WORKING PAPER

Asset purchases as a remedy for the original sin redux

NORGES BANK RESEARCH

8 | 2021

YASIN MIMIR AND
ENES SUNEL

NORGES BANK

Working papers fra Norges Bank, fra 1992/1 til 2009/2 kan bestilles over e-post:
111facility@norges-bank.no

Fra 1999 og senere er publikasjonene tilgjengelige på www.norges-bank.no

Working papers inneholder forskningsarbeider og utredninger som vanligvis ikke har fått sin endelige form. Hensikten er blant annet at forfatteren kan motta kommentarer fra kolleger og andre interesserte. Synspunkter og konklusjoner i arbeidene står for forfatternes regning.

Working papers from Norges Bank, from 1992/1 to 2009/2 can be ordered by e-mail
FacilityServices@norges-bank.no

Working papers from 1999 onwards are available on www.norges-bank.no

Norges Bank's working papers present research projects and reports (not usually in their final form) and are intended inter alia to enable the author to benefit from the comments of colleagues and other interested parties. Views and conclusions expressed in working papers are the responsibility of the authors alone.

ISSN 1502-8190 (online)
ISBN 978-82-8379-203-4 (online)

Asset purchases as a remedy for the original sin redux[1]

Yasin Mimir[2] Enes Sunel[3]

September 20, 2021

Abstract

We provide a theory on how a wider foreign lending base of local-currency sovereign debt may lead to destabilising effects (the original sin redux). Bond sell-offs by foreigners induce domestic banks to fund the government, reducing the credit for investment and tightening financial conditions. Currency mismatches exacerbate the ensuing deterioration in financial sector balance sheets, which amplifies the repercussions of the initial shock by prompting private sector capital outflows and larger currency depreciations. We then explore the role of central bank government bond and firm security purchases in countervailing the ramifications of bond sell-offs. Our estimated model reflects the regularities of the representative emerging-market economy that deployed quantitative easing policies during the pandemic. It further offers an explanation to the puzzle of stable exchange-rate dynamics accompanied by a reduction in excess sovereign bond yields and larger room for conventional monetary policy easing. We conclude asset purchases should be large in size to have a persistent effect on financial conditions and are less effective when they de-anchor inflation expectations or pose risks to a consolidated government balance sheet.

Keywords: Asset purchases, original sin redux, Bayesian estimation.
JEL Classification: E62, E63, G21

[1]A previous version of this paper was circulated with the title "Quantitative Easing in Emerging-Market Economies". We would like to thank Paola Di Casola, Massimo Ferrari, Georgios Georgiadis, Gene Kindberg-Hanlon, Boris Hofmann, Serdar Kabaca, Jesper Linde, Giovanni Lombardo, Łukasz Rawdanowicz, Kasper Roszbach, and seminar participants at Norges Bank, OECD, Sveriges Riksbank, Bank of England, European Central Bank, Federal Reserve Board, World Bank, Bank for International Settlements, Bank of Canada and the Computing in Economics and Finance, 2021 meetings. The views in this paper should not be reported as representing the views of Norges Bank or the OECD or of its member countries. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank or the OECD. The usual disclaimer applies.

[2]Norges Bank, Monetary Policy Department, Bankplassen 2, 0151 Oslo, Norway, Phone: +4792082946, yasin.mimir@norges-bank.no, Personal homepage: http://www.yasinmimir.com

[3]OECD, Economics Department. 2 Rue Andre Pascal, 75775 Paris CEDEX 16, France, Phone: +33642849838, email: enessunel@gmail.com, Personal homepage: https://sites.google.com/site/enessunel/

1 Introduction

The increase in the foreign ownership of emerging-market economy (EME) domestic-currency government debt has increased the vulnerability of these countries' local-currency (LC) bond markets to large reversals in global risk appetite. The underlying forces of the ensuing original sin redux, as coined by Carstens and Shin (2019), were at full speed when the COVID-19 shock hit EMEs hard: (i) the VIX, a commonly used yardstick to measure volatility in global risk appetite rose more than five standard deviations above its historical average (Figure 1.7.1 in IMF (2020)) and (ii) the foreign-holdings share of domestic-currency EME sovereign bonds collapsed, with an associated surge in these bonds' yields (Figure 1).[1]

How did macroeconomic policymakers in financially open economies cope with such perverse dynamics that directly affected the pricing of their benchmark sovereign borrowing instruments? What benefits, risks and limitations could arise from intervening in the trade of those asset classes, especially considering that some of the intervening countries might have a poor track record of inflation credibility compared with financially mature and advanced economies? This paper aims to address these questions by exploring the effects of domestic-currency asset purchases by central banks in EMEs that were implemented in response to the COVID-19 crisis.

Our questions are fairly new to the literature, as EMEs used these measures for the first time to address the pandemic shock. In sharp contrast, advanced economy central banks have been using quantitative easing (QE) measures intensively since the Global Financial Crisis. QE policies proved useful to further ease overall borrowing conditions and counteract deflationary forces when conventional monetary policy interest rates hit an effective lower bound (Sims and Wu, 2021). Asset purchases in EMEs on the other hand, primarily aimed at compensating for the bond sell-off by foreign investors, guided price discovery and curbed further surges in local benchmark bond yields at the onset of the pandemic. Central banks also aimed to signal that they were ready to purchase sovereign bonds should the anticipation of a large fiscal expansion undermine investor confidence.[2]

[1] A higher level of foreign-held debt that is denominated in domestic currency is useful for EMEs as it transfers the exchange-rate risk to foreign investors. Since the latter typically measures losses in hard currency, they increase the pace of their bond sell-offs in times of stress precisely when EME currencies tend to depreciate, the downside of increased exposure to large swings in global risk sentiment, hence the term redux. See Borri (2018) and Bertaut et al. (2021).

[2] See Arslan et al. (2020), Hartley and Rebucci (2020), IMF (2020), Fratto et al. (2021) and WB (2021) on the goals of asset purchases in EMEs.

We develop a framework building on the New Keynesian small open economy model with a banking sector constructed by Mimir and Sunel (2019) (MS, hereafter). In this setup, in contrast to advanced economies, the financial system of EMEs is mainly represented by commercial banks facing currency mismatches in their short-term liabilities. Contrary to MS, domestic banks additionally lend to the government in LC, long-term bonds in Gertler and Karadi (2013) and Sims and Wu (2021). We further expand on these papers by assuming that foreign investors also hold domestic-currency bonds and that their demand is subject to a sell-off shock (capturing the original sin redux phenomenon) and responds negatively to the country risk. With the real supply of these government bonds being fixed as a debt rule, in normal times, government bond market equilibrium implies fluctuations in the foreign investor demand for government bonds, which will necessarily affect the asset portfolio of domestic banks, leading to financial crowding out effects studied by Bocola (2016) and Kirchner and van Wijnbergen (2016).

Agency costs and associated incentive compatibility constraints in our setup impose endogenous leverage limits 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). However, we depart from this study and resemble MS in our assumption that domestic depositors are better equipped to monitor banks to prevent them from diverting a fraction of their deposits. These theoretically plausible features of financial frictions produce an empirically realistic ranking for corporate loans, long-term sovereign bonds and bank deposit interest rates.

We estimate the model over the historical episode of 2002Q1-2019Q4 for the average of 13 EMEs identified in Arslan et al. (2020) and IMF (2020) as having implemented QE during the COVID-19 crisis. A first subset of model parameters are calibrated to match deterministic long-term macroeconomic ratios, various interest rate (and spread) concepts, the LC government bonds-to-GDP ratio and foreign investors' share in outstanding LC sovereign bonds. A second set of model parameters (that affect model dynamics) are estimated by using Bayesian techniques based on the unweighted averages of detrended data on key macroeconomic and financial variables across the countries in our sample (see Figure 1).

Using our estimated model, we first describe how the so-called original sin redux can be at play in EMEs and find that bond sell-off shocks triggered by foreigners tighten domestic financial conditions and cause real investment to decline. Financial crowding out effects play a central role in the transmission of bond sell-off shocks by calling for banks to replace foreign lenders in holding government bonds in response to the shock. This curbs banks' capacity for lending to non-financial firms and reduces asset prices. Lower asset prices further tighten financial constraints and reduce bank borrowing from depositors and foreign lenders. This exacerbates capital outflows, leading to a sharper depreciation in the exchange-rate and a rise in inflation.

We introduce government bond and private security purchases to our model as respective quantity- and price-based policy rules, following the taxonomy of asset purchases in EMEs during the pandemic provided by Fratto et al. (2021). Specifically, government bond purchases replace the bond sell-off by foreigners, as observed with the announcement of asset purchase policies in EMEs during the pandemic.[3] Private security purchases, on the other hand, rise when loan-deposit spreads are higher, which occurs in bad times due to financial frictions.[4]

We first uncover the transmission mechanism of asset purchases in EMEs and find that they ease financial conditions without creating currency depreciation risks. This offers a solution to the currency dynamics puzzle discussed by Hartley and Rebucci (2020). These authors first observe that large spillovers from advanced economy QE implementations and foreign exchange interventions did not insulate EMEs from sharp currency depreciations during the Global Financial Crisis. Consequently, considering the unprecedented capital outflows from EMEs during the pandemic, they conclude that the transmission mechanism of asset purchases in these countries must be genuinely different from advanced economies in explaining the absence of a currency depreciation bout, which was also confirmed by Arslan et al. (2020), IMF (2020), Fratto et al. (2021) and WB (2021). According to our simulations, in response to discretionary QE policy shocks, the central bank is able to boost sovereign bond and private firm security prices thanks to the absence of agency costs in the financing of these purchases. The virtuous feedback loop from elevated asset prices to the balance sheet of banks allows them to borrow more from both depositors and foreign lenders. Hence, the

[3]This reflects the experience of the average QE-implementing EME during the pandemic as reported by IMF (2020): Central bank holdings of outstanding EME domestic-currency government bonds increased by 0.8% of GDP between end-February and June 2020, slightly more than offsetting the decline in holdings of non-residents (0.7% of GDP) during the same period one-to-one. 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 visualization, see Figure E.1 in the Online Appendix.

