation rate | 12 | 0 | 1 | 46 | 0 | 0 | 34 | 0 | 3 | 2 | 2 | 0 |
| Domestic credit spreads | 53 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 19 | 0 | 0 | 0 |
| Excess yield of government bonds | 7 | 0 | 20 | 7 | 0 | 57 | 2 | 0 | 5 | 1 | 0 | 0 |

*Note:* The table reports the theoretical variance decomposition of key macroeconomic and financial model variables at selected time horizons. Excess yield of government bonds is the nominal yield differential between domestic currency denominated 10-year sovereign bonds and the US short-term rate.

# C Sensitivity analysis

## C.1 Bond purchases when they de-anchor inflation expectations

Our baseline analysis confirms that with perfectly anchored inflation expectations, central bank sovereign bond purchases in EMEs can stabilize the effects of bond sell-off shocks without inflationary repercussions. In this extension, to introduce de-anchored inflation expectations upon asset purchase announcements, we resolve the intermediate goods producers' price setting problems, which modifies New Keynesian Phillips curves in our environment (see Section A.6). Figure E.8 demonstrates that, although nominal excess yields under sovereign bond purchases leading to de-anchored inflation expectations fall to a lower level than in the case with no-QE policy (dashed lines versus fine-dashed lines in the bottom-left panel), inflation becomes more persistent and higher in a present discounted sense in this case relative to the case of bond purchases with anchored inflation expectations (dashed line versus solid lines in the bottom-right panel).

## C.2 Costly asset purchases

Figure E.9, displays the dynamics of selected model variables in response to a sovereign bond sell-off shock that peaks at 4.5% of GDP (fine-dashed lines) with no asset purchases and two other economies that entail public asset purchases, with one featuring leakages that amount to as large as 30% of bonds purchased by the central bank (dashed lines) so that $\tau^{gCB} = 0.3$ and another with no efficiency costs (solid lines), i.e. $\tau^{gCB} = 0$. Simulations imply that central bank cannot fully eliminate the financial crowding out effects on commercial bank balance sheets (top-right panel), but still, bond purchases continue to deliver substantial easing in overall financial conditions, and primarily in excess bond yields. In Figure E.10, we conduct a similar experiment, this time considering the efficacy of private asset purchases in response to adverse country risk premium shocks. With a similar degree of asset intermediation imperfections ($\tau^{CB} = 0.3$), private security purchases continue to stabilize country risk premium shocks (dashed lines against fine-dashed lines) although at a reduced rate relative to the case with no costs (solid lines).

### C.3 Transmission of the country risk premium and asset purchases

This section explores the effect of structural parameters related to sovereign risk on overall model dynamics and the effectiveness of asset purchases. Specifically, Figure E.11 compares the cases with no asset purchases (fine-dashed lines) and public asset purchases (dashed lines) in response to the government bond sell-off shock presented in Figure 3 in the manuscript. Dotted lines that are counterparts of these refer to cases with a debt elasticity of country risk premium $\psi$, that is 10 times larger. Figure E.12 on the other hand, compares the cases with no asset purchases (fine-dashed lines) and private asset purchases (dashed lines) in response to the country risk premium shock presented in Figure 4 in the manuscript. Dotted lines that are counterparts of these refer to cases with a country risk premium elasticity of foreign investor-held government bonds, $v_{g^\star}$, that is reduced by half.

## D References

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*ton University Press*, 2003, *Princeton University Press*, Princeton, NJ.

# E Figures left out to the online appendix

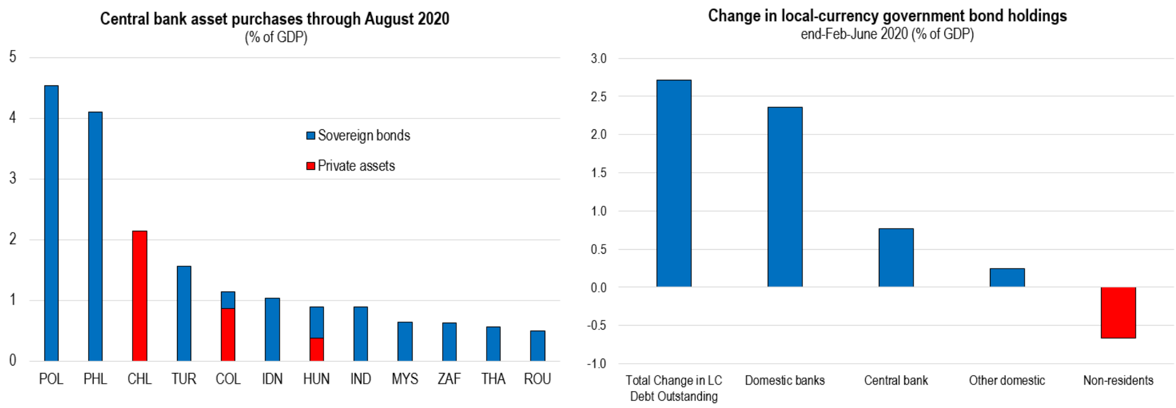


**Figure E.1:** Assets on the left panel correspond to bank bonds for the case of Chile and Colombia. Private asset purchases are in mortgage bonds for the case of Hungary. The rest of purchases are in secondary market sovereign bonds. The right panel shows averages across 9 countries that are reported by the IMF regarding central banks' sovereign bond purchases. Data sources are the IMF Global Financial Stability Report October 2020 database and authors' calculations.

