Fear (no more) of Floating: Asset Purchases and Exchange Rate Dynamics

This paper studies the impact of local-currency asset purchases by emerging market economy central banks on financial conditions, capital flows and exchange rates, and the implications for conventional monetary policy.

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Keywords: Asset purchases, exchange rate, conventional monetary policy

JEL codes: E62, E63, G21

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1 Introduction

Monetary policy in many emerging market economies has often been procyclical to curb inflation and the effects of currency depreciation on balance sheets. The ensuing fear of floating exists even though *de jure* exchange rate regimes endorse currency fluctuations as a shock absorber (Calvo and Reinhart (2002), Kaminsky et al. (2005) and Cordella et al. (2014)). This paper provides a theory on emerging market economy (EME) central bank asset purchases to investigate if such interventions could leave room for maneuver for conventional monetary policy to accommodate capital outflows and mitigate the fear of floating. The question is new to the literature, as EME central banks have embarked on asset purchases for the first time to respond to the COVID-19 crisis, which – in addition to positive spillovers from advanced economy monetary policy easing – might have made it easier to reduce policy rates in contrast with their experience during the global financial crisis (see Figure 1).[1]

We extend Gertler and Karadi (2013) and Sims and Wu (2021) models of central bank asset purchases to an EME setup with currency mismatch. Our paper features two key departures from these advanced economy studies. First, we consider a financial system that is mainly represented by commercial banks who borrow local currency (LC) deposits from households and foreign currency (FC) funds from rest of the world, while lending to home-based, non-financial intermediate goods producers in domestic currency.[2] Secondly, we expand on these papers by assuming that in addition to domestic banks, LC government bonds are also held by foreign investors, whose demand for those assets is subject to a sell-off shock. Consequently, in normal times, government bond market equilibrium implies that fluctuations in the foreign investor demand for government bonds would affect the asset portfolio of domestic banks, leading to financial crowding out effects studied by Bocola (2016), Kirchner and van Wijnbergen (2016) and Chari et al. (2020). To the best of our knowledge, this paper is the first study that

[1] Asset purchases in EMEs were primarily aimed at replacing the sharp government bond sell-off by foreign investors and curbing further surges in local bond yields that occurred at the onset of the pandemic. For further insights on EME asset purchase objectives, see Arslan et al. (2020), Fratto et al. (2021), Hartley and Rebucci (2020), IMF (2020) and WB (2021).

[2] Currency mismatches faced by banks and non-banks in EMEs are important as they lead to tightening of financial conditions upon exchange rate depreciation, which offsets the benefits of rising net exports (Kearns and Patel, 2016). Banerjee et al. (2020) point out that currency depreciation in EMEs depresses the investment outlook of non-financial corporations when their balance sheet reflects currency mismatch. Even though banks could be insulated from direct currency mismatches due to regulatory requirements in certain cases, in our framework, bankers and intermediate goods producers can be considered as a combined entrepreneur agent, whose consolidated balance sheet is adversely impacted by abrupt currency depreciations, as firms produce cash flows in domestic currency.

quantitatively investigates the macroeconomic effects of asset purchase policies in EMEs using an estimated small open economy DSGE model.

Agency costs and the associated incentive compatibility constraints in our setup impose an endogenous leverage limit on banks, tying holdings of risky assets to their bank capital. We assume government bonds are harder to divert, making them a safer asset relative to corporate loans as in Gertler and Karadi (2013). We also assume that domestic depositors are better equipped to monitor banks to prevent them from diverting a fraction of their deposits or incur lower losses than foreign lenders in the event of a bank default (Fornaro, 2015). These tractable features of financial frictions produce an empirically realistic ranking for corporate loan, long-term sovereign bond and bank deposit interest rates and allows the model to reflect empirically relevant systemic deviations from the uncovered interest parity (UIP) condition (di Giovanni et al., 2021).

We estimate the version of the model without asset purchases using Bayesian techniques to capture business cycle regularities of selected EMEs, in which central banks purchased assets during the COVID-19 crisis, over the pre-pandemic period of 2002Q1-2019Q4. The analysis of the transmission of asset purchase shocks using our estimated model allows us to arrive at two important conclusions: Asset purchases ease financial conditions without creating currency depreciation risk in EMEs; and accordingly, create room for maneuver for conventional monetary policy during episodes of financial stress. The first finding suggests that, in contrast with the results of Dedola et al. (2021) regarding advanced economies, the decline in risk premia enabled by asset purchases in EMEs dominates the effect of declining interest rate differentials vis-à-vis the rest of the world and helps the exchange rate appreciate. It also offers a solution to the puzzle of a fairly stable exchange rate outlook upon the announcement of asset purchases in EMEs, as confirmed by event analyses in Arslan et al. (2020), Fratto et al. (2021), Hartley and Rebucci (2020), IMF (2020) and WB (2021), which focus on the height of the COVID-19 shock.

Our model simulations suggest that discretionary purchases of government bonds by the central bank (asset purchase shocks) boost sovereign bond and non-financial firm security prices. The rise in asset prices reduces the real term premium on government bonds, relaxes leverage constraints faced by commercial banks and allows banks to borrow more from foreign lenders. Hence, the currency appreciates due to the ensuing boost in private sector capital inflows. With an expanded funding base and credit supply of banks, intermediation margins decline and real investment increases. The appreciation of the currency also passes through via imported goods prices and reduces inflation.[3] The milder inflation outlook and eased financial conditions result in lower long-term sovereign bond yields, and lead to a conventional monetary policy easing. Private asset purchase shocks do not create a substitution effect on bank balance sheets, nonetheless, they expand the credit supply as central bank purchases are not bound by agency costs. This financial multiplier effect boosts asset prices more than the case of bond purchases as in Gertler and Karadi (2013).

In our analysis, we differentiate between adverse shocks that affect foreign investors' demand for local- versus FC denominated claims against EMEs. This distinction is important because an abrupt rise in the country risk premium – which directly increases FC borrowing costs – may be the root cause of a LC sovereign bond sell-off by foreign investors. Identifying these two types of shocks separately in the data could be challenging for event analyses that use high-frequency data. We first show government bond sell-off shocks tighten domestic financial conditions in EMEs and cause real investment to decline. In this case, banks find it more profitable to replace foreign lenders holding government bonds amid rising bond yields. This creates a financial crowding out effect, restraining lending to non-financial firms, curbs asset prices and weakens bank balance sheets. The ensuing tightening of domestic financial conditions exacerbates the initial capital outflow, leading to a sharper depreciation in the exchange rate and a rise in inflation. In contrast, country risk premium shocks directly increase foreign funding costs of banks and are magnified by a further widening of UIP deviations due to stronger financing constraints of banks. This leads to a credit crunch in the economy, accompanied by a sharp rise in intermediation margins and a slump in investment. Conventional monetary policy exacerbates the effects of both shocks, as they are in either case inflationary.

Our next key finding suggests that asset purchases are effective in mitigating government bond sell-off shocks but not country risk premium shocks. Specifically, under both shocks, government bond purchases are designed to replace the bond sell-off by foreigners, whilst private security purchases respond to rising loan-deposit spreads, which occurs in bad times due to financial frictions.[4] A government bond purchase policy, which replaces foreign investors,

[3]Simulations also suggest that home goods inflation increases thanks to the policy easing provided by asset purchases. However, the currency appreciation-induced decline in imported goods inflation dominates this effect so that aggregate inflation declines upon asset purchases.

[4]These modalities follow the taxonomy of asset purchases in EMEs during the pandemic provided by Fratto et al. (2021). IMF (2020) also reports that central bank holdings of outstanding EME domestic-currency government bonds increased on average by 0.8% of GDP between end-February and June 2020, slightly more than offsetting one-to-one the decline in holdings of non-residents (0.7% of GDP) during the same period. The evidence also supports the financial crowding out channel: banks absorbed close to 90% of the total rise in outstanding LC EME government bonds (i.e. 2.4 percentage points out of 2.7% of GDP). For a visualisation, see Figure E.1 in the Online Appendix.

prevents a sharp rise in commercial bank holdings of sovereign bonds in response to the bond sell-off shock. The avoided crowding out of private credit boosts prices of corporate securities and expands the borrowing capabilities of banks via the financial accelerator. A private asset purchase policy cannot alleviate the financial crowding out effects of the bond sell-off shock, yet, it directly acts as a financial multiplier, by expanding the total amount of securities and hence boosting asset prices. Thus, by the transmission mechanisms of asset purchases described above, both policies create room for maneuver for conventional monetary policy in response to bond sell-off shocks and facilitate a decline in policy interest rates, mitigating the fear of floating.[5]

We find that neither government bond nor private security purchases are effective in reducing excess government bond yields in response to country risk premium shocks. This is due to the fact that while government bond purchases address the increases in real term premia, they have limited power in reducing the abrupt increase in UIP deviations and the cost of foreign debt, on which country risk premium shocks have a first order-of-magnitude impact. Private security purchases, on the other hand, partly contain the rise in intermediation margins and UIP deviations, which limits the decline in bank credit and real investment. However, even they have limited scope for compressing excess long-term bond yields in response to country risk premium shocks.

Finally, we assess the persistence of the compressing effects of asset purchases on bond yields during the pandemic that have been estimated by Arslan et al. (2020), Fratto et al. (2021), IMF (2020), and WB (2021). Our estimated model implies that those effects could have persisted only under large-scale purchases. To this end, we conduct counterfactual experiments against a baseline public bond purchase policy that replicates the repercussions of the COVID-19 shock in EMEs. The counterfactual of a no-asset purchase response yields negligibly higher increases in government bond yields, currency depreciation and inflation after one quarter. In sharp contrast, when public bond purchases by the central bank are counterfactually increased to the levels observed in large advanced economies during the pandemic, we observe that the central bank could have reduced excess government bond yields in a statistically significant manner

[5]This leads to the intriguing question of why EMEs refrained from embarking on asset purchases during the global financial crisis (GFC), differing from their response to the pandemic. Arguably, there are two strong reasons: limited experience of deploying asset purchases, as advanced economies deployed them for the first time back then; and a lower foreign ownership share of LC sovereign bonds prior to GFC, compared with pre-COVID conditions (12% for the average EME in our sample in 2008 relative to 21% in 2019), limiting the transmission of foreigners' bond sell-off.

by 13 basis points in annualised terms after one quarter relative to a no-intervention case. Our findings also confirm that asset purchases under credible monetary policy frameworks are not inflationary and do not elevate depreciation risks even if they had been as large as those in advanced economies.

Related literature. Our paper contributes to the unconventional monetary policy literature including Cúrdia and Woodford (2011), Gertler and Karadi (2013) and Sims and Wu (2021) among others. These studies find that government bond and private security purchases ease financial conditions, boost economic activity and inflation in advanced, closed economies and are more effective when financial imperfections are more severe or conventional monetary policy is restrained by a zero lower bound. Ellison and Tischbirek (2014) find that there is room to jointly deploy government bond purchases and short-term interest policy outside liquidity trap episodes to reduce inflation and output fluctuations. We differ from these contributions by introducing currency mismatches faced by banks and government bond sell-offs by foreigners in an estimated open economy setup. Dedola et al. (2013) explore welfare gains from the coordination of costly private asset purchases in financially integrated regions, while abstracting from the nominal side. We depart from them by considering monetary policy feedbacks to asset purchases and exchange rate dynamics.

The exchange rate implications of asset purchases in our setup genuinely diverge from studies that consider portfolio rebalancing effects of asset purchases including Alpanda and Kabaca (2020) and Kolasa and Wesołowski (2020) among others. This line of work abstracts from the borrowers channel so that the absorption of government bonds by the central bank induces the private sector to hold foreign assets, leading to capital outflows and an exchange rate depreciation. In our case, asset purchases strengthen the balance sheet of banks, which boosts their foreign borrowing capacity and appreciates the currency. Therefore, our insights fill a gap in the literature by offering transmission channels to understand the neutral stance of EME currencies documented by Arslan et al. (2020), Fratto et al. (2021), Hartley and Rebucci (2020), IMF (2020) and WB (2021) upon the announcement of EME central bank asset purchases in response to the COVID-19 shock.

This paper also relates to the literature studying the balance sheet implications of government bond holdings by banks. To name a few, Chari et al. (2020) demonstrate that under no commitment to debt repayment, bank holdings of sovereign debt make defaults more costly ex post and render financial repression optimal. In our framework, positive bank holdings of sovereign debt remains in equilibrium, because it relaxes bankers' financing constraints. Bocola (2016) shows risky sovereign bond holdings limit the lending capacity of banks and lead to precautionary deleveraging when reduced-form sovereign default risk rises. Kirchner and van Wijnbergen (2016) illustrate that when banks lend to the government, debt-financed fiscal expansion crowds out private lending and reduces the growth effects of fiscal stimulus. All three studies preclude the foreign-lending base of the government and hence the repercussions of bond sell-offs by foreign lenders. Recent empirical studies by Broner et al. (2021) and Priftis and Zimic (2020) introduce this channel and document that when government spending is foreign-debt financed, fiscal multipliers become larger. We bring a new angle to the literature by showing that the adverse repercussions of the foreigners' government bond sell-off in episodes of stress may reduce the gains from larger fiscal multipliers and offer central bank asset purchases as a remedy to countervail these effects.

The rest of the paper is organised as follows. The next section describes our analytical environment with an emphasis on the financial sector and the government. Section 3 describes our model estimation strategy, conducts quantitative experiments uncovering the transmission channels of asset purchases and, using our estimated model, demonstrates the efficacy of asset purchases during the COVID-19 crisis against counterfactual scenarios. Section 4 explores the sensitivity of our findings to some key EME properties. Finally, Section 5 concludes the paper.

2 Model economy

The analytical framework is a medium-scale New Keynesian small open economy model inhabited by households, banks, non-financial firms, capital producers, and a government. Financial frictions define bankers as a key agent in the economy. The modeling of the banking sector extends Gertler and Karadi (2013) and Sims and Wu (2021) to incorporate that banks obtain external financing from both domestic depositors and international investors, bearing currency risk and lending to domestic non-financial, intermediate goods producers. Banks also make loans to the government by purchasing LC, long-term government bonds. For tractability, we abstract from lending to foreign production firms. The consolidated government makes an exogenous stream of spending, borrows from abroad in addition to domestic banks and determines monetary policy, possibly including unconventional measures such as central bank asset purchases. Variables that are denominated in FC or related to the rest of the world are indicated by an asterisk. For brevity, we include key model equations in the main text. A full list of structural shocks used in the estimation of the model can be found in the lower panel of Table 3. Interested readers might refer to Online Appendix A for detailed derivations of the optimisation problems of agents, explicit formulations of the shock processes and a definition of the competitive equilibrium.