[4]Both asset purchases are financed by issuing short-term, risk-free government bonds to banks (or interest-bearing reserves), which are perfect substitutes for household deposits. These short-term bonds endogenously adjust in equilibrium to meet the increase in asset purchases due to Walras' Law, essentially making QE costless. In Section 4.2, we relax this assumption and consider the efficiency costs of QE policies.

currency appreciates due to the ensuing boost in capital inflows. With an expanded funding base for banks, credit supply increases and intermediation margins decline. The appreciation of the currency also passes through via imported goods prices and reduces inflation.[5] The milder inflation outlook and eased financial conditions jointly result in lower long-term sovereign bond yields, and even a monetary policy easing, achieving the intended goal of asset purchases.

Our next key finding suggests that rule-based QE policies mitigate the effects of foreign investor government bond sell-off shocks. Given that sovereign bonds are fixed in supply, a government bond purchase policy by the central bank replaces foreign investors and prevents a sharp rise in commercial bank holdings of sovereign bonds in response to the shock.[6] The avoided crowding out of private credit boosts prices for private firm securities and expands the borrowing capabilities of banks via the financial accelerator. Thus, by virtue of the transmission mechanism described above, central banks counteract the original sin redux in EMEs by purchasing sovereign bonds during risk-off episodes that are defined by a reversal in global risk sentiment.

Central bank purchases of private assets cannot alleviate the financial crowding out effects of the bond sell-off shock. Nonetheless, they act directly as a financial multiplier, as in Gertler and Karadi (2013), by expanding the total amount of securities and hence boosting asset prices, resulting in an overall relaxation of banks' balance sheet constraints. Indeed, we find that private asset purchases that are around one-third of bond purchases deliver a similar magnitude of stabilization of the fluctuations generated by a bond sell-off shock. This result is robust to taking into account endogenous feedbacks from increased country risk premia to foreign demand for LC government bonds.

Finally, we find that high-frequency estimates of bond yield reductions from asset purchases during the pandemic could have persisted only under large-sized purchase programs. We conduct a series of counterfactual experiments and analyze how they compare with a baseline QE policy implementation that exactly replicates the repercussions of the COVID-19 shock in EMEs. The counterfactual of a no-QE policy response yields negligibly higher increases in government bond yields, currency depreciations and inflation after one quarter. In sharp contrast, when public

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

[6]A fixed government bond supply reflects the idea of limited fiscal space in EMEs during the pandemic (IMF, 2021), in addition to ensuring well-defined fiscal dynamics as in Gertler and Karadi (2013) and Sims and Wu (2021).

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 by 13 basis points in annualized terms after one quarter relative to a no-QE policy case. Our findings also comfortably confirm that QE policies in EMEs with 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.

In a number of extensions, we explore the risks and limitations of asset purchase measures in EMEs. Firstly, we show that if bond purchases lead to a de-anchoring in inflation expectations, they bring a smaller reduction in real excess bond yields while leading to higher and more persistent inflation. Secondly, when efficiency costs posing balance sheet risks to the consolidated government are introduced, both QE measures yield less stabilization in response to the bond sell-off shock. When EME monetary policy interest rates are hypothetically assumed to have hit an effective lower bound during the pandemic, the bond yield reduction from QE policies still emerges as robust. This is because higher real bond yields from the "finance channel" are offset by lower inflation owing to the "aggregate demand channel" under higher interest rates. Finally, we find asset purchases continue to reduce excess bond yields even without a reduction in global interest rates, notwithstanding that overall financial conditions are tighter in this case relative to our baseline.

Related literature. We fill a gap in the literature by offering transmission channels for shocks that are propagated by larger foreign ownership of LC sovereign debt and asset purchases in EMEs, using an estimated structural model of unconventional monetary policy and balance sheet effects on banks. In this sense, we complement insights from recent empirical studies such as Arslan et al. (2020), Hartley and Rebucci (2020) and IMF (2020), Fratto et al. (2021) and WB (2021) and show that the reported long-term sovereign bond yield reduction effects of QE in EMEs are short-lived.

This paper is placed in a strand of a vast body of literature studying the balance sheet implications of government bond holdings by banks. To name a few, Bocola (2016) shows risky sovereign bond holdings leave less room for banks to lend to private firms and additionally lead to precautionary deleveraging when reduced-form sovereign default risk rises. Kirchner and van Wijnbergen (2016) demonstrate that when banks hold domestic government debt, debt-financed fiscal expansion crowds out private lending and reduces the growth effects of fiscal stimulus. Both studies abstract from the foreign-lending base of the government and hence do not capture the repercussions of the bond sell-offs by international lenders. Priftis and Zimic (2020) introduce this channel in their empirical study deploying SVARs and document that when government spending shocks are foreign-debt financed, investment multipliers of fiscal stimulus are higher. Broner et al. (2021) arrive at similar empirical results using local projections and mitigating the endogeneity problems. We introduce a new angle to this 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 documented by these studies and offer central bank asset purchases as a remedy to countervail these effects.

This paper contributes to the unconventional monetary policy literature pioneered by Gertler and Karadi (2013). These authors find government bond and private security purchases ease financial conditions, boost real economic activity and inflation in advanced, closed economies. Sims and Wu (2021) extend this work by including other unconventional monetary policy measures and conclude that QE policies are more effective than negative interest rate or forward guidance policies in easing financial conditions in advanced economies. We differ from these contributions by introducing currency mismatches faced by banks and government bond sell-offs by foreigners in an open economy setup, allowing us to account for the repercussions of the original sin redux.

Our paper closely relates to studies on asset purchase policies in open economy frameworks. Dedola et al. (2013) explore welfare gains from the coordination of costly private asset purchases in financially integrated regions. We differ from these authors, who abstract from monetary policy by considering currency dynamics and monetary policy feedbacks to asset purchases. Kolasa and Wesołowski (2020) show EME central banks can partly offset spillover effects from QE in large economies with reciprocal asset purchases, reducing net capital inflows and limiting the appreciation of their currency, which hinder their net exports. We depart from them by showing that the "borrower's channel" proves key in understanding the neutral stance of EME currencies upon QE implementations during the pandemic, as stronger bank balance sheets enabled by more accommodative financial conditions upon QE boosted capital inflows and appreciated the currency.

Finally, this paper complements a literature including Alfaro and Kanczuk (2009), Durdu et al. (2009), Jeanne and Ranciere (2011), Hur and Kondo (2016) and Bianchi et al. (2018) among others, which consider hard-currency asset purchases by the central bank. These contributions focus on the role of international reserves in reducing sudden stop or debt rollover risks. In a more recent study, Bocola and Lorenzoni (2020) find foreign reserves reduce financial panic risks when the banking system is highly leveraged. We depart from this earlier work by considering the role of central bank purchases of LC assets in mitigating the negative repercussions of capital outflows.

The rest of the paper is organized 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 purchase measures and, using our estimated model, demonstrates the efficacy of asset purchases during the COVID-19 crisis against counterfactual scenarios. Section 4 discusses the risks and limitations of asset purchase policies by relaxing some of our key modeling assumptions. 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 closely follows MS in that banks obtain external financing from both domestic depositors and international investors, bearing currency risk and lending to domestic non-financial, intermediate goods producers. We then extend this setup by assuming that banks additionally make loans to government by purchasing LC, long-term government bonds as in Gertler and Karadi (2013), Bocola (2016) and Sims and Wu (2020). For tractability, we assume that banks do not lend 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 asset purchases. Unless otherwise stated, variables denoted by upper (lower) case characters represent nominal (real) values in domestic currency. Variables that are denominated in foreign currency or related to the rest of the world are indicated by an asterisk. For brevity, we include key model equations in the main text. Interested readers might refer to the Online Appendix A for detailed derivations of the optimization problems of agents and explicit formulations of the shock processes and Online Appendix B for 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, leisure and holding real money balances. The household utility function is subject to a consumption preference shock to capture large swings in consumption, as occurred during the pandemic. 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 as in Galí and Monacelli (2005) and Gertler et al. (2007) and supply labor. They also save in LC deposits within financial intermediaries owned by the banker members of other households. The balance of these deposits is denoted by D_t, which promises to pay a net nominal risk-free rate r_{nt} in the next period. There are no interbank frictions so that r_{nt} coincides with the short-term policy rate of the central bank. Furthermore, the borrowing contract is real in the sense that the risk-free rate is determined based on the expected inflation. By assumption, households cannot directly save in productive capital, and only banker members of households are able to borrow in hard currency.[7]

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 have to satisfy an incentive compatibility constraint. This in turn restrains funds raised by bankers and limits the credit extended to nonfinancial firms and the government, leading to nonnegative loan-deposit spreads faced by both borrowers. We formulate the diversion feature so that in equilibrium, loan rates charged by banks to firms and the government as well as domestic/foreign bank funding rates align 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,

[7] The government in our environment also borrows from foreign investors but by issuing domestic currency, long-term bonds. Additionally introducing hard currency public debt would not alter our main findings.

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

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 nonfinancial 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 borrowing in real domestic units. n_{jt} is the real net worth of banker j.

Bankers' profits from lending operations build up their net worth. Therefore, their bank capital evolves into the next period as,

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

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 premiums 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. Finally, the last term highlights the contribution of internal funds, that are 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 currency units) satisfy the following definitions

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

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

where r_n denotes the net nominal deposit rate, R_n^* is the gross nominal US interest rate that follows an autoregressive stochastic process, S is the nominal exchange rate of foreign currency in domestic currency units and P is the aggregate domestic price index. Cost of foreign debt R_{t+1}^* reflects a risk premium $\Psi_t = \exp(\psi\, \widehat{nfd_t}) \exp(\psi_t^{rp})$ over US interest rates R_{nt}^*, as in MS, where nfd_t stands for net foreign debt; the sum of the foreign debt of bankers b_t^* and the government b_t^{g*} (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. Linking this premium with net aggregate foreign indebtedness accounts for potential spillover effects of sovereign debt on domestic banks' balance sheet as in Corsetti and Müller (2015). We also consider country risk premium shocks hitting this premium to capture 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. This insight suggests a microfoundation to deviations from the uncovered interest parity condition as demonstrated by MS.

