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MONETARY POLICY IN THE OPEN ECONOMY WITH DIGITAL CURRENCIES

by Pietro Cova*, Alessandro Notarpietro*, Patrizio Pagano‡ and Massimiliano Pisani*

Abstract

We assess the transmission of a monetary policy shock in a two-country New Keynesian model featuring a global private stablecoin and a central bank digital currency (CBDC). In the model, cash and digital currencies are imperfect substitutes that differ as to the liquidity services they provide. We find that in a digital-currency economy, where the stablecoin is a significant means of payment, the domestic and international macroeconomic effects of a monetary policy shock can be smaller or larger than in a (benchmark) mainly-cash economy, depending on how the assets backing the stablecoin supply respond to the shock. The benchmark transmission of the monetary policy shock can nonetheless substantially be restored in the digital-currency economy 1) if the stablecoin is fully backed by cash or 2) if the CBDC is a relevant means of payment.

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Contents

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1 Introduction[1]

The retail payment system is undergoing a big change, pushed by the diffusion of new technologies. In advanced economies the use of physical cash is declining and digital means of payments are increasing.[2] If these trends were to persist or even accelerate, cash would end up losing its central role, becoming a means of payment that people would be reluctant to use because it would be less tailored to their needs. Global tech giants, the so-called "big techs" or "fintech" companies, may indirectly favor the decline in the use of cash by contributing to the rapid take-up of so-called stablecoins (SCs), i.e., digital units of value (currencies not physically minted) designed to minimise fluctuations in their price against a reference currency or basket of currencies.

The increasing demand and diffusion of international digital currencies issued by the private sector, including SCs, are under scrutiny. On the one hand, SCs could further drive innovation in payments, satisfying the need for more efficient and cheaper cross-border payments and remittances, compared to other existing means of payment. On the other hand, SCs raise concerns as their issuer cannot guarantee the certainty of the value of the payment instrument it offers to consumers. Moreover, large take-ups of SCs

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[2]According to Panetta (2021), "if given the choice, almost half of euro area consumers would prefer to pay with cashless means of payments, such as cards. Internet sales in the euro area have doubled since 2015. Cash is increasingly used as a store of value and decreasingly as a means of payment, a trend that the pandemic has accelerated. And while the cash stock has continued to increase and has even been boosted by the pandemic owing to higher precautionary demand for cash, only about 20% of the cash stock is now used for payment transactions, down from 35% fifteen years ago."

could jeopardize monetary sovereignty as this new means of payment may be intensively used across borders.[3] To satisfy the changing preferences of households and firms for digital means of payment, central banks are analysing and planning to issue their own digital currency (central bank digital currency, CBDC) .[4]

In this paper we evaluate the domestic and international macroeconomic effects of a monetary policy shock in a standard mainly-cash economy and compare it to that in a counterfactual scenario where digital currencies (SC and CBDC) are more important than cash in providing liquidity services. We focus on how the presence of private and central bank digital currencies affect the macroeconomic transmission of a monetary policy shock under alternative assumptions on the preferences for the digital currencies, their substitutability with cash, and the composition of the assets that back the SC.

The analysis is based on a two-country New Keynesian model.[5] Different from the standard specification, we relax the cashless-economy assumption. Specifically, we assume that in each country (one labeled Home, the other Foreign) households need liquidity to reduce transaction costs associated with consumption activity. Liquidity is a constant-elasticity-of substitution (CES) bundle composed by the physical cash issued by the central bank, the digital currency issued by the private fund, the CBDC, and the domestic (riskless) government bond. These assets are imperfect substitutes for the

[3]Adrian and Mancini-Griffoli (2019) claim that "transfers in digital money are nearly costless and immediate, and thus are often more attractive than card payments or bank-to-bank transfers especially across borders. People might sell their car for a digital-currency payment as the funds would immediately show up in their account, without any settlement lag and corresponding risks."

[4]For a discussion of characteristics of the CBDC see De Bonis and Ferrero (2020), ECB (2020) and Board of Governors of the Federal Reserve System (2022).

[5]For a description of the canonical New Keynesian model, see Woodford (2003). For a description of the two-country version of the model, see Benigno (2009).

liquidity services provided.

We model the private digital currency to capture, in a stylized way, the main features of existing SCs as opposed to generic cryptocurrencies.[6] The private digital currency is a SC issued by a profit-maximizing private fund owned by Foreign households. The SC is a claim on the private fund and is fully backed by Foreign cash, Foreign and Home (one-period riskless) sovereign bonds.[7] The value of the SC is thus linked to the prices of the assets that back it. This private digital currency is used as a source of liquidity in both countries. Thus, the Foreign country exports to the Home country not only goods but also SCs. Cash is, for simplicity, country-specific and issued by each central bank only to domestic households.[8] We allow Home households only to use a CBDC issued by the domestic central bank. The exchange rate of the CBDC vis-à-vis domestic cash is assumed fixed in nominal terms and equal to one. Households change the composition of their liquidity bundle in response to a given (monetary policy) shock according to (i) their preferences for each asset as liquidity provider and (ii) the assets' pecuniary returns (which are zero in the case of cash and digital currencies).

We simulate a standard monetary policy shock (i.e., a one-period shock to the Taylor rule guiding the central bank) and compare its transmission in the mainly-cash and in the digital-currency economies. Our main results are the following. In a digital-currency economy, where the SC is a significant

[6]A cryptocurrency is a digital token that can be transferred from peer to peer via cryptographic schemes that do not require identification. A SC is a particular type of cryptocurrency, whose value is always pegged to that of the underlying assets. See Adrian and Mancini-Griffoli (2019), Bullmann et al. (2019), and ECB Crypto Assets Task Force (2020).

[7]We speculate that the results we discuss below would not differ substantially if the SC is issued in the Home country and backed by domestic rather than foreign cash. In the paper we focus on the case of a SC issued in one country and the CBDC in the other to investigate the spillover effects between the two economies.

[8]We do not consider issues related to a currency, such as the U.S. Dollar, having a 'global' status. On the so-called 'exorbitant' privilege, see Cova et al. (2016).

means of payment, the domestic and international macroeconomic effects of a monetary policy shock can be smaller or larger than in a (benchmark) mainly-cash economy, depending on how the assets backing the SC supply respond to the shock. The benchmark transmission of the monetary policy shock can nonetheless substantially be restored in the digital-currency economy 1) if the SC is fully backed by cash or 2) if the CBDC is a relevant means of payment.

This paper contributes to the literature on the role of digital currencies for the monetary policy transmission mechanism in the open economy. Uhlig and Xie (2020) extend the basic New Keynesian model to evaluate the macroeconomic effects of the parallel currencies that are not under the control of a foreign central bank and are subject to exogenous exchange rate shocks. They focus on the unit-of-account role of currencies, i.e., their role in pricing decisions by producers. Ferrari et al. (2020) examine the open-economy implications of the introduction of a CBDC by developing a two-country DSGE model with financial frictions. CBDC can amplify the international spillovers of shocks, thereby increasing international linkages. Moreover, domestic issuance of a CBDC increases asymmetries in the international monetary system by reducing monetary policy autonomy in foreign economies. Benigno et al. (2019) use a two-country model featuring two national currencies and a global cryptocurrency issued by the private sector. They find that the cryptocurrency reduces monetary policy autonomy in both countries. Brunnermeier and Niepelt (2019) develop a model where a CBDC coupled with central bank pass-through funding need not imply a credit crunch nor undermine financial stability. According to Brunnermeier et al. (2019) digital currencies may cause an upheaval of the international monetary system, because countries that are socially or digitally integrated with their neighbors may face digital dollarization. CBDC could ensure that public money remains a relevant unit of account. Different from these contributions, we focus on a global SC and a domestic CBDC as sources of liquidity and on the domestic and international transmission of a monetary policy shock in a digitalised economy. As in Canzoneri et al. (2008) and in Cova et al. (2019), we assume that liquidity is provided by a bundle of assets. In this paper we add to the bundle, besides cash and government bonds, a SC and a CBDC. Thus, we assume the coexistence of different means of payment, providing different degrees of liquidity, which should be the case at least in the initial phase of digitalisation of the payment system.[9] We also endogeneize the supply of the SC, linking the digital currency to the assets that back it through the maximization problem solved by the fund.

The rest of the paper is organized as follows. The next section describes the model setup. Section 3 reports the calibration and illustrates the simulated scenarios. Section 4 contains the results. Section 5 concludes.

2 Model

We develop a two-country New Keynesian model with nominal price rigidities. One country is labeled Home, the other Foreign. In each country there is a representative household that consumes a bundle of domestic and imported non-durable goods, supplies labour under perfect competition to the representative domestic firm and invests in financial assets. Different from the canonical model, we allow for several financial assets and currencies that provide liquidity services: physical cash issued by each central bank to domestic households; CBDC issued by the Home central bank to domestic

[9] For possible scenarios see ECB (2020).

households; SC, issued to both Home and Foreign households by a fund owned by the Foreign households; one-period sovereign bonds, issued by the fiscal authorities in domestic currency and paying the domestic monetary policy rate. All these financial assets enter a household's liquidity bundle, provide liquidity services and, thus, reduce the transaction costs associated with consumption activity. There is imperfect substitutability among these assets, because they differ for the amount of provided liquidity services. There is also a one-period bond, issued by the households and denominated in Foreign currency, which is internationally traded and does not provide liquidity services. The Foreign fund is also a novel feature of the model and it captures the SC nature of the private digital currency. The fund acts under perfect competition and maximizes profits by issuing the SC, backed by domestic physical cash and Home and Foreign sovereign bonds.[10]

Remaining features of the model are rather standard, except for the emission of CBDC by the central bank. Each country is specialized in the production of an intermediate good that is internationally traded for consumption purposes. In each country there is a representative firm producing a tradeable good under monopolistic competition using labor supplied by the domestic household as input. Each firm is price-setter and nominal price rigidities hold. Domestic and foreign nominal prices are set in the government currency of the destination market taking into account local demand conditions and nominal-price quadratic adjustment costs (local currency pricing assumption).[11] Firms' profits from monopolistic competition

[10]The fund maximizes profits based on financial variables alone. Thus we do not capture returns of Big Techs from user data and potential lock-in effects in multi-sided markets. Such players may even be willing to operate the SC at a loss because they reap other rewards. We leave the analysis of these relevant dimensions of the SC issuer maximization problem for future research.

[11]Adjustment costs are similar to Rotemberg (1982). The prices are also indexed to previous-period inflation and to the inflation target of the central bank, with corresponding weights summing to 1.

are rebated in a lump-sum way to the domestic household. Each country's central bank sets the monetary policy according to a Taylor rule, where the policy rate reacts to its previous-period value (to capture inertia in the monetary policy conduct) and to the current inflation rate and quarterly output growth. In the case of the Home country, the central bank transfers physical cash and CBDC in a lump-sum way to domestic households and consistent with the Taylor rule-based policy rate. The amounts of cash and CBDC are determined by the household's corresponding demands. The exchange rate between cash and CBDC is constant and set to one. They are imperfect substitutes among each other and with other financial assets.[12] Similarly, the Foreign central bank transfers physical cash in a lump-sum way to domestic households and the fund consistently with the Taylor rule-based policy rate. The nominal exchange rate between Home and Foreign government currencies is determined to guarantee the equilibrium in goods and financial markets. Finally, in each country the fiscal authority issues one-period riskless sovereign bonds and stabilizes public debt by changing lump-sum taxes paid by domestic households according to a fiscal rule. In what follows we report the key equations of the model, i.e., those that describe the liquidity bundle, the Foreign fund that issues the SC, the monetary policy, and the fiscal policy.[13]

2.1 The liquidity bundle

Similarly to Schmitt-Grohe and Uribe (2004) we assume that in each country the representative household pays a transaction cost for each consumption purchase proportional to consumption, with a factor of proportionality that

[12]In the case of perfect substitutability, i.e., with elasticity of substitution equal to plus infinity, it would not be possible to determine the quantity of cash and CBDC separately.