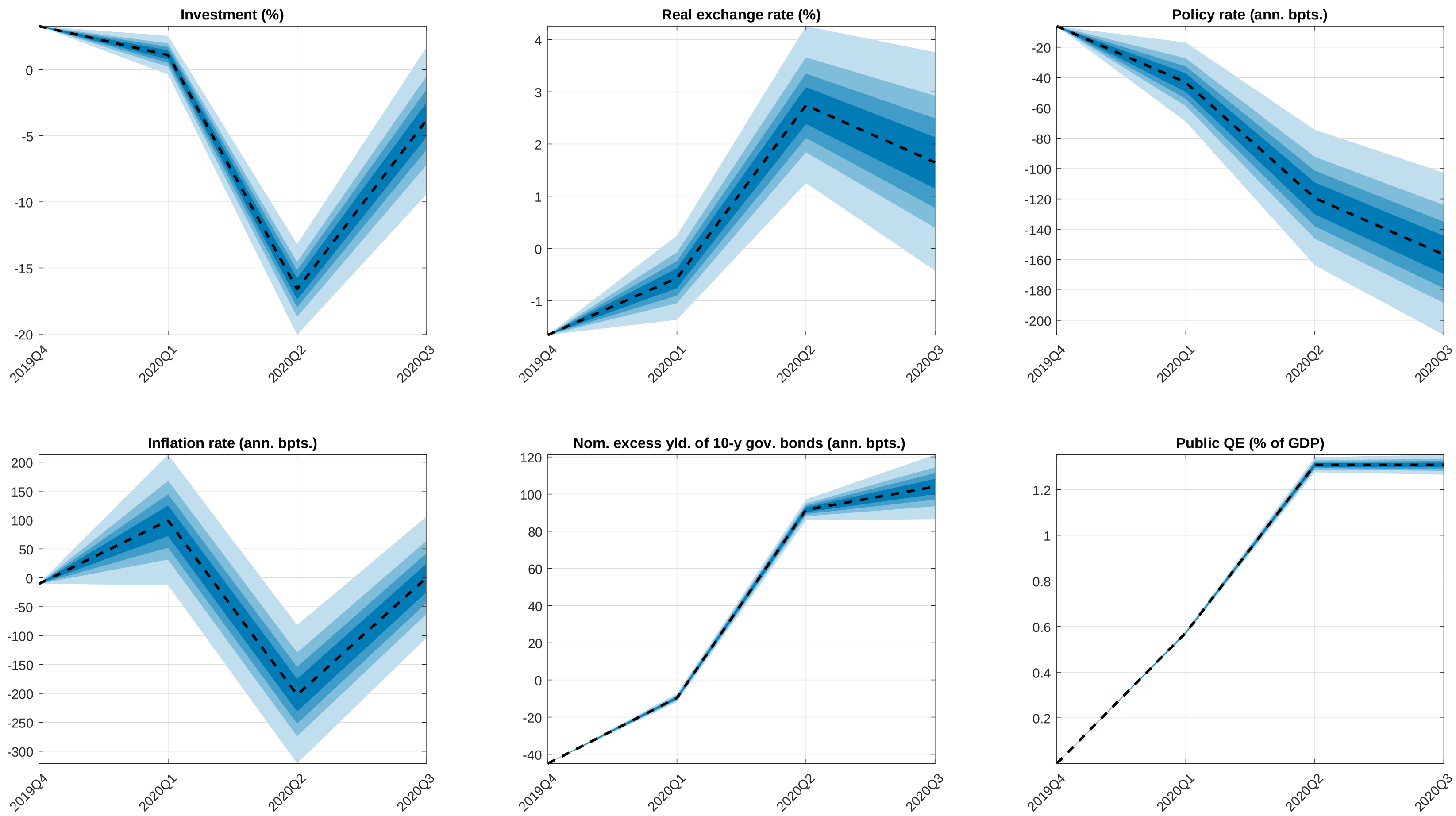


**Figure E.2:** Effects of adopting baseline asset purchase policies during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline asset purchase policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3. 30%, 50%, 68% and 90% confidence intervals are also depicted. Foreign-held government bonds share is assumed to stay at its 2020Q2 level relative to its trend due to lack of data. Public bond purchase policy positively responds to foreign lenders' government bond sell-off. Increases in the real exchange rate denote depreciations.

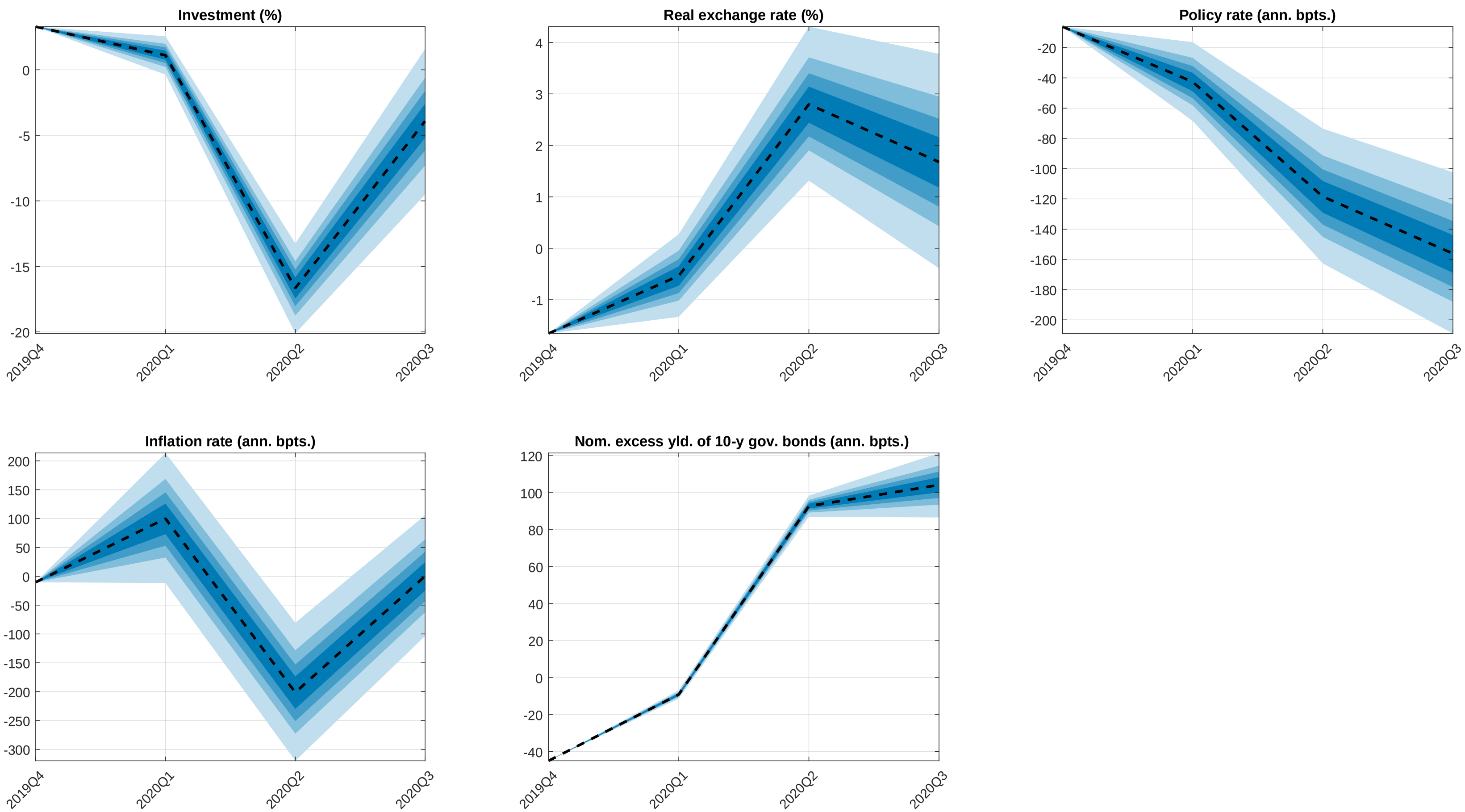


**Figure E.3:** Effects of adopting no asset purchase policies during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline asset purchase policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3. 30%, 50%, 68% and 90% confidence intervals are also depicted. Foreign-held government bonds share is assumed to stay at its 2020Q2 level relative to its trend due to lack of data. Increases in the real exchange rate denote depreciations.