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 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

$$R^g_{t+1} = \frac{\kappa_{gt} + (1-\delta_g)q^g_{t+1}}{q^g_t}. \tag{4}$$

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

$$R^{YTM,g}_t = \frac{\kappa_{gt}}{q^g_t} + 1 - \delta_g \tag{5}$$

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

$$1 + i^{YTM,g}_t = R^{YTM,g}_t \pi_{t+1}, \tag{6}$$

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

$$EY^g_t = 1 + i^{YTM,g}_t - R^*_{nt}. \tag{7}$$

2.2.3 Net worth maximization

Bankers maximize 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}. For a given level of net worth, the optimal amount of foreign debt can be solved for by using the balance sheet. Bankers solve the following recursive value maximization problem,

$$V_{jt} = \max_{l_{jt}, b^g_{jt}, d_{jt}} E_t \Big\{ \Lambda_{t,t+1} \Big[(1-\theta) n_{jt+1} + \theta V_{jt+1} \Big] \Big\}. \tag{8}$$

For nonnegative premiums on credit to the non-financial firms and credit to the government, the solution to the value maximization problem of banks would lead to an unbounded magnitude of assets. In order to rule out such a scenario, we follow Gertler and Karadi (2011) 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 choices of l_{jt} and b^g_{jt} should be incentive compatible. Therefore, the following constraint is imposed on bankers,

$$V_{jt} \geq \lambda \Big(q_t l_{jt} + \omega_g q^g_t b^g_{jt} - \omega_d d_{jt} \Big), \tag{9}$$

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.

We introduce two different asymmetries in financial frictions by including only ω_g fraction of government bonds into and excluding ω_d fraction of domestic deposits from diverted assets. The first asymmetry of including only ω_g fraction of government bonds into the diverted assets is due to the idea that it would be more difficult to divert government bonds making them less risky compared to the security claims issued by nonfinancial firms. The second asymmetry of excluding ω_d fraction of domestic deposits from diverted assets hinges on the idea that domestic depositors would arguably have a comparative advantage over foreign depositors in recovering assets in case of a bankruptcy. Furthermore, they would also be better equipped than international lenders to monitor domestic bankers.[8]

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 (9) holds with equality at all times. The solution to the net worth maximization problem implies,

$$q_t l_{jt} + \omega_g q^g_t b^g_{jt} - \omega_d d_{jt} = \frac{\nu_t}{\lambda - \nu^l_t} n_{jt} = \kappa_{jt} n_{jt}, \tag{10}$$

This endogenous constraint, which emerges from the costly enforcement problem described above, ensures that bankers' risky assets are proportional to their net worth defining bank leverage κ_{jt}

[8]See MS for a detailed discussion of a similar type of asymmetry in the diversion of bank assets.

endogenously. The condition 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.

One key aspect of our analysis is to introduce asymmetry in the diversion of asset classes by taking $0 < \omega_g < 1$. This allows us to differentiate equilibrium real loan rates and government bond rates as they do so in the data. The asymmetry on the funding side on the other hand $0 < \omega_d < 1$, facilitates us to match the empirical funding composition of banks and makes the model consistent with the violation of the uncovered interest parity condition.

2.2.4 Aggregation

All households behave symmetrically, so that we can aggregate equation (10) over j and obtain the following aggregate relationship:

$$q_t l_t + \omega_g q_t^g b_t^g - \omega_d d_t = \kappa_t n_t, \tag{11}$$

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 (11) shows that aggregate credit to nonfinancial firms plus the divertable portion of credit to government net of nondivertable 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 (11) into the net worth evolution equation (2) 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, $n_{t+1} = n_{et+1} + n_{nt+1}$.

2.3 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. Fluctuations in this asset price and government bond prices are the main driver of the financial accelerator, which operates through bankers' endogenous borrowing limits. Intermediate goods firms use this new capital for production at time $t+1$. We also assume that capital producers incur investment adjustment costs 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, acquire capital and labor and 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.

Fiscal policy. On the spending side, 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.

The government borrows in long-term, domestic currency bonds $\bar{b^g}$ in addition to raising taxes to finance its expenditures. To ensure the closure of the fiscal block, we assume that the fiscal branch follows a debt rule in the form of a constant real supply of LC government bonds so that,

$$q_t^g \bar{b^g} = q_t^g b_t^g + q_t^g b_t^{g*} + q_t^g b_t^{gCB}. \tag{12}$$

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

The total supply of sovereign bonds are held by bankers b_t^g, foreigners b_t^{g*} and the central bank b_t^{gCB} should the monetary branch 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,

$$\log(b_t^{g*}) = \rho_{g*} \log(b_{t-1}^{g*}) + (1-\rho_{g*}) \left[\log b^{\bar{g}*} + v_{g*} \log(\Psi_t)\right] + \varepsilon_t^{g*}, \tag{13}$$

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

Monetary policy. The central bank deploys both conventional and unconventional monetary policy tools. Under a (managed) floating exchange rate regime, we first consider an augmented Taylor-type interest rate rule that allows responses to inflation, output gap and nominal currency depreciations,

$$\log\left(\frac{1+r_{nt}}{1+\overline{r_n}}\right) = \rho_{r_n} \log\left(\frac{1+r_{nt-1}}{1+\overline{r_n}}\right) + (1-\rho_{r_n}) \left[\varphi_\pi \log\left(\frac{\pi_t}{\overline{\pi}}\right) + \varphi_y \log\left(\frac{y_t}{\overline{y}}\right) + \varphi_\eta \log\left(\frac{\eta_t}{\overline{\eta}}\right)\right] + \varepsilon_t^{R_n}, \tag{14}$$

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.[9] $\varepsilon_t^{R_n}$ stands for discretionary monetary policy shocks. To be general, we also allow for interest rate smoothing in the monetary policy rule so that $0 \leq |\rho_{r_n}| < 1$.

[9]Even though the central bank's mandate does not explicitly include stabilizing the exchange rate, a de facto fear of floating motive as discussed by Calvo and Reinhart (2002) induces it to respond to exchange rate fluctuations. In recent work, MS has shown that in EMEs, it is optimal to respond to exchange rate fluctuations that are triggered by external financial shocks.

Asset purchases. In addition to conventional policy interest rates, the central bank also employs asset purchase policies to guide price discovery and ease financial conditions. 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.[10] Let government bond purchases by the central bank be defined as

$$q_t^g b_t^{gCB} = \varphi_t^g q_t^g \bar{b^g}(1 - \tau^{gCB}) \tag{15}$$

with φ_t^g denoting the time-varying share of LC government bonds purchased by the central bank. We assume that this bond purchase policy function is designed to mitigate market dislocations. Thus, the share of LC bonds purchased by the central bank follows

$$\varphi_t^g = \rho_{\varphi^g} \varphi_{t-1}^g + (1 - \rho_{\varphi_g}) \left[\bar{\varphi^g} + v_g \left(\frac{q_t^g b_t^{g*}/y_t}{q^g b^{g*}/y} \right) \right] + \varepsilon_t^{\varphi^g}, \tag{16}$$

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 bond holdings-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.

Following a similar logic, purchases of securities issued by non-financial intermediate goods producers are defined as

$$q_t l_t^{CB} = \varphi_t^l q_t \bar{l}_t (1 - \tau^{CB}) \tag{17}$$

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. Hence, market clearing for private securities necessitates

$$q_t \bar{l}_t = q_t l_t + q_t l_t^{CB}. \tag{18}$$

We assume that purchases of private securities by the central bank are designed to mitigate loan-deposit spreads that tend to rise in response to adverse financial shocks. Therefore, the share of private securities held by the central bank follows

[10] IMF (2020) reports that Chile, Colombia and Hungary are among QE-implementing EMEs that purchased bank bonds or mortgage bonds as private assets. The remaining central banks purchased LC sovereign bonds (Fratto et al., 2021).

$$\varphi_t^l = \rho_{\varphi^l} \varphi_{t-1}^l + (1 - \rho_{\varphi_l}) \left[\bar{\varphi^l} + v_l E_t \log \left(\frac{R_{kt+1} - R_{t+1}}{R_k - R} \right) \right] + \varepsilon_t^{\varphi^l}, \tag{19}$$

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.

A key issue regarding the feasibility of QE policies is the concern that asset purchases might transfer risk from private sector lenders to the central bank, which could undermine both the efficacy of such policies and the central bank's hard-earned independence as discussed by Cecchetti and Schoenholtz (2020). In order to capture those frictions, we introduce efficiency losses to asset purchase policies in the form of leakages. That is, constant fractions of $0 < \tau^{gCB}, \tau^{CB} < 1$ sovereign bond and private security purchases are simply lost in (15) and (17) as central bankers are not experts on financial assets intermediation.

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 on 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).[11]

Consolidated government. Money supply in this economy is demand-determined and compensates for the cash demand of workers. Consequently, the money market clearing condition reads

$$M_{0t} = M_t,$$

where M_{0t} denotes the supply of monetary base at date t. The consolidated government finances the consumption of final goods g_t, interest payments over debt and asset purchases by new issuance

[11]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 QE policies 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, (9).

of LC long-term bonds, seigniorage levied on households, lump-sum taxes and the net interest earned by asset purchases. The flow budget constraint of the government would then read

$$g_t + (R_t^g - 1)\bar{b^g} = \frac{M_{0t} - M_{0t-1}}{P_t} + \tau_t + (R_t^g - R_t)q_{t-1}^g b_{t-1}^{gCB} + (R_{kt} - R_t)q_{t-1} l_{t-1}^{CB}. \quad (20)$$

Notice that as implied by equations (15) and (17), leakages in asset purchases directly result in losses to the central bank and reduce the profits remitted to the consolidated government. It is then even possible to argue that any increase in these efficiency losses would induce the central bank to resort to partial monetization of government or firm debt, as government outlays shown on the left-hand side of budget constraint (20) shall be matched with increased seigniorage revenues under declining profits remitted by the central bank.