[13]The remaining equations are more standard and are reported in the Appendix.

is an increasing function of liquidity velocity. In the Foreign country case, the transaction cost is:[14]

$$\tau_t^* = \left(\frac{A^*}{v_t^*}\right)(v_t^* - \bar{v}^*)^2, \tag{1}$$

where v^* is the velocity, $\bar{v}^*$ is the satiation level of velocity and $A^* > 0$ is a parameter. Velocity depends in turn on nominal spending for consumption and overall liquidity holdings, according to the relation

$$v_t^* = \frac{P_t^* C_t^*}{\tilde{M}_t^*}, \tag{2}$$

where P^* is the consumption deflator, C^* is real consumption, and $\tilde{M}^*$ is overall liquidity holdings.

The liquidity bundle $\tilde{M}^*$ used for transaction services associated with consumption purposes is

$$\tilde{M}_t^* = \left[a_{M_G^*}^{\frac{1}{\lambda_L}}\left(M_{G,t}^{HOU*}\right)^{\frac{\lambda_L-1}{\lambda_L}} + a_{M_D^*}^{\frac{1}{\lambda_L}}\left(M_{D,t}^*\right)^{\frac{\lambda_L-1}{\lambda_L}} + \left(1 - a_{M_G^*} - a_{M_D^*}\right)^{\frac{1}{\lambda_L}}\left(B_{G,t}^{F,HOU*}\right)^{\frac{\lambda_L-1}{\lambda_L}}\right]^{\frac{\lambda_L}{\lambda_L-1}}, \tag{3}$$

where $\tilde{M}_t^*$ is composed by the physical cash $M_{G,t}^{HOU*}$, digital currency $M_{D,t}^*$, and domestic government bonds $B_{G,t}^{F,HOU*}$, $\lambda_L > 0$ is the elasticity of substitution among the different assets, $a_{M_G^*}, a_{M_D^*}$ are parameters measuring the weight of the corresponding asset in the bundle ($0 < a_{M_G^*}, a_{M_D^*} < 1$, $a_{M_G^*} + a_{M_D^*} < 1$).[15] In the case of Foreign households, the digital currency $M_{D,t}^*$ is equal to the quantity of SC $M_{SC,t}^*$ issued by the Foreign fund, con-

[14]Similar equations hold in the Home country.

[15]Superscript HOU denotes the stock of assets - physical cash and government bonds - held by households. The holdings of these assets by the fund, as shown in the next subsection, are instead denoted by superscript FU*.

verted in Foreign currency units:

$$M^*_{D,t} = S^{F,SC}_t M^*_{SC,t}, \tag{4}$$

where the variable $S^{F,SC}_t$ is the nominal exchange rate of the Foreign government currency vis-à-vis the digital currency (number of Foreign government currency units per unit of digital currency).

In the case of Home households, the digital currency is a bundle composed by the SC issued by the Foreign fund, $M_{SC,t}$, and the CBDC issued by the Home central bank $M_{CBDC,t}$

$$M_{D,t} = \left[a_{M_{CBDC}}^{\frac{1}{\lambda_D}} M_{CBDC,t}^{\frac{\lambda_D - 1}{\lambda_D}} + (1 - a_{M_{CBDC}})^{\frac{1}{\lambda_D}} \left(S^{H,SC}_t M_{SC,t} \right)^{\frac{\lambda_D - 1}{\lambda_D}} \right]^{\frac{\lambda_D}{\lambda_D - 1}}, \tag{5}$$

where $a_{M_{CBDC}}$ is the weight of the CBDC in the bundle ($0 < a_{M_{CBDC}} < 1$) and $\lambda_D > 0$ is the elasticity of substitution between the SC and the CBDC. The variable $S^{H,SC}_t$ is the nominal exchange rate of the Home government currency vis-à-vis the SC (number of Home currency units per unit of SC). Thus, we assume coexistence of different means of payment, providing different degrees of liquidity, which is very likely to be the case at least in the initial phase of digitalisation of the payment system. The household maximizes her intertemporal utility separable in consumption and labor, subject to the budget constraint, in which the transaction cost (see Eq. 1) enters as it pre-multiplies consumption. The first-order conditions with respect to consumption, labor, and the several financial assets correspond to consumption demand, labor supply, and demands for the multiple assets, respectively. The asset demands are such that the expected returns are equalized. The returns have both pecuniary and non-pecuniary components, with the latter associated with the provided liquidity services.

The optimality conditions of Foreign households with respect to consumption C_t^*, physical cash $M_{G,t}^{HOU*}$, SC $M_{SC,t}^*$, and domestic government bond holdings, $B_{G,t}^{F,HOU*}$ are as follows:

$$\Lambda_t^* = \frac{\left(C_t^* - \xi C_{t-1}^*\right)^{-\sigma}}{\left[1 + 2A^* \left(v_t^* - \bar{v}^*\right)\right]}, \quad (6)$$

$$1 - A^* \left[(v_t^*)^2 - (\bar{v}^*)^2\right] a_{M_G^*}^{\frac{1}{\lambda_L}} \left(\frac{\tilde{M}_t^*}{M_{G,t}^{HOU*}}\right)^{\frac{1}{\lambda_L}} = E_t \left(\beta \frac{\Lambda_{t+1}^*}{\Lambda_t^*} \frac{P_t^*}{P_{t+1}^*}\right), \quad (7)$$

$$1 - A^* \left[(v_t^*)^2 - (\bar{v}^*)^2\right] a_{M_D^*}^{\frac{1}{\lambda_L}} \left(\frac{\tilde{M}_t^*}{S_t^{F,SC} M_{SC,t}^*}\right)^{\frac{1}{\lambda_L}} = E_t \left(\beta \frac{\Lambda_{t+1}^*}{\Lambda_t^*} \frac{P_t^*}{P_{t+1}^*} \frac{S_{t+1}^{F,SC}}{S_t^{F,SC}}\right), \quad (8)$$

$$1 - A^* \left[(v_t^*)^2 - (\bar{v}^*)^2\right] \left(1 - a_{M_G^*} - a_{M_D^*}\right)^{\frac{1}{\lambda_L}} \left(\frac{\tilde{M}_t^*}{B_{G,t}^{F,HOU*}}\right)^{\frac{1}{\lambda_L}}$$
$$= R_t^* E_t \left(\beta \frac{\Lambda_{t+1}^*}{\Lambda_t^*} \frac{P_t^*}{P_{t+1}^*}\right), \quad (9)$$

where Λ_t^* is the marginal value of wealth, $0 \leq \xi < 1$ is a parameter measuring consumption's (external) habit and $\sigma > 0$ is a parameter corresponding to the inverse of the intertemporal elasticity of substitution.[16] Eq. 6 states that the marginal value of wealth is lowered by the transaction costs. Eq. 7 states that the current value of physical cash holdings, which yield zero pecuniary returns, but provide transaction services (the left-hand side of the equation), should be equal to the real present value of the return on saving (the right-hand side of the equation), i.e., the household's stochastic discount factor in real terms. A similar intuition holds for the demand of SC, as illustrated by Eq. 8. Eq. 9 shows that the presence of a liquidity premium, decreasing in the stock of government bonds outstanding (left-hand side of the equation),

[16]The remaining first order conditions are reported in the Appendix.

determines the spread between the interest rate on short-term government bonds, R^*, and that on an illiquid asset, as measured by the stochastic discount factor. Thus, due to the presence of transaction services, interest rates differ from a standard model in which assets are perfect substitutes. The 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 services (measured by its weight in the transaction technology, i.e., parameters $a_{M_G^*}$ and $a_{M_D^*}$ in the definition of $\tilde{M}_t^*$) and its "pecuniary" return. At the margin, expected returns of different assets are equated, taking into account the transaction services provided by each asset.[17]

Similar equations hold for the Home households, with one exception. In the case of Home households, Eq. 4 does not hold. Instead, the Home digital currency is defined by Eq. 5. Thus, on top of equations similar to Eqs. 6, 7, 9, the following two additional first-order conditions with respect to CBDC M_{CBDC}, and SC $M_{SC,t}$ also characterize Home households' optimal choices, respectively:

$$1 - A\left[(v_t)^2 - (\bar{v})^2\right] a_{M_D}^{\frac{1}{\lambda_L}} a_{M_{CBDC}}^{\frac{1}{\lambda_D}} \left(\frac{\tilde{M}_t}{M_{D,t}}\right)^{\frac{1}{\lambda_L}} \left(\frac{M_{D,t}}{M_{CBDC,t}}\right)^{\frac{1}{\lambda_D}} = E_t\left(\beta\frac{\Lambda_{t+1}}{\Lambda_t}\frac{P_t}{P_{t+1}}\right), \quad (10)$$

$$1 - A\left[(v_t)^2 - (\bar{v})^2\right] a_{M_D}^{\frac{1}{\lambda_L}} \left(1 - a_{M_{CBDC}}\right)^{\frac{1}{\lambda_D}} \left(\frac{\tilde{M}_t}{M_{D,t}}\right)^{\frac{1}{\lambda_L}} \left(\frac{M_{D,t}}{S_t^{H,SC} M_{SC,t}}\right)^{\frac{1}{\lambda_D}} = E_t\left(\beta\frac{\Lambda_{t+1}}{\Lambda_t}\frac{P_t}{P_{t+1}}\frac{S_{t+1}^{H,SC}}{S_t^{H,SC}}\right). \quad (11)$$

[17] 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.

2.2 The Foreign fund

The representative Foreign fund issues under perfect competition the SC to both Home and Foreign households. It is owned by Foreign households and maximizes the expected stream of profits with respect to the amounts of issued SC, Foreign government bonds, Home government bonds, and Foreign physical cash (the latter three assets back the SC). Thus, it maximizes

$$E_t \left(\sum_{j=0}^{\infty} \beta^j \frac{\Lambda^*_{t+j}}{\Lambda^*_t} \Omega^{FU*}_{t+j} \right), \tag{12}$$

where $\beta^j \Lambda^*_{t+j} / \Lambda^*_t$ is the representative Foreign household's stochastic discount factor between generic periods t and $t+j$ – with $0 < \beta < 1$ being the household's rate of time preference and Λ^*_{t+j} and Λ^*_t the Foreign household's marginal utility of consumption in period $t+j$ and t, respectively. The term Ω^{FU*}_{t+j} represents the period-$t+j$ profits in real terms, i.e., deflated by the Foreign consumption price index. Real profits in the generic period t are

$$\begin{aligned} \Omega^{FU*}_t = & \left(S^{F,SC}_t \frac{M^{FU*}_{SC,t}}{P^*_t} - S^{F,SC}_t \frac{M^{FU*}_{SC,t-1}}{P^*_t} \right) \\ & - \left(\frac{M^{FU*}_{G,t}}{P^*_t} - \frac{M^{FU*}_{G,t-1}}{P^*_t} \right) \\ & - \left(\frac{B^{F,FU*}_{G,t}}{P^*_t} - R^*_{t-1} \frac{B^{F,FU*}_{G,t-1}}{P^*_t} \right) \\ & - \left(\frac{S_t B^{H,FU*}_{G,t}}{P^*_t} - R_{t-1} \frac{S_t B^{H,FU*}_{G,t-1}}{P^*_t} \right) + TR^{FU*}_t, \end{aligned} \tag{13}$$

where P^*_t is the period-t Foreign consumption deflator, $M^{FU*}_{G,t}$ is the (physical) cash issued by the Foreign central bank and held by the fund, $B^{F,FU*}_{G,t}$ is the fund's holdings of Foreign government bonds paying the (gross) Foreign monetary policy rate R_t^*, $B_{G,t}^{H,FU*}$ is the holdings of Home government bonds denominated in Home currency terms and paying the Home monetary policy rate R_t, and S_t is the nominal exchange rate of Foreign government currency vis-à-vis Home government currency, defined as number of Foreign currency units per unit of Home currency. The variable TR_t^{FU*} represents transfers from the domestic government. The fund converts Foreign cash, Foreign government bonds, and Home government bonds into SC quantities subject to the following technology constraint:

$$M_{SC,t}^{FU*} = \Bigg[b_{M_G^{FU*}}^{\frac{1}{\lambda_{FU}}} \left(\frac{M_{G,t}^{FU*}}{P_t^*}\right)^{\frac{\lambda_{FU}-1}{\lambda_{FU}}} + b_{B_G^{F,FU*}}^{\frac{1}{\lambda_{FU}}} \left(\frac{B_{G,t}^{F,FU*}}{P_t^*}\right)^{\frac{\lambda_{FU}-1}{\lambda_{FU}}} + \left(1 - b_{M_G^{FU*}} - b_{B_G^{F,FU*}}\right)^{\frac{1}{\lambda_{FU}}} \left(\frac{S_t B_{G,t}^{H,FU*}}{P_t^*}\right)^{\frac{\lambda_{FU}-1}{\lambda_{FU}}} \Bigg]^{\frac{\lambda_{FU}}{\lambda_{FU}-1}}, \quad (14)$$

where $\lambda_{FU} > 0$ is the elasticity of substitution and $0 < b_{M_G^{FU*}}, b_{B_G^{F,FU*}} < 1$, and $\left(1 - b_{M_G^{FU*}} - b_{B_G^{F,FU*}}\right)$ are the weights of cash issued by the Foreign central bank, the Foreign sovereign bond, and the Home sovereign bond, respectively $\left(b_{M_G^{FU*}} + b_{B_G^{F,FU*}} < 1\right)$. The implied first-order conditions provide the fund's supply of SC and demands of cash and sovereign bonds.[18] Finally, consistent with the assumptions of a global SC market and perfectly competitive fund, the law of one price holds for SC, i.e., the SC price is the same in both countries when expressed in the same currency.

[18] They are reported in the Appendix.

2.3 Monetary and fiscal policy rules

In each country the central bank sets the policy rate according to the Taylor rule. In the Foreign country, it is

$$\left(\frac{R_t^*}{\bar{R}^*}\right)^4 = \left(\frac{R_{t-1}^*}{\bar{R}^*}\right)^{4\rho_R} \left(\frac{\Pi_{t,t-3}^*}{\left(\bar{\Pi}^*\right)^4}\right)^{(1-\rho_R)\rho_\pi} \left(\frac{Y_t^*}{Y_{t-1}^*}\right)^{(1-\rho_R)\rho_y} \epsilon_{R^*}. \tag{15}$$

The parameter ρ_R $(0 < \rho_R < 1)$ captures inertia in interest-rate setting, while the term $\bar{R}^*$ represents the steady-state gross nominal policy rate. The parameters ρ_π and ρ_y are respectively the weights of the gross yearly CPI inflation rate $\Pi_{t,t-3}^* \equiv P_t^*/P_{t-4}^*$, in deviation from the (steady-state) target $\left(\bar{\Pi}^*\right)^4$, and the gross quarterly growth rate Y_t^*/Y_{t-1}^* of output Y^*. The variable ϵ_{R^*} is the exogenous shock to the monetary policy rate.[19] The Foreign central bank transfers physical cash to Foreign households and to the Foreign fund in a lump-sum way, consistent with the corresponding demands and with the monetary policy rule. Similarly, the Home central bank transfers physical cash and CBDC in a lump-sum way to domestic households, consistent with its Taylor rule-based policy rate (the Home Taylor rule is similar to the Foreign one). The amounts of cash and CBDC are determined by the household's corresponding demands. In the case of the Home central bank, the amount of money supplied by the central bank is equal to the sum of physical cash and CBDC, i.e.

$$M_t^S = M_{G,t}^{HOU} + M_{CBDC,t}. \tag{16}$$

The Foreign government budget constraint (the consolidated central

[19] A similar equation holds in the Home country.

bank and fiscal authority budget constraint) is

$$B^*_{G,t} - B^*_{G,t-1} R^*_{t-1} + M^{S*}_t - M^{S*}_{t-1} = TR^*_t, \tag{17}$$

where $B^*_{G,t}$ is a one-period nominal bond that pays the (gross) interest rate R^*_t ($B^*_{G,t} > 0$ is public debt) and $M^{S*}_t > 0$ is the amount of money supplied by the central bank. The variable $TR^*_t > 0$ (< 0) are lump-sum transfers (lump-sum taxes) to domestic households and to the fund (i.e., $TR^*_t = TR^{HOU*}_t + TR^{FU*}_t$).

The fiscal authority follows a fiscal rule defined on lump-sum transfers as a percentage of domestic output, tr, to bring the public debt as a percentage of domestic output, $b^*_{G,t-1} > 0$, in line with its (steady-state) target $\bar{b}^*_G$. The rule is

$$\frac{tr^*_t}{\bar{tr}^*} = \left(\frac{b^*_{G,t-1}}{\bar{b}^*_G}\right)^{\phi}, \tag{18}$$

where the parameter ϕ is lower than zero, calling for a reduction (increase) in lump-sum transfers relative to the steady-state value $\bar{tr}^*$ whenever the previous-period public debt is above (below) the target. We choose lump-sum transfers to stabilize public finances as they are non-distortionary and, thus, allow for a clean evaluation of the transmission mechanism of the monetary policy shock.

3 Calibration and simulated scenarios

3.1 Calibration

The model is calibrated at quarterly frequency. For simplicity we assume that Home and Foreign have equal size and symmetric structure. The only exceptions are the SC-issuing fund, which is owned by the Foreign households only, and the CBDC, which is issued only by the Home central bank and held only by Home households. Parameters are set in line with the existing literature and to the same value across countries when possible.

Table 1 reports the steady-state values of households' consumption, import, and public debt (all as % of GDP, the only exception is public debt reported as % of annualized GDP). It also shows the steady-state nominal interest rate, set to 1.98% in annualized percentage points. Private consumption is set to 100% of GDP, given that there is no investment in physical capital and no public consumption in the model. Public debt supply is set to 60%.

Table 2 contains the parameters of households' preferences and of the fund's and firms' technologies that allow us to get the values in Table 1. The household's discount factor is set to 0.9951. Cash has a relatively large weight in the households' liquidity bundle (see Eq. 3), while SC's and government's weights are small. The elasticity of substitution among different assets is set to 1 (Cobb-Douglas case). In the case of Home households there is an additional layer in the liquidity bundle, because the digital currency does not coincide with SC as in the Foreign case, but it is a bundle of Foreign SC and Home CBDC (see Eq. 5). It is assumed that the former has a larger weight than the latter. The elasticity of substitution is set to 1. In the Foreign fund's bundle (see Eq. 14), the weight of Foreign cash is larger than that of Foreign and Home bonds. The elasticity of substitution between cash and bonds is set to 1. Table 3 reports the calibration of the monetary and fiscal rules. Each central bank strongly reacts to inflation and, to a lower extent, to output growth. For fiscal rules, lump-sum transfers are changed to stabilize public debt.

3.2 Simulated scenarios

We assess how the digital currencies affect the macroeconomic transmission of the (standard) monetary policy shock by considering alternative weights of SC and CBDC in the liquidity bundle under alternative assumptions on (i) the assets that back the SC and (ii) the substitutability among the different sources of liquidity.

All scenarios are run under perfect foresight. Thus, there is no uncertainty and agents fully anticipate the values of the monetary policy rate, with the exception of the monetary policy shock in the first period (which surprises economic agents).

4 Results

4.1 Expansionary Foreign monetary policy shock

Fig. 1-2 contain the domestic and international macroeconomic effects of an exogenous one-period one-percentage-point reduction (annualized terms) in the Foreign monetary policy rate under the following alternative assumptions: (i) mainly-cash economy, in which the (benchmark) weights of physical cash and digital currency in both Home and Foreign liquidity bundles, i.e. parameters $a^*_{M_G}$ and $a^*_{M_D}$ in Eq. 3, are set to 0.8 and 0.1, respectively (black continuous line); (ii) digital-currency economy, characterized by lower and higher weights of cash and digital currency, respectively, i.e. $a^*_{M_G} = 0.5$ and $a^*_{M_D} = 0.4$ (red dashed line); (iii) on top of the assumptions of case (ii), a higher weight of CBDC in the Home household's liquidity bundle is assumed in the digital-currency economy, i.e., in Eq. 5 the CBDC parameter $a_{M_{CBDC}}$ is set to 0.9 (0.2 in the other cases) and the corresponding weight of the SC to 0.1 (0.8) (green crossed line). After the initial period, in which the monetary policy shock materializes, the policy rate resumes to follow the Taylor rule (see Eq. 15).

As shown in Fig. 1, the sign of responses of the main Foreign variables is as expected, i.e., household's consumption increases, consistent with the higher available liquidity and the implied lower transaction cost, inducing firms to raise output and prices (inflation increases).

The Foreign household substitutes cash for SC and sovereign bonds, given that the SC price has increased and the sovereign bonds pay a lower interest rate (i.e., the Foreign monetary policy rate).

The increase in Foreign output is lower in the case of a higher weight of the SC in the household's portfolio (digital-currency economy, red-dashed line). The increase in Foreign government currency, associated with the monetary stimulus, is less effective in reducing the transaction cost paid by Foreign households, because of the lower weight of cash in the liquidity bundle. As the expansionary monetary policy lowers the returns on bonds, the fund reduces bond holdings. Since they are used to back the SC, the supply of SC falls. In equilibrium, the reduction in the supply of SC, whose weight in the liquidity bundle is higher in the digital-currency economy, limits the increase in overall liquidity. Consumption increases less than in the benchmark (mainly-cash) economy. Hence, the stimulating effect on economic activity is lower in the digital-currency economy than in the mainly-cash economy.

As shown in Fig. 2, in all cases considered the spillovers to the Home economic activity are expansionary as both output and inflation increase. The higher Foreign aggregate demand is partly satisfied by higher imports (i.e., higher Home exports). Home consumption decreases, because the Home central bank follows the Taylor rule (Eq. 15) and, thus, raises the policy rate to stabilize domestic inflation and economic activity. The higher Home policy rate and the lower Foreign monetary policy rate favour the appreciation in real terms of the Home government currency vis-à-vis its Foreign counterpart. The decrease in Home consumption and the increase in Home output imply the rise in Home savings, which finance the higher Foreign consumption.

In the case of the digital-currency economy the spillovers to Home output are smaller, because the lower increase in Foreign aggregate demand limits the increase in Home exports. Home consumption decreases less, consistent with the lower increase in the Home policy rate.

Fig. 1-2 show also the case of a larger weight of CBDC in the Home household's liquidity bundle in the digital-currency economy (green crossed lines), namely one in which the CBDC parameter $a_{M_{CBDC}}$ in Eq. 5 is set to 0.9 (0.2 in the other cases) and the weight of the SC to 0.1 (0.8).

Relative to the case of a high weight of the SC, in the initial periods Home household's liquidity increases because it reflects the larger weight of the CBDC, whose supply increases. Thus, the Home transaction cost initially falls, sustaining Home consumption, which decreases to a smaller extent. Home economic activity and inflation both increase. Subsequently, Home liquidity decreases, consistent with the fall in both cash and CBDC. Home households reduce their SC holdings in favor of Foreign household's SC holdings. The latter increase to a larger extent, reducing the transaction cost. Thus, Foreign consumption increases more than in the case of smaller CBDC weight and its response is closer to the benchmark case (see Fig. 1). Responses of all the main Home and Foreign macroeconomic variables are closer to their counterparts in the benchmark (less digitalized) economy.