2.1 Households

The economy is inhabited by a large number of infinitely-lived identical households, who derive utility from consumption and leisure. For the sake of brevity, we demonstrate a cashless economy as in Woodford (2003). The household utility function is also subject to a consumption preference shock. Each household is composed of a worker and a banker member who perfectly insure each other. Workers consume a constant-elasticity-of-substitution (CES) aggregate of domestic and imported tradable goods and supply labor. They also save in LC deposits within financial intermediaries owned by the banker members of other households. The nominal balance of these deposits is denoted by D_t, which pays a net real rate of $R_{t+1} - 1$ in the next period. There are no interbank frictions so that the nominal counterpart of the deposit rate coincides with the short-term policy rate of the central bank r_{nt}. By assumption, households cannot directly save in productive capital, and only banker members of households are able to borrow in FC.[6]

2.2 Banks

The main financial friction in this economy originates in the form of a moral hazard problem between bankers and their funders and leads to an endogenous borrowing constraint on the former. The agency problem is such that depositors (both domestic and foreign) believe that bankers might divert a certain fraction of their assets for their own benefit. Therefore, while funding their assets, banks face an incentive compatibility constraint. This in turn restrains funds raised by bankers and limits the credit extended to non-financial firms and the government, leading to non-negative loan-deposit spreads faced by both borrowers. We formulate the diversion feature so that in equilibrium, rates of return on corporate securities and government

[6] The government also borrows from foreign investors but by issuing domestic currency, long-term bonds. Additionally introducing FC public debt would not alter our main findings on the transmission of LC asset purchases.

bonds as well as bank funding rates over domestic or foreign deposits are ranked in the model as they do in the data.

2.2.1 Balance sheet

The period-t balance sheet of a banker j denominated in terms of the domestic final good reads,

$$q_t l_{jt} + q_t^g b_{jt}^g = d_{jt} + b_{jt}^* + n_{jt}. \quad (1)$$

Banks hold two types of assets: Loans made to production firms and to the government. The former asset class is securities l_{jt} issued by non-financial firms against their physical capital demand and is priced at q_t, the nominal price of these claims Q_t deflated by the aggregate price index P_t. The latter class is long-term LC government debt, denoted by b_{jt}^g to represent real government bonds purchased by banker j. It is priced at q_t^g. On the liability side, d_{jt} stands for real domestic deposits and b_{jt}^* is the foreign debt in real domestic goods units. The latter satisfies $b_{jt}^* = s_t \tilde{b_{jt}^*}$ where $s_t = \frac{S_t P_t^*}{P_t}$ stands for the real exchange rate with S_t denoting the nominal exchange rate of FC in domestic currency units, P_t^* denoting the foreign price level and $\tilde{b_{jt}^*}$ standing for foreign debt of banks denominated in real foreign goods units. The latter satisfies $\tilde{b_{jt}^*} = \frac{B_{jt}^*}{P_t^*}$ with B_{jt}^* standing for the FC denominated nominal borrowing of banker j. Consequently, b_{jt}^* explicitly captures the impact of fluctuations in the real exchange rate on bank balance sheets. n_{jt} is the real net worth of banker j.

Bankers' capital evolves into the next period by incorporating profits from lending operations:

$$n_{jt+1} = \left[R_{kt+1} - R_{t+1}^*\right] q_t l_{jt} + \left[R_{t+1}^g - R_{t+1}^*\right] q_t^g b_{jt}^g - \left[R_{t+1} - R_{t+1}^*\right] d_{jt} + R_{t+1}^* n_{jt}. \quad (2)$$

where R_{kt+1} denotes the state-contingent real return earned on claims against firms and R_{t+1}^g denotes the real return earned from holding long-term government bonds. This equation illustrates that individual bankers' net worth depends positively on the premia of the returns earned on assets over the cost of foreign debt, $R_{kt+1} - R_{t+1}^*$ and $R_{t+1}^g - R_{t+1}^*$. The third term on the right-hand side shows the excess cost of raising domestic deposits as opposed to foreign debt, a function of deviations from the UIP condition. Finally, the last term is the contribution of internal funds, multiplied by R_{t+1}^*, the opportunity cost of raising one unit of external funds via foreign borrowing.

The real deposit rate R_{t+1} and the borrowing rate of foreign debt R^*_{t+1} (denominated in real domestic goods units) satisfy the following definitions

$$R_{t+1} = (1 + r_{nt}) \frac{P_t}{P_{t+1}}$$

$$R^*_{t+1} = \Psi_t R^*_{nt} \frac{S_{t+1}}{S_t} \frac{P_t}{P_{t+1}} \quad \forall t, \tag{3}$$

where r_n denotes the net nominal deposit rate and R^*_n is the gross nominal US interest rate that follows an autoregressive stochastic process. Cost of foreign debt R^*_{t+1} reflects a risk premium $\Psi_t = \exp(\psi \, \widehat{nfd}_t) \exp(\psi^{rp}_t)$ over US interest rates R^*_{nt}, as in Gertler et al. (2007), where nfd_t stands for net foreign debt; the sum of the foreign debt of bankers b^*_t and the government $b^{g^*}_t$ (defined below). $\widehat{nfd}_t$ denotes a log-deviation from the steady-state and $\psi > 0$ is the foreign debt elasticity of country risk premium. We also consider country risk premium shocks, $\exp(\psi^{rp}_t)$, hitting this premium to capture exogenous fluctuations in sovereign spreads.

Banks find it profitable to make loans to both non-financial firms and the government only if

$$E_t \left\{ \Lambda_{t,t+1+i} \left[R_{kt+1+i} - R^*_{t+1+i} \right] \right\} \geq 0 \text{ and } E_t \left\{ \Lambda_{t,t+1+i} \left[R^g_{t+1+i} - R^*_{t+1+i} \right] \right\} \geq 0 \;\; \forall t,$$

where $\Lambda_{t,t+1+i} = \beta^{i+1} \left[\frac{U_c(t+1+i)}{U_c(t)} \right]$ denotes the $i+1$ periods-ahead stochastic discount factor of households, whose banker members operate as financial intermediaries. In the following, we also establish that $E_t \left\{ \Lambda_{t,t+1+i} \left[R_{t+1+i} - R^*_{t+1+i} \right] \right\} > 0 \;\; \forall t$, so that the cost of domestic debt entails a positive premium over the cost of foreign debt at all times, suggesting a microfoundation to deviations from the UIP condition.

In order to rule out any possibility of complete self-financing, we assume that bankers have a finite life and survive to the next period only with probability $0 < \theta < 1$. At the end of each period, $1 - \theta$ measure of new bankers are born and are remitted $\frac{\epsilon^b}{1-\theta}$ fraction of the assets owned by exiting bankers in the form of start-up funds.

2.2.2 Net worth maximisation

Bankers maximise the expected discounted value of the terminal net worth of their financial firm V_{jt}, by choosing the amount of security claims purchased l_{jt}, the amount of government bonds purchased b^g_{jt} and the amount of domestic deposits d_{jt}. The recursive maximisation problem is

$$V_{jt} = \max_{l_{jt}, b^g_{jt}, d_{jt}} E_t \Big\{ \Lambda_{t,t+1} \Big[(1-\theta) n_{jt+1} + \theta V_{jt+1} \Big] \Big\}. \tag{4}$$

For a given net worth, the optimal foreign debt choice b^*_{jt} can be backed out from the balance sheet.

For non-negative premia on credit to non-financial firms and credit to the government, the solution to the value maximisation problem of banks would lead to an unbounded magnitude of assets. In order to rule out such a scenario, we follow Gertler and Kiyotaki (2010) and introduce an agency problem between depositors and bankers. Specifically, lenders believe that banks might divert λ fraction of their total divertable assets, where divertable assets constitute total credit extended to non-financial firms plus a fraction ω_g, of government bonds purchased minus a fraction ω_d, of domestic deposits. When lenders become aware of the potential confiscation of assets, they would initiate a bank run, which would lead to the liquidation of the bank altogether. In order to rule out bank runs in equilibrium, in any state of nature, bankers' optimal asset choices should be incentive compatible. Therefore, the following constraint is imposed on bankers,

$$V_{jt} \geq \lambda \Big(q_t l_{jt} + \omega_g q^g_t b^g_{jt} - \omega_d d_{jt} \Big), \tag{5}$$

where λ, ω_g and ω_d are constants between zero and one. This inequality suggests that the liquidation cost of bankers from diverting funds V_{jt} should be greater than or equal to the diverted portion of assets. When this constraint binds, bankers would never choose to divert funds and lenders would adjust their position and restrain their lending to bankers, accordingly.[7]

We introduce two different asymmetries in financial frictions by including only $0 < \omega_g < 1$ fraction of government bonds into and excluding $0 < \omega_d < 1$ fraction of domestic deposits from diverted assets. The first asymmetry suggests that it would be more difficult to divert government bonds, making them less risky compared to the security claims issued by non-financial firms. The second asymmetry hinges on the idea that domestic depositors would arguably have a comparative advantage over foreign depositors in recovering assets in case of

[7] We log-linearly approximate the stochastic equilibrium around the deterministic steady state. Therefore, we confine our interest to cases in which the incentive constraint of banks is always binding so that (5) holds with equality at all times.

a bankruptcy. Furthermore, they would also be better equipped than international lenders to monitor domestic bankers.[8]

We conjecture the optimal value of financial intermediaries to be a linear function of firm loans, government bonds, domestic deposits and bank capital. That is,

$$V_{jt} = \nu_t^l q_t l_{jt} + \nu_t^g q_t^g b_{jt}^g - \nu_t^* d_{jt} + \nu_t n_{jt}. \tag{6}$$

Among these recursive objects, ν_t^l and ν_t^g represent the expected marginal values of credit extended to non-financial firms and government, ν_t^* stands for the expected excess cost of borrowing from domestic savers and ν_t denotes the expected marginal value of bank capital at the end of period t.

The first-order conditions and the associated Lagrange multiplier μ_t of this problem are

$$\nu_t^l(1+\mu_t) = \lambda\mu_t, \tag{7}$$

$$\nu_t^g(1+\mu_t) = \lambda\mu_t\omega_g, \tag{8}$$

$$\nu_t^*(1+\mu_t) = \lambda\mu_t\omega_d, \tag{9}$$

$$\nu_t^l q_t l_{jt} + \nu_t^g q_t^g b_t^g - \nu_t^* d_{jt} + \nu_t n_{jt} - \lambda\left(q_t l_{jt} + \omega_g q_t^g b_{jt}^g - \omega_d d_{jt}\right) \geq 0 \tag{10}$$

respectively. Since the incentive constraint of banks is always binding, $\mu_t > 0$ and (10) holds with equality. Combining (7) and (8) yields, $\nu_t^g = \omega_g \nu_t^l$. Combining (7) and (9) yields, $\nu_t^* = \omega_d \nu_t^l$. Inserting these equations into the binding version of (10) and rearranging terms lead to the key leverage constraint in our setup,

$$q_t l_{jt} + \omega_g q_t^g b_{jt}^g - \omega_d d_{jt} = \frac{\nu_t}{\lambda - \nu_t^l} n_{jt} = \kappa_{jt} n_{jt}. \tag{11}$$

This condition ensures that bankers' risky assets are proportional to their net worth, defining bank leverage κ_{jt} endogenously. It further suggests that all else equal, bank leverage decreases with the fraction of divertable funds λ and increases with the expected marginal value of extending credit to firms ν_t^l and the expected marginal value of bank capital ν_t.

We replace V_{jt+1} in equation (4) by inserting the one-period ahead leverage constraint (11) into the binding version of the one-period ahead incentive compatibility constraint (5) to obtain,

[8] For further elaborations of creditor discrimination favoring domestic lenders, see Broner et al. (2014), Fornaro (2015) and Mimir and Sunel (2019).

$$\tilde{V}_{jt} = E_t\Big\{\Xi_{t,t+1} n_{jt+1}\Big\}, \tag{12}$$

where $\tilde{V}_{jt}$ stands for the optimised value and $\Xi_{t,t+1} = \Lambda_{t,t+1}\Big[1 - \theta + \theta\lambda\kappa_{t+1}\Big]$ represents the augmented stochastic discount factor of bankers, which is a weighted average defined over the likelihood of survival. Replacing the left-hand side to verify our linear conjecture on bankers' value (6) and using equation (2), we find that ν_t^l, ν_t^g, ν_t^* and ν_t should satisfy,

$$\nu_t^l = E_t\Big\{\Xi_{t,t+1}\left[R_{kt+1} - R_{t+1}^*\right]\Big\}, \tag{13}$$

$$\nu_t^g = E_t\Big\{\Xi_{t,t+1}\left[R_{t+1}^g - R_{t+1}^*\right]\Big\}, \tag{14}$$

$$\nu_t^* = E_t\Big\{\Xi_{t,t+1}\left[R_{t+1} - R_{t+1}^*\right]\Big\}, \tag{15}$$

$$\nu_t = E_t\Big\{\Xi_{t,t+1} R_{t+1}^*\Big\}, \tag{16}$$

Equations (13) and (14) suggest that bankers' marginal valuation of credit to non-financial firms and to the government are equal to the expected discounted premia between respective loan rates minus the benchmark cost of foreign funds. These equations and condition $\nu_t^g = \omega_g \nu_t^l$ under $0 < \omega_g < 1$ imply that the spread between loan and government bond rates will be positive as in the data. Equation (15) defines the marginal excess cost of raising funds via domestic deposits instead of foreign debt. This premium will always be positive (that is, $\nu_t^* > 0$) by the virtue of financial constraints always binding $\mu, \lambda > 0$ and the asymmetry on the funding side $0 < \omega_d < 1$ leading to condition (9).[9] This also implies that the UIP condition, shown by equation (15) breaks in the model, consistent with the data. In particular, these UIP deviations become larger when overall financial frictions become more intense (higher λ), or when adverse financial shocks make the incentive compatibility constraint more binding (higher Lagrange multiplier μ), consistent with the empirical evidence presented by di Giovanni et al. (2021). Finally, equation (16) shows that marginal value of internal financing should be equal to the expected discounted opportunity cost of raising foreign borrowing.

[9] Financial frictions would vanish when none of the assets are diverted, i.e. $\lambda = 0$ and bankers never have to exit, i.e. $\theta = 0$, resulting in $\Xi_{t,t+1}$ simply collapse to the pricing kernel of households $\Lambda_{t,t+1}$. This case would also imply efficient intermediation of funds, driving the arbitrage between the lending and deposit rates down to zero.

2.2.3 Aggregation

All households behave symmetrically, so that we can aggregate equation (11) over j and obtain the following aggregate relationship:

$$q_t l_t + \omega_g q_t^g b_t^g - \omega_d d_t = \kappa_t n_t, \tag{17}$$

where $q_t l_t$, $q_t^g b_t^g$, d_t and n_t represent aggregate levels of their bank-specific counterparts defined above. Equation (17) shows that aggregate credit to non-financial firms plus the divertable portion of credit to government net of non-divertable domestic deposits can only be up to an endogenous multiple of aggregate bank capital. Furthermore, fluctuations in asset prices q_t and q_t^g, would feed back into fluctuations in bank capital via this relationship. This would be the source of the financial accelerator mechanism in our model and would play a crucial role in the transmission of asset purchase policies into the real economy, as we demonstrate below.