The case for reducing excess bond yields. 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, the definition of excess bond yields (7) can be rewritten as

$$EY_t^g = (R_t^{YTM,g} - R_t)\pi_{t+1} + (R_t - R_t^*)\pi_{t+1} + R_t^*\pi_{t+1} - R_{nt}^*. \quad (21)$$

The first term of the right-hand side of this decomposition represents the inherent yield premium of long-term government bonds over short-term real deposit rates in the EME. Consider now a negative country risk premium shock that hits the EME as it would have done during the pandemic. The negative financial shock increases banks' funding costs, stresses their balance sheets and drives a decline in asset prices of both private credit and government bonds, causing this real yield premium to widen. The second term of equation (21) is banks' funding premium, and it also becomes wider during financial stress episodes, as we demonstrate in the next section. Finally, the spread between the last two terms of equation (21) increases in a straightforward way as R_t^* by definition, adds country risk premia on US short-term interest rates. Therefore, if the central bank can boost sovereign bond prices by exercising asset purchases, it may partly offset the negative repercussions of the external financial shock by reversing its 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 (15) and (17) can be combined with their respective market clearing conditions (12) and (18) to arrive at

$$q_t^g \bar{b^g} = \frac{1}{1-\varphi_t^g(1-\tau^{gCB})}\left[q_t^g b_t^g + q_t^g b_t^{g*}\right] \tag{22}$$

$$q_t \bar{l}_t = \frac{1}{1-\varphi_t^l(1-\tau^{CB})} q_t l_t. \tag{23}$$

Given that asset purchase rules φ_t^g and φ_t^l are bounded above by one and assets intermediated by commercial banks are subject to agency costs and hence are tied by the leverage constraint (11), the fractions in front of privately intermediated assets *multiply* them 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 (5), achieving the primary objective of bond purchases by the central bank. The implications of asset purchases on private securities are even starker: by the multiplier effect, the central bank can directly expand the supply of credit to intermediate goods producers as well as boosting asset prices. Finally, we underscore that in addition to reducing profits from asset purchases, the efficiency losses make the multiplier effects from bond and security purchases lower, hampering the efficacy of QE policies.

This completes the discussion of our analytical framework. A full description of solutions to the optimization problem of model agents and the resource constraints are included in Online Appendix A and the definition of a competitive equilibrium is left to Online Appendix B.

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 QE policies using our estimated model. We first analyze discretionary asset purchase shocks both for sovereign bonds and non-financial firm securities. Then, we judge the effectiveness of rule-based QE policies 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.

3.1 Model calibration and estimation

We choose the model parameters based on a quarterly data set covering the sample period from 2002Q1 to 2019Q4. The data set includes 13 EMEs identified in Arslan et al. (2020) to have implemented QE 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 unweighted averages of HP-filtered data across the countries in our sample (presented in Figure 1). Computations are done by using the *RISE* toolbox.[12] 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 .

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 premiums. Price variables are consumer price inflation and the policy rate. Finally, international variables include the real exchange rate, the U.S. Fed Funds rate and foreign investors' share in outstanding LC sovereign bonds. The data sources we use are Refinitiv and international sources such as the BIS, IMF, OECD and WB. Further information on the computation of the empirical counterpart of targeted moments and specific data sources can be found in Online Appendix C.

[12]"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 households' quarterly discount factor β at 0.9968 to match an average annualized real deposit rate of 1.3%. The relative utility weight of labor χ is calibrated as 397.7 to fix hours worked in the steady state at 0.3333. We choose the relative utility weight of money balances v as 0.0159 to match 6.37 as the annual output velocity of M1. 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-intermediation margin of annualized 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 utilization d is calibrated as 0.0424 to normalize the steady-state rate of capital utilization at unity. We calibrate the additive parameter of the quarterly depreciation rate of capital δ as 0.1157 to match an annualized 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. Following the practice in the literature, 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 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 steady-state coupon payment paid by long-term government bonds to be $\bar{\kappa}_g = \frac{\delta_g + \bar{R}_n^* - 1}{\bar{R}_n^*} = 0.0198$. The steady-state fractions of government bond and private asset purchases by the central bank are chosen depending on whether the policy is discretionary or ruled-based. Under discretionary public and private QE policies, they are set to 0.0001. Under rule-based public and private QE policies, they are calibrated to be 0.1 and 0.15, respectively. We set the persistence of QE policies 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 QE policies 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 public QE 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 QE 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 public QE policy 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 QE policy 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 QE policies 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. 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.

The further details about implementing system priors in the estimation are included in Online Appendix D.

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 and 3 display the marginal priors.

Small open economy DSGE models tend to be sensitive to the external debt-elastic risk premium parameters in the sense that small changes in these parameters can have large effects on the model's behaviour. We estimate ψ^{rp} 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.

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 shocks have a prior mean of 0.1, but some prior means have been somewhat calibrated to better fit some moments. Due to the wide priors on the standard deviations, the shock calibration 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.

3.2 Asset purchases ease financial conditions without currency depreciation risks

We first discover that QE policies ease financial conditions with no currency depreciation and inflation risks in Figure 2. This finding emerges from an experiment, in which we study discretionary public (solid lines) and private (dashed lines) asset purchases at 1.5% of GDP, which is representative of the average EME central bank asset purchase through August 2020 (see IMF (2020)).[13] We achieve this by adjusting the magnitude of innovations to asset purchase policy

[13] 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, local-currency sovereign bonds from the secondary market.

formulations (16) and (19) to target a particular asset purchase size while setting the response coefficients v_g and v_l in these policy rules equal to zero. Government bond prices q_t^g become elevated following central bank sovereign bond purchases, which are not subject to any leverage constraint, as implied by the financial multiplier condition (22). This directly reduces the excess bond premium on long-term, domestic-currency government bonds by about 5 basis points per annum, feeds back into commercial bank capital and further enhances banks' loan-making capacity via the so-called financial accelerator mechanism as described by Gertler and Karadi (2011) (solid lines in Figure 2). Recall that the supply of local-currency government bonds $\bar{b^g}$ is fixed. Therefore, bond purchases by the central bank allow commercial banks to reduce their government bond holdings (top-right panel) and lend more to the private sector (by more than 0.5% relative to a deterministic trend). This boosts asset prices for private securities, helping to reduce loan-deposit spreads by close to 90 basis points in annualized terms. With stronger balance sheets, banks can borrow more from both depositors and foreign lenders, which enables capital inflows, appreciating the real exchange rate and thus reducing inflation. Finally, the concurrent decline in inflation creates room for monetary policy easing, leading to higher investment as well as output (the top row).

We find outright private security purchases to be more effective than sovereign bond purchases in reducing long-term government bond yields (dashed lines in Figure 2). From a quantitative perspective, private asset purchases appear to have a bond yield compression effect that is three times as large as public asset purchases of the same size. We identify two key reasons behind this finding. Firstly, thanks to the financial multiplier relation (23), central bank's discretionary purchases of firm securities directly expand the level of total private credit in the economy $q_t\bar{l}_t$, while the transmission of government bond purchases only work via sovereign bond prices as the total supply of bonds is fixed (see condition (22)). The rest of model dynamics then follow a similar reasoning to those implied by the public QE, underpinned by stronger bank balance sheets, better borrowing terms that are further improved by monetary policy accommodation and increased real activity, all working under larger magnitudes. Secondly, the nature of financial constraints in the economy makes private asset purchases more effective. In particular, while the fixed supply of sovereign bonds crowds in private bank lending under sovereign bond purchases by the central bank, less government bond holdings by commercial banks imply that they are foregoing a safer asset (relative to private credit), which partly alleviates financial constraints. Specifically, since banks can divert a smaller fraction of sovereign bonds, a unit of portfolio re-balancing towards firm securities causes the agency cost constraint (9) to bind more tightly under public QE relative to the private QE, partly offsetting the crowding in effect.

3.3 Rule-based asset purchases counteract the original sin redux

In this section, we first provide a microfoundation to the repercussions of the original sin redux (increased susceptibility of LC sovereign debt to fluctuations in global risk sentiment) using the bond sell-off shocks that EMEs suffered during the COVID-19 crisis as a natural laboratory. After exploring the transmission of bond sell-off shocks, we investigate how useful the rule-based asset purchase policies that are described in Section 2.5 can be in stabilizing them.

We present the effectiveness of the rule-based public (solid lines) and private (dashed lines) asset purchases compared with a no-QE case (dotted lines) in response to a local-currency government bond sell-off shock of 1.5% of GDP (modeled as a disturbance to the process in (13)) in Figure 3. Under the economy with no asset purchase policies, banks are forced to replace the bond sell-off by foreigners (top-right panel), which crowds out private credit to non-financial firms (first panel of the second row). The reduced supply of bank credit bids down both sovereign bond and private firm security prices, leading to an expansion of excess yields on long-term sovereign bonds over US interest rates and loan-deposit intermediation margins (panels in the third row) of about 5 and more than 200 basis points per annum, respectively. This suggests that (external) sovereign bond sell-off shocks might have very large amplification effects on domestic financial conditions. Banks' foreign borrowing capacity is hindered by weaker balance sheets under depressed asset prices, exacerbating capital outflows initiated by the sovereign bond sell-off. This results in a depreciated currency and a surge in the current account balance-to-GDP ratio (bottom-left panel). The exchange-rate depreciation raises imported goods prices and passes through to overall domestic prices, inducing conventional monetary policy to further exacerbate the impact of the shock with the aim of stabilizing inflation and the fear of floating. Consequently, the overall tightening in domestic financial conditions depresses both investment and the GDP of the economy (panels in the first row).

We find that public asset purchases that replace foreign investors one-to-one reduce the rise in excess bond yields over the US interest rates by half, and substantially mitigate the decline in private credit, the depreciation of currency and the rise in the intermediation margins as well as inflation (solid lines in Figure 3). A key channel through which the central bank short-circuits the bond sell-off shock is that commercial banks are no longer required to increase their government bond holdings upon the shock (the top-right panel), as the central bank addresses the bond market dislocation by purchasing assets. This prevents the crowding out of private credit to 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 excess bond yields and credit spreads relative to the case of no-QE policy. The stronger bank balance sheets present better foreign-borrowing prospects for banks, limiting total capital outflows and reducing the currency depreciation relative to the case of no intervention with asset purchases. By corollary, the reversal in the current account-to-GDP ratio emerges to be around two-thirds of the case with no asset purchases (bottom-left panel).