Overall, we find that the transmission of a monetary policy shock is somewhat smaller in the digital-currency economy than in the mainly-cash economy.[20] The macroeconomic effects of a monetary policy shock are smaller if households have a larger preference for private digital currency than for government currencies (physical cash and CBDC) and, thus, the central bank is less able to modify overall households' liquidity for consumption purposes. At the same time, the transmission of a monetary policy shock in the digital-currency economy is close to the one in the mainly-cash economy provided the central bank issues CBDCs and there is a sufficiently large household's demand for them.[21]

4.2 The role of government bonds' supply

In the simulations reported in the previous section the supply of the Foreign government bonds largely decreases on impact, as the calibration of the fiscal rule (Eq. 18) in each country commands a relatively mild decrease in lump-sum taxes following the reduction in the public debt-to-output ratio (the latter decreases after the Foreign monetary policy shock because of the output increase). Thus, fewer Foreign government bonds are available to both households and fund. The latter uses Home and Foreign bonds to back, jointly with Foreign cash, the SC. As a result, the supply of SC falls.

Fig. 3-4 report the effects of the Foreign monetary policy shock under the assumption that Home and Foreign fiscal authorities stabilize public debt more than in the cases reported in the previous section.[22] Relative to the

[20]This result would hold also in absence of CBDC. Simulation results available upon request.

[21]Results would be symmetric to those reported in this section in the case of a positive, i.e., restrictive, monetary policy shock, given that the model is close to linear. Assessing the role of nonlinearities, such as the effective lower bound on the monetary policy rate, is left for future research.

[22]We set the coefficient in the both Home and Foreign fiscal rules to -10, a much higher

benchmark calibration, now the supply of public debt initially decreases less and subsequently returns to its baseline level at a faster pace, temporarily overshooting it. Thus, there is a relatively larger supply of Foreign government bonds available to back the supply of SCs. In fact, the latter now increases in the medium run, instead of decreasing as in the previous section, stimulating Foreign liquidity compared to the mainly-cash economy. The transaction cost decreases, sustaining household's consumption, economic activity, and inflation, whose responses, in the case of digital-currency economy (red dashed lines) are somewhat larger than those in the benchmark case of the mainly-cash economy (black continuous lines). Expansionary, trade-related, spillovers to the Home economy are also enhanced and larger than those in the benchmark economy.

Thus, if the SC is a significant means of payment, the responses of its supply and of the assets that back it matter for the size of the macroeconomic effects of a monetary policy shock, because the SC greatly affects the overall liquidity available to households. Finally, as in the previous section, Home and Foreign responses are closer to the corresponding benchmark ones (black continuous line) in the case of high CBDC weight (green line with crosses).

4.3 The case of a 100%-cash-backed SC

A widely debated question is whether the currency composition of assets backing SCs should be adjusted to hedge users against losses originating from fluctuations of the exchange rate of domestic (Home and Foreign) currencies (e.g. as in the case of token-based cryptocurrencies).[23]

value in absolute terms than the benchmark value, equal to -0.007 (see parameter ϕ in Eq. 18).

[23] This concern has received some concrete attention. For example, in the White Paper published by the Diem consortium in 2020 the possibility of including single-currency SCs alongside the multi-currency version is explicitly mentioned to warrant the full preser-

In our setup the SC is backed by various liquid assets whose supplies are under the direct control of public authorities (i.e. cash and government bonds), which constitute overall government liabilities. To further explore the importance of the asset composition backing the SC we also consider an alternative calibration of the model assuming that the SC is fully backed only by the cash issued by the Foreign country, where the Fund is resident. This is obtained by setting $b_{M_G^{FU*}}$ equal to 1 in Eq. 14.[24]

As shown in Fig. 5, this 100%-cash-backing implies that there essentially is no distinction between the responses of the mainly-cash economy and the digital-currency economy in response to a Foreign monetary policy shock, since the supply of the SC adjusts one-for-one to changes in the supply of cash.[25] Therefore, having a SC fully backed by government cash issued in the country of residence of the Fund ("100%-backing") does not alter the benchmark transmission of the monetary policy shock.[26] Importantly, this would not be the case if the SC was backed by both Foreign cash and Foreign bonds: under such an assumption, the effects of a monetary policy shock

vation of the value of Diem for potential users. However, even the single-currency version of Diem would still be backed by a reserve of "cash or cash-equivalents and very short-term government securities denominated" in the single currency. Thus its price could still be subject to the price variations of the underlying assets, even if these are very liquid and are subject to small price fluctuations, at least in normal times. See https://www.diem.com/en-us/white-paper/.

[24]For numerical reasons the parameter is set to a value very close to one, so that the coefficients of Foreign and Home government bonds are very close to zero.

[25]The result holds regardless of whether the shock is of Home or Foreign origin; Fig. 5 reports for the sake of brevity only the response to the Home monetary policy shock.

[26]Such a design of the SC would only be profitable to the Fund under the assumption that the emission of private digital currencies enables first and foremost issuers, as highlighted among others by Brunnermeier and Niepelt (2019) and BIS (2021), to "product differentiate" their currency so as to combine the standard functions served by money with traditionally separate functions (data gathering, social networking services, anonymity in transactions). The economic value of these latter functions may by far outstrip any profit maximizing motivation of the private issuer. Agur et al. (2020) include some of these separate functions in their analysis on the optimal design of CBDCs. However, in their work these characteristics are introduced exogenously (i.e. they rely on some particular ad hoc parameters) and, more importantly when compared to our work, they do not consider the private supply of digital currencies (such as a SC), but only the way these characteristics may affect the designing of a CBDC.

would be different from the benchmark case, because, as reported in Sections 4.1 and 4.2, the Fund would react by changing both the SC supply and the portfolio composition of assets that back the SC. In equivalent terms, the presence of a government bond component in the SC definition implies a lower ability of the central bank to alter households' transaction costs by changing the supply of cash.[27]

4.4 Expansionary Home monetary policy shock, CBDC, and elasticity of substitution across means of payment

Fig. 6 reports responses of Home variables to an exogenous one-period one-percentage-point reduction in the Home monetary policy rate. Qualitatively they are not different from the corresponding responses of Foreign variables in the case of lower Foreign monetary policy rate (Fig. 1).

The Home household substitutes cash and CBDC for sovereign bonds, whose return has decreased following the expansionary monetary policy shock (the bonds pay the Home policy rate), and SC, whose price has increased following the depreciation of the Home currency.

In the case of a bigger weight of the digital-currency bundle (red dashed lines) the stimulating macroeconomic effects of the lower policy rate are somewhat smaller. The supply of physical cash increases, but it reduces transaction costs to a much lower extent because it has a smaller weight in the liquidity bundle. Similarly, the supply of CBDC increases, but its weight in the digital-currency bundle is small.

The effects of the Home monetary policy shock on Home consumption, output, and inflation in the digital-currency economy are only slightly larger if in the digital-currency economy the CBDC weight is increased (green

[27] Results are available upon request.

crossed lines), because the Home household rises the CBDC holdings proportionally less than in the digital-currency economy with low CBDC weight (red dashed lines).

To get a transmission of the Home monetary policy shock more in line with the one in the mainly-cash economy it is necessary that, in addition to having a high weight in the Home liquidity bundles of consumers, the CBDC be a "good" substitute for other means of payment. To show it, we run the Home monetary policy shock under the assumption of a higher elasticity of substitution across assets: namely we set the parameter λ_L in Eq. 3 to 2.5 instead of 1 as in the benchmark case. Fig. 7 shows the results. Under this calibration it clearly emerges that the transmission of a monetary policy shock in the digital-currency economy, when the weight of the CBDC in the liquidity bundle is high (green crossed lines), is similar to that of the mainly-cash economy (black continuous line). CBDC holdings increase to a much larger extent. The implied larger reduction in the transaction costs favors the responses of inflation, output, and consumption, that now overlap with the responses for the case of a low weight of digital currency and a correspondingly high weight of cash in the liquidity bundles.

Overall, the transmission of the monetary policy shock is similar in both a digital-currency and mainly-cash economies if the CBDC has a relatively large weight and is highly substitutable to other means of payment.

5 Conclusions

We have evaluated the role of a global SC and a CBDC in the domestic and international transmission of a monetary policy shock by developing a two-country New Keynesian model featuring digital currencies among the sources of domestic and international liquidity.

We have shown that the transmission of a monetary policy shock can be affected by the privately issued SC. The macroeconomic effects of the shock in the digital-currency economy are smaller than in a mainly-cash economy because the central bank is less able to modify households' liquidity, which depends more on private digital currency than on cash. Still, changes in the supply of the SC and different shares of the assets backing it matter for the size of the macroeconomic effects the shock. In particular, if the SC is 100% backed by Foreign cash, then the transmission of the Foreign monetary policy shock remains largely unchanged, as the supply of SC must adjust one-for-one to changes in the supply of cash. Independently of the backing of the SC issued in the Foreign country, the central bank of the Home country can restore the benchmark transmission of the monetary policy shock also by issuing a CBDC, if there is a sufficiently large demand for it.

We have deliberately neglected some important issues associated with the diffusion of digital currencies. In particular, private banking sector and, more generally, financial intermediation could have a non-trivial role in, and could be widely affected by, the issuance of both SC and CBDC and be a source of international spillovers.[28] Moreover, a welfare analysis could be conducted, to evaluate the optimal monetary policy in presence of digital currencies. We leave these interesting issues for future research.

[28] See Burlon et al. (2022).

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Table 1: Main variables

	Home	Foreign
Macroeconomic variables		
Consumption	100	100
Import	25	25
Inflation	0	0
Financial variables		
Nominal interest rate (illiquid bond)	1.98	1.98
Cash	93	104
Digital currency	12	12
SC	10	12
CBDC	2	–
Public debt	60	60
Private (illiquid) bond	0	0

Note: Consumption and import reported as % of output.Nominal interest rate and inflation as annualized percentage point. Public debt, digital currences and illiquid boonds as % of annualized output;

Table 2: Preferences and technology

Parameter	Home	Foreign
Households' preferences		
Discount factor β	0.9951	0.9951
Habit ξ	0.7	0.7
Intertemporal elasticity of substitution $1/\sigma$	1.0	1.0
Labor Frish elasticity τ	0.5	0.5
Household's liquidity bundle		
Elast. of subst. btw cash, digit. curr., and sovr. bond λ_L	1.0	1.0
Weight of cash $a_{M_G}, a_{M_G^*}$	0.8	0.8
Weight of digital curency $a_{M_D}, a_{M_D^*}$	0.1	0.1
Weight of sovereign bond $1 - a_{M_G} - a_{M_D}, 1 - a_{M_G^*} - a_{M_D^*}$	0.1	0.1
Transaction cost A	0.132	0.132
Liquidity velocity $\bar{v}$	0.045	0.045
Home household's digital-currency bundle		
Elasticity of subst. btw SC and CBDC λ_D	1	–
Weight of CBDC $a_{M_{CBDC}}$	0.2	–
Weight of SC $1 - a_{M_{CBDC}}$	0.8	–
Adj. costs on illiquid bond		
ϕ_{b1}	0.15	–
ϕ_{b2}	0.30	–
Fund's technology		
Elasticity of substitution between cash and sov. bonds λ_{FU}	–	1.0
Weight of cash $b_{M_G^{FU*}}$	–	0.5
Weight of Foreign sovereign bond $b_{B_G^{F,FU*}}$	–	0.25
Weight of Home sovereign bond $1 - b_{M_G^{FU*}} - b_{B_G^{F,FU*}}$	–	0.25
Firms' technology		
Adjustment costs on domestic price κ_H, κ_F^*	400	400
Adjustment costs on export price κ_H^*, κ_F	400	400
Dom.price index. to previous period sector infl. ind_H, ind_F^*	0.5	0.5
Exp. price index. to previous period sector infl. ind_H^*, ind_F	0.5	0.5
Elasticity of substitution among brands θ	6	6
Elast. of subst. between domestic and imported goods ρ	1.5	1.5
Weight of domestic goods $a_H, 1 - a_H^*$	0.75	0.75
Weight of imported goods $1 - a_H, a_H^*$	0.25	0.25
Country size n, $1 - n$	0.5	0.5