The evolution of aggregate net worth depends on that of the surviving bankers n_{et+1}, which might be obtained by substituting the aggregate bank capital constraint (17) into the net worth evolution equation (2) to obtain

$$\begin{aligned} n_{et+1} = \theta \Big\{ \Big[(R_{kt+1} - R^*_{t+1})\kappa_t + R^*_{t+1} \Big] n_t + \Big[(R^g_{t+1} - R^*_{t+1}) - \omega_g (R_{kt+1} - R^*_{t+1}) \Big] q_t^g b_t^g \\ + \Big[\omega_d (R_{kt+1} - R^*_{t+1}) - (R_{t+1} - R^*_{t+1}) \Big] d_t \Big\} \end{aligned} \tag{18}$$

and adding up the start-up funds of the new entrants n_{nt+1}. The latter is equal to $\frac{\epsilon^b}{1-\theta}$ fraction of exiting banks' assets $(1-\theta)(q_t l_t + q_t^g b_t^g)$. Therefore, $n_{nt+1} = \epsilon^b (q_t l_t + q_t^g b_t^g)$. As a result, the transition for the aggregate bank capital becomes, $n_{t+1} = n_{et+1} + n_{nt+1}$.

2.2.4 Excess bond yields

The key financial variable of interest in our study is the spread between LC long-term EME sovereign bond rates and the short-term US Treasury rate. A few elaborations are in order before we define this spread. First, we use the Macaulay (1938) formulation to tractably model long-term government debt issuance. Specifically, we assume that the long-term sovereign bond promises to pay geometrically decaying payments of $\kappa_{gt}, \kappa_{gt+1}(1-\delta_g), \kappa_{gt+2}(1-\delta_g)^2, ..., 0$ with κ_{gt} denoting periodic coupon payments in terms of the numeraire good and δ_g representing the bond decay rate. We assume that a structural shock – akin to a capital quality shock in Gertler and Karadi (2011) – hits steady-state coupon payments $\bar{\kappa}_g$ to capture long-term bond yield fluctuations that originate from non-fundamental factors, allowing us to estimate historical long-term bond yield dynamics for the average EME in our sample.

The Macaulay (1938) formulation spares us from keeping track of a large dimensional state space of historical non-matured debt balances and is flexible, as the decay rate can be calibrated to match equilibrium bond maturities. According to this formulation, gross real per-period return from holding government bonds satisfies

$$R^g_{t+1} = \frac{\kappa_{gt} + (1-\delta_g)q^g_{t+1}}{q^g_t}. \tag{19}$$

Domestic banks, foreign investors (and the central bank if it purchases sovereign bonds) earn the same real return over this asset. This return can then be converted to a real yield-to-maturity with

$$R^{YTM,g}_t = \frac{\kappa_{gt}}{q^g_t} + 1 - \delta_g \tag{20}$$

and to a net nominal yield-to-maturity for long-term bonds as

$$1 + i^{YTM,g}_t = R^{YTM,g}_t \pi_{t+1}, \tag{21}$$

where π is the gross inflation rate of aggregate prices. Therefore, normalising gross inflation rate to 1 in the United States, the excess bond yield of domestic currency, long-term EME government bonds over US short-term rates becomes

$$EY^g_t = 1 + i^{YTM,g}_t - R^*_{nt}. \tag{22}$$

2.3 Capital producers

Capital producers operate in a perfectly competitive market, purchase investment goods and transform them into new capital. At the end of period t, they sell both newly produced and repaired capital to the intermediate goods firms at the unit price of q_t. Intermediate goods firms use this new capital for production at time $t+1$. We also assume that capital producers incur investment adjustment costs, providing a basis for Tobin's q, while producing new capital. Finally, they return any earned profits to households, who own them.

2.4 Firms

Final and intermediate goods are produced by a representative final good producer and a continuum of intermediate goods producers that are indexed by $i \in [0,1]$ respectively. Among these, the former repackages the differentiated varieties produced by the latter and sells them in the domestic market. The latter, on the other hand, finances productive capital by selling security claims to banks and demands labour to operate in a monopolistically competitive market. In order to assume rigidity in price setting, we assume that intermediate goods firms face menu costs.

2.5 Government

The government sector is composed of a fiscal and a monetary authority that interact more strongly than those in canonical New Keynesian models due to the existence of government bond purchases by the central bank in crisis times.

Fiscal policy. The government makes expenditures on final goods $g_t(g_t^H, g_t^F)$, which follow an autoregressive stochastic process and fall on home g^H and imported goods g^F through a CES aggregator. It then borrows in long-term, domestic currency bonds $\bar{b^g}$ and raises lump-sum taxes τ from households to finance its expenditures. To ensure the closure of the fiscal block and well-defined fiscal dynamics as in Gertler and Karadi (2013) and Sims and Wu (2021), we assume that the fiscal branch follows a debt rule in the form of a constant real supply of LC government bonds,

$$q_t^g \bar{b^g} = q_t^g b_t^g + q_t^g b_t^{g^*} + q_t^g b_t^{gCB}. \tag{23}$$

This assumption also reflects the features that fiscal space has been limited in EMEs during the COVID-19 crisis (IMF, 2021) and bond purchases by the central bank have mostly been in the nature of secondary market purchases (i.e., the central banks did not purchase newly issued public debt), as the modality of asset purchases during the pandemic crisis suggested (Fratto et al., 2021).[10]

Sovereign bonds are held by bankers b_t^g, foreigners $b_t^{g^*}$ and the central bank b_t^{gCB} should the central bank want to embark on asset purchase policies. We assume that bonds held by foreigners follow an exogenous process, which entails a negative feedback from increasing country risk premia and reflects exogenous reversals in global risk appetite toward sovereign bonds. That is,

$$\log(b_t^{g^*}) = \rho_{g^*} \log(b_{t-1}^{g^*}) + (1-\rho_{g^*}) \left[\log \bar{b^{g^*}} + v_{g^*} \log(\Psi_t)\right] + \varepsilon_t^{g^*}, \tag{24}$$

[10]When we relax this assumption and investigate its implications, we have found that an increase in supply of LC bonds needs to be financed by higher government bond purchases by foreign investors, leading to a larger external risk premium and a reduced foreign borrowing by private banks.

with $\upsilon_{g^*} < 0$ reflecting the negative feedback from country risk to foreign demand for sovereign bonds and $\varepsilon_t^{g^*}$ denoting bond sell-off shocks drawn from a Gaussian distribution with zero mean and constant variance.

Conventional monetary policy. The central bank deploys the same interest rate policy during both normal and crisis times. We consider an augmented Taylor-type interest rate rule that allows responses to inflation, output gap and nominal currency depreciations,

$$\log\left(\frac{1+r_{nt}}{1+\overline{r_n}}\right) = \rho_{r_n}\log\left(\frac{1+r_{nt-1}}{1+\overline{r_n}}\right) + (1-\rho_{r_n})\left[\varphi_\pi \log\left(\frac{\pi_t}{\overline{\pi}}\right) + \varphi_y \log\left(\frac{y_t}{\overline{y}}\right) + \varphi_\eta \log\left(\frac{\eta_t}{\overline{\eta}}\right)\right] + \varepsilon_t^{r_n}, \tag{25}$$

where r_{nt} is the short-term policy rate, π_t is the gross CPI inflation rate, y_t is GDP, $\eta_t = \frac{S_t}{S_{t-1}}$ is the gross depreciation rate of the nominal exchange rate vis-à-vis the US dollar and variables with bars denote respective steady-state values that are targeted by the central bank.[11] $\varepsilon_t^{r_n}$ stands for monetary policy shocks. To be general, we also allow for interest rate smoothing in the monetary policy rule so that $0 \le |\rho_{r_n}| < 1$.

Asset purchases. In extreme episodes of financial stress, we assume that the central bank could additionally deploy asset purchases to guide price discovery and ease financial conditions.[12] Motivated by the experience of EME central banks during the pandemic, we consider the possibility of both LC long-term government bond and private security purchases.[13] Let government bond purchases by the central bank be defined as

$$q_t^g b_t^{gCB} = \varphi_t^g q_t^g \bar{b^g}(1-\tau^{gCB}) \tag{26}$$

with φ_t^g denoting the time-varying share of government bonds purchased by the central bank. A key issue regarding the feasibility of asset purchase policies is the concern that they might transfer risk from private sector lenders to the central bank, which could undermine the efficacy of such policies. In order to capture those frictions, we introduce the possibility of efficiency

[11] Although the central bank's mandate does not explicitly include stabilising the exchange rate, a de facto fear of floating as discussed by Calvo and Reinhart (2002) induces it to respond to currency fluctuations. In recent work, Mimir and Sunel (2019) have shown that in EMEs, it is optimal to respond to currency fluctuations that are triggered by external financial shocks. In the current paper, we estimate the persistence and response parameters of the augmented Taylor rule (25) using Bayesian methods. The estimated modes of the response coefficients (see Table 2) satisfy the modified Taylor principle for determinacy – as discussed by Woodford (2003) – under interest-rate rules that display inertia.

[12] The description of asset purchases is included for completeness. The calibration and estimation of our quantitative model takes as reference the pre-pandemic period of EMEs and hence excludes asset purchases.

[13] IMF (2020) reports that Chile, Colombia and Hungary are among asset purchase-implementing EMEs that purchased bank bonds or mortgage bonds as private assets. The remaining central banks purchased LC sovereign bonds in response to the COVID-19 crisis. Fratto et al. (2021) also report that government bond purchases were quantity-based and private asset purchases were price-based, responding to tightening financial conditions.

losses to asset purchase policies in the form of leakages. That is, a constant fraction $0 < \tau^{gCB} < 1$ of bond purchases is simply lost in (26) as central bankers are not experts on financial assets intermediation.

We assume that the bond purchase policy function is designed to mitigate market dislocations. Thus, the share of bonds purchased by the central bank follows

$$\varphi_t^g = \rho_{\varphi^g}\varphi_{t-1}^g + (1-\rho_{\varphi_g})\left[\bar{\varphi}^g + v_g\left(\frac{q_t^g b_t^{g^*}/y_t}{q^g b^{g^*}/y}\right)\right] + \varepsilon_t^{\varphi^g}, \tag{27}$$

with $\bar{\varphi}^g$ denoting the steady state share of LC bonds held by the central bank, ρ_{φ^g} measuring the persistence of the asset purchase policy rule and $v_g < 0$ denoting a response parameter that calls for increased purchases should the foreign-held government bonds-to-GDP ratio decline. We calibrate v_g to ensure that all of the bond sell-off by foreigners is replaced by the central bank which was the experience of EME central banks at the onset of the pandemic. $\varepsilon_t^{\varphi^g}$ is a Gaussian shock with zero mean and constant variance that captures discretionary bond purchase policy shocks.

Central bank purchases of securities issued by nonfinancial intermediate goods producers read

$$q_t l_t^{CB} = \varphi_t^l q_t \bar{l}_t (1-\tau^{CB}) \tag{28}$$

with φ_t^l denoting the time-varying share of securities purchased by the central bank and $\bar{l}_t$ standing for the total supply of private securities. Similar to the case of government bond purchases, $0 < \tau^{CB} < 1$ captures efficiency losses in (28). Market clearing for private securities necessitates

$$q_t \bar{l}_t = q_t l_t + q_t l_t^{CB}. \tag{29}$$

We assume that purchases of private securities by the central bank are designed to tame loan-deposit spreads – as in Gertler and Karadi (2011) – that tend to rise in response to adverse financial shocks. Therefore, the share of private securities held by the central bank follows

$$\varphi_t^l = \rho_{\varphi^l}\varphi_{t-1}^l + (1-\rho_{\varphi_l})\left[\bar{\varphi}^l + v_l E_t \log\left(\frac{R_{kt+1}-R_{t+1}}{R_k - R}\right)\right] + \varepsilon_t^{\varphi^l}, \tag{30}$$

with $\bar{\varphi}^l$ denoting the steady state share of private securities held by the central bank, ρ_{φ^l} measuring the persistence of the security purchase policy rule and $v_l > 0$ denoting a response parameter that calls for increased purchases should loan-deposit spreads rise. We calibrate v_l to obtain empirically realistic private asset purchase quantities by the central bank. Finally, $\varepsilon_t^{\varphi^l}$ is an innovation drawn from a Gaussian distribution with zero mean and constant variance, capturing discretionary shocks to the private security purchases policy.

The central bank finances purchases of private securities and government bonds by issuing interest-bearing short-term bonds to households, which can be thought as a perfect substitute for deposits earning the nominal net deposit rate of r_{nt}. Since the central bank always repays these bonds, assets intermediated by it are not subject to an agency problem and are not bound by leverage constraints, in contrast to the assets intermediated by banks (see Section 2.2.2).[14]

Consolidated government. The consolidated government finances the consumption of final goods and net interest payments over rolled over debt by lump-sum taxes and the net interest earned by asset purchases. The flow budget constraint of the government reads

$$g_t + (R_t^g - 1)\bar{b}^g = \tau_t + (R_t^g - R_t)q_{t-1}^g b_{t-1}^{gCB} + (R_{kt} - R_t)q_{t-1}l_{t-1}^{CB}. \tag{31}$$

Notice that as implied by equations (26) and (28), leakages in asset purchases directly result in losses to the central bank and reduce the profits remitted to the consolidated government. During normal times, there are no asset purchases, so that the last two terms of (31) would disappear.

The case for reducing excess bond yields in crisis periods. The incentive of the central bank to reduce sovereign bond yields during stress episodes is understood better if excess sovereign bond yield is broken down into its components. Specifically, (22) can be rewritten as

$$EY_t^g = (R_t^{YTM,g} - R_t)\pi_{t+1} + (R_t - R_t^*)\pi_{t+1} + R_t^*\pi_{t+1} - R_{nt}^*. \tag{32}$$

The first term of this decomposition represents the inherent real yield premium of long-term government bonds over short-term real deposit rates in the EME. Both bond sell-off and country risk premium shocks would stress bank balance sheets and drive a decline in asset prices, causing this real yield premium to widen. In addition, both shocks would lead to a currency depreciation, which passes through to domestic prices and increase inflation, feeding into the fear of floating and raising nominal excess yields. An adverse country risk premium shock would additionally raise banks' foreign funding costs R_t^*, whose effect would be propagated

[14] This ensures that these short-term bonds endogenously adjust in equilibrium to meet the increase in asset purchases due to Walras' Law as in Gertler and Karadi (2013). An equivalent alternative for the financing of asset purchases might entail issuing interest-paying reserves to domestic banks. Assuming that ω_d fraction of those reserves could be diverted ensures that they become perfect substitutes for household deposits. See the incentive compatibility constraint, (5).

by a rise in the second term of (32), the UIP deviation during financial stress episodes (see Section 2.2.2). Therefore, if the central bank can boost sovereign bond prices by conducting asset purchases, it may partly offset the negative repercussions of the external financial shocks by reversing their transmission.

We conclude the analytical description of our environment by demonstrating how asset purchases by the central bank help ease financial conditions in the economy. Equations (26) and (28) can be combined with their respective market clearing conditions (23) and (29) to arrive at

$$q_t^g \bar{b^g} = \frac{1}{1 - \varphi_t^g (1 - \tau^{gCB})} \left[q_t^g b_t^g + q_t^g b_t^{g^*} \right] \tag{33}$$

$$q_t \bar{l}_t = \frac{1}{1 - \varphi_t^l (1 - \tau^{CB})} q_t l_t. \tag{34}$$

Asset purchase rules φ_t^g and φ_t^l are bounded above by one and assets intermediated by commercial banks are tied by the leverage constraint (17). Therefore, the fractions in equations (33) and (34) multiply privately intermediated assets at a rate that is greater than one. For the case of government bonds, the fixed supply means that the government bond price q_t^g will increase, helping reduce excess bond yields via (20). For the case of purchases of private securities, the central bank can directly expand the supply of credit to intermediate goods producers as well as boosting asset prices. Finally, we underscore that the efficiency losses denoted by $0 < \tau^{gCB}, \tau^{CB} < 1$ would reduce the financial multiplier effects of asset purchase policies.