Private asset purchases bring the same degree of stabilisation as public QE even with asset purchases of only 0.6% of GDP (dashed lines in Figure 3). In this experiment, we calibrate the size of private asset purchases to match the decline in bank credit under no QE interventions 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' utilization of the safe asset role of government bonds.[14] These channels dominate the financial crowding out effect and ease overall financial conditions.

3.4 Private asset purchases are more successful against country risk premium shocks

How do asset purchases work when sovereign bond sell-offs interact with fluctuations in country risk premia? This section answers this question by endogenizing reductions in foreign-held EME sovereign bond holdings in response to orthogonal country risk premium shocks. To that end, we rely on the foreign bond holdings process (13), which entails a negative feedback from

[14] This however, is notwithstanding that, as opposed to the case of discretionary purchases, private QE expands an already depressed level of private credit in this case, because the economy is hit by the bond sell-off shock, which stresses the financial system.

country risk premium Ψ_t to sovereign bonds held by foreign investors b_t^{g*} with $v_{g*} < 0$. In this setup, Figure 4 illustrates the impact of an orthogonal country risk premium shock of 172 basis points in annualized terms and the efficacy of alternative QE policies.[15]

The risk premium shock under no asset purchases immediately raises the cost of foreign debt for banks, which they find lower in normal times (dotted-dashed lines in Figure 4). As per the transmission channels described by MS, 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 (the panel in the third row). 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, there is a sharp credit crunch 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 does not accommodate the shock and calls for a tightening, as capital outflows triggered by both the endogenous government bond sell-off and reduced foreign debt of banks result in a depreciation of the currency. As a result, real investment declines by 2% relative to the deterministic trend.

We find that government bond purchases that only address the market dislocation created by foreigners are not effective in stabilizing the impacts of this country risk premium shock (solid lines in Figure 4). In particular, the tightening in funding conditions for banks is so strong that crowding in private credit in commercial banks' balance sheets comes with limited use. By contrast, the inability of banks to resort to the safe government bonds even tightens funding (and accordingly lending) conditions more, as displayed by panels in the second and the third rows.

The rule-based private asset purchases on the other hand (calibrated to attain a size of 0.6% of GDP 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, in contrast to the case of bond sell-off shocks, even private asset purchases have limited scope for compressing excess long-term bond yields in response to

[15]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 and conventional monetary policy displays a fear of floating as in MS, with a strong response of the Taylor-type interest rate rule (14) to inflation.

country risk premium shocks. Our understanding of this finding is improved by analyzing the decomposition of excess bond yields into inherent maturity premium and premiums that arise from financial frictions in equation (21). While asset purchases more directly address the increases in the maturity premium (the first term), they 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 the country risk premium shocks have a direct impact, as implied by equation (3).

3.5 How did asset purchases in EMEs work during the pandemic?

After uncovering the transmission mechanism of asset purchases using a series of experiments, we finally conduct a counterfactual analysis centered around the COVID-19 shock. We first take our estimated model without QE policies at 2019Q4 as our initial condition before replicating the baseline event. We then filter realizations for the structural shock processes that are employed in the estimation routine to replicate the data corresponding to the 2020Q1-2020Q3 episode for key variables in the baseline model specification. This case entails public asset purchases of 1.3% of GDP, as occurred in the average EME through August 2020. The remaining counterfactual scenarios use identical path of shock realisations to isolate the impact of alternative asset purchase regimes.

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 clearly indicate that excess government bond yields are virtually identical between the baseline economy and the counterfactual with no asset purchases.[16] 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 an aggressive private QE policy of purchasing firm securities at 6.8% of GDP.

[16]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 as a result of 10,000 Monte Carlo simulations for the out-of-estimation sample of 2020Q1-2020Q3. The associated fan charts showing alternative confidence bands for each counterfactual can be found between Figures E.2 and E.7 in the Online Appendix.

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). Our conclusion that QE policies' financial easing benefits 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 QE policies. These findings are consistent with our discussion of the transmission mechanism of such policies so far and support the conjectures by Benigno et al. (2020).

4 Extensions: risks and limitations of asset purchases

In this section, we provide three extensions to our benchmark analysis. Firstly, we consider how the efficacy of sovereign bond purchases changes when inflation expectations are de-anchored. Secondly, we investigate how asset purchase policies would have been affected from efficiency costs. Finally, we explore how QE measures would have performed if EME central banks had not been able to simultaneously reduce their monetary policy interest rates during the pandemic.

4.1 Bond purchases are less effective when they de-anchor inflation expectations

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. Our baseline analysis confirms that with perfectly anchored inflation expectations, central bank sovereign bond purchases in EMEs can stabilize the effects of bond sell-off shocks without inflationary repercussions. In this extension, we relax this assumption and consider a scenario in which when bond purchases are announced, intermediate goods producers engage in partly backward-looking indexation rather than fully getting feedback from the central bank's inflation target while computing their price-setting costs. This is ensured by resolving the intermediate goods producers' price setting problems, which modifies New Keynesian Phillips curves in our environment (see Online Appendix B.6).

We find that when central bank bond purchases de-anchor inflation expectations, asset purchases reduce excess bond yields to a lesser extent and at a cost of higher inflation. Figure 5 demonstrates that, although nominal excess yields under sovereign bond purchases leading to de-anchored inflation expectations fall to a lower level than in the case with no-QE policy (dashed lines versus fine-dashed lines in the bottom-left panel), inflation becomes more persistent and higher in a present discounted sense in this case relative to the case of bond purchases with anchored inflation expectations (dashed line versus solid lines in the bottom-right panel). We further conclude that the efficacy of bond purchases under de-anchored inflation expectations in reducing excess yields is hindered not only in terms of keeping inflation dynamics in check, but also in reducing the real term premium between sovereign bonds and domestic short-term interest rates (dashed versus solid lines in the top-left panel), denoted by the first term in the excess yield decomposition (21).

4.2 Asset purchases ease financial conditions even when they are costly

Our baseline analysis abstracts from efficiency costs of central bank asset purchases. However, it is sensible to consider imperfect asset intermediation by monetary authorities as central banks lack expertise in managing private assets and there are implementation risks as sovereign debt would be partly monetized should governments not repay the central bank. In this extension, we capture those imperfections by using our asset purchase formulations (15) and (17), in which we capture the efficiency costs of QE implementations in a reduced form way by the introduction of proportional losses $0 < \tau^{g^{CB}}, \tau^{CB} < 1$ in asset purchases. These losses essentially reduce the remitted profits from asset purchases to the consolidated government as shown in (20).

We find that both public and private asset purchases continue to ease financial conditions in response to bond sell-off and country risk premium shocks, respectively. Figure 6, displays the dynamics of selected model variables in response to a sovereign bond sell-off shock that peaks at 4.5% of GDP (fine-dashed lines) with no asset purchases and two other economies that entail public asset purchases, with one featuring leakages that amount to as large as 30% of bonds purchased by the central bank (dashed lines) so that $\tau^{gCB} = 0.3$ and another with no efficiency costs (solid lines), i.e. $\tau^{gCB} = 0$. Simulations imply that imperfections in bond purchases prevent the central bank from fully eliminating the financial crowding out effects on commercial bank balance sheets (top-right panel), hindering the easing of overall financial conditions vis-à-vis the economy with costless asset purchases. Nonetheless, we observe that even costly bond purchases continue to deliver substantial easing in overall financial conditions, and primarily in excess bond yields, in the economy. In Figure 7, we conduct a similar experiment, this time considering the efficacy of private asset purchases in response to adverse country risk premium shocks. With a similar degree of asset intermediation imperfections ($\tau^{CB} = 0.3$), private security purchases continue to stabilize country risk premium shocks (dashed lines against fine-dashed lines) although at a reduced rate relative to the case with no costs (solid lines).

4.3 The impact of domestic or foreign conventional monetary policy spillovers on the effectiveness of asset purchases

Our COVID-19 crisis counterfactuals all assume 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 has already hit an effective lower bound (ELB) in 2019Q4 so that it cannot be lower than its level prior to the pandemic.[17] Second, we repeat the counterfactual exercises while fixing world interest rates at their level in 2019Q4, shutting down this positive financial spillover to the domestic economy.

Simulation results reported in the first column of Table 5 demonstrate that while bond yields are weakly 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 domestic conventional monetary policy. Specifically, bond yield reductions from asset purchases (relative to a no-QE policy regime) emerge similar in size relative

[17] It is plausible to think that EME central banks may face an ELB for policy interest rates that is strictly greater than zero as opposed to advanced economies, as the former typically operate in small open economies with a positive country risk premium. In this section, we ensure a binding ELB by re-filtering monetary policy shocks and keeping all the other structural shocks at their previously filtered levels without the ELB constraint.

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 (6). Policy interest rates that hit a binding effective lower bound raise banks' funding costs, reduce their loan-making capacity and depress sovereign bond prices q_t^g, accordingly. This results in a rise in the real yield-to-maturity of long-term bonds as per the inverse relationship (5) between asset prices and yields. On the other hand, as displayed by the second and fifth columns of Table 5, when interest rates hit an ELB, due to the ensuing monetary policy tightening relative to the baseline experiments, the exchange rate depreciates by less and inflation declines more. Therefore, by (6), nominal excess yields on sovereign bonds emerge as similar to the case of no monetary policy spillovers.

Finally, Table 6 illustrates, when world interest rates are not allowed to decline during the pandemic period, an alternative modality and size of asset purchase policies bring about a similar degree of LC bond yield compression and an overall easing in domestic financial conditions (column 1) compared with the set of baseline experiments (Table 4). This is notwithstanding that regardless of the implemented QE policies, the exchange rate of the economy depreciates more (leading to higher inflation) and investment gets a bigger hit relative to all economies in the baseline experiment (Table 4) in the absence of the positive financial spillovers from the reduction in global interest rates.

5 Conclusion

This paper quantitatively explored the efficacy of unprecedented asset purchases by emerging-market economy central banks during the pandemic, through the lens of the original sin redux. A wider foreign lending base of sovereign debt makes emerging-market sovereign bonds more susceptible to sell-off cycles as attested during the COVID-19 crisis. The ensuing capital outflows and exchange-rate depreciation further exacerbate the tightening in overall financial conditions in these economies, as private sector balance sheets are prone to currency mismatch. With our work, we provide a theory as to how the original sin redux may play out in emerging markets, by uncovering the transmission mechanism of bond sell-off shocks triggered by foreign investors.