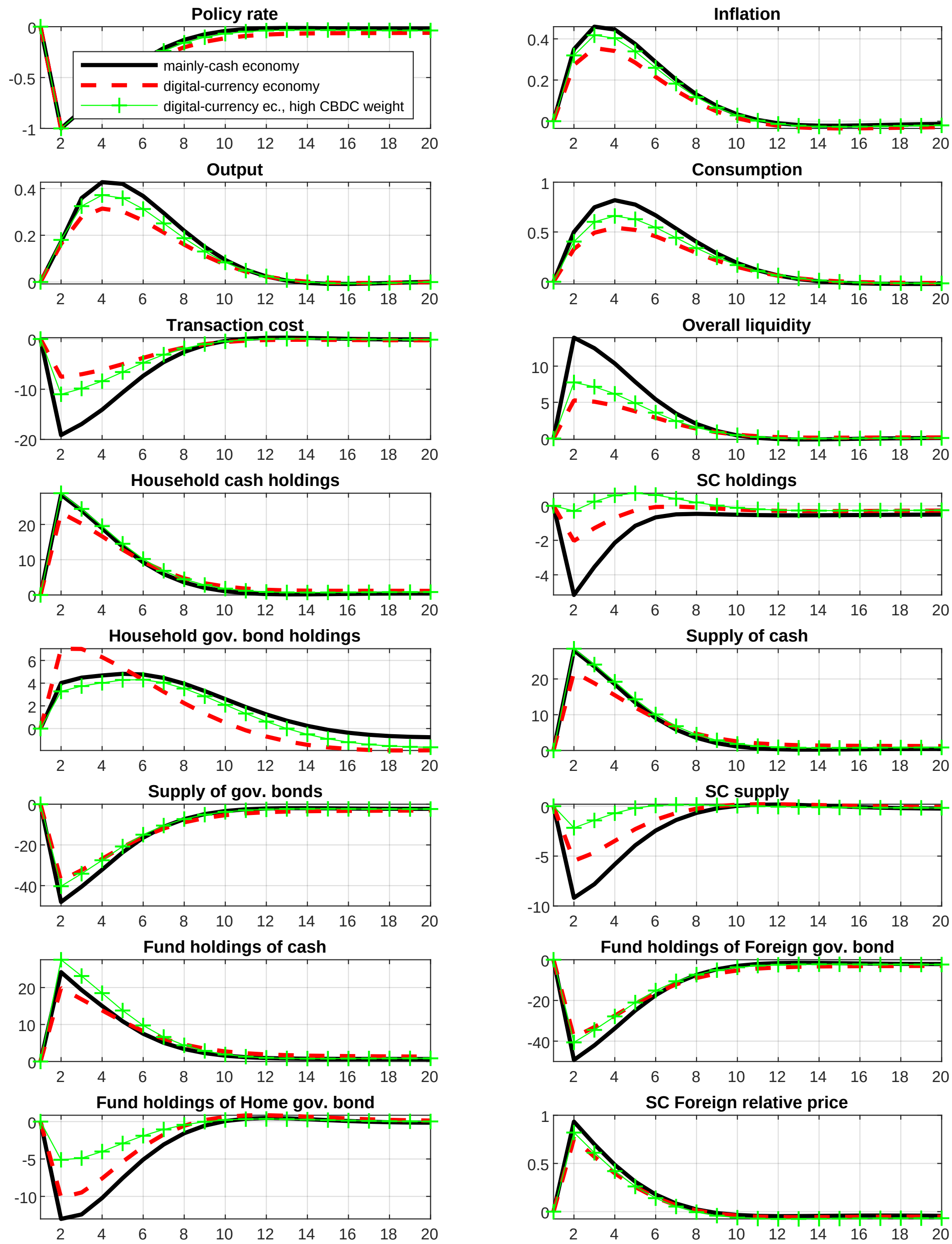
Note: "*" refers to Foreign. If only one symbol is reported, then it is the same for both countries.

Table 3: Monetary and fiscal policy rules

Parameter	Home	Foreign
Monetary policy rules		
Lagged interest rate ρ_R, ρ_{R^*}	0.87	0.87
Inflation ρ_π, ρ_{π^*}	1.7	1.7
Output growth ρ_y, ρ_{y^*}	0.1	0.1
Inflation target $\bar{\Pi}, \bar{\Pi}^*$	0.0	0.0
Fiscal policy rules		
Public debt ϕ, ϕ^*	-0.007	-0.007

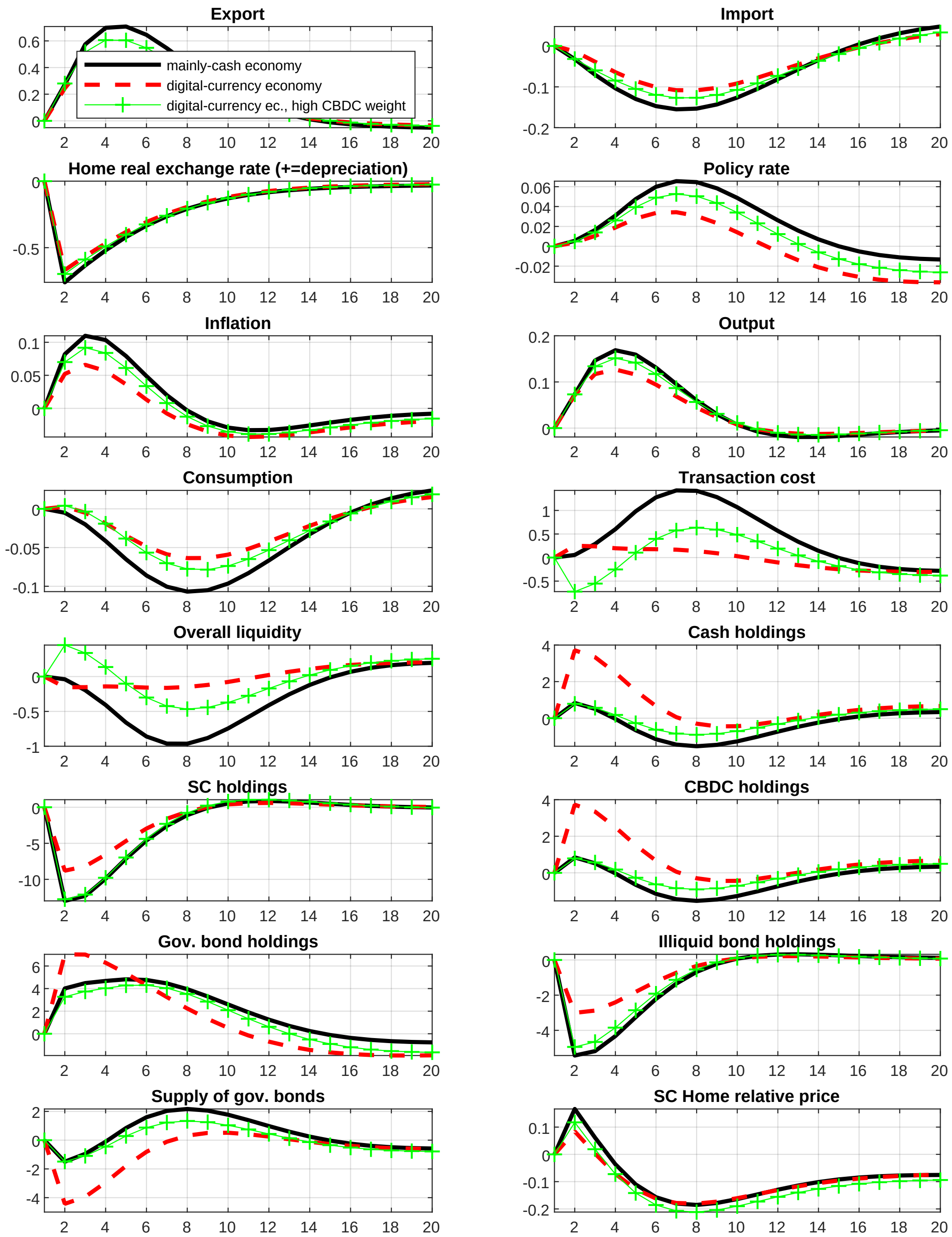
Note: "*" refers to Foreign. If only one symbol is reported, then it is the same for both countries.

Figure 1: Foreign monetary policy shock: Foreign variables



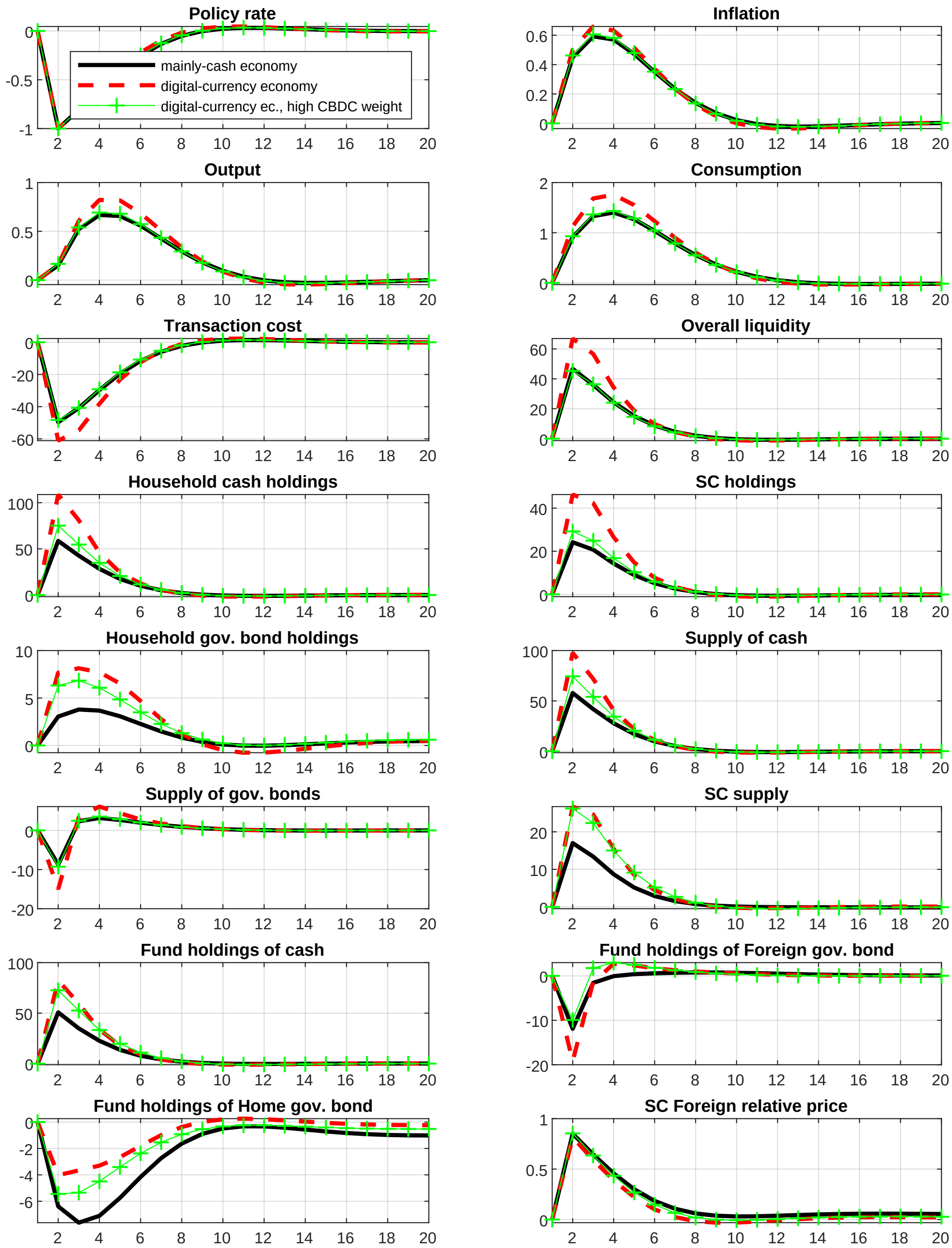
Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation rates and interest rates: annualized pp deviation. SC=stablecoin. SC relative price is in units of domestic consumption.