3 Quantitative analysis

In this section, we describe our model calibration and estimation procedure, and conduct a number of quantitative experiments to explore the implications of asset purchases using our estimated model. We first analyse discretionary asset purchase policies (asset purchase shocks) both for sovereign bonds and non-financial firm securities. We then judge the effectiveness of rule-based asset purchases in mitigating the repercussions of a sovereign bond sell-off shock driven by foreign investors. In a third experiment, we repeat the same exercise under endogenous bond sell-offs responding to country risk premium shocks. Finally, we conduct counterfactual experiments that uncover the effectiveness of alternative public and private asset purchase policies in the context of the COVID-19 shock that hit the average EME in our sample based on a conditional forecasting exercise using our estimated DSGE model.

3.1 Model calibration and estimation

We choose parameters of the model without asset purchases based on a quarterly data set covering the pre-pandemic period of 2002Q1-2019Q4. The data set includes 13 EMEs identified in Arslan et al. (2020) to have implemented asset purchases during the COVID-19 crisis. A first subset of model parameters that affect the deterministic steady-state of the model are calibrated to match important long-run macroeconomic ratios, various interest rates, bond and credit spreads, the LC government bonds-to-GDP ratio and foreign investors' share in outstanding LC sovereign bonds. Bond maturity is calibrated to ten years, using the geometrically decaying coupon modelling in Sims and Wu (2021). A second set of dynamic model parameters are estimated by using Bayesian techniques, as outlined in An and Schorfheide (2007), based on the simple averages of HP-filtered data across the countries in our sample (presented in Figure 1). The business cycle properties of the simple averages and the median of our cross-country HP-filtered data resemble each other quite closely. Computations are done by using the *RISE* toolbox.[15] We first describe the data used for the estimation, give an account of how the model's steady state is calibrated and report on our prior and posterior distributions. A full list of all parameters in the model is provided in Tables 1, 2 and 3. Further information on the computation of the empirical counterpart of targeted moments and specific data sources can be found in Online Appendix B.1.

The data set used in the calibration and the estimation of the model covers Chile, Colombia, Hungary, India, Indonesia, Korea, Mexico, the Philippines, Poland, Romania, South Africa, Thailand, and Turkey. 12 macroeconomic time series including domestic and international variables are used in the estimation. The data for the real variables are in constant prices from the national accounts. Real domestic variables included are GDP, consumption, exports, government expenditures, and investment. Financial variables are the nominal excess yield on 10-year government bonds and country risk premia. Price variables are consumer price inflation and the policy rate. Finally, international variables include the real exchange rate, the US Fed Funds rate and foreign investors' share in outstanding LC sovereign bonds. The data sources we use are Refinitiv, Factset and international sources such as the BIS, IMF, OECD and WB.

[15]"Rationality In Switching Environments" (*RISE*) is an object-oriented Matlab toolbox for solving and estimating nonlinear Regime-Switching DSGE models. The toolbox developed by Junior Maih is freely available for downloading at https://github.com/jmaih/RISE_toolbox.

3.1.1 Calibration of the steady state

Table 1 lists a set of parameters calibrated to hit key long-term moments for the average economy in our sample. We set a households' quarterly discount factor β at 0.9968 to match an average annualised real deposit rate of 1.3%. The utility weight of labor χ is calibrated as 397.7 to fix hours worked in the steady state at 0.3333. The steady-state share of domestic goods in the consumption composite $\bar{\omega}$ is set at 0.5 to match an average consumption-to-output ratio of 0.59.

The next block of parameters are in the financial sector. The diverted assets ratio λ, proportional transfers to new financial sector entrants ϵ^b, the non-diverted domestic deposits ratio ω_d and the diverted government bonds ratio ω_g are jointly calibrated as 0.79, 0.0026, 0.1769, and 0.4230, respectively, to match the following four targets: an average loan-foreign borrowing spread of annualised 415 basis points, an average bank leverage of 6.41, a foreign debt share of 31.72% for banks and an annualized 10-year government bond excess yield of 123 basis points over short-term deposit rates. We also pick a survival probability for bankers θ^b of 0.92, implying an average life of 3.1 years for financial intermediaries in emerging markets.

Regarding the technology parameters, we follow the literature in setting capital share in production α at 0.3. The scaling parameter of capital utilisation d is calibrated as 0.0424 to normalise the steady-state rate of capital utilisation at unity. We calibrate the additive parameter of the quarterly depreciation rate of capital δ as 0.1157 to match an annualised private credit-to-GDP ratio of 45%. We set the elasticity of substitution between varieties in final output ϵ at 11 to have a steady-state mark-up value of 1.1.

On the external sector, we set the mean of foreign output $y^* = \bar{0}.1324$ to match the long-run mean of trade volume-to-output ratio of 71%. The long-run mean of quarterly foreign real interest rate is set to 10 basis points to match average real 3-month U.S. Treasury yields for the 2002-2008 episode, to avoid negative world interest rates.

Finally, we calibrate parameters regarding the government and the central bank. The model is approximated around a zero net rate of inflation at the steady-state. We calibrate the steady-state ratio of government spending-to-output ratio, $\bar{g} = 0.145$ to match its value in the data. The quarterly government debt limit is chosen as $b_g = \bar{0}.0935$ to match the average annual LC government debt-to-GDP ratio of 24%. The foreign holdings share of LC government bonds is set at $\bar{\zeta} = 0.17$ to replicate its empirical counterpart. We set the decay rate of real long-term LC government bonds, δ_g, at 0.0189, to match the bond maturity of 10 years, following the identity in the Macaulay (1938) formulation that links quarterly bond duration ($D = 40$) to the risky yields ($R_g = 1.0063$) and the bond decay rate $D = \frac{R_g}{\delta_g + R_g - 1}$. This implies a steady-state coupon payment paid by long-term government bonds to be $\bar{\kappa}_g = \frac{\delta_g + \bar{R}_n^* - 1}{\bar{R}_n^*} = 0.0198$.

Parameters that govern the average level of government bond or private asset purchases by the central bank during stress episodes are chosen depending on whether the policy is discretionary or rule-based. Under discretionary public and private asset purchases, they are set to 0.0001. Under rule-based public and private asset purchases, they are calibrated to be 0.1 and 0.15, respectively. We set the persistence of asset purchase rules to be 0.9 in the case of discretionary policies and to be zero in the case of rule-based policies. The response coefficients of public and private asset purchases to foreign investor-induced bond sell-off and to private credit spreads are calibrated depending on the type of shock. Under bond sell-off shocks (country risk premium shocks), the response coefficient of the bond purchase rule to the deviation of the ratio of the foreign-held share of LC government bonds to GDP from its steady-state is set at -0.17 (-2.23), while that of private security purchase rule to the deviation of loan-deposit spread from its steady-state is calibrated at 6.04 (26.44). We choose the standard deviation of the discretionary bond purchase shock as 3.16 to match government bond purchases of 1.5% of GDP through August 2020, while we set that of the discretionary private security purchase shock as 0.33 to match private asset purchases of 0.6% of GDP during the same period. The costs of both public and private asset purchases to the consolidated government budget are set at 0.3 for illustrative purposes.

3.1.2 Choice of priors for the estimation

In total, we estimate 41 parameters, of which 18 are dynamic non-shock-related parameters, There are 23 shock-related parameters, of which 12 are shock standard errors and 11 shock persistence parameters (see the lower panel of Table 3 for a full list of shocks). We use two types of priors in estimating the model: system priors and marginal priors. We particularly employ system priors in combination with marginal priors in order to reflect our specific beliefs about the variances of the observed variables that are used in the estimation. Further details about implementing system priors in the estimation are included in Online Appendix B.2.

We use a mixed approach in setting the marginal priors. For some parameters, we use the existing literature, empirical analysis and comparable models to find suitable prior values.

Additionally, for some parameters, we calibrate the model to match the targeted model moments referred to in the previous section on system priors, and set these values as the prior means. Finally, some priors are set based on the model's properties, including impulse responses to specific shocks, and correlation patterns.

Table 2 displays marginal priors, posterior modes and posterior standard deviations of the dynamic non-shock related parameters of the model. Posterior modes of the parameters regarding households, firms, external sector and monetary policy are broadly consistent with the existing literature. For instance, the posterior mode of the external debt-elastic risk premium parameter, ψ, has been estimated to be $4.9 \cdot 10^{-4}$, which is broadly in line with Schmitt-Grohé and Uribe (2003).[16] The other non-standard parameter that is specific to our model is the country risk premium elasticity of foreign-held government bonds, $v_{g^\star}$. Its estimated posterior mode implies that a 100 basis points increase in the country risk premium reduces government bonds held by foreigners by 3.8%.

Table 3 displays the marginal priors of the persistence and standard deviations of structural shocks as well as their posterior modes and posterior standard deviations. There are 12 shocks in the model, equal to the number of observable variables. All shocks are assumed to follow first-order autoregressive processes, except for the domestic monetary policy shock, which is a pure innovation. Hence, there are 11 persistence parameters. All shocks are assumed to have an inverse gamma distribution with a standard deviation of 2. Most standard deviations of shocks have a prior mean of 0.1, but some prior means have been somewhat calibrated to better fit some empirical moments, such as the standard deviations of the observables. Due to the wide priors on the standard deviations, the prior mean selection of the standard deviations of shocks is expected to have limited impact on the estimation results. The persistence parameters are given a beta distribution with a prior mean of 0.5 and a standard deviation of 0.2.

We conduct forecast error variance decomposition exercises at one quarter, one year and five year ahead horizons for key macroeconomic and financial variables considered in the analysis. These exercises (see Table B.1 in Online Appendix B for detailed results) reveal that total factor productivity, price mark-up, import demand and marginal technical efficiency of investment shocks tend to explain a significant part of the fluctuations in key model variables.

[16] Small open economy DSGE models tend to be sensitive to the external debt-elastic risk premium parameters. We estimate external debt elasticity of country risk premium, ψ, based on a tight prior that was set to obtain empirically relevant effects of an external risk premium shock and to obtain a reasonably faster convergence of model variables to their steady states after shocks attenuate.

3.2 Asset purchases ease financial conditions without currency depreciation risks

We first discover that asset purchases in EMEs ease financial conditions with no currency depreciation or inflation risks in Figure 2. This finding emerges from studying the impulse-response functions of selected model variables (implied by fixing estimated model parameter values to their mode) to discretionary purchases of government bond (solid lines) and private security (dashed lines) at 1.5% of GDP, which are representative of the average EME central bank asset purchase through August 2020 (IMF, 2020).[17] For ease of exposition, we abstract from efficiency costs of asset purchases, which are introduced in Section 4.5 for completeness.

Bond purchases by the central bank allow commercial banks to tilt their assets portfolio towards credit to non-financial firms and directly boost government bond prices q^g. The former implication relates to the fixed supply of government bonds $\bar{b^g}$ and the latter result hinges on the financial multiplier condition (33) in the absence of leverage constraints in asset purchases. Increased bank demand for non-financial firm securities boosts private asset prices and higher bond prices directly reduce the real term premium $R^{YTM,g} - R$ defined in equation (32). The rise in both asset prices feeds back into bank net worth and raises loans to private sector, thanks to the financial accelerator mechanism as described by Gertler and Kiyotaki (2010). Stronger balance sheets also allow banks to borrow more from both depositors and foreign lenders, leading to capital inflows and an appreciation in the nominal exchange rate. Concurrent with the easing in financial conditions, UIP deviations $R - R^*$ (that are labeled as funding spread in Figure 2) narrow and loan-deposit spreads shrink by close to 90 basis points in annualised terms. The currency appreciation passes through to aggregate prices via imported goods prices and reduces inflation. Consequently, with lower real term premia, reduced financial amplification and lower inflation, nominal excess yields of long-term government bonds over world interest rates decline. Largely affected by the nominal exchange rate, the real exchange rate also appreciates and the current account deficit widens. The decline in inflation creates room for monetary policy easing, resulting in higher real investment.

Private asset purchases (dashed lines in Figure 2) have an excess nominal bond yield compression and an overall easing of financial conditions that are about three times as large as public asset purchases of the same size. This well-documented result (Gertler and Karadi, 2013) hinges on stronger multiplier effects – as shown in (33) and (34) – from central bank

[17] Among central banks that purchased private assets, the central banks of Chile and Colombia purchased bank bonds and the central bank of Hungary purchased mortgage bonds. For government bond purchases, we confine our interest to the purchases of long-term, domestic-currency sovereign bonds from the secondary market.

purchases of firm securities and the nature of financial constraints in the economy. In particular, while sovereign bond purchases by the central bank crowds in private bank lending, lower government bond holdings by commercial banks imply that they are foregoing a safer asset (relative to private credit), which partly alleviates financial constraints. Therefore, a unit of portfolio re-balancing towards private assets causes the agency cost constraint (5) to bind more tightly under bond purchases relative to private security purchases, partly offsetting the crowding in effect in the former.

3.3 The case for rule-based asset purchases in counteracting bond sell-off shocks

In this section, we first describe the transmission mechanism of foreign investors' LC government bond sell-off, a negative demand shock of 1.5% of GDP for LC assets, modeled as a disturbance to process (24). Under the economy with no asset purchases (dotted-dashed lines in Figure 3), the reduced demand for government bonds bids down sovereign bond prices. Therefore, banks find it profitable to shift their portfolio towards bonds amid higher bond yields, which crowds out private credit to non-financial firms. The ensuing decline in the supply of bank credit in addition to the collapse in bond prices lowers firm security prices, which leads to an expansion of the real term premium of government bonds, UIP deviations and loan-deposit intermediation margins of about 4, 45 and 200 basis points per annum, respectively. This suggests that (external) sovereign bond sell-off shocks might have non-negligible amplification effects on domestic financial conditions. Banks' foreign borrowing capacity is hindered by weaker balance sheets – as attested by a collapse in bank net worth – under depressed asset prices. This results in the initial capital outflow due to the sovereign bond sell-off to spill over to the private sector. Therefore, the nominal exchange rate depreciates, which raises imported goods prices and passes through to aggregate domestic prices. Conventional monetary policy further exacerbates the shock by raising policy interest rates with the aim of stabilising inflation. With a higher real term premium on bonds and higher inflation, nominal excess yields on long-term sovereign bonds over world interest rates go up, domestic financial conditions tighten and real investment gets depressed. The dynamics of the real exchange rate depreciation closely follow that of the nominal exchange rate, ultimately leading to an improvement in the current account balance-to-GDP ratio.