We further contribute to the literature by offering a solution to the puzzle of asset purchase interventions not leading to perverse exchange-rate dynamics in emerging markets amid capital outflows during the pandemic, noting the importance of credible monetary policy frameworks. Finally, we quantitatively established that the high frequency estimates of bond yield reductions from asset purchases during the onset of the pandemic could have persisted only under large-scale programs that are representative of advanced economies. The main policy implication of our analysis is that asset purchases in credible emerging markets can be useful to guide price discovery in times of stress but not to manage aggregate demand over the business cycle.

Our work can be extended in a few dimensions. We assume that asset purchases are transitory. This assumption can be relaxed to consider a permanent expansion of the central bank's balance sheet to explore the effects on inflation dynamics. To sharpen our understanding, we abstracted from foreign-currency interventions. Including those may provide valuable insights on currency implications of asset purchases. Finally, the framework can be extended to a two-country setup to directly account for spillovers from large, advanced economy asset purchase policies to emerging markets. We leave those compelling questions to future research.

6 References

Alfaro, Laura and Fabio Kanczuk, "Optimal reserve management and sovereign debt," *Journal of International Economics*, 2009, *77(1)*, 23–36.

An, Sungbae and Frank Schorfheide, "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 2007, *26* (2-4), 113–172.

Arslan, Yavuz, Mathias Drehmann, and Boris Hofmann, "Central bank bond purchases in emerging market economies," 2020. BIS Bulletin No. 20.

Arslanalp, Serkan and Takahiro Tsuda, "Tracking Global Demand for Emerging Market Sovereign Debt," 2014. IMF Working Paper No. 14/39.

Benigno, Gianluca, Jon Hartley, Alicia García-Herrero, Alessandro Rebucci, and Elina Ribakova, "Credible emerging market central banks could embrace quantitative easing to fight COVID-19," 2020. https://voxeu.org/article/credible-emerging-market-central-banks-could-embrace-quantitative-easing-fight-covid-19.

Bertaut, Carol C., Valentina Bruno, and Hyun Song Shin, "Original Sin Redux," 2021. SSRN Electronic Journal, April 5.

Bianchi, Javier, Juan Carlos Hatchondo, and Leonardo Martinez, "International Reserves and Rollover Risk," *American Economic Review*, 2018, *108(9)*, 2629–2670.

Bocola, Luigi, "The Pass-Through of Sovereign Risk," *Journal of Political Economy*, 2016, *124(4)*, 879–926.

and Guido Lorenzoni, "Financial Crises, Dollarization, and Lending of Last Resort in Open Economies," *American Economic Review*, 2020, *110(8)*, 2524–2557.

Borri, Nicola, "Local currency systemic risk," *Emerging Markets Review*, 2018, *34*, 111–123.

Broner, Fernando, Daragh Clancy, Aitor Erce, and Alberto Martin, "Fiscal Multipliers and Foreign Holdings of Public Debt," *Review of Economic Studies*, 2021. Forthcoming.

Calvo, Guillermo A. and Carmen M. Reinhart, "Fear of Floating," *Quarterly Journal of Economics*, 2002, *117(2)*, 379–408.

Carstens, Agustín and Hyun Song Shin, "Emerging markets aren't out of the woods yet," 2019. Foreign Affairs, March 15.

Cecchetti, Stephen G. and Kermit L. Schoenholtz, "The Fed Goes to War: Part 2," 2020.

https://www.moneyandbanking.com/commentary/2020/3/25/the-fed-goes-to-war-part-2.

Corsetti, Giancarlo and Gernot J. Müller, "Fiscal Multipliers: Lessons from the Great Recession for Small Open Economies," *Report to the Swedish Fiscal Policy Council*, 2015, *2.*

Dedola, Luca, Peter Karadi, and Giovanni Lombardo, "Global implications of national unconventional policies," *Journal of Monetary Economics*, 2013, *60*, 66–85.

Durdu, Ceyhun Bora, Enrique G. Mendoza, and Marco E. Terrones, "Precautionary demand for foreign assets in Sudden Stop economies: An assessment of the New Mercantilism," *Journal of Development Economics*, 2009, *89(2)*, 194–209.

Fratto, Chiara, Brendan Harnoys Vannier, Borislava Mircheva, David de Padua, and Hélène Poirson, "Unconventional Monetary Policies in Emerging Markets and Frontier Countries," 2021. IMF Working Paper, 21/14.

Galí, Jordi and Tommaso Monacelli, "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 2005, *72*, 707–734.

Gertler, Mark and Peter Karadi, "A Model of Unconventional Monetary Policy," *Journal of Monetary Economics*, 2011, *58*, 17–34.

and , "QE 1 vs. 2 vs. 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool," *International Journal of Central Banking*, 2013, *9(1)*, 5–53.

, Simon Gilchrist, and Fabio Natalucci, "External Constraints on Monetary Policy and the Financial Accelerator," *Journal of Money, Credit, and Banking*, 2007, *39(2/3)*, 295–330.

Hartley, Jonathan S. and Alessandro Rebucci, "An Event Study of COVID-19 Central Bank Quantitative Easing in Advanced and Emerging Economies," 2020. CEPR Discussion Paper Series, DP14841, June.

Hur, Sewon and Illenin Kondo, "A theory of rollover risk, sudden stops, and foreign reserves," *Journal of International Economics*, 2016, *103*, 44–63.

IMF, "Bridge to Recovery," *Global Financial Stability Report*, 2020. October.

, "A Fair Shot," *Fiscal Monitor*, 2021. April.

Jeanne, Olivier and Romain Ranciere, "The Optimal Level of Reserves for Emerging Market Countries: a New Formula and Some Applications," *Economic Journal*, 2011, *121(555)*, 905–930.

Kirchner, Markus and Sweder van Wijnbergen, "Fiscal deficits, financial fragility, and the effectiveness of government policies," *Journal of Monetary Economics*, 2016, *80*, 51–68.

Kolasa, Marcin and Grzegorz Wesołowski, "International spillovers of quantitative easing," *Journal of International Economics*, 2020, *126*, 103330.

Macaulay, Frederick R., "Some Theoretical Problems Suggested by the Movements of Interest Rates, Bond Yields, and Stock Prices in the United States Since 1856," 1938. New York: Columbia University Press.

Mimir, Yasin and Enes Sunel, "External Shocks, Banks, and Optimal Monetary Policy: A Recipe for Emerging Market Central Banks," *International Journal of Central Banking*, 2019, *15(2)*, 235–299.

Priftis, Romanos and Srečko Zimic, "Sources of Borrowing and Fiscal Multipliers," *Economic Journal*, 2020, *131(633)*, 498–519.

Sims, Eric and Jing Cynthia Wu, "Wall Street vs. Main Street QE," 2020. NBER Working Paper, 27295.

and , "Evaluating Central Banks' Tool Kit: Past, Present, and Future," 2021, *118*, 135–160.

WB, "Global Economic Prospects," 2021. January, World Bank.

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
Utility parameter for real money balances	υ	0.0159	Output to M1 ratio of 6.37
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
Sensitivity of foreign-held LC bonds to country risk premium	$\upsilon*$	-403.67	EME bond sell-off in 2020Q2 due to country risk premium shock
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.

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
ψ	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
$\upsilon*$	Sens. of for.-held LC bonds to risk prem.	N	-77	10	-67.28	2.80
ψ_{rp1}	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_{rn}	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. After thinning by a factor of 10, posterior statistics are computed from 2,200,000 draws generated by the Random Walk Metropolis-Hastings algorithm using 20 chains with an acceptance rate tuned to 0.25, where the first 200,000 are used as burn-in.

Table 3: Marginal prior and posterior distributions, shock parameters

			Prior		Posterior	
		Distr.	Mean	Std. Dev.	Mode	Std. Dev.
Shock persistence						
ρ_A	Temporary 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
ρ_{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
Shock std. dev.'s						
σ_A	Temporary 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 preimum	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
σ_{R_n*}	U.S. interest rate	Γ^{-1}	0.1	200	0.1|	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. After thinning by a factor of 10, posterior statistics are computed from 2,200,000 draws generated by the Random Walk Metropolis-Hastings algorithm using 20 chains with an acceptance rate tuned to 0.25, where the first 200,000 are used as burn-in.

Table 4: The small size of EME central bank asset purchases resulted in short-lived easing in financial conditions

	(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 public QE	80	2.3	-127	8.4	-212	-16.3
	[75,85]	[0.8,3.9]	[-172,-81]	[8.3,8.6]	[-332,-89]	[-19.8,-12.9]
Aggressive private QE	80	2.1	-127	6.8	-212	-15.3
	[75,85]	[0.7,3.7]	[-172,-82]	[6.7,6.8]	[-330,-91]	[-18.8,-11.9]
Aggressive public QE[b]	72	2.0	-133	21.0	-220	-16.0
	[66,75]	[0.4,3.6]	[-179,-87]	[20.1,21.3]	[-341,-97]	[-19.4,-12.6]
Aggressive private QE[b]	72	1.8	-133	10.2	-218	-14.4
	[67,77]	[0.3,3.3]	[-177,-88]	[10.1,10.2]	[-337,-97]	[-17.9,-11.0]

Note: Effects of adopting counterfactual quantitative easing 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 presents 2020Q2 cross-country averages of the actual data. 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 are still short-lived under no monetary policy accommodation

	(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 quantitative easing 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 efficacy of EME central bank asset purchases does not change under no 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 quantitative easing 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.