Figure 2: Foreign monetary policy shock: Home variables



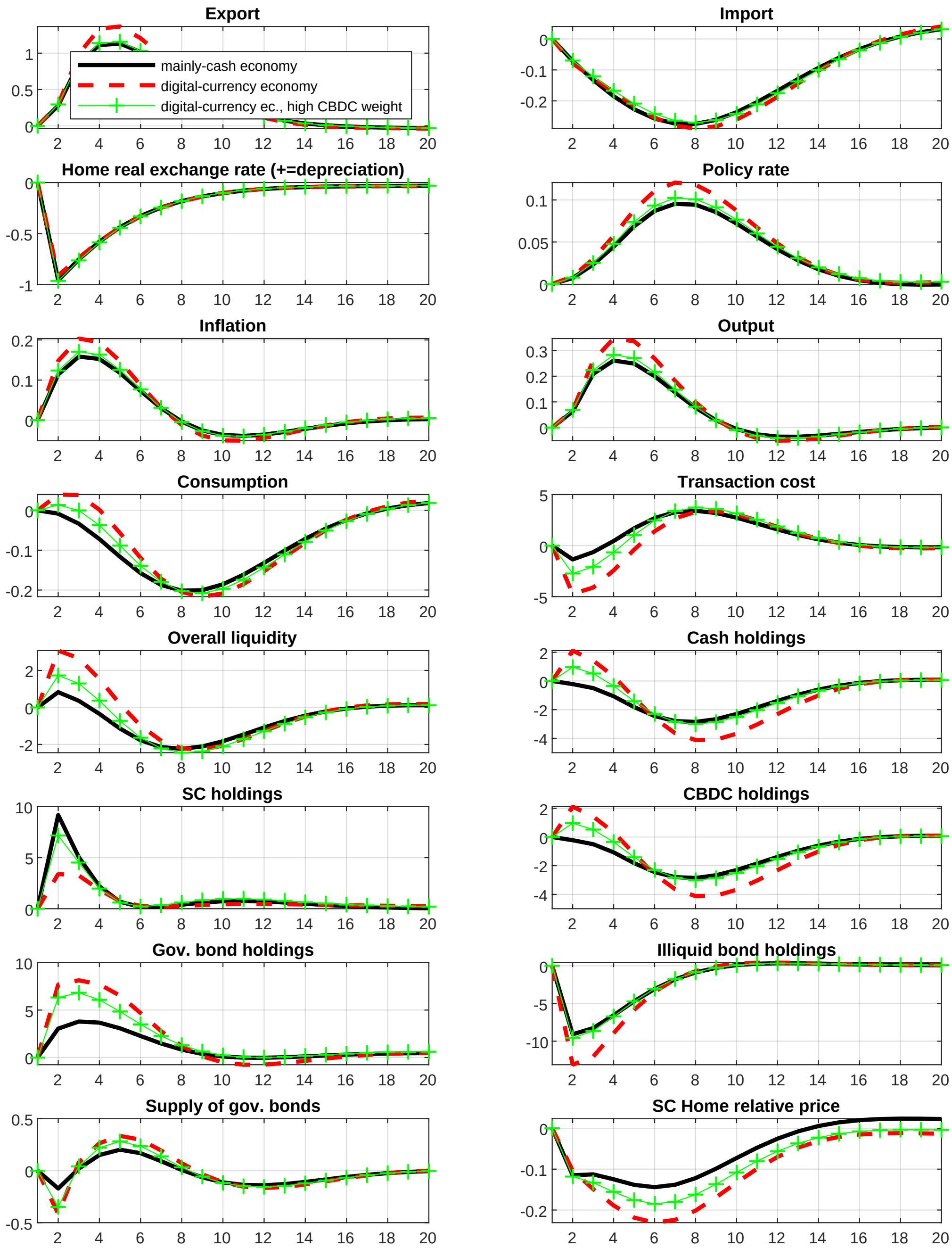
Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation rates and interest rates: annualized pp deviation; illiquid bonds: ratio to GDP, pp deviation. SC=stablecoin. SC relative price is in units of domestic consumption.

Figure 3: Foreign monetary policy shock and stable supply of gov. bonds: Foreign variables



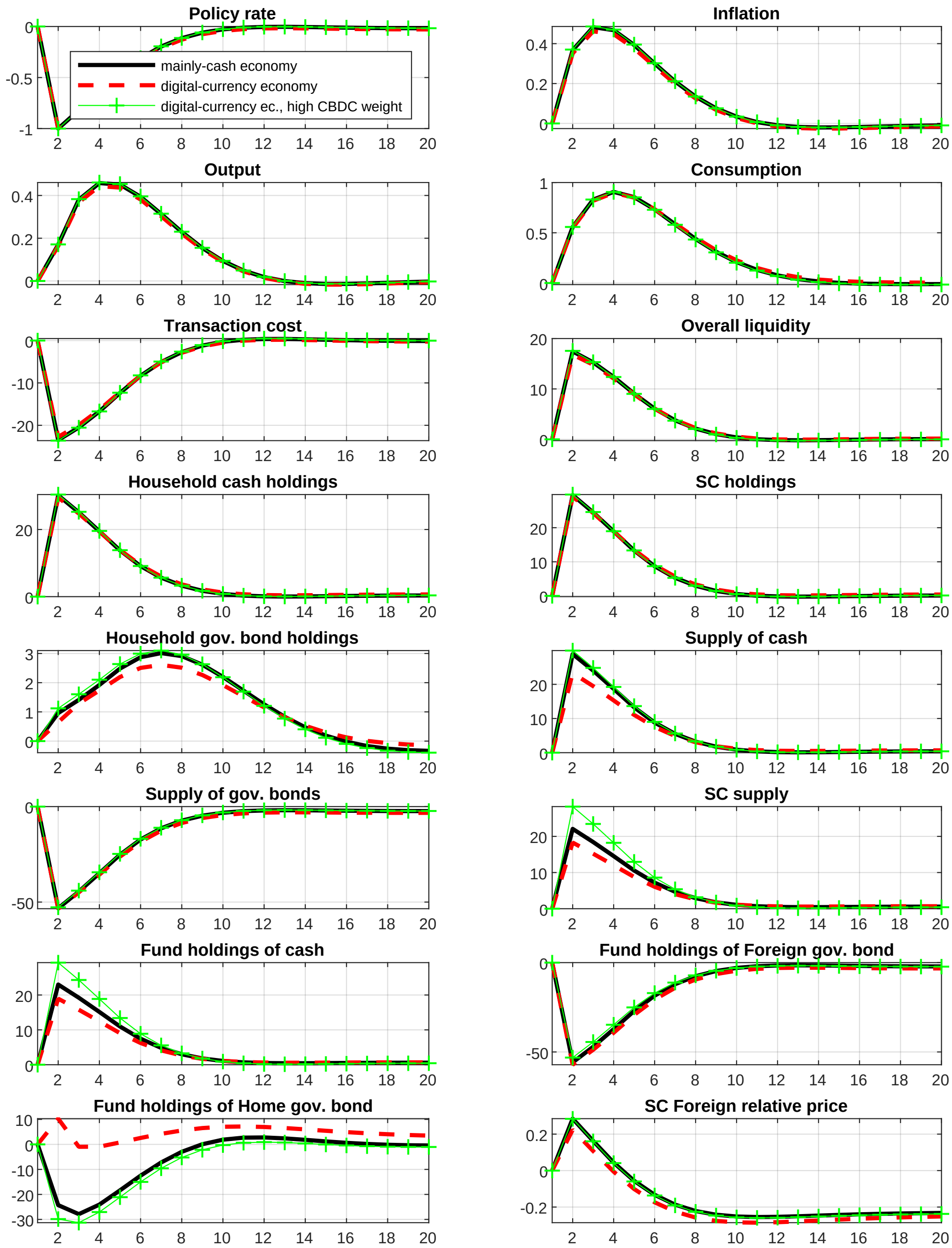
Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation rates and interest rates: annualized pp deviation. SC=stablecoin. SC relative price is in units of domestic consumption.

Figure 4: Foreign monetary policy shock and stable supply of gov. bonds: Home variables



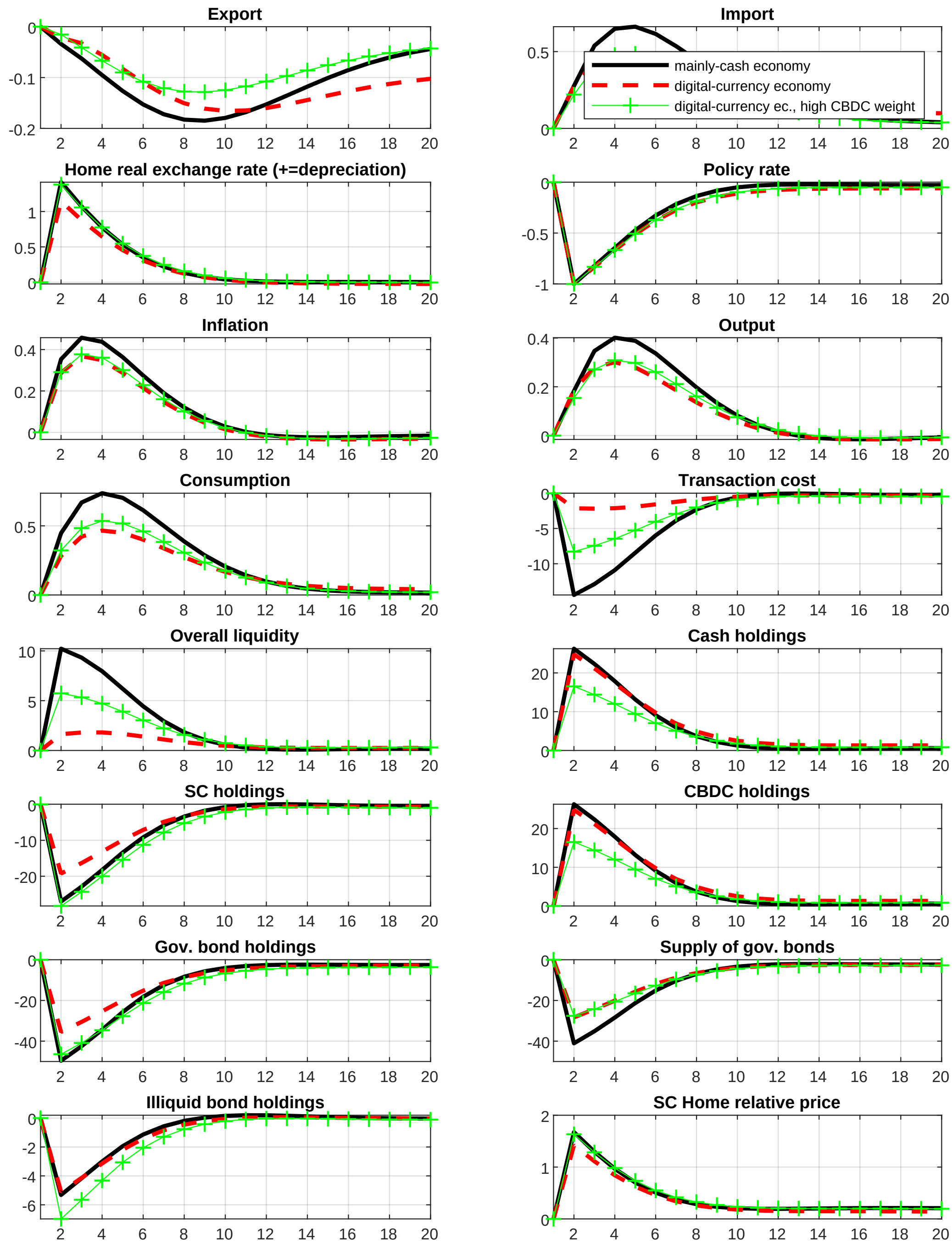
Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation rates and interest rates: annualized pp deviation; illiquid bonds: ratio to GDP, pp deviation. SC=stablecoin. SC relative price is in units of domestic consumption.