In Figure 3, we also present the effectiveness of rule-based public (solid lines) and private (dashed lines) asset purchases – described in Section 2.5 – in response to the government bond sell-off shock. We find that public asset purchases that replace foreign investors reduce the rise in excess nominal bond yields over world interest rates by half, and substantially mitigate the decline in private credit, the depreciation of currency, the rise in the intermediation margins, widening UIP deviations as well as inflation (solid lines versus dotted lines). A key channel through which the central bank short-circuits the bond sell-off shock is that commercial banks no longer increase their government bond holdings upon the shock, as the central bank addresses the bond market dislocation by purchasing these assets. This prevents the crowding out of private credit to non-financial firms, and limits the collapse in sovereign bond and non-financial firm security prices. Stronger asset prices in turn limit the tightening in financial conditions as measured by lower rises in the real term premium, a reduced widening in the UIP deviation and credit spreads. The stronger bank balance sheets present better foreign borrowing prospects for banks, limiting total capital outflows and reducing the currency depreciation and the rise in inflation. By corollary, the reversal in the current account-to-GDP ratio and the increase in policy interest rates emerge as lower, creating room for maneuver on conventional monetary policy.

Private asset purchases bring about a similar degree of stabilisation in response to the bond sell-off shock, with purchases of about 0.5% of GDP (dashed lines in Figure 3). In this experiment, we calibrate the size of asset purchases to match the decline in bank credit under public asset purchases as a percentage of the economy's steady-state output. As discussed in the previous section, the improved efficacy of non-financial firm security purchases in easing overall financial conditions hinges on the total credit base expansion with central bank purchases of firm securities facing no financial constraints and commercial banks' utilisation of the safe asset role of government bonds.[18]

3.4 Asset purchases are less effective under country risk premium shocks

The previous section establishes that there is room for asset purchases in mitigating the tightening of financial conditions upon adverse shocks hitting foreign investors' demand for domestic-currency assets. However, it is empirically challenging to identify if external demand shocks for financial assets are hitting directly local or foreign-currency assets. For instance, an abrupt rise in the market gauge of riskiness of an EME would directly raise the cost of

[18] This is notwithstanding that, as opposed to the case of asset purchase shocks, rule-based private asset purchases in response to the bond sell-off shock expand an already depressed level of credit.

foreign-currency denominated borrowing of banks but also could trigger a LC government bond sell-off by foreign investors. Our framework allows us to make this distinction since the foreign bond holdings process (24) entails a negative feedback from country risk premium Ψ_t to sovereign bonds held by foreign investors $b_t^{g^*}$ with $v_{g^*} < 0$, wherein we estimate this responsiveness by Bayesian techniques. Using this formulation, we are able to explore the effectiveness of asset purchases in mitigating country risk premium shocks that coincide with a decline in government bond holdings of foreigners.

In particular, Figure 4 illustrates the impact of an orthogonal country risk premium shock of 172 basis points in annualised terms and the efficacy of alternative asset purchase policies.[19] The country risk premium shock without asset purchases directly raises the cost of foreign debt for banks (dotted-dashed lines). This disturbance is amplified by financial frictions as attested by a rise in the funding spread $R_{t+1} - R^*_{t+1}$, the excess cost of domestic deposits faced by commercial banks over borrowing from abroad (or UIP deviations). Less favorable funding conditions for both deposits and foreign debt depress bank capital, and further tighten endogenous leverage constraints that banks face while making loans to the government and non-financial firms. As a result, a credit crunch occurs in the economy (by about 3% relative to the trend) and both loan-deposit intermediation margins and excess yields on sovereign bonds expand sharply (by about 100 and 60 basis points per annum, respectively). Monetary policy tightens and thus amplifies the shock, as capital outflows triggered by both the reduced foreign demand for bank borrowing and the endogenous government bond sell-off result in a depreciation of the currency and higher inflation. As a result, real investment declines by about 1.5%.

We find that government bond purchases that only address the market dislocation created by foreigners are not effective in stabilising the impacts of this country risk premium shock (solid lines in Figure 4). In particular, the tightening of funding conditions for banks is so strong that crowding in private credit in commercial banks' balance sheets comes with limited use. Furthermore, the inability of banks to resort to the safe government bonds tightens funding (and accordingly lending) conditions even more. In contrast, rule-based private asset purchases (calibrated to resemble the level in the bond sell-off shock experiment) partly boost bank capital, reduce loan-deposit and funding spreads and mitigate the collapse in private credit as well as investment (dashed lines in Figure 4). However, strikingly different from the case of bond

[19] This increase in the country risk premium is representative of the JP Morgan-EMBIG spread hikes that occurred during the pandemic in 2020Q2 relative to the preceding quarter. Simulations also assume in this case that the endogenous reduction in foreign-held sovereign bonds resembles the bond sell-off in 2020Q2.

sell-off shocks, even private asset purchases have limited scope for compressing excess long-term bond yields in response to country risk premium shocks. Analysing the decomposition of excess bond yields – offered by equation (32) – into inherent maturity premium and premia that arise from financial frictions illuminates our understanding of this result. Asset purchases have limited power in reducing the abrupt increase in the funding spread and the cost of foreign debt (the second and third terms), on which country risk premium shocks have a direct impact, as implied by equation (3). The ensuing sharp rise in foreign borrowing rates also paves the way for a sizable currency depreciation, which explains a larger part of the excess yield increase via inflation, differing from the case of bond sell-off shocks.

3.5 How did EME central bank asset purchases work during the pandemic?

In this exercise, we conduct a counterfactual analysis centered around the COVID-19 shock, building on the theoretical insights that are explored so far. We first take our estimated model without asset purchases at 2019Q4 as our initial condition before replicating a baseline event. We then filter realisations for the estimated structural shock processes to replicate the data corresponding to the 2020Q1-Q3 episode for key variables in the baseline model specification. Modelling the epidemiological features of the pandemic and a number of the unprecedented lockdown measures in EMEs are beyond the scope of this paper. Therefore, instead, we use our filtered structural shocks to capture some of the key ramifications of the COVID-19 crisis. These include a collapse in consumption and investment, encapsulated by shocks to consumption preferences and marginal investment efficiency, respectively capturing the effects of lockdown measures and supply chain disruptions. On the other hand, large negative shocks hitting the preferences for imported goods as well as foreign output, capturing the global repercussions of the pandemic in severely hampering global trade. As such, these filtered shocks emerge as an order-of-magnitude larger than their estimated historical standard deviations. The baseline COVID-19 event reflects a parametrisation of the public asset purchase rule (27) that implies purchases of 1.3% of GDP, as it exactly occurred in the average EME through August 2020 (IMF, 2020). The remaining counterfactual scenarios use identical paths of structural shock realisations as in the baseline scenario to isolate the impact of alternative rule-based asset purchases. In each scenario, we re-calibrate the parameters of the policy rules (27) and (30) to manifest alternative sizes of asset purchases.

We find that the high-frequency (one-week average) excess bond yield compression estimated by the recent literature (as exemplified by Arslan et al. (2020), Hartley and Rebucci (2020), IMF (2020) and WB (2021)) cannot be sustained for a quarter under public asset purchases that reflect the EME central bank experience during the pandemic. The top two rows of Table 4, accompanied by solid and fine-dashed lines in Figure 5, clearly indicate that excess government bond yields are virtually identical between the baseline economy and the counterfactual with no asset purchases.[20] Indeed, under the counterfactual of advanced economy-size public asset purchases of 8.4% of GDP, excess yields of long-term sovereign bonds decline by 13 basis points per annum, which is around half of the IMF (2020)'s average estimates for the bond yield compression across specifications. Taking this level of yield reduction efficacy as a calibration reference implies a (required) aggressive private asset purchase policy at 6.8% of GDP.

Simulations imply two major findings: firstly, bond yield reductions could have been statistically significant at 90% confidence level only for aggressive asset purchase policies. Secondly, the 6-day average bond yield compression of more than 20 basis points in EMEs as estimated by the IMF (2020) could have survived a full quarter only if public (private) asset purchases had been as large as 21% (11%) of GDP, which is arguably untenable for EMEs (the last two rows of Table 4 and solid-dotted and dashed lines in Figure 5). Our conclusion that financial easing benefits of asset purchases during a disaster-type shock are limited goes together with the observation that asset purchases in EMEs with credible monetary policy frameworks are not inflationary and would not have been so even if they had been larger (see Table 4). Specifically, as asset purchases get larger, the central bank gets closer to slashing between 0.5 to 4 percentage points of the total decline in investment, while attaining a less depreciated exchange rate, lower inflation and lower policy interest rates, which complement asset purchases. These findings are consistent with our discussion of the transmission mechanism of such policies so far, that asset purchases increase the room for maneuver for conventional monetary policy in EMEs (see also the top-right panel of Figure 5).

[20]The table reports key variables' deviation from an HP-trend as of 2020Q2 both in terms of a point estimate as well as 90% confidence interval bands that emerge from 10,000 Monte Carlo simulations for the out-of-estimation sample of 2020Q1-Q3. The associated fan charts showing alternative confidence bands for each counterfactual can be found between Figures E.2-E.7 in the Online Appendix.

3.6 Asset purchases under conventional monetary policy spillovers

In this section, we explore the impact of domestic and foreign conventional monetary policy spillovers on the efficacy of asset purchases in EMEs. Our COVID-19 crisis counterfactuals - described in Section 3.5 - all entail that conventional monetary policy in both the domestic economy and rest of the world complement asset purchase policies (Figure 1), as occurred during the pandemic, which may have a non-trivial impact on the efficacy of asset purchases. In this section, we shut down these complementarities one at a time. First we re-run our counterfactual experiments under the assumption that the domestic central bank policy rate cannot be lower than its level at 2019Q4, i.e., prior to the pandemic. It is plausible to think that EME central banks could be facing such a constraint, as they typically operate in small open economies with a positive country risk premium vis-à-vis advanced economies. We ensure this constraint on domestic policy rates by re-filtering the structural shocks. Second, we repeat the counterfactual exercises while fixing world interest rates at their level in 2019Q4, switching off this positive external financial spillover.

Simulation results reported in the first column of Table 5 demonstrate that while bond yields are slightly higher than our baseline COVID-19 experiments (in Section 3.5), the effectiveness of asset purchases in EMEs in reducing excess bond yields during the pandemic did not hinge on potential spillovers from conventional domestic monetary policy. Specifically, bond yield reductions from asset purchases (relative to a no-asset purchase policy regime) emerge similar in size relative to the counterfactuals that simultaneously feature policy interest rate cuts (see the first column of Table 4). Intriguingly, this finding relates to opposing effects of conventional monetary policy on excess bond yields. Consider the definition of nominal long-term bond yields (21). Policy interest rates that cannot go lower raise banks' funding costs, reduce their loan-making capacity and depress sovereign bond prices q_t^g, accordingly. This raises the real yield-to-maturity of long-term bonds as per the inverse relationship (20) between asset prices and yields. On the other hand, as displayed by the second and fifth columns of Table 5, when interest rates cannot go further down, due to the ensuing monetary policy tightening relative to the baseline experiments, currency depreciates by less and inflation declines more. Therefore, by (21), nominal excess yields on sovereign bonds emerge as similar to the case without monetary policy spillovers.

Finally, when world interest rates are counterfactually not allowed to decline, the level of excess yields mechanically declines relative to the baseline experiments (Table 4), as the benchmark interest rate is now higher (Table 6). Nonetheless, alternative modality and size of asset purchase policies bring about a similar degree of LC bond yield compression and an overall easing of domestic financial conditions (column 1). This is notwithstanding that regardless of the implemented asset purchase policies, the exchange rate of the economy depreciates more (leading to higher inflation) and investment takes a bigger hit relative to all economies in the baseline experiments in the absence of the positive financial spillovers from the reduction in global interest rates.

4 Sensitivity analysis

This section explores several dimensions through which the efficacy of asset purchases could be affected. These include (i) studying the (dis)inflationary effects of asset purchases under different degrees of the exchange rate pass-through; (ii) considering the possibility of a de-anchoring of inflation expectations; (iii) taking an environment with less severe financial frictions; (iv) exploring the role of some key structural parameters that affect how country risk is transmitted to the rest of the economy; and (v) efficiency losses that emanate from imperfect asset intermadiation by the central bank in the context of the potency of asset purchases.

4.1 Exchange rate pass-through and asset purchases

We find that asset purchases in EMEs are disinflationary, which departs from the case of advanced economies and hinges on two key features of our setup. These are the financial openness of the economy and the exchange rate pass-through. In closed, advanced economy environments, a strengthening of bank balance sheets due to asset purchases boosts aggregate demand mainly via stronger investment and causes inflation to increase. In our environment, stronger bank balance sheets upon asset purchases additionally allow banks to borrow more from foreign lenders, boost capital inflows and appreciate the domestic currency. The ensuing decline in the imported goods inflation then passes through to aggregate prices and makes asset purchases disinflationary.

In this section, we explore the role of the exchange rate pass-through on the inflationary effects of asset purchases. This is achieved by comparing the dynamics of selected variables of interest to asset purchase shocks (Figure 6) under the baseline parametrisation and an alternative one for each asset purchase shock with reduced exchange rate pass-through (dotted lines). The latter economies entail an arbitrarily high menu cost parameter ($\varphi^F = 1000$ instead of 146.63) in the Rotemberg (1982)-type price adjustment costs, which implies that the New Keynesian Phillips curve of foreign goods has an attenuated transmission of currency fluctuations to the relative price of foreign goods (see equation (A.28) in the Online Appendix). The upper panel of Figure 6 clearly indicates that although asset purchases boost home goods price inflation as found in closed, advanced economy studies, the dynamics of aggregate inflation are mostly determined by an-order-of-magnitude larger fluctuations in foreign goods prices (lines without dots). In addition, when the exchange rate pass-through is lower (dotted lines), we find that even though asset purchases continue to appreciate the domestic currency and narrow the loan-deposit intermediation margins to the same extent (middle panels), the imported inflation stays at a considerably higher level, shrinking the disinflationary and hence the bond yield reducing effects of assets purchases. A byproduct of higher inflation in low pass-through economies is a tighter monetary policy stance, which curbs home goods inflation alongside real marginal costs and the domestic demand (bottom panels).

4.2 De-anchoring of inflation expectations upon government bond purchases

The chronic inflation history of some EMEs has cast a shadow of skepticism on central bank asset purchases in these countries during the pandemic with the fear that purchases of government bonds could derail inflation expectations. In this extension, we relax the assumption of anchored inflation expectations and consider a scenario in which when bond purchases are announced, intermediate goods producers engage in increasingly more backward-looking indexation while computing their price-setting costs (see Online Appendix C.1). We find that in this case, asset purchases reduce excess bond yields to a lesser extent and at the cost of higher and more persistent inflation (see Figure E.8 in the Online Appendix). We further conclude that the reduced efficacy of bond purchases extends to lowering the real term premium between sovereign bonds and domestic short-term interest rates, denoted by the first term in the excess yield decomposition (32).

4.3 Asset purchases under milder financial frictions

In this exercise, we compare the implications of government bond purchase shocks in the baseline economy with an alternative in which financial frictions are less severe. This is achieved by reducing the diversion parameter λ in the incentive constraint of banks from 0.79 to 0.4, while leaving the rest of model parameters unchanged. Figure 7 demonstrates that with milder financial frictions, the easing of financial conditions – and the concurrent stimulus in real investment – that is brought by government bond purchases is smaller, including the appreciation effects of asset purchases on the exchange rate. With milder frictions, relaxing the balance sheet of banks becomes less important, so that banks find it less useful to borrow more from both depositors and foreigners upon bond purchases by the central bank, leading to a smaller deterioration in the current account and an appreciation in the exchange rate over the course of the simulation horizon.