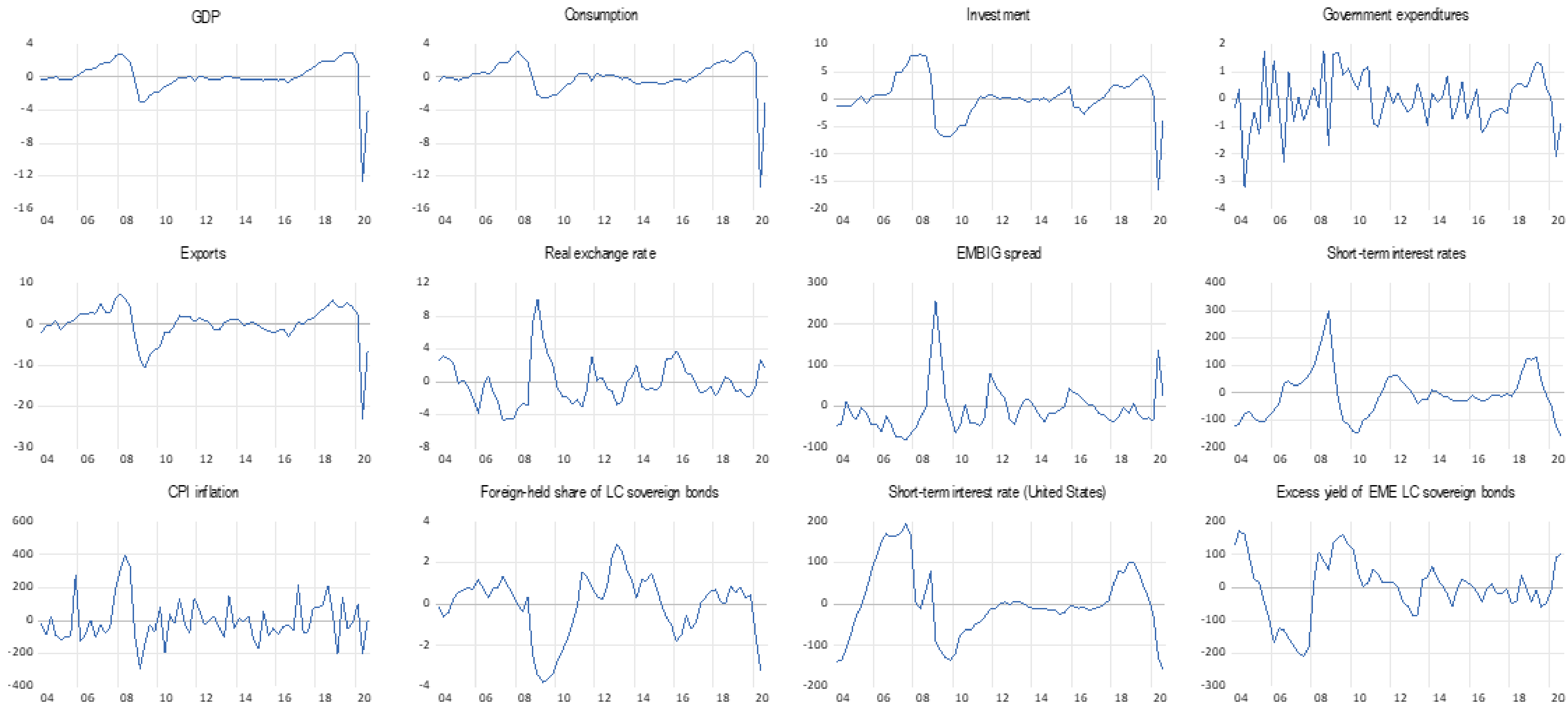

Figure 1: Cyclically adjusted key macroeconomic and financial variables. The average of HP-filtered series for Chile, Colombia, Hungary, Indonesia, India, Korea, Mexico, the Philippines, Poland, Romania, Thailand, Turkey and South Africa for the period of 2004Q1-2020Q3. National account variables and real depreciation are in per cent 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 over the US short–term rate. Using median series instead of the average across countries produces similar cyclical fluctuations. Sources: OECD Economic Outlook 108 database; Refinitiv; and Arslanalp and Tsuda (2014), regularly updated as the IMF Sovereign Debt Investor Base database; and authors' calculations.

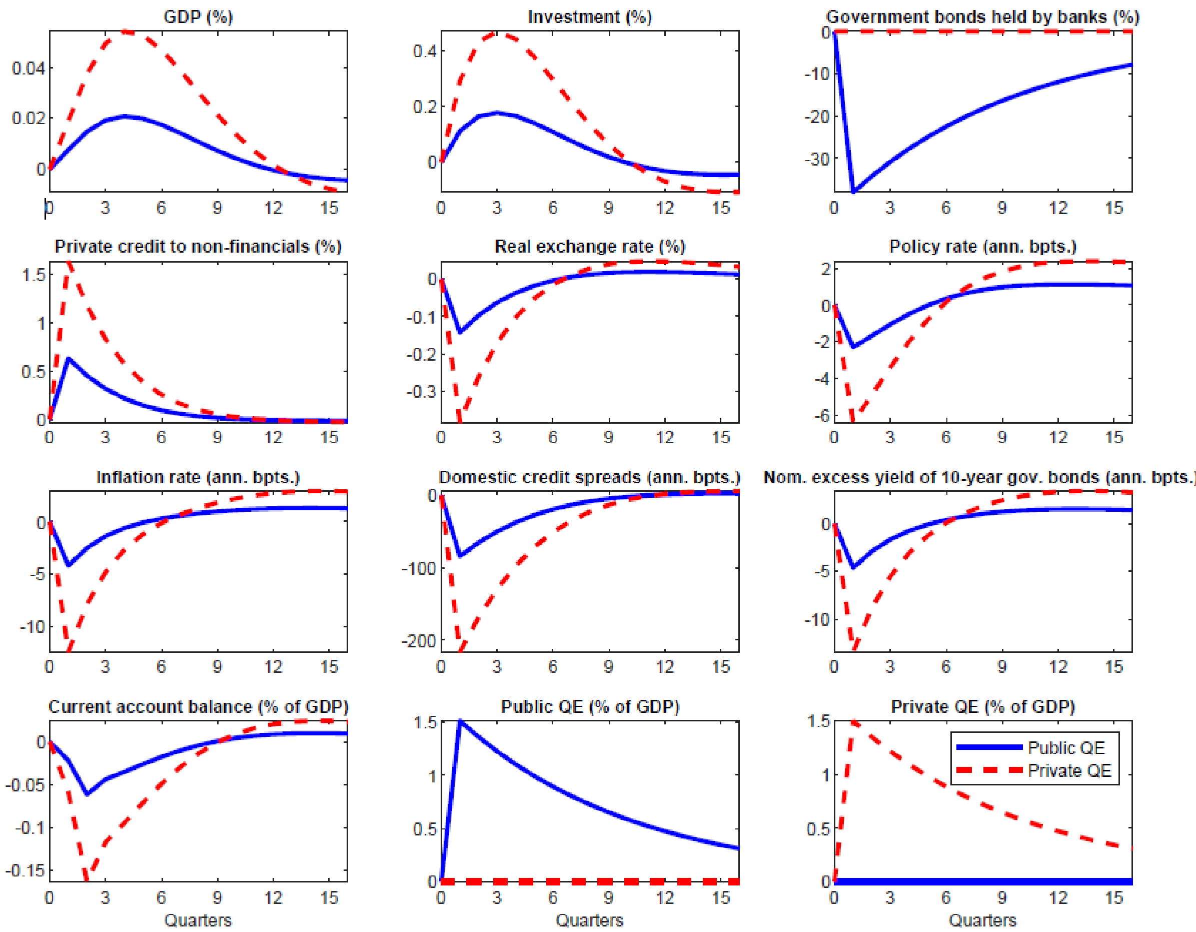

Figure 2: Impulse-response functions of selected model variables to discretionary quantitative easing policy shocks. Deviations from the steady state. Asset purchase-to-GDP ratio is representative of EME central bank sovereign bond purchases during the COVID-19 crisis. Increases in the real exchange rate denote depreciation. Excess yield is over the US short–term rate.

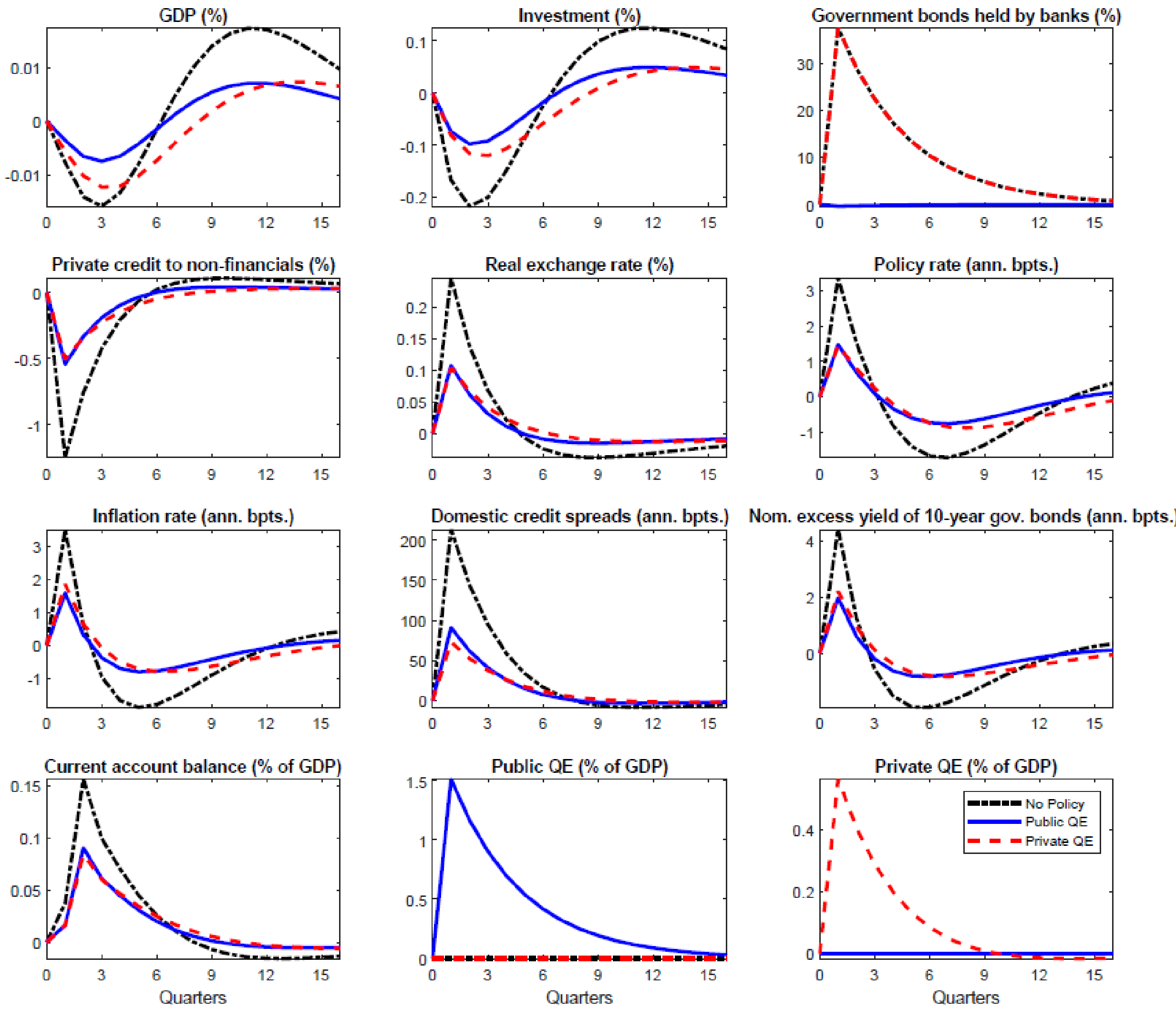

Figure 3: Impulse-response functions of selected model variables to an orthogonal bond sell-off shock of 1.5% of GDP. Deviations from the steady state. Public asset purchase policy rule is calibrated to ensure that the central bank entirely makes up for bonds sold by foreign investors (1.5% of GDP at 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. Increases in the real exchange rate denote depreciation. Excess yield is over the US short–term rate.