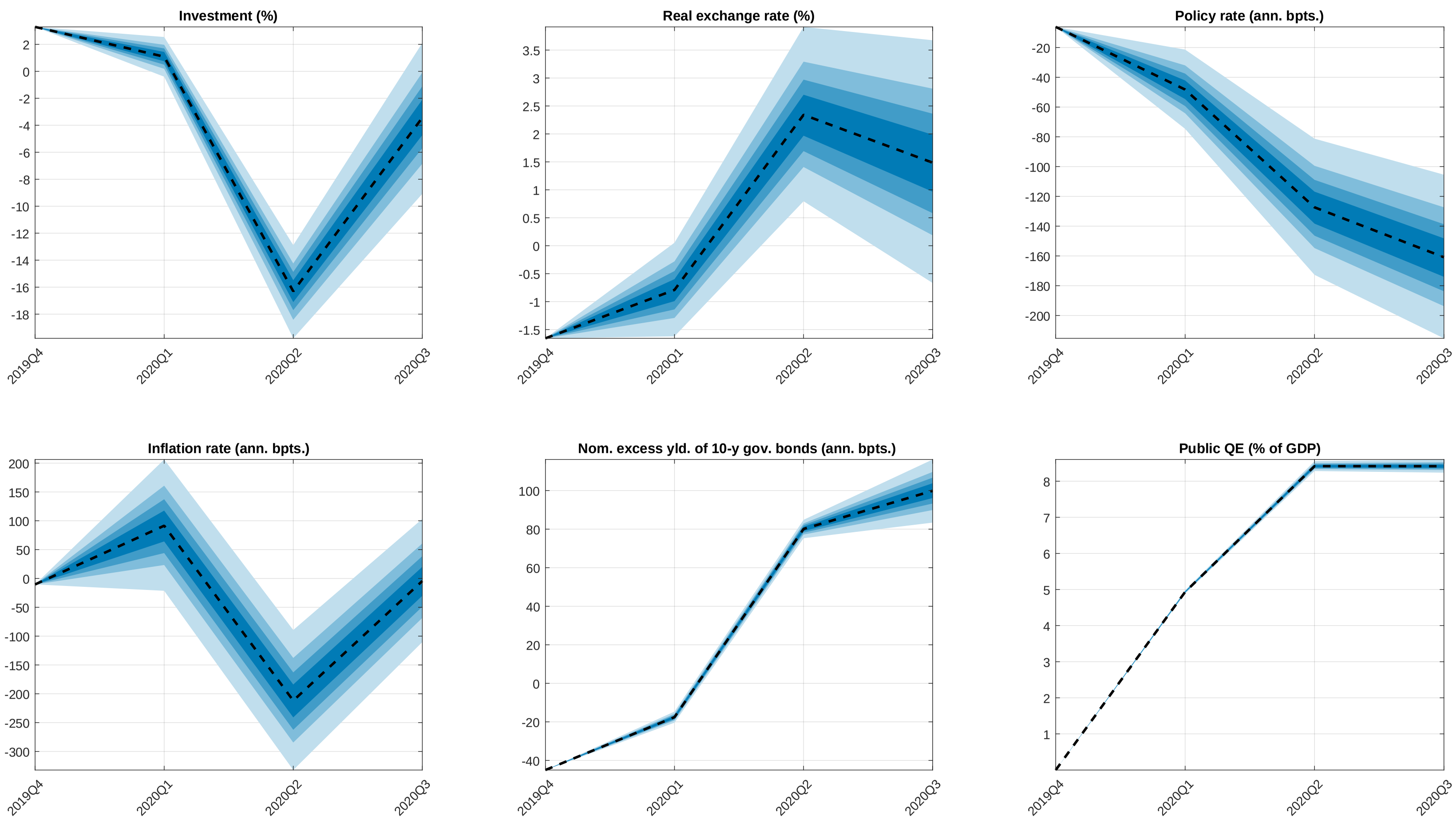


**Figure E.4:** Effects of adopting aggressive public bond purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline asset purchase policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3. 30%, 50%, 68% and 90% confidence intervals are also depicted. Foreign-held government bonds share is assumed to stay at its 2020Q2 level relative to its trend due to lack of data. Public bond purchase policy positively responds more than one-to-one to foreign lenders' government bond sell-off. Increases in the real exchange rate denote depreciations.