Figure 5: Foreign monetary policy shock with SC fully backed by cash: Foreign variables



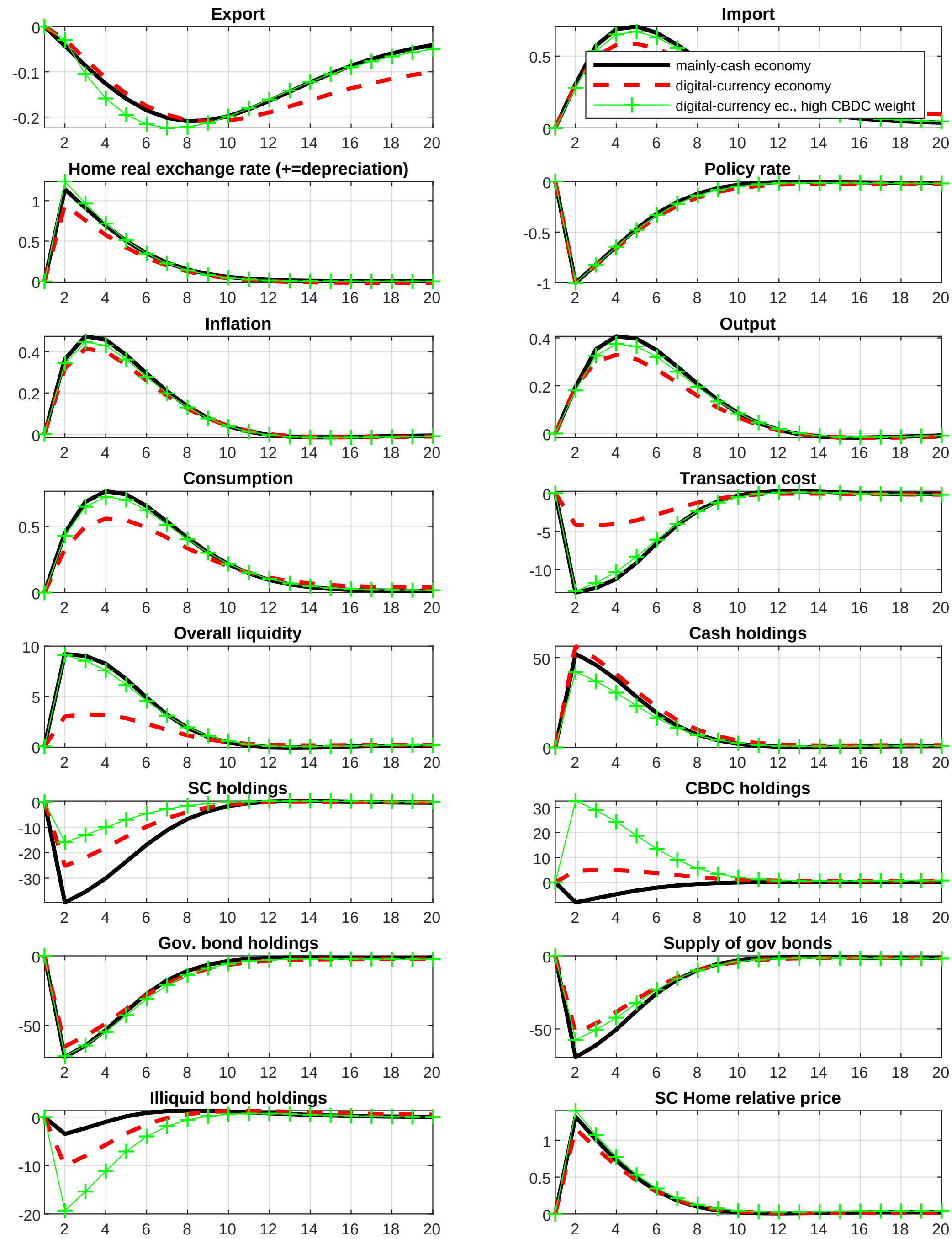
Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation rates and interest rates: annualized pp deviation. SC=stablecoin. SC relative price is in units of domestic consumption.

Figure 6: Home monetary policy shock: Home variables



Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation rates and interest rates: annualized pp deviation; illiquid bonds: ratio to GDP, pp deviation. SC=stablecoin. SC relative price is in units of domestic consumption.

Figure 7: Home monetary policy shock under high λ_L: Home variables



Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation rates and interest rates: annualized pp deviation; illiquid bonds: ratio to GDP, pp deviation. SC=stablecoin. SC relative price is in units of domestic consumption.

Appendix: Model equations

A.1 Firm

A.1.1 Home final sector

- Consumption bundle

$$C_t = \left[a_H^{\frac{1}{\rho}} C_{H,t}^{\frac{\rho-1}{\rho}} + (1 - a_H)^{\frac{1}{\rho}} C_{F,t}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \tag{A.1}$$

- Consumption bundle of Home goods

$$C_{H,t} = \left[\left(\frac{1}{n} \right)^{\theta} \int_0^n C_{H,t}(h)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}} \tag{A.2}$$

- Consumption bundle of Foreign goods

$$C_{F,t} = \left[\left(\frac{1}{1-n} \right)^{\theta} \int_n^1 C_{F,t}(f)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}} \tag{A.3}$$

- Home demand for Home good

$$nY_{H,t} = a_H \left(\frac{P_{H,t}}{P_t} \right)^{-\rho} nC_t \tag{A.4}$$

- Home demand for Foreign good

$$(1-n) Y_{F,t} = (1 - a_H) \left(\frac{P_{F,t}}{P_t} \right)^{-\rho} nC_t \tag{A.5}$$

- Consumption price deflator

$$P_t = \left[a_H P_{H,t}^{1-\rho} + (1 - a_H) P_{F,t}^{1-\rho} \right]^{\frac{1}{1-\rho}} \tag{A.6}$$

- Home-good price deflator

$$P_{H,t} = \left[\int_0^n P_{H,t}\left(h\right)^{1-\theta} dh\right]^{\frac{1}{1-\theta}} \tag{A.7}$$

- Foreign-good price deflator

$$P_{F,t} = \left[\int_n^1 P_{F,t}\left(f\right)^{1-\theta} df\right]^{\frac{1}{1-\theta}} \tag{A.8}$$

- Home-good inflation rate in Home

$$\pi_{H,t} \equiv \frac{P_{H,t}}{P_{H,t-1}} \tag{A.9}$$

- Foreign-good inflation rate in Home

$$\pi_{F,t} \equiv \frac{P_{F,t}}{P_{F,t-1}} \tag{A.10}$$

- Home CPI inflation rate

$$\pi_t \equiv \frac{P_t}{P_{t-1}} \tag{A.11}$$

Similar equations holds in the Foreign final sector.

A.1.2 Home intermediate sector

- Production function

$$Y_t = L_{D,t} \tag{A.12}$$

- Labor demand

$$\frac{W_t}{P_t} = \frac{MC_t}{P_t} \tag{A.13}$$

- Home price-setting of Home-produced good

$$
\begin{aligned}
&(1-\theta)\frac{P_{H,t}}{P_t}+\theta\frac{MC_t}{P_t}=\kappa_H\left(\frac{P_{H,t}/P_{H,t-1}}{\pi_{H,t-1}^{ind_H}\pi_{target}^{1-ind_H}}-1\right)\frac{P_{H,t}/P_{H,t-1}}{\pi_{H,t-1}^{ind_H}\pi_{target}^{1-ind_H}}\\
&-\beta E_t\left(\frac{\Lambda_{t+1}\pi_{t+1}^{-1}}{\Lambda_t}\kappa_H\left(\frac{P_{H,t+1}/P_{H,t}}{\pi_{H,t}^{ind_H}\pi_{target}^{1-ind_H}}-1\right)\frac{P_{H,t+1}^2/P_{H,t}^2Y_{H,t+1}}{\pi_{H,t}^{ind_H}\pi_{target}^{1-ind_H}Y_{H,t}}\right)
\end{aligned}
\tag{A.14}
$$

- Foreign price-setting of Home-produced good

$$
\begin{aligned}
&(1-\theta)\frac{P_{H,t}^*}{P_t^*}+\theta\frac{MC_t}{P_t}\frac{1}{rs_t}=\kappa_H^*\left(\frac{P_{H,t}^*/P_{H,t-1}^*}{\pi_{H,t-1}^{*ind_H}\pi_{target}^{1-ind_H}}-1\right)\frac{P_{H,t}^*/P_{H,t-1}^*}{\pi_{H,t-1}^{*ind_H}\pi_{target}^{1-ind_H}}\\
&-\beta E_t\left(\frac{\Lambda_{t+1}\pi_{t+1}^{-1}\Delta s_{t+1}}{\Lambda_t}\kappa_H^*\left(\frac{P_{H,t+1}^*/P_{H,t}^*}{\pi_{H,t}^{*ind_H}\pi_{target}^{1-ind_H}}-1\right)\frac{P_{H,t+1}^{*2}/P_{H,t}^{*2}Y_{H,t+1}^*}{\pi_{H,t}^{*ind_H}\pi_{target}^{1-ind_H}Y_{H,t}^*}\right)
\end{aligned}
\tag{A.15}
$$

A.2 Home household

- Preferences for consumption C_t demand and labor supply $L_{S,t}$

$$
E_0\left(\sum_{t=0}^{\infty}\beta^t\frac{(C_t-\xi C_{t-1})^{1-\sigma}}{(1-\sigma)}-\frac{L_{S,t}^{1+\tau}}{1+\tau}\right)
\tag{A.16}
$$

- Budget constraint

$$
\begin{aligned}
&B_{G,t}^{HOU}-B_{G,t-1}^{HOU}R_{t-1}+M_{G,t}^{HOU}-M_{G,t-1}^{HOU}+S_t^{H,SC}M_{SC,t}-S_t^{H,SC}M_{SC,t-1}\\
&+M_{CBDC,t}-M_{CBDC,t-1}+B_t-S_tB_{t-1}R_{t-1}^{illiq}\left(1-\phi_{b,t-1}\right)\\
&=W_tL_t+\Pi_t^{prof}-P_t\left(1+\tau_t\right)C_t+TR_t
\end{aligned}
\tag{A.17}
$$

- Adjustment cost on illiquid bond[29]

[29]The variable b_t is the Home aggregate position in the bond expressed in domestic currency terms and divided by the domestic aggregate position and $\bar{b}$ its steady-state value. The aggregate position is taken as given by the representative household when

$$\phi_{b,t} \equiv \phi_{b1} \frac{\exp\left(\phi_{b2}\left(b_t - \bar{b}\right)\right) - 1}{\exp\left(\phi_{b2}\left(b_t - \bar{b}\right)\right) + 1} \tag{A.18}$$

- Liquidity bundle $\tilde{M}$

$$\tilde{M}_t = \left[a_{M_G}^{\frac{1}{\lambda_L}} \left(M_{G,t}^{HOU}\right)^{\frac{\lambda_L - 1}{\lambda_L}} + a_{M_D}^{\frac{1}{\lambda_L}} M_{D,t}^{\frac{\lambda_L - 1}{\lambda_L}} + \left(1 - a_{M_G} - a_{M_D}\right)^{\frac{1}{\lambda_L}} \left(B_{G,t}^{HOU}\right)^{\frac{\lambda_L - 1}{\lambda_L}} \right]^{\frac{\lambda_L}{\lambda_L - 1}} \tag{A.19}$$

- Home digital-currency bundle

$$M_{D,t} = \left[a_{M_{CBDC}}^{\frac{1}{\lambda_D}} M_{CBDC,t}^{\frac{\lambda_D - 1}{\lambda_D}} + \left(1 - a_{M_{CBDC}}\right)^{\frac{1}{\lambda_D}} \left(S_t^{H,SC} M_{SC,t}\right)^{\frac{\lambda_D - 1}{\lambda_D}} \right]^{\frac{\lambda_D}{\lambda_D - 1}} \tag{A.20}$$

- Foreign household's digital currency $M_{D,t}^*$

$$M_{D,t}^* = S_t^{F,SC} M_{SC,t}^* \tag{A.21}$$

- Transaction cost τ_t

$$\tau_t = \frac{A}{v_t} \left(v_t - \bar{v}\right)^2 \tag{A.22}$$

- Liquidity velocity v_t

$$v_t = \frac{P_t C_t}{\tilde{M}_t} \tag{A.23}$$

- FOC with respect to consumption C_t

$$\Lambda_t = \frac{\left(C_t - \xi C_{t-1}\right)^{-\sigma}}{1 + 2A\left(v_t - \bar{v}\right)} \tag{A.24}$$

making her optimal choices.