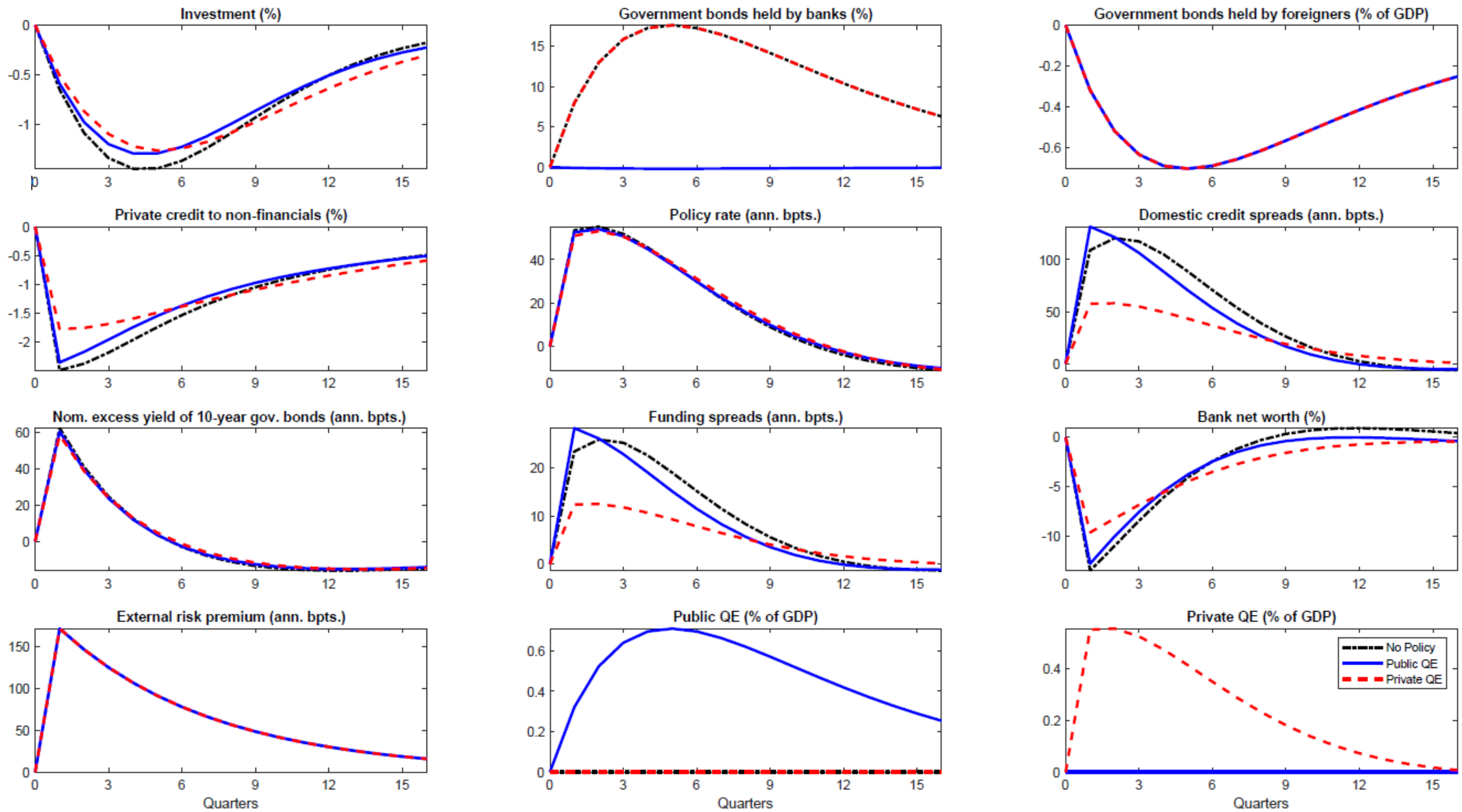

Figure 4: Impulse-response functions of selected model variables to an orthogonal country risk premium shock. Deviations from the steady state. The country risk premium shock is calibrated to replicate 172 basis points increase (from 2020Q1 to 2020Q2) in the cyclically adjusted annualized EMBIG bond spreads in the average EME economy. The endogenous sensitivity of sovereign bond sell-offs to the country risk premium is calibrated 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. Interest rate rule features an inflation coefficient of 1.5 to reflect a fear of floating. Increases in the real exchange rate denote depreciation. Funding spread is the positive uncovered interest parity deviation beyond country risk premium and expected depreciation that emerges due to financial frictions. Excess yield is over the US short–term rate.

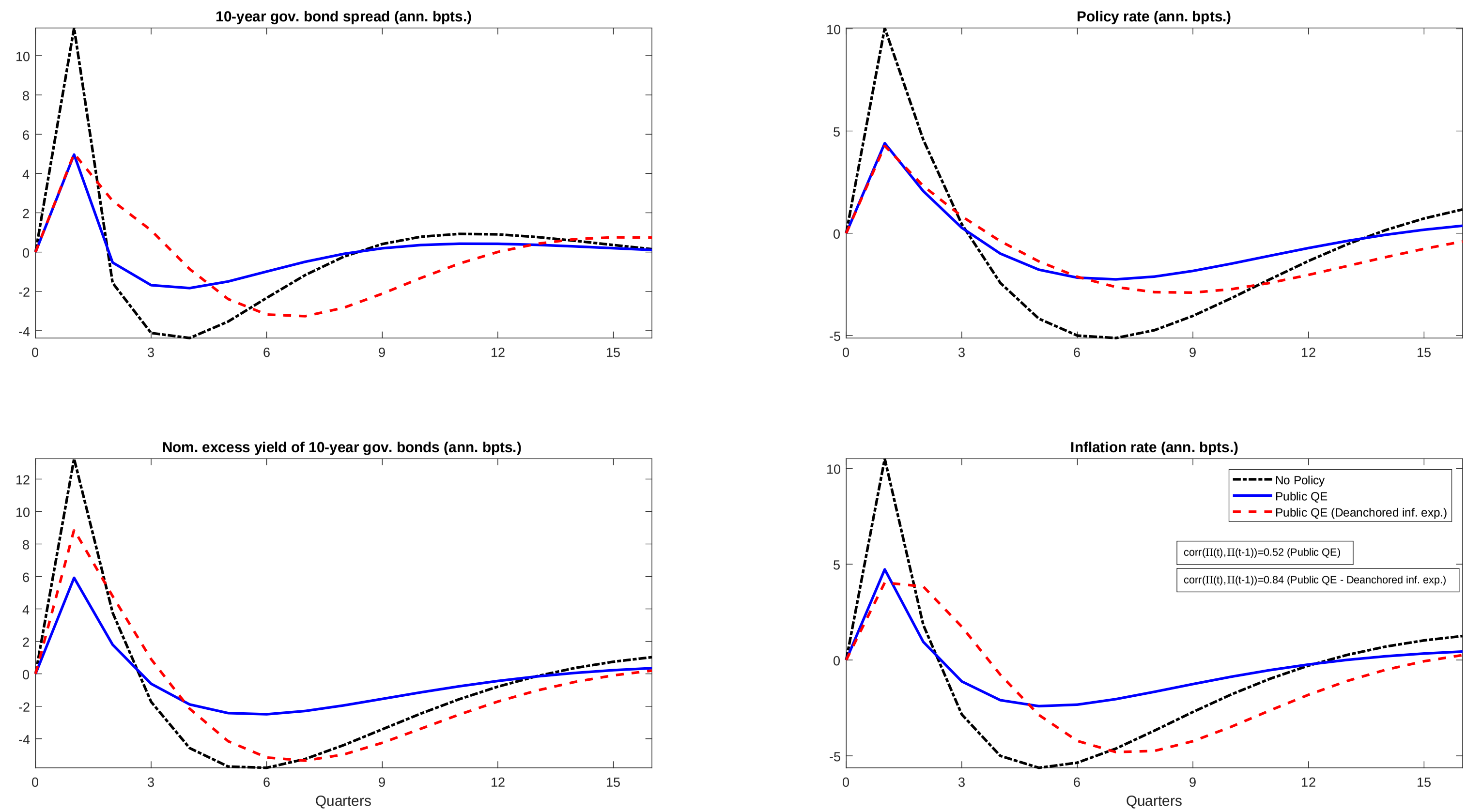

Figure 5: Deviations from the steady state in response to a bond sell-off shock. The solid lines are the case of a public asset purchases policy program that reaches 4.5% of GDP at the peak. The dashed lines differ from this case by assuming that intermediate good producers partially take previous period's rate of inflation rather than the target inflation as their reference in computing their menu cost. 10-year spreads are the difference between the real yield-to-maturity of government bonds and the real short-term deposit rate. Nominal excess yield is over the US short–term rate.