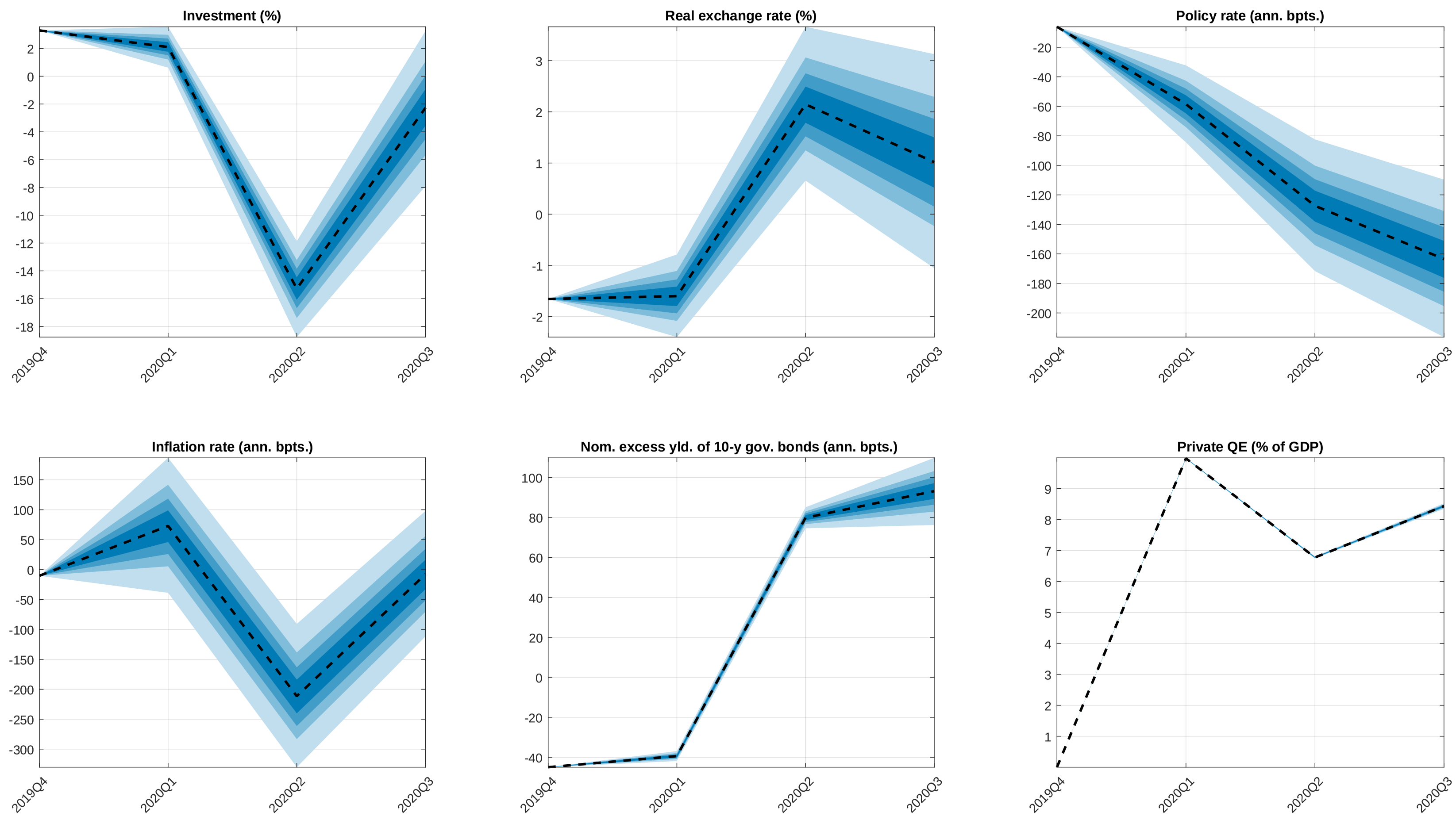


**Figure E.5:** Effects of adopting aggressive private security purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline asset purchase policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3. 30%, 50%, 68% and 90% confidence intervals are also depicted. Foreign-held government bonds share is assumed to stay at its 2020Q2 level relative to its trend due to lack of data. Private asset purchase policy positively responds to increases in loan-deposit spreads. Increases in the real exchange rate denote depreciations.

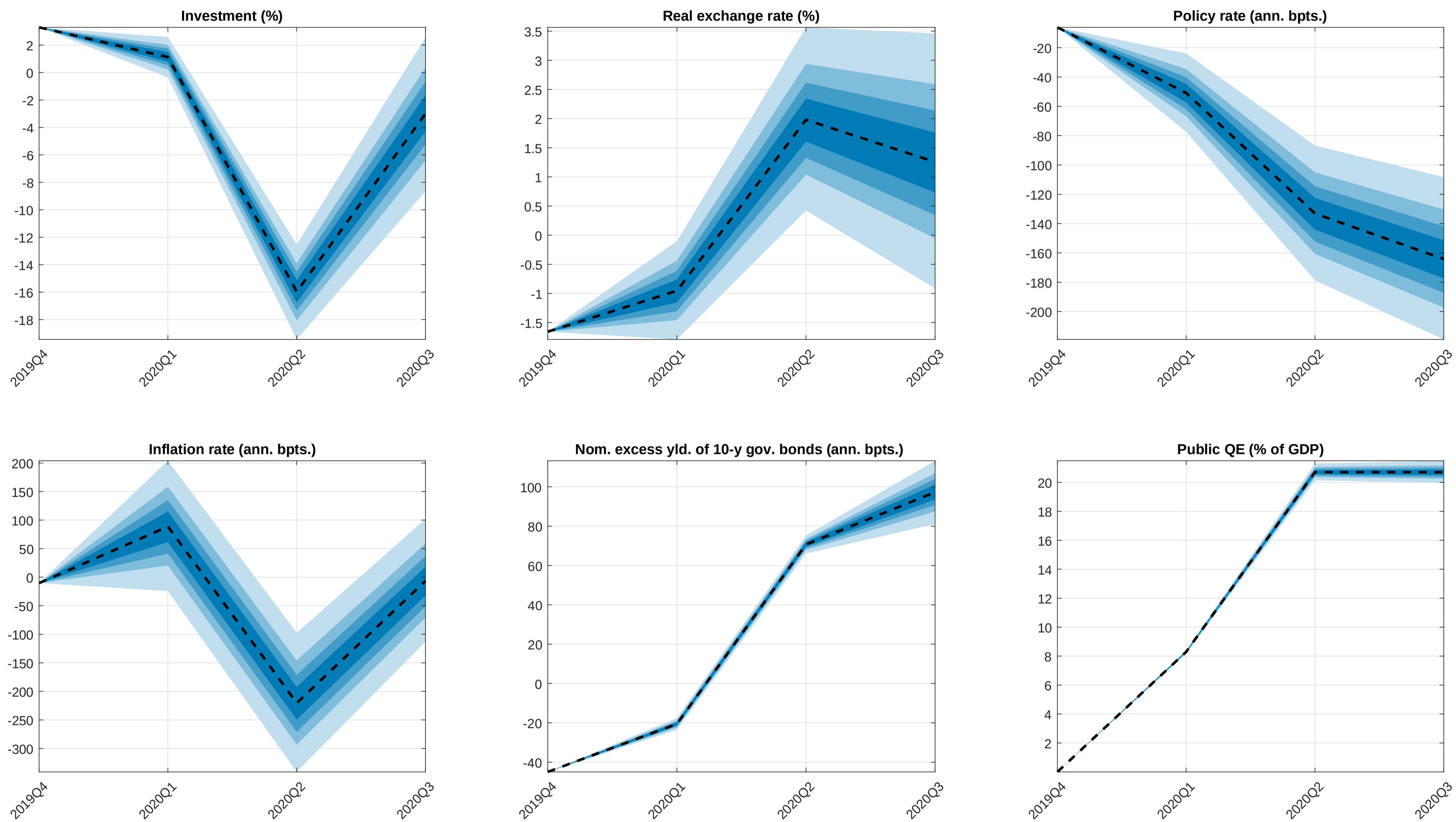


**Figure E.6:** Effects of adopting (advanced economy-type) aggressive public bond purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline asset purchase policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3. 30%, 50%, 68% and 90% confidence intervals are also depicted. Foreign-held government bonds share is assumed to stay at its 2020Q2 level relative to its trend due to lack of data. Public bond purchase policy positively responds more than one-to-one to foreign lenders' government bond sell-off. Increases in the real exchange rate denote depreciations.