- FOC with respect to labor supply $L_{S,t}$

$$\frac{W}{P_t} = L_{S,t}^{\tau} \Lambda_t^{-1} \tag{A.25}$$

- FOC with respect to illiquid bond B_t

$$1 = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} R_t^{illiq} \left(1 - \phi_{b,t}\right) \right) \tag{A.26}$$

- FOC with respect to physical cash $M_{G,t}^{HOU}$

$$1 - A\left(v_t^2 - \bar{v}^2\right) a_{M_G}^{\frac{1}{\lambda_L}} \left(\frac{\tilde{M}_t}{M_{G,t}^{HOU}} \right)^{\frac{1}{\lambda_L}} = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} \right) \tag{A.27}$$

- FOC with respect to domestic government bond holdings $B_{G,t}^{HOU}$

$$\begin{aligned} 1 - A\left(v_t^2 - \bar{v}^2\right) \left(1 - a_{M_G} - a_{M_D}\right)^{\frac{1}{\lambda_L}} \left(\frac{\tilde{M}_t}{B_{G,t}^{HOU}} \right)^{\frac{1}{\lambda_L}} \\ = R_t \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} \right) \end{aligned} \tag{A.28}$$

- (Home household's) FOC with respect to CBDC $M_{CBDC,t}$

$$\begin{aligned} 1 - A\left(v_t^2 - \bar{v}^2\right) a_{M_D}^{\frac{1}{\lambda_L}} a_{M_{CBDC}}^{\frac{1}{\lambda_D}} \left(\frac{\tilde{M}_t}{M_{D,t}} \right)^{\frac{1}{\lambda_L}} \left(\frac{M_{D,t}}{M_{CBDC,t}} \right)^{\frac{1}{\lambda_D}} \\ = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} \right) \end{aligned} \tag{A.29}$$

- (Home household's) FOC with respect to SC $M_{SC,t}$

$$1 - A\left(v_t^2 - \bar{v}^2\right) a_{M_D}^{\frac{1}{\lambda_L}} a_{M_{SC}}^{\frac{1}{\lambda_D}} \left(\frac{\tilde{M}_t}{M_{D,t}}\right)^{\frac{1}{\lambda_L}} \left(\frac{M_{D,t}}{S_t^{H,SC} M_{SC,t}}\right)^{\frac{1}{\lambda_D}} = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} \frac{S_{t+1}^{H,SC}}{S_t^{H,SC}}\right) \quad (A.30)$$

- (Foreign household's) FOC with respect to SC $M^*_{SC,t}$

$$1 - A\left(v_t^{*2} - \bar{v}^{*2}\right) a_{M_D}^{\frac{1}{\lambda_L}} \left(\frac{\tilde{M}^*_t}{S_t^{F,SC} M^*_{SC,t}}\right)^{\frac{1}{\lambda_L}} = \beta E_t \left(\frac{\Lambda^*_{t+1}}{\Lambda^*_t} \frac{P^*_t}{P^*_{t+1}} \frac{S_{t+1}^{F,SC}}{S_t^{F,SC}}\right) \quad (A.31)$$

A.3 The Foreign fund

- Profits

$$E_t \left(\sum_{j=0}^{\infty} \beta^j \frac{\Lambda^*_{t+j}}{\Lambda^*_t} \Omega^{FU*}_{t+j}\right), \quad (A.32)$$

$$\begin{aligned}
\Omega_t^{FU*} = & \left(S_t^{F,SC} \frac{M^{FU*}_{SC,t}}{P^*_t} - S_t^{F,SC} \frac{M^{FU*}_{SC,t-1}}{P^*_t}\right) \\
& - \left(\frac{M^{FU*}_{G,t}}{P^*_t} - \frac{M^{FU*}_{G,t-1}}{P^*_t}\right) \\
& - \left(\frac{B^{F,FU*}_{G,t}}{P^*_t} - R^*_{t-1} \frac{B^{F,FU*}_{G,t-1}}{P^*_t}\right) \\
& - \left(\frac{S_t B^{H,FU*}_{G,t}}{P^*_t} - R_{t-1} \frac{S_t B^{H,FU*}_{G,t-1}}{P^*_t}\right) \\
& + TR_t^{FU*} \quad (A.33)
\end{aligned}$$

- Technology constraint

$$M_{SC,t}^{FU*} = \Bigg[\quad b_{M_G^{FU*}}^{\frac{1}{\lambda_{FU}}} \left(\frac{M_{G,t}^{FU*}}{P_t^*}\right)^{\frac{\lambda_{FU}-1}{\lambda_{FU}}} + b_{B_G^{F,FU*}}^{\frac{1}{\lambda_{FU}}} \left(\frac{B_{G,t}^{F,FU*}}{P_t^*}\right)^{\frac{\lambda_{FU}-1}{\lambda_{FU}}}$$

$$+ \left(1 - b_{M_G^{FU*}} - b_{B_G^{F,FU*}}\right)^{\frac{1}{\lambda_{FU}}} \left(\frac{S_t B_{G,t}^{H,FU*}}{P_t^*}\right)^{\frac{\lambda_{FU}-1}{\lambda_{FU}}} \Bigg]^{\frac{\lambda_{FU}}{\lambda_{FU}-1}} \tag{A.34}$$

- FOC with respect to SC $M_{SC,t}^{FU*}$

$$E_t \left(\frac{R_t^* rel_t^* - \pi_{t+1} rel_{t+1}^*}{R_t^*}\right) = \kappa_t^* \tag{A.35}$$

- Foreign consumer price-to-Home consumer ratio

$$rel_t^* \equiv \frac{P_t^*}{P_t} \tag{A.36}$$

- FOC with respect to Foreign cash $M_{G,t}^{FU*}$

$$\frac{\left(R_t^{illiq*} - 1\right)}{R_t^{illiq*}} = \kappa_t^* b_{M_G^{FU*}}^{\frac{1}{\lambda_{FU}}} \left(\frac{M_{SC,t}^{FU*}}{M_{G,t}^{FU*}}\right)^{\frac{1}{\lambda_{FU}}} \tag{A.37}$$

- FOC with respect to Foreign bond $B_{G,t}^{F,FU*}$

$$E_t \left(\frac{R_t^{illiq*} - R_t^*}{\pi_{t+1}^* R_t^{illiq*}}\right) = \kappa_t^* b_{B_G^{F,FU*}}^{\frac{1}{\lambda_{FU}}} \left(\frac{M_{SC,t}^{FU*}}{B_{G,t}^{F,FU*}}\right)^{\frac{1}{\lambda_{FU}}} \tag{A.38}$$

- FOC with respect to Home bond $B_{G,t}^{H,FU*}$

$$E_t \left(\frac{R_t^{illiq*} - R_t}{\Delta s_{t+1} \pi_{t+1}^* R_t^{illiq*}}\right) = \kappa_t^* \left(1 - b_{M_G^{FU*}} - b_{B_G^{F,FU*}}\right)^{\frac{1}{\lambda_{FU}}} \left(\frac{M_{SC,t}^{FU*}}{B_{G,t}^{H,FU*}}\right)^{\frac{1}{\lambda_{FU}}} \tag{A.39}$$

A.4 Home government

- Monetary policy rule

$$\left(\frac{R_t}{\bar{R}}\right)^4 = \left(\frac{R_{t-1}}{\bar{R}}\right)^{4\rho_R}\left(\frac{\Pi_{t,t-3}}{\bar{\Pi}^4}\right)^{(1-\rho_R)\rho_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{(1-\rho_R)\rho_y}\epsilon_R \quad (A.40)$$

- Year-on-year inflation rate

$$\Pi_{t,t-3} \equiv \pi_t \pi_{t-1} \pi_{t-2} \pi_{t-3} \quad (A.41)$$

- Government budget constraint

$$B_{G,t} - B_{G,t-1}R_{t-1} + M_t^S - M_{t-1}^S = TR_t \quad (A.42)$$

- Fiscal rule

$$\frac{tr_t}{\bar{tr}} = \left(\frac{b_{G,t-1}}{\bar{b}_G}\right)^\phi \quad (A.43)$$

A.5 Market clearing conditions

- Home good

$$nY_t = nY_{H,t} + nY_{H,t}^* \quad (A.44)$$

- Foreign good

$$(1-n)\,Y_t^* = (1-n)\,Y_{F,t} + (1-n)\,Y_{F,t}^* \quad (A.45)$$

- Home government bond

$$B_{G,t} = nB_{G,t}^{HOU} + (1-n)B_{G,t}^{H,FU*} \quad (A.46)$$

- Foreign bond

$$B^*_{G,t} = (1-n)B^{HOU*}_{G,t} + (1-n)B^{F,FU*}_{G,t} \tag{A.47}$$

- SC

$$(1-n)M^{FU*}_{SC,t} = nM_{SC,t} + (1-n)M^*_{SC,t} \tag{A.48}$$

- Home cash

$$nM^S_t = nM^{HOU}_{G,t} + nM_{CBDC,t} \tag{A.49}$$

- Foreign cash

$$(1-n)M^{S*}_t = (1-n)M^{HOU*}_{G,t} + (1-n)M^{FU*}_{G,t} \tag{A.50}$$

- Illiquid bond

$$nB_t + (1-n)B^*_t = 0 \tag{A.51}$$

- Home labor

$$nL_{D,t} = nL_{S,t} \tag{A.52}$$

- Foreign labor

$$(1-n)L^*_{D,t} = (1-n)L^*_{S,t} \tag{A.53}$$

A.6 Real exchange rate and net foreign asset position

- Home real exchange rate

$$\frac{RS_t}{RS_{t-1}} \equiv \frac{\Delta s_t \pi^*_t}{\pi_t} \tag{A.54}$$

- Home nominal exch. rate change vis-à-vis the Foreign currency (increase=depreciation of the Home currency)

$$\Delta s_t \equiv \frac{S_t}{S_{t-1}} \tag{A.55}$$

- Home net foreign asset position

$$\begin{aligned} & nB_t - nB_{t-1} R_{t-1}^{illiq} \left(1 - \phi_{b,t-1}\right) + \\ & + nB_{G,t}^{HOU} - nB_{G,t-1}^{HOU} R_{t-1} + \left(-B_{G,t} + B_{G,t-1} R_{t-1}\right) \\ & + nM_{SC,t} - nM_{SC,t-1} = nS_t P_{H,t}^{*} Y_{H,t}^{*} - (1-n) P_{F,t} Y_{F,t} \end{aligned} \tag{A.56}$$

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