4.4 Transmission of the country risk premium and asset purchases

Modelling endogenous default is beyond the scope of this paper. Therefore, we assumed throughout that a higher external indebtedness increases the country risk premium, via a debt elastic risk premium parameter $\psi = 4.9 \cdot 10^{-4}$ (see Section 2.2.1). Nonetheless, we estimate this parameter using Bayesian techniques while parametrising our benchmark model, taking as reference the country risk premium dynamics of EMEs. In this section, first, we explore the implications of increasing the debt elasticity of risk premium parameter ten-fold. Figure E.11 in the Online Appendix reassuringly confirms that making this change has no material impact on model dynamics in response to government bond sell-off shocks under the cases of both no asset purchases and government bond purchases (Figure 3).

The final experiment we conduct is to reduce the recalibrated value of the country risk premium elasticity of foreign-held government bonds $v_{g^\star}$ by half, which could play an important role for model dynamics in response to country risk premium shocks (Figure 4). For brevity, the results are presented in Figure E.12 in the Online Appendix. Mitigating the endogenous government bond sell-off by foreign investors in response to an exogenous rise in the country risk premium creates a milder pressure on banks to replace foreigners in holding these government bonds. As a result, in the case of both no asset purchases and the case of private asset purchases, private credit to non-financial firms, bank capital and real investment decline less upon the shock, relative to the case of the baseline parametrisation. However, the degree in which private asset purchases mitigate the negative effects of the shock stays fairly comparable with the baseline model.

4.5 Costly asset purchases

Our baseline analysis abstracts from efficiency costs of central bank asset purchases. In this extension, we consider imperfect asset intermediation by monetary authorities as central banks lack expertise in managing private assets. Those imperfections are captured by the introduction of proportional losses $\tau^{gCB}, \tau^{CB} = 30\%$ in asset purchase rules (26) and (28). We find that leakages in government bond purchases result in partial mitigation of financial crowding out effects on commercial bank balance sheets, hindering the easing of overall financial conditions vis-à-vis the economy with costless asset purchases (Section C.2 and Figure E.9 in the Online Appendix). Concurrently, private security purchases contain the financial amplification – in response to country risk premium shocks – at a reduced rate, when they are costly (Figure E.10 in the Online Appendix).

5 Conclusion

This paper focused on situations in which asset purchases in EMEs may lend a hand to conventional monetary policy, partly alleviating the problem of procyclical monetary policy in response to capital outflows in EMEs. The unprecedented experiment of EME central banks' asset purchase interventions during the COVID-19 crisis provides a natural platform to explore the validity of our insights. This is particularly due to the puzzle of stable currency dynamics in these countries upon the announcement of these interventions, which was at odds with many observers, owing to the chronic inflation history and concerns regarding monetary policy credibility in EMEs.

Our analysis shed light to three key dimensions. Firstly, we explain why asset purchases did not lead to perverse exchange rate dynamics in emerging markets amid large capital outflows during the pandemic. Secondly, we demonstrated that the easing of overall financial conditions owing to central bank asset purchases creates room for maneuver for conventional monetary policy, mitigating the fear of floating in bad times. Thirdly, we established that asset purchases are more useful in response to demand shocks that hit domestic-currency assets, rather than country risk premium shocks that reduce the foreign demand for both local and foreign-currency assets. As a quantitative experiment, we also laid out that the asset-purchases induced bond yield reduction estimates obtained using high-frequency data in response to the COVID-19 shock could have persisted only under large-scale programs that are seen in advanced economies. This leads to the policy implication that asset purchases by credible emerging-market central banks can be useful to guide price discovery in times of stress but not to systematically manage aggregate demand.

Our work can be extended in a few dimensions. The assumption of transitory asset purchases could be relaxed to consider a permanent expansion of the central bank's balance sheet to explore the effects on inflation dynamics, especially including the possibility of monetising government debt. Incorporating FX interventions, macroprudential policies or capital flow management tools may provide valuable insights on the measures that differ in the currency denomination or aim to address alternative financial stability concerns. Finally, extending the framework to a two-country setup would more directly account for financial spillovers from large, advanced economies to emerging markets and enrich the exchange rate determination in our environment. We leave those compelling avenues to future research.

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Table 1: Steady-state and policy parameters

Description	Parameter	Value	Target
Preferences			
Quarterly discount factor	β	0.9968	Annualized real deposit rate of 1.3%
Labor disutility parameter	χ	397.7	Steady state hours worked of 0.33
Share of domestic consumption goods	$\overline{\omega}$	0.5	Consumption-to-GDP ratio of 0.59
Financial intermediaries			
Fraction of diverted bank loans	λ	0.79	Annualized loan-deposit spread of 415 bps.
Proportional transfer to new bankers	ϵ^b	0.0026	Commercial bank leverage of 6.41
Fraction of non-diverted domestic deposits	ω_d	0.1769	Foreign funding share of banks of 31.7%
Fraction of diverted government bonds	ω_g	0.4230	Annualized 10-year gov. bond spread of 123 bps.
Survival probability of bankers	θ^b	0.9200	Survival duration of 3 years for bankers
Firms			
Share of capital in output	α	0.3	Labor share of output of 0.70
Scaling parameter for utilization rate	φ_u	0.0424	Steady-state utilization rate of 1
Steady-state utilization rate	$\overline{u}$	1	Normalization
Depreciation rate of capital	δ	0.1157	Annualized private credit-to-GDP ratio of 0.45
Elasticity of substitution among varieties	ϵ	11	Steady-state gross mark-up of 1.1
External sector			
Average foreign output	$\bar{y}^*$	0.1324	Trade volume to GDP ratio of 0.71
Average foreign nominal policy rate	$\bar{R}_n^*$	1.001	Average effective U.S. federal funds rate
Monetary authority and government			
Average annual gross inflation	$\bar{\Pi}$	1	Normalization
Steady state gov. expenditure to GDP ratio	$\bar{g}$	0.1450	Gov. spending to GDP ratio of 0.145
Quarterly government debt limit	$\bar{b}_g$	0.0935	Local currency government bonds to GDP ratio 0.243
Fraction of total LC gov. bonds held by foreigners	$\bar{\zeta}$	0.17	Foreign holdings share of total local currency gov. bonds
Decay rate of real long-term government bonds	δ_g	0.0189	10 years of maturity of long-term government bonds
Coupon rate of real long-term government bonds	$\bar{\kappa}_g$	0.0198	Implied by risk-free world interest rates and the decay rate
Steady-state fraction of gov. bond purchases by central bank	$\bar{\varphi}_g$	$0.0001^a/0.1^b/0.1^c/0.1^d$	Discretionary and rule-based policy experiments
Steady-state fraction of private asset purchases by central bank	$\bar{\varphi}_s$	$0.0001^a/0.15^b/0.15^c/0.15^d$	Discretionary and rule-based policy experiments
Persistence of public QE policy	ρ_g	$0.9^a/0^b/0^c/0^d$	Discretionary and rule-based policy experiments
Persistence of private QE policy	ρ_s	$0.9^a/0^b/0^c/0^d$	Discretionary and rule-based policy experiments
Response coeff. of public QE policy to bond sell-off	υ_g	$0^a/-0.17^b/-2.23^c/-0.17^d$	Discretionary and rule-based policy experiments
Response coeff. of private QE policy to credit spreads	υ_s	$0^a/6.04^b/26.44^c/5.53^d$	Discretionary and rule-based policy experiments
Std. dev. of discretionary shock to public QE policy	σ_{φ_g}	3.16	Bond purchases of 1.5% of GDP through August 2020
Std. dev. of discretionary shock to private QE policy	σ_{φ_s}	0.33	Private security purchases of 0.56% of GDP
Cost of public QE policy to consolidated government budget	τ_g	0.3^d	Illustrative costly public QE experiment
Cost of private QE policy to consolidated government budget	τ_s	0.3^d	Illustrative costly private QE experiment

Note: ^{a}: Discretionary policy, ^{b}: Rule-based policy under bond sell-off shock, ^{c}: Rule-based policy under country risk premium shock, and ^{d}: Costly rule-based QE policy. See Online Appendix B.1 for further information on the computation of the empirical counterpart of targeted moments and specific data sources.

Table 2: Marginal prior and posterior distributions, dynamic parameters

			Prior		Posterior	
		Distr.	Mean	Std. Dev.	Mode	Std. Dev.
Households						
σ	Risk aversion	N	2	0.1	2.04	0.07
h_b	Habit persistence in cons.	β	0.8	0.1	0.83	0.06
ξ	Inverse Frisch elasticity	N	3	0.1	2.99	0.03
γ	Elas. of subs. btw. H and F cons. goods	N	0.5	0.2	1.79	0.56
Firms						
φ_H	Rotemberg adj. costs (H goods)	Γ	150	10	224	7.23
φ_F	Rotemberg adj. costs (F goods)	Γ	150	10	146.63	6.50
ϕ	Investment adj. costs	Γ	20	2	9.96	1.18
ϱ	Elas. of util. w.r.t. I/K ratio	Γ	1	0.5	1.26	0.28
γ_i	Elas. of subs. btw. H and F inv. goods	N	0.25	0.1	0.36	0.10
ω_i	Share of H inv. goods	β	0.25	0.1	0.90	0.09
External sector						
Γ_X	Terms-of-trade elasticity of exports	N	1	0.1	0.87	0.15
υ_{g^*}	Sens. of for.-held LC bonds to risk prem.	N	-77	10	-67.28	2.80
ψ	Debt-elastic risk premium	Γ	0.0015	0.0005	0.00049	0.00026
ν_F	Persistence of export demand	β	0.25	0.1	0.47	0.11
Monetary policy						
ρ_{r_n}	Policy rule inertia	β	0.7	0.1	0.85	0.04
φ_Π	Response to inflation	N	2	0.3	0.82	0.56
φ_Y	Response to output gap	Γ	0.25	0.125	0.24	0.03
φ_E	Response to nominal exchange rate	Γ	0.3	0.2	0.16	0.25

Note: The table lists the prior means and prior standard deviations of the model's parameters as well as their posterior modes and posterior standard deviations. We use beta, gamma and normal distributions for different types of the model's parameters. The estimated monetary policy rule coefficients satisfy the modified Taylor principle under interest-rate rules with inertia (Woodford, 2003).

Table 3: Marginal prior and posterior distributions, shock parameters

			Prior		Posterior	
		Distr.	Mean	Std. Dev.	Mode	Std. Dev.
Persistence parameters						
Symbol	*Name of the structural shock*					
ρ_A	Total factor productivity	β	0.5	0.2	0.05	0.08
ρ_c	Consumption preference	β	0.5	0.2	0.45	0.14
ρ_i	Marg. eff. of investment	β	0.5	0.2	0.16	0.10
ρ_g	Government spending	β	0.5	0.2	0.13	0.04
ρ_{rp}	Country risk premium	β	0.5	0.2	0.86	0.01
ρ_{y*}	Foreign output	β	0.5	0.2	0.65	0.19
$\rho_{R_n^*}$	U.S. interest rate	β	0.5	0.2	0.78	0.04
ρ_ϵ	Price markup	β	0.5	0.2	0.27	0.17
ρ_ζ	Global bond sell-off	β	0.5	0.2	0.78	0.01
ρ_ω	Import demand	β	0.5	0.2	0.87	0.07
ρ_{κ_g}	Gov. bond. coupon	β	0.5	0.2	0.27	0.03
Volatility parameters						
Symbol	*Name of the structural shock*					
σ_A	Total factor productivity	Γ^{-1}	10	200	9.73	0.78
σ_c	Consumption preference	Γ^{-1}	10	200	5.79	27.71
σ_i	Marg. eff. of investment	Γ^{-1}	10	200	18.48	2.50
σ_g	Government spending	Γ^{-1}	10	200	0.96	0.44
σ_{rp}	Country risk premium	Γ^{-1}	0.1	200	0.08	5.28e-03
σ_{y*}	Foreign output	Γ^{-1}	5	200	3.8163	0.03
σ_{r_n}	Domestic policy rate	Γ^{-1}	0.1	200	0.06	0.01
$\sigma_{R_n^*}$	U.S. interest rate	Γ^{-1}	0.1	200	0.11	2.91e-03
σ_ϵ	Price markup	Γ^{-1}	10	200	74.06	23.20
σ_ζ	Global bond sell-off	Γ^{-1}	3	200	3.26	0.069
σ_ω	Import demand	Γ^{-1}	3	200	1.23	0.45
σ_{κ_g}	Gov. bond. coupon	Γ^{-1}	10	200	11.50	0.44

Note: Standard deviations of shocks are multiplied by 100. The table lists the prior means and prior standard deviations of the model's parameters as well as their posterior modes and posterior standard deviations. The persistence and standard deviation parameters of shock processes are distributed with the beta and the inverse gamma distributions, respectively.

Table 4: The implications of baseline and alternative EME central bank asset purchases in response to the COVID-19 shock

	(1)	(2)	(3)	(4)	(5)	(6)
	Excess LC government bond yields	**Real exchange rate**	**Monetary policy rate**	**Asset purchases**	**Inflation**	**Investment**
2020Q2	Annualized basis point change	% change	Annualized basis point change	% of GDP	Annualized basis point change	% change
No QE policy	93	2.8	-118	*n.a.*	-201	-16.7
	[87,98]	[1.3,4.3]	[-163,-74]	*n.a.*	[-320,-81]	[-20.1,-13.2]
Public QE[a]	92	2.7	-119	1.3	-202	-16.6
	[86,97]	[1.3,4.3]	[-164,-74]	[1.3,1.3]	[-321,-82]	[-20.0,-13.2]
Aggressive	80	2.3	-127	8.4	-212	-16.3
public QE	[75,85]	[0.8,3.9]	[-172,-81]	[8.3,8.6]	[-332,-89]	[-19.8,-12.9]
Aggressive	80	2.1	-127	6.8	-212	-15.3
private QE	[75,85]	[0.7,3.7]	[-172,-82]	[6.7,6.8]	[-330,-91]	[-18.8,-11.9]
Aggressive	72	2.0	-133	21.0	-220	-16.0
public QE[b]	[66,75]	[0.4,3.6]	[-179,-87]	[20.1,21.3]	[-341,-97]	[-19.4,-12.6]
Aggressive	72	1.8	-133	10.2	-218	-14.4
private QE[b]	[67,77]	[0.3,3.3]	[-177,-88]	[10.1,10.2]	[-337,-97]	[-17.9,-11.0]

Note: Effects of adopting baseline and counterfactual asset purchase policies during the COVID-19 crisis. Changes relative to the HP-filtered trend at quarterly frequency. Increases in the real exchange rate denote depreciations. Asset purchases are as a share of steady state GDP. Ranges in square brackets are 90% confidence intervals. [a]This row constitutes the baseline case and coincides with the cross-country averages of the actual data in 2020Q2. The remaining rows represent the outcome of counterfactual exercises. [b]Asset purchase sizes in these rows are calibrated to match the 6-day average bond yield compression of 22 basis points in EMEs as estimated by the IMF (2020) report.