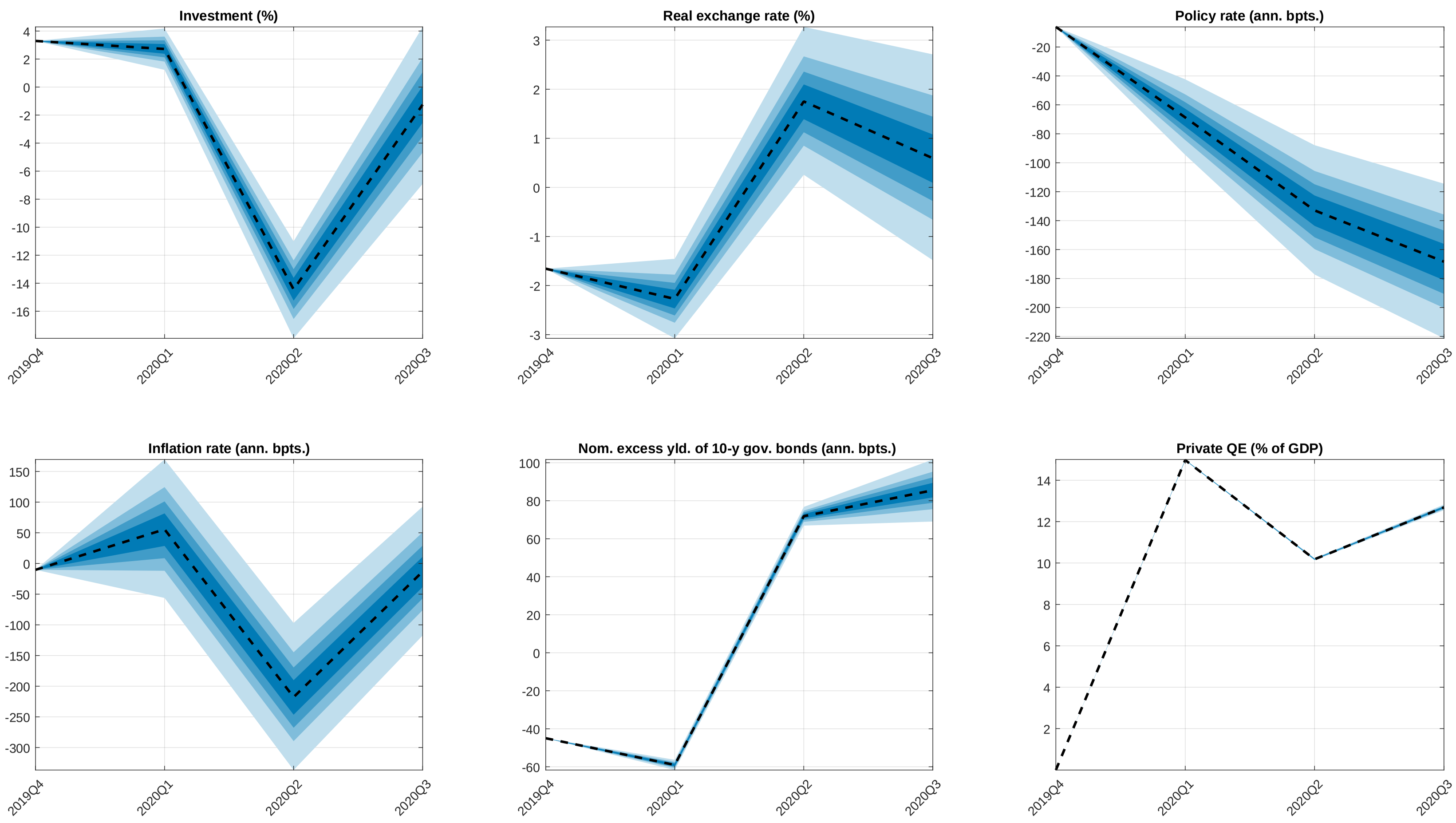


**Figure E.7:** Effects of adopting (advanced economy-type) aggressive private security purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline asset purchase policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3. 30%, 50%, 68% and 90% confidence intervals are also depicted. Foreign-held government bonds share is assumed to stay at its 2020Q2 level relative to its trend due to lack of data. Private asset purchase policy positively responds to increases in loan-deposit spreads. Increases in the real exchange rate denote depreciations.

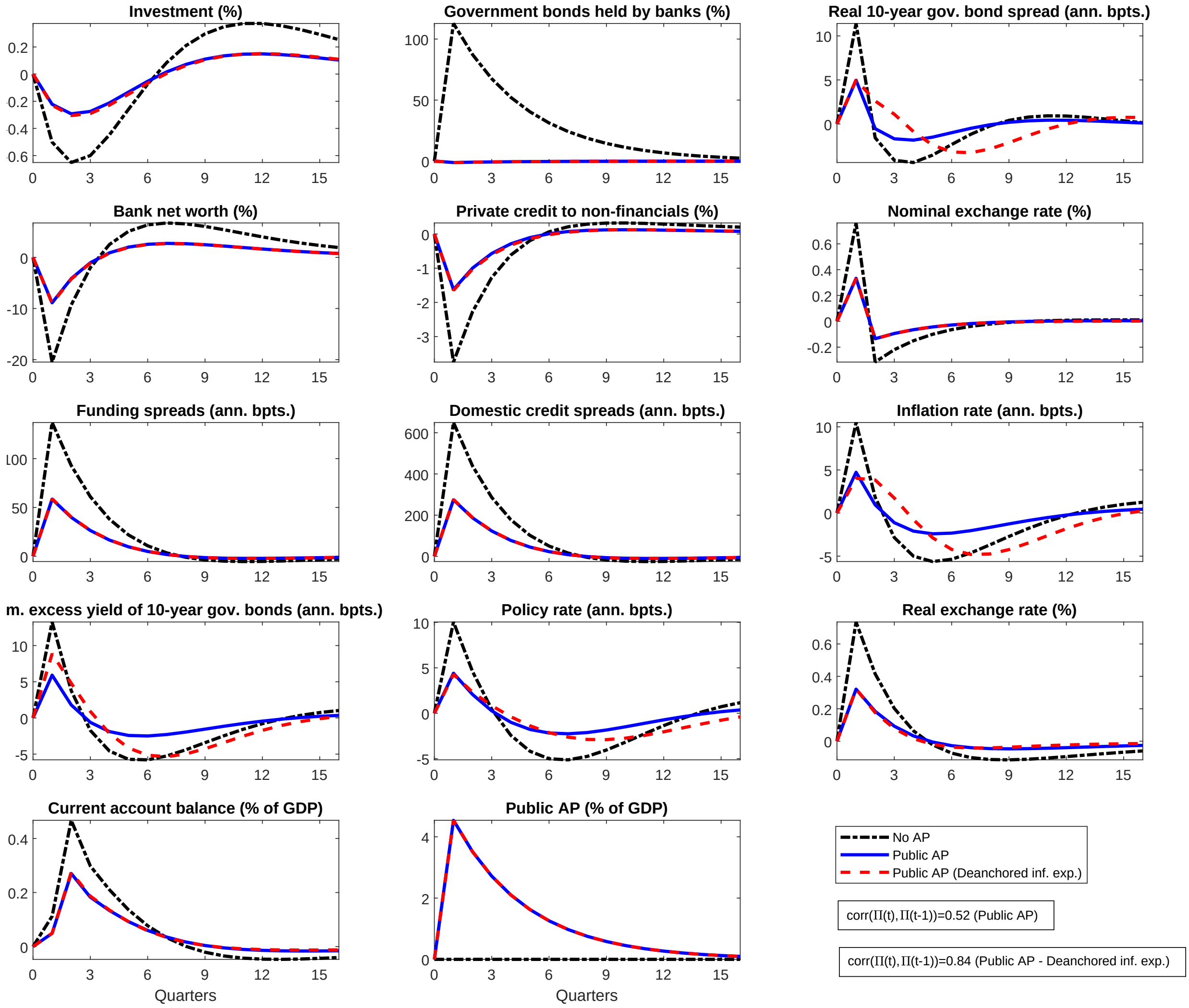


**Figure E.8:** Deviations from the steady state in response to a bond sell-off shock. The solid lines are the case of a public asset purchases policy program that reaches 4.5% of GDP at the peak. The dashed lines differ from this case by assuming that intermediate good producers partially take previous period's rate of inflation rather than the target inflation as their reference in computing their menu cost. Funding spread is the positive UIP deviation beyond country risk premium and expected exchange rate depreciation. Increases in the exchange rate denote depreciation. Real government bond spread is over domestic deposit rate. Nominal excess yield is over the US short–term rate.

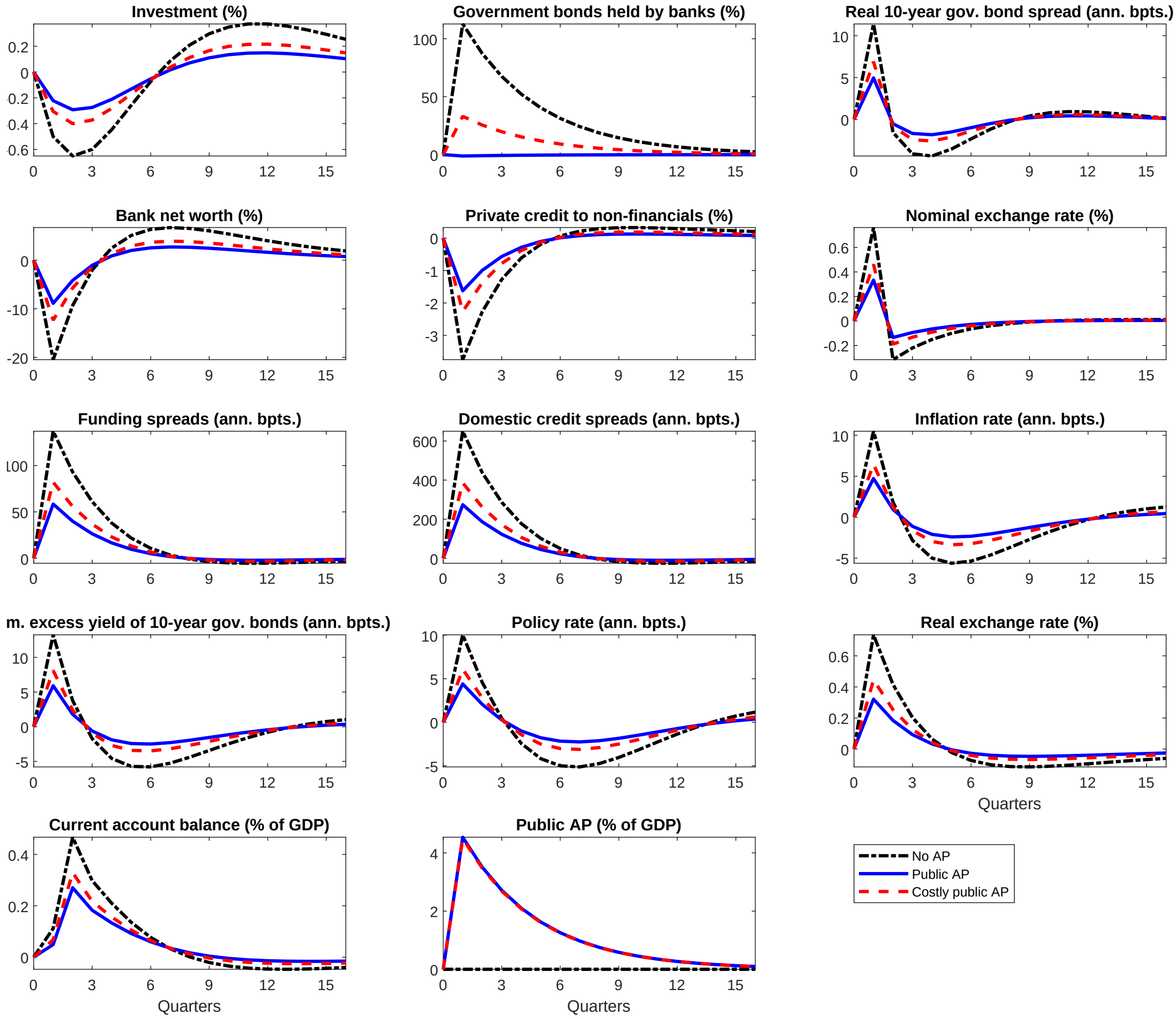


**Figure E.9:** Deviations from the steady state. The solid lines are the case of a public asset purchases policy program that reaches 4.5% of GDP at the peak in response to a concomitant bond sell-off shock. The dashed lines differ from this case by assuming that there are efficiency costs to the intermediation of government bonds by the central bank. Funding spread is the positive UIP deviation beyond country risk premium and expected exchange rate depreciation. Increases in the exchange rate denote depreciation. Real government bond spread is over domestic deposit rate. Nominal excess yield is over the US short–term rate.

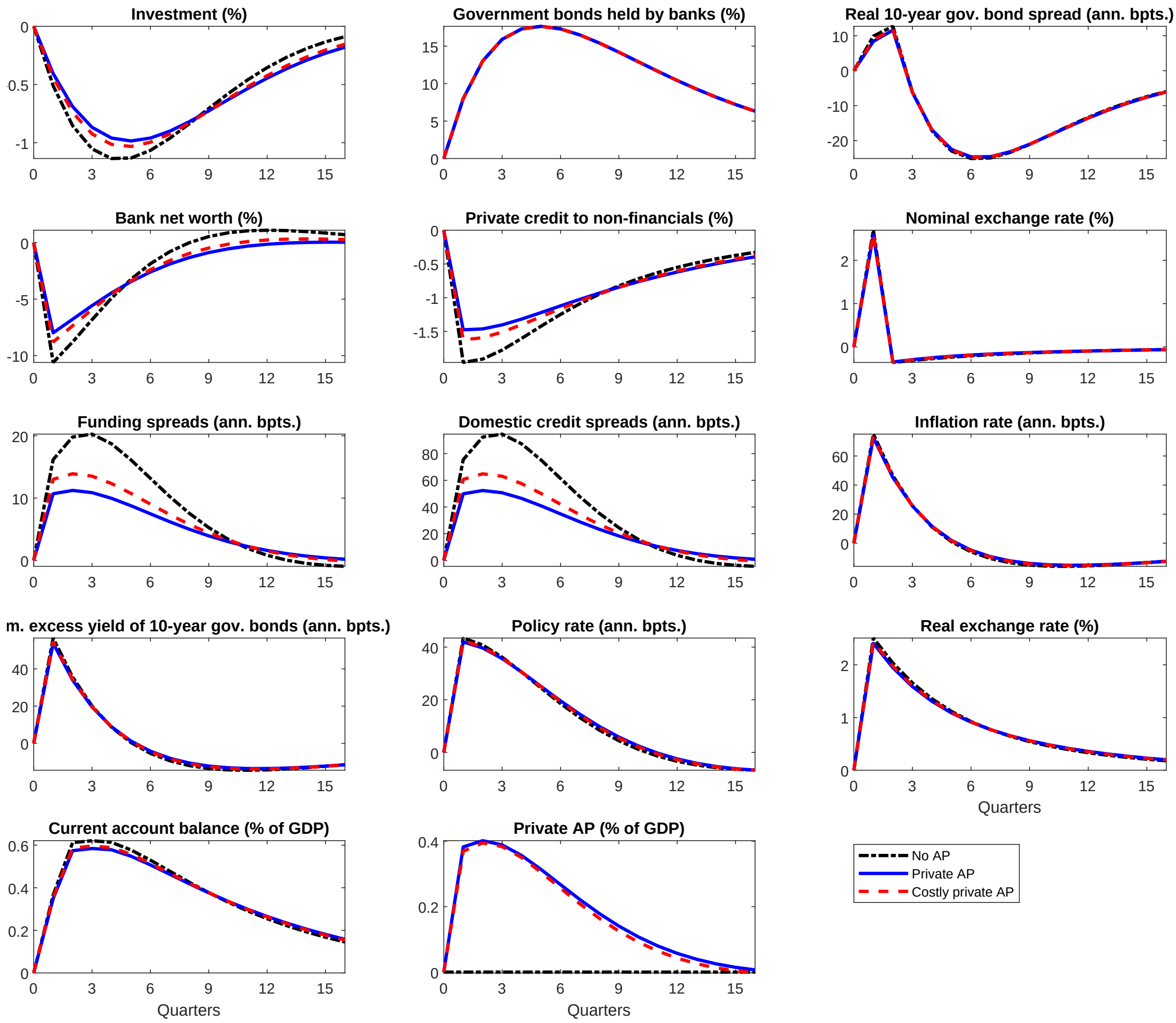


**Figure E.10:** Deviations from the steady state. The solid lines are the case of a private asset purchases policy program that reaches 0.5% of GDP at the peak in response to a country risk premium shock of 172 basis points in annualized terms. The dashed lines differ from this case by assuming that there are efficiency costs in intermediation of private securities by the central bank. Funding spread is the positive UIP deviation beyond country risk premium and expected exchange rate depreciation. Increases in the exchange rate denote depreciation. Real government bond spread is over domestic deposit rate. Nominal excess yield is over the US short–term rate.

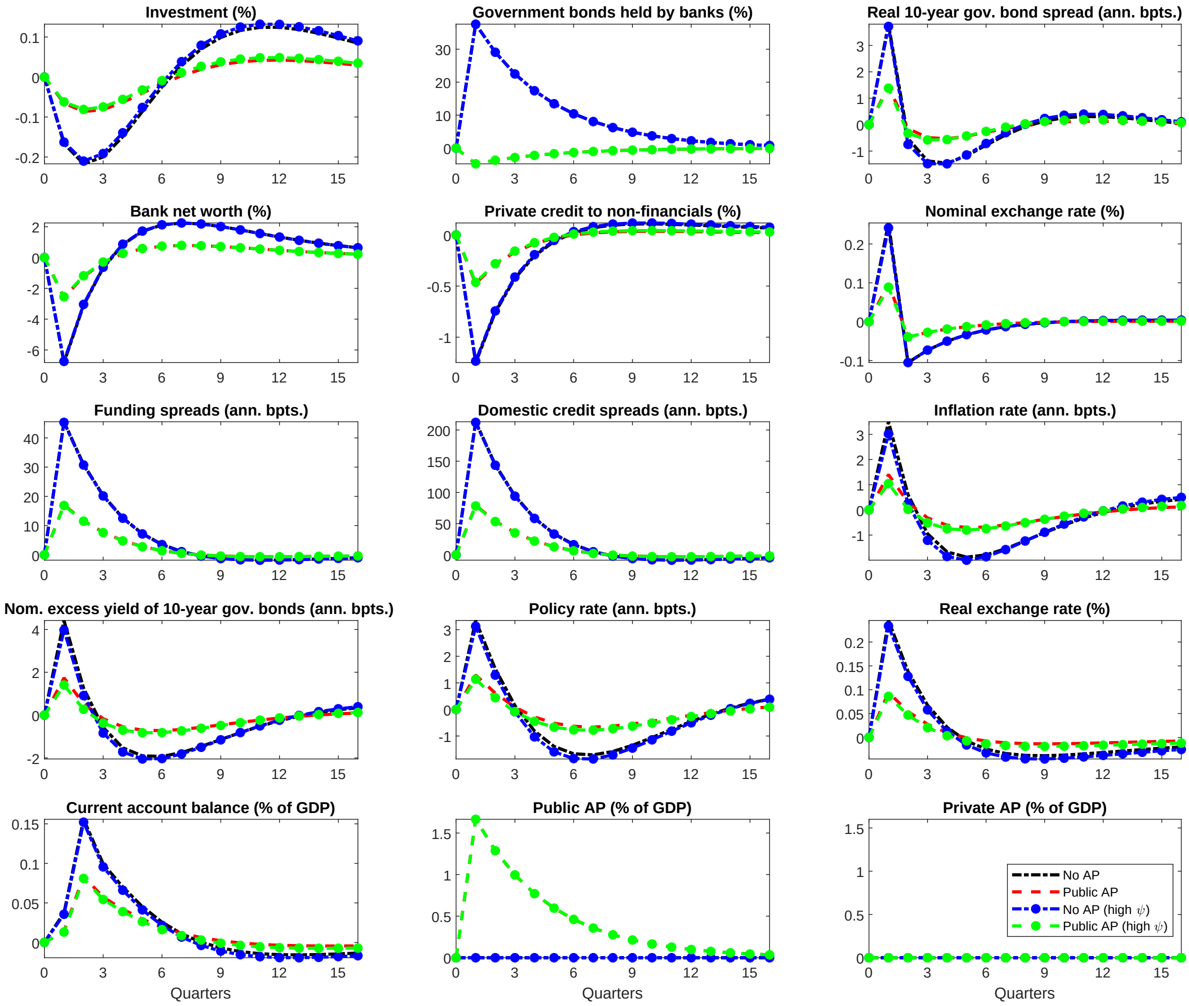


**Figure E.11:** Deviations from the steady state. The lines without dots are the cases with no asset purchases (fine-dashed lines) and public asset purchases (dashed lines) in response to the government bond sell-off shock presented in Figure 3 in the manuscript. Dotted lines that are counterparts of these refer to cases with a debt elasticity of country risk premium, $\psi$, that is 10 times larger. Funding spread is the positive UIP deviation beyond country risk premium and expected exchange rate depreciation. Increases in the exchange rate denote depreciation. Real government bond spread is over domestic deposit rate. Nominal excess yield is over the US short–term rate.

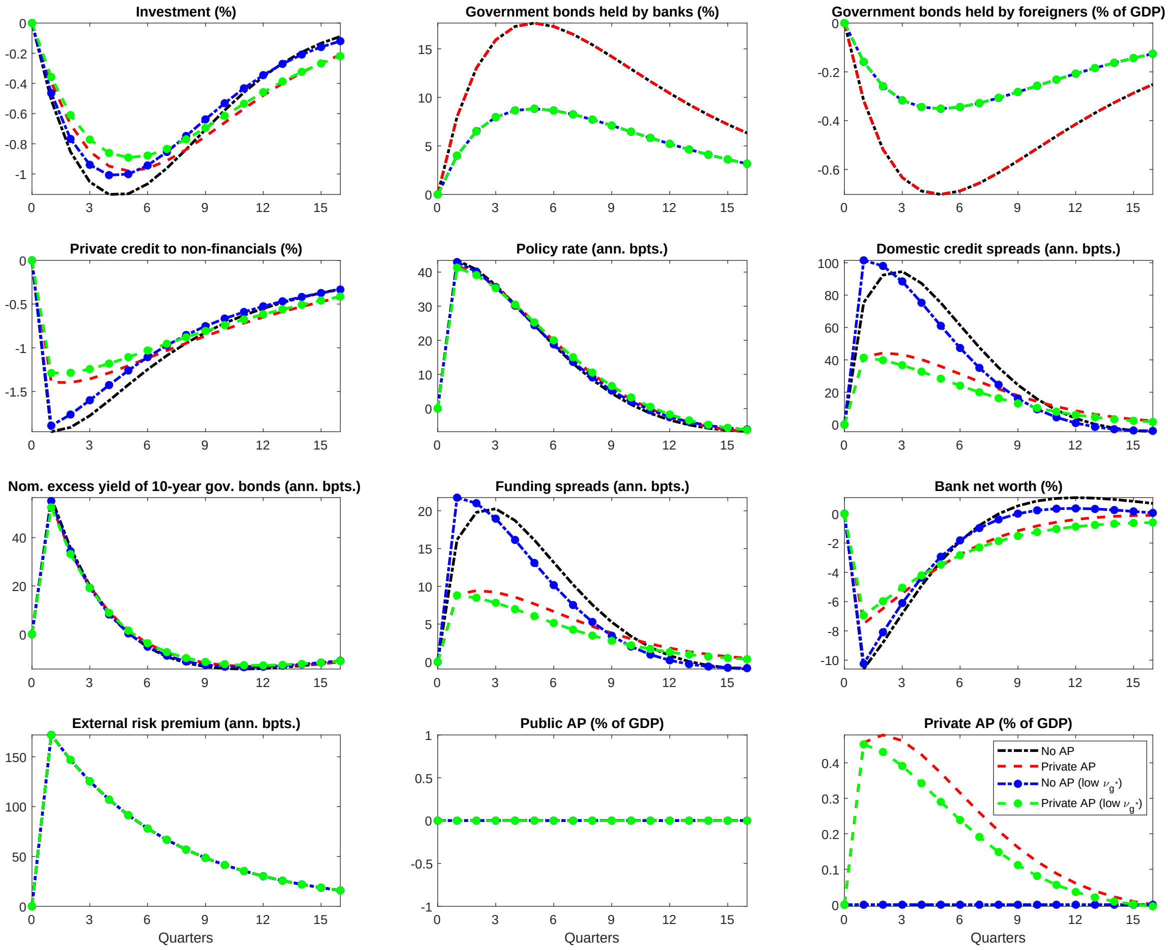


**Figure E.12:** Deviations from the steady state. The lines without dots are the cases with no asset purchases (fine-dashed lines) and private asset purchases (dashed lines) in response to the country risk premium shock presented in Figure 4 in the manuscript. Dotted lines that are counterparts of these refer to cases with a country risk premium elasticity of foreign investor-held government bonds, $\upsilon_{g^\star}$, that is reduced by half. Funding spread is the positive UIP deviation beyond country risk premium and expected exchange rate depreciation. Increases in the exchange rate denote depreciation. Real government bond spread is over domestic deposit rate. Nominal excess yield is over the US short–term rate.