Table 5: The effects of EME central bank asset purchases without accompanying conventional monetary policy easing

	(1)	(2)	(3)	(4)	(5)	(6)
	Excess LC government bond yields	**Real exchange rate**	**Monetary policy rate**	**Asset purchases**	**Inflation**	**Investment**
2020Q2	Annualized basis point change	% change	Annualized basis point change	% of GDP	Annualized basis point change	% change
No QE policy	95	1.7	-6	*n.a.*	-226	-17.0
	[89,100]	[0.2,3.2]	[-51,40]	*n.a.*	[-345,-105]	[-20.5,-13.6]
Public QE	93	1.6	-6	1.3	-228	-16.9
	[88,99]	[0.1,3.1]	[-51,-39]	[1.3,1.3]	[-346,-107]	[-20.4,-13.6]
Aggressive public QE	82	1.1	-6	8.4	-239	-16.7
	[77,86]	[-0.4,2.7]	[-52,40]	[8.3,8.6]	[-359,-117]	[-20.2,-13.2]
Aggressive private QE	82	1.0	-6	6.8	-238	-15.7
	[77,88]	[-0.5,2.5]	[-51,-39]	[6.7,6.8]	[-356,-117]	[-19.2,-12.3]
Aggressive public QE	72	0.7	-6	21.0	-249	-16.3
	[67,77]	[-0.8,2.3]	[-52,40]	[20.1,21.3]	[-370,-126]	[-19.8,-12.9]
Aggressive private QE	75	0.5	-6	10.2	-245	-14.9
	[70,80]	[-1.0,2.0]	[-51,39]	[10.1,10.2]	[-363,-124]	[-18.4,-11.4]

Note: Effects of adopting counterfactual asset purchase policies during the COVID-19 crisis. Changes relative to the HP-filtered trend at quarterly frequency. Increases in the real exchange rate denote depreciations. Asset purchases are as a share of steady state GDP. Ranges in square brackets are 90% confidence intervals.

Table 6: The effects of EME central bank asset purchases without accompanying conventional monetary policy easing in the US

2020Q2	(1) **Excess LC government bond yields** Annualized basis point change	(2) **Real exchange rate** % change	(3) **Monetary policy rate** Annualized basis point change	(4) **Asset purchases** % of GDP	(5) **Inflation** Annualized basis point change	(6) **Investment** % change
No QE policy	76	4.3	-91	*n.a.*	-163	-16.9
	[71,82]	[2.9,5.9]	[-135,-46]	*n.a.*	[-282,-43]	[-20.4,-13.5]
Public QE	75	4.29	-92	1.3	-165	-16.86
	[69,81]	[2.8,5.8]	[-137,-47]	[1.3,1.3]	[-283,-44]	[-20.3,-13.5]
Aggressive public QE	64	3.9	-100	8.4	-174	-16.6
	[59,68]	[2.3,5.5]	[-145,-54]	[8.3,8.6]	[-294,-51]	[-20.0,-13.1]
Aggressive private QE	64	3.7	-100	6.8	-173	-15.6
	[59,69]	[2.2,5.2]	[-144,-55]	[6.7,6.8]	[-292,-52]	[-19.0,-12.1]
Aggressive public QE	54	3.5	-106	21.0	-182	-16.2
	[50,59]	[2.0,5.1]	[-151,-59]	[20.1,21.3]	[-303,-59]	[-19.7,-12.8]
Aggressive private QE	56	3.3	-105	10.2	-179	-14.7
	[51,61]	[1.8,4.8]	[-150,-60]	[10.1,10.2]	[-298,-58]	[-18.2,-11.3]

Note: Effects of adopting counterfactual asset purchase policies during the COVID-19 crisis. Changes relative to the HP-filtered trend at quarterly frequency. Increases in the real exchange rate denote depreciations. Asset purchases are as a share of steady state GDP. Ranges in square brackets are 90% confidence intervals.

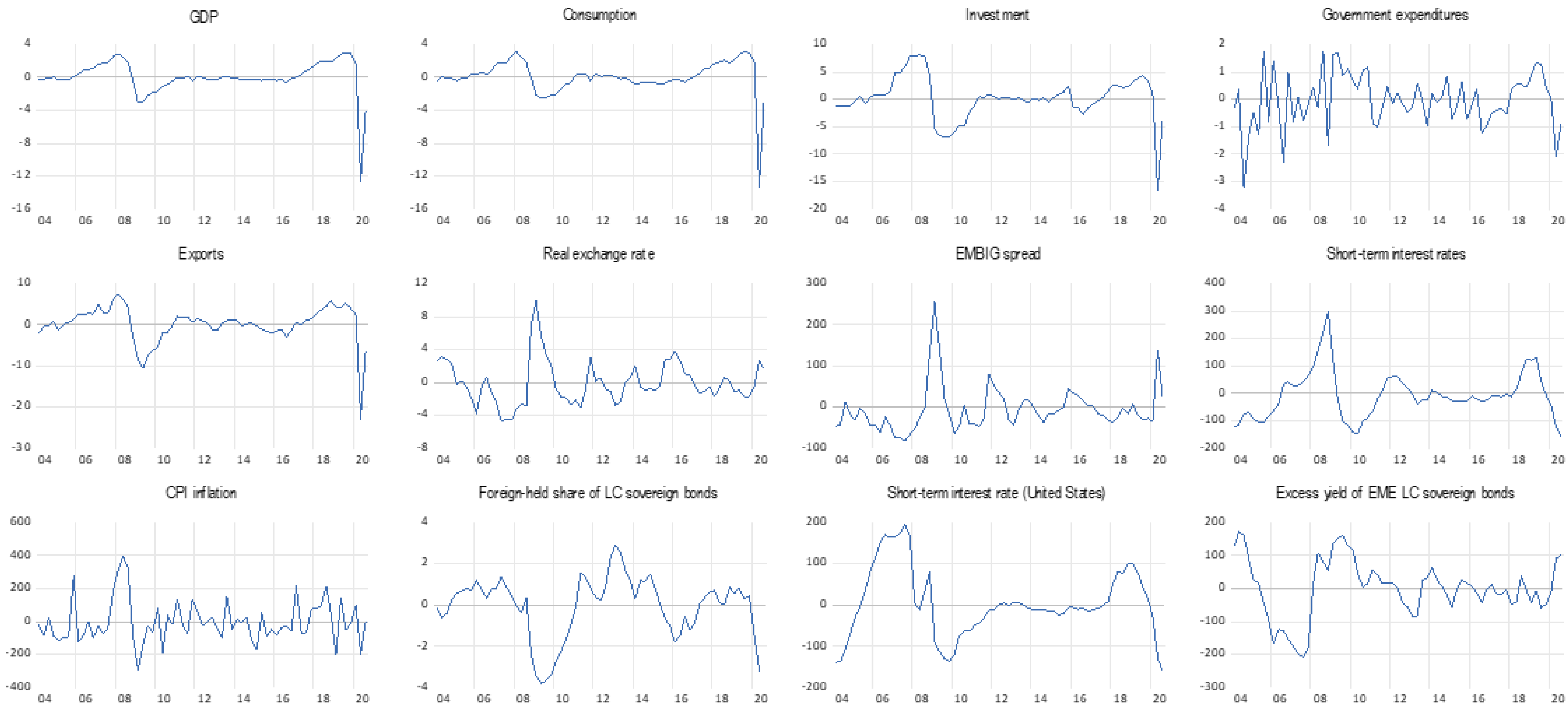

Figure 1: The simple average of HP-filtered key macroeconomic and financial variables for Chile, Colombia, Hungary, Indonesia, India, Korea, Mexico, the Philippines, Poland, Romania, Thailand, Turkey and South Africa for the period of 2004Q1-2020Q3. Using median series instead of the average across countries produces similar cyclical fluctuations. National account variables and real depreciation are in percent deviation from the trend; interest rates, EMBIG spreads, and CPI inflation are in annualized basis point deviation from the trend; foreign holding share of local-currency government bonds is shown as percentage point deviation from the trend. Excess yield is the nominal yield differential between 10-year government bonds and the US short–term rate. Sources: OECD Economic Outlook 108 database; Factset; Refinitiv; and Arslanalp and Tsuda (2014), regularly updated as the IMF Sovereign Debt Investor Base database; and authors' calculations.

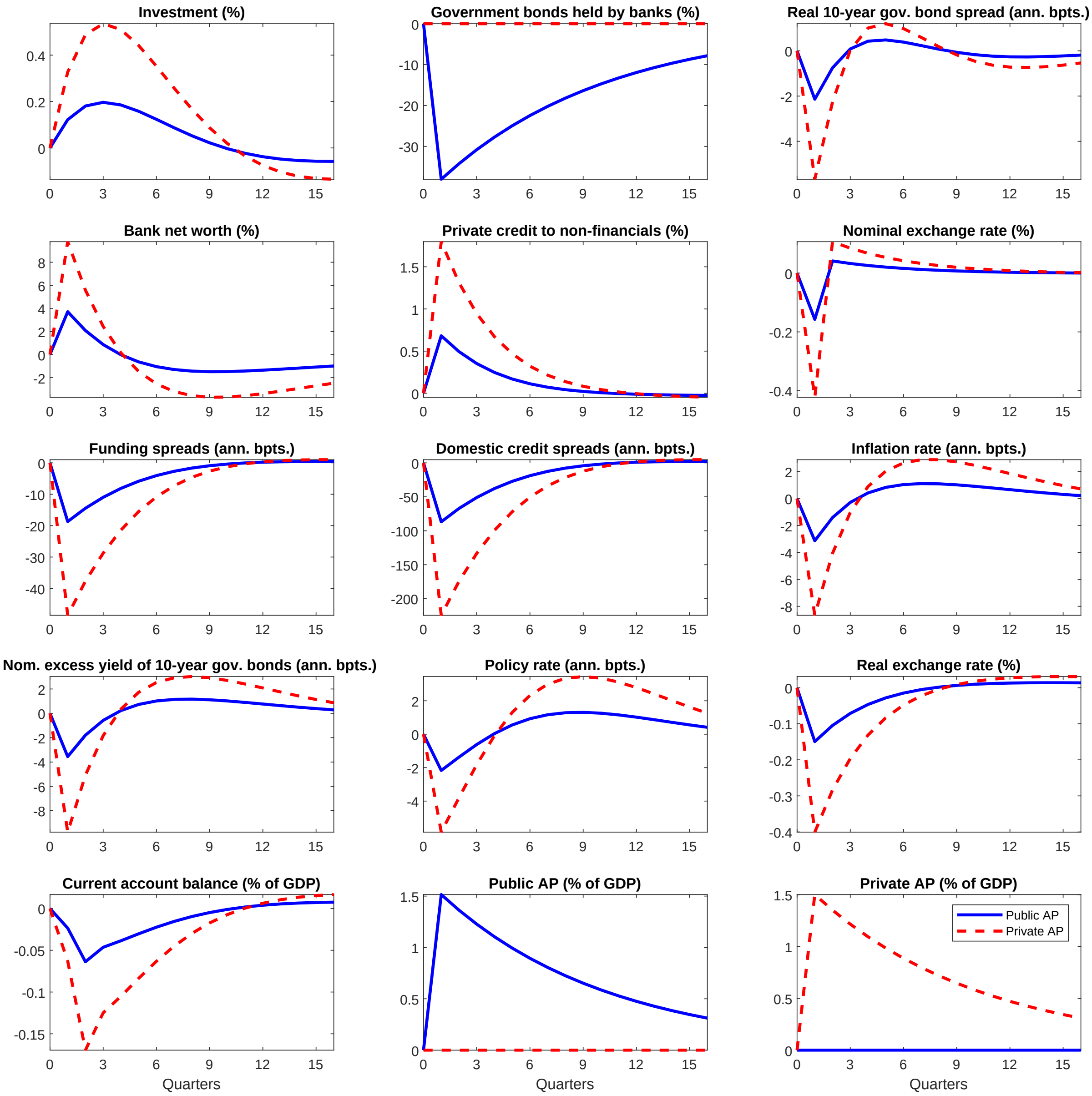

Figure 2: Impulse-response functions of selected model variables to asset purchase shocks. Deviations from the steady state. Asset purchase-to-GDP ratios are representative of EME central bank sovereign bond and private asset purchases as of August 2020, during the COVID-19 crisis. Funding spread is 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.

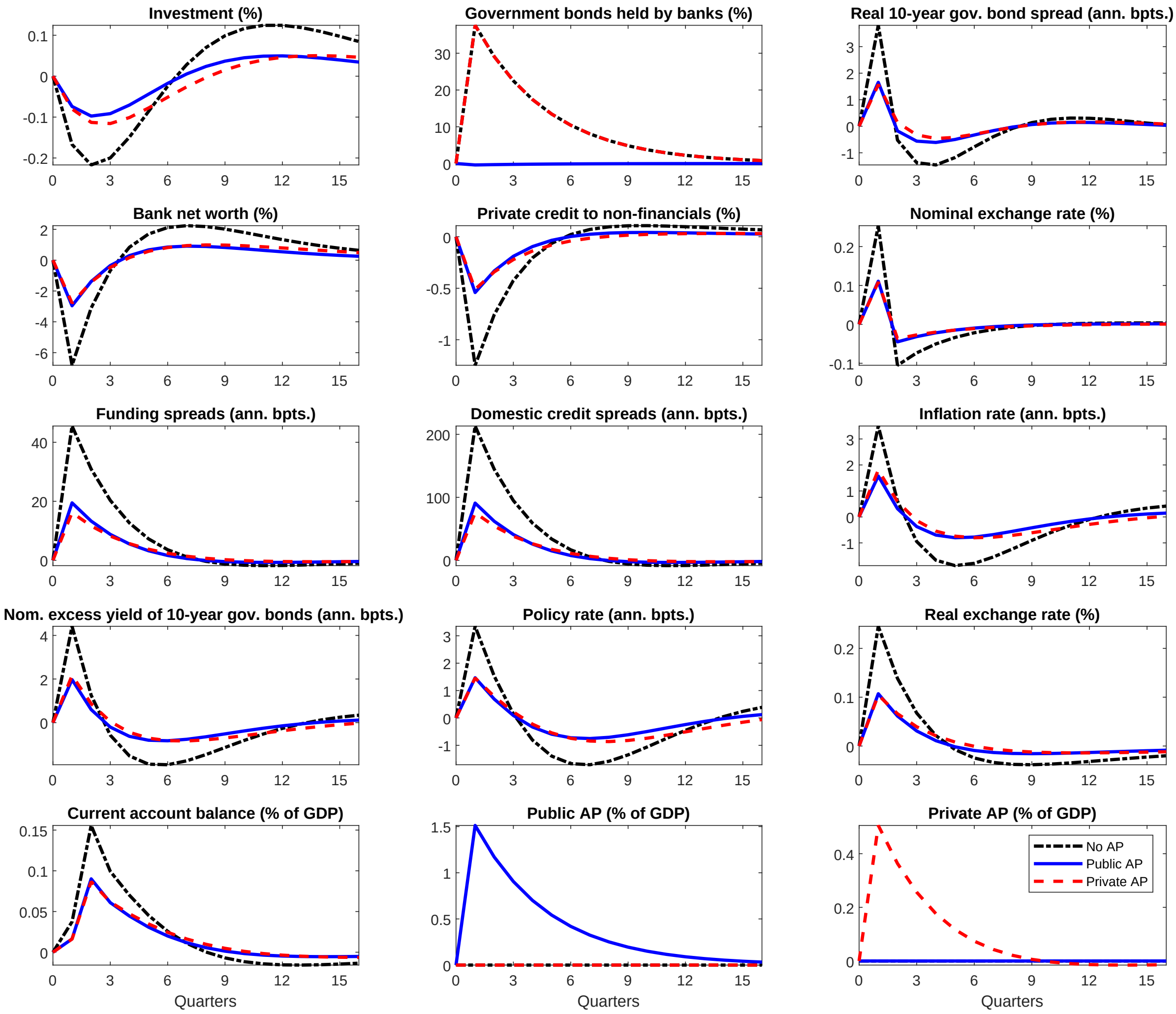

Figure 3: Impulse-response functions of selected model variables to an orthogonal bond sell-off shock of 1.5% of GDP. Deviations from the steady state. Public asset purchase policy rule is calibrated to ensure that the central bank entirely makes up for bonds sold by foreign investors (1.5% of GDP at the peak). Private asset purchase policy rule positively responds to domestic credit spreads and is calibrated to imply asset purchases that match the decline in private credit as a share of GDP. 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.

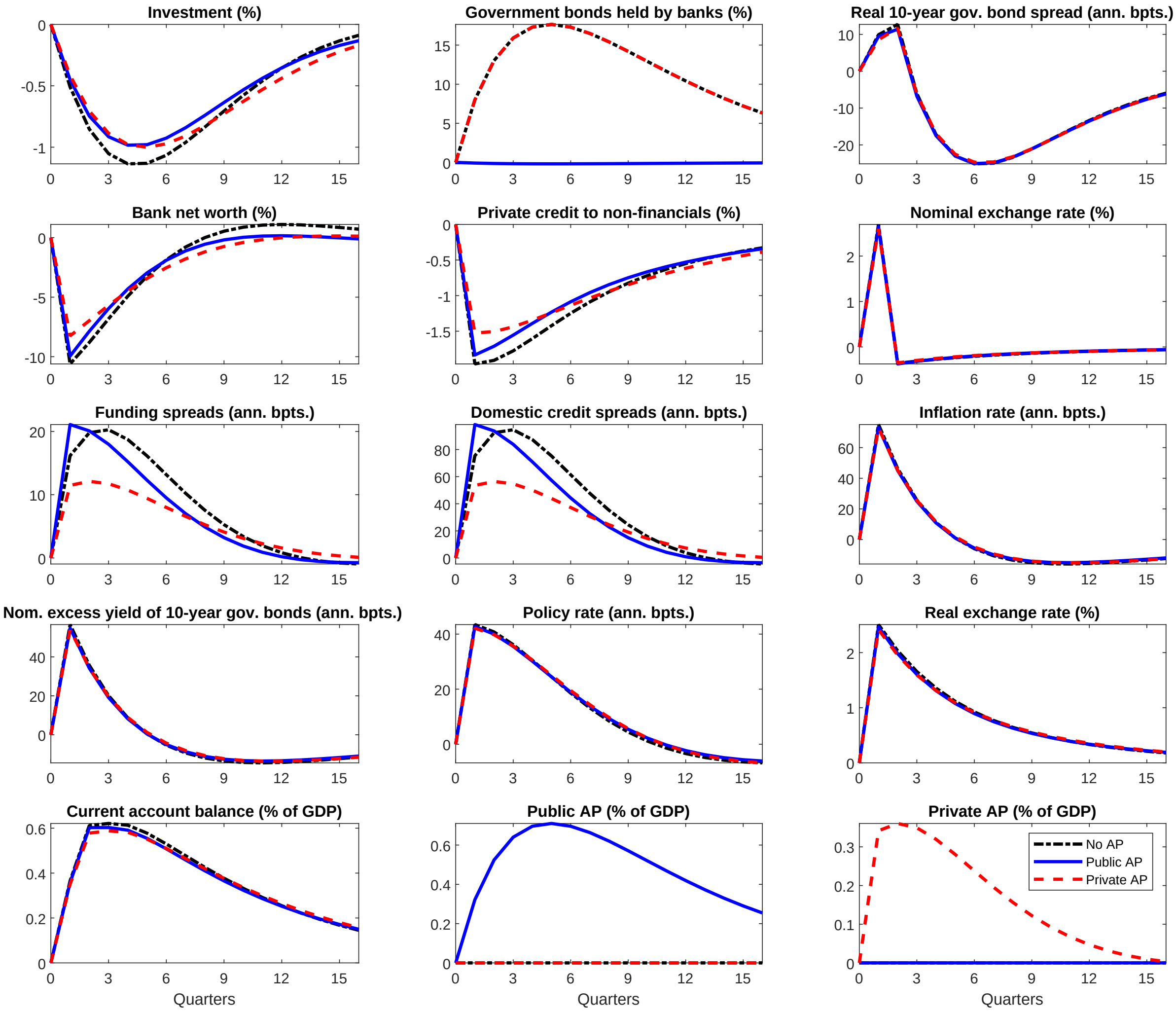

Figure 4: Impulse-response functions of selected model variables to an orthogonal country risk premium shock. Deviations from the steady state. The country risk premium shock is calibrated to replicate 172 basis points increase (from 2020Q1 to 2020Q2) in the cyclically adjusted annualized EMBIG bond spreads in the average EME economy. The endogenous sensitivity of sovereign bond sell-offs to the country risk premium is recalibrated to reflect the EME bond sell-off in 2020Q2. Public asset purchase policy is calibrated to replace foreign investors upon the bond sell-off. Private asset purchase policy is calibrated to imply an asset purchases-to-GDP ratio at the peak as in Figure 3. 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.

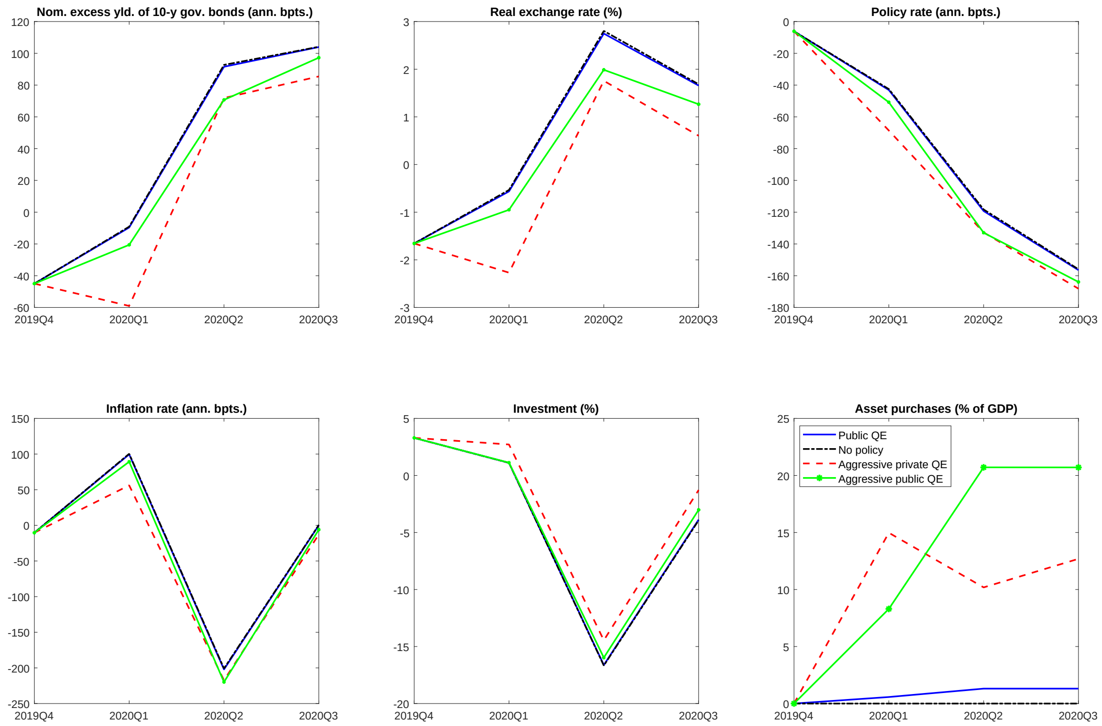

Figure 5: Evolution of key model variables reported in Table 4 under different asset purchase modalities. Deviations from steady state. Solid and fine-dashed lines refer to the baseline model with government bond purchases and the counterfactual with no asset purchases (shown in the first two rows of Table 4 for 2020Q2), respectively. Solid-dotted and dashed lines correspond to advanced-economy type asset purchase modalities that are reported in the last two rows of Table 4 for 2020Q2. Increases in the exchange rate denote depreciation. Nominal excess yield is over the US short–term rate.

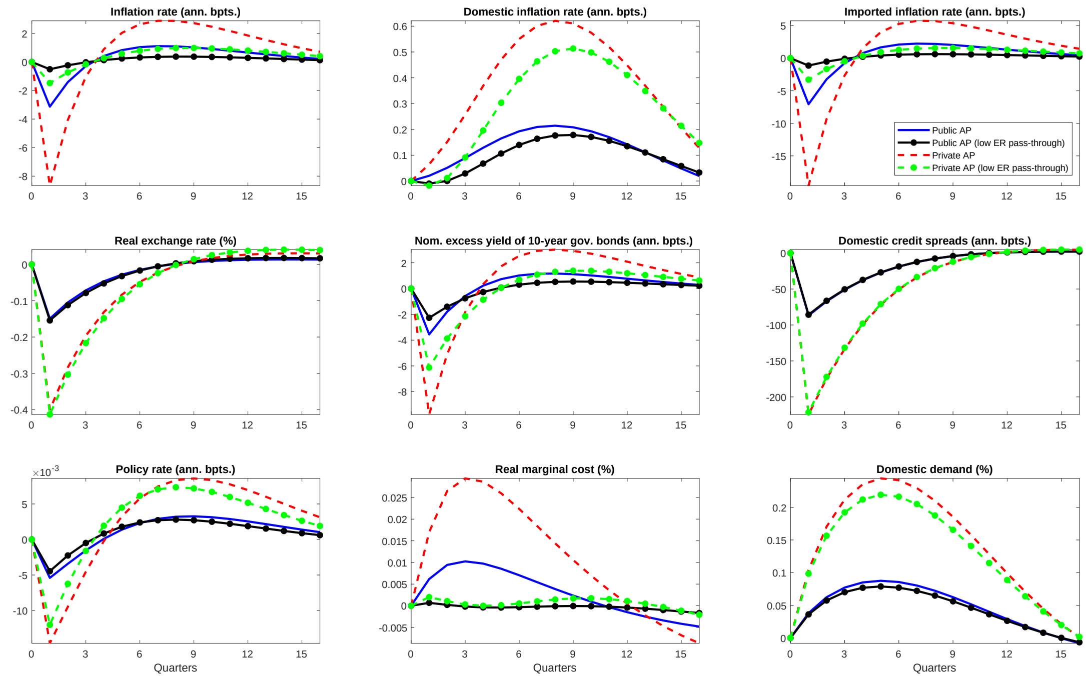

Figure 6: Impulse-response functions of selected model variables to asset purchase shocks under the baseline parameterization and an alternative with low exchange rate pass-through. Deviations from the steady state. Increases in the exchange rate denote depreciation. Nominal excess yield is over the US short–term rate. Asset purchase-to-GDP ratios on impact of the shock coincide with those in Figure 2.

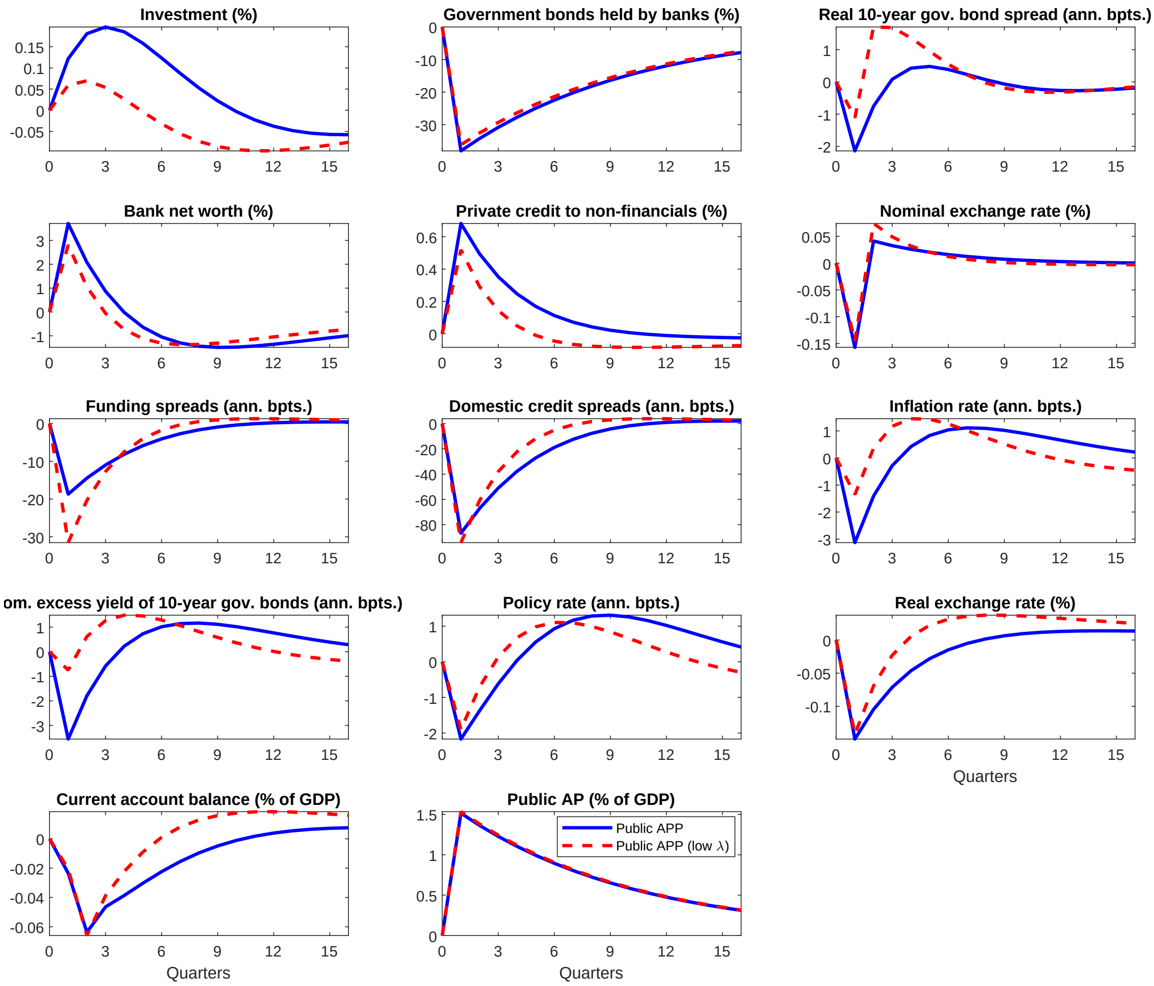

Figure 7: Impulse-response functions of selected model variables to government bond purchase shocks under the baseline parameterization (solid lines) and an alternative with less severe financial frictions (dashed lines). Deviations from the steady state. Increases in the exchange rate denote depreciation. Nominal excess yield is over the US short–term rate. Government bond purchase-to-GDP ratios on impact of the shock coincide with those in Figure 2.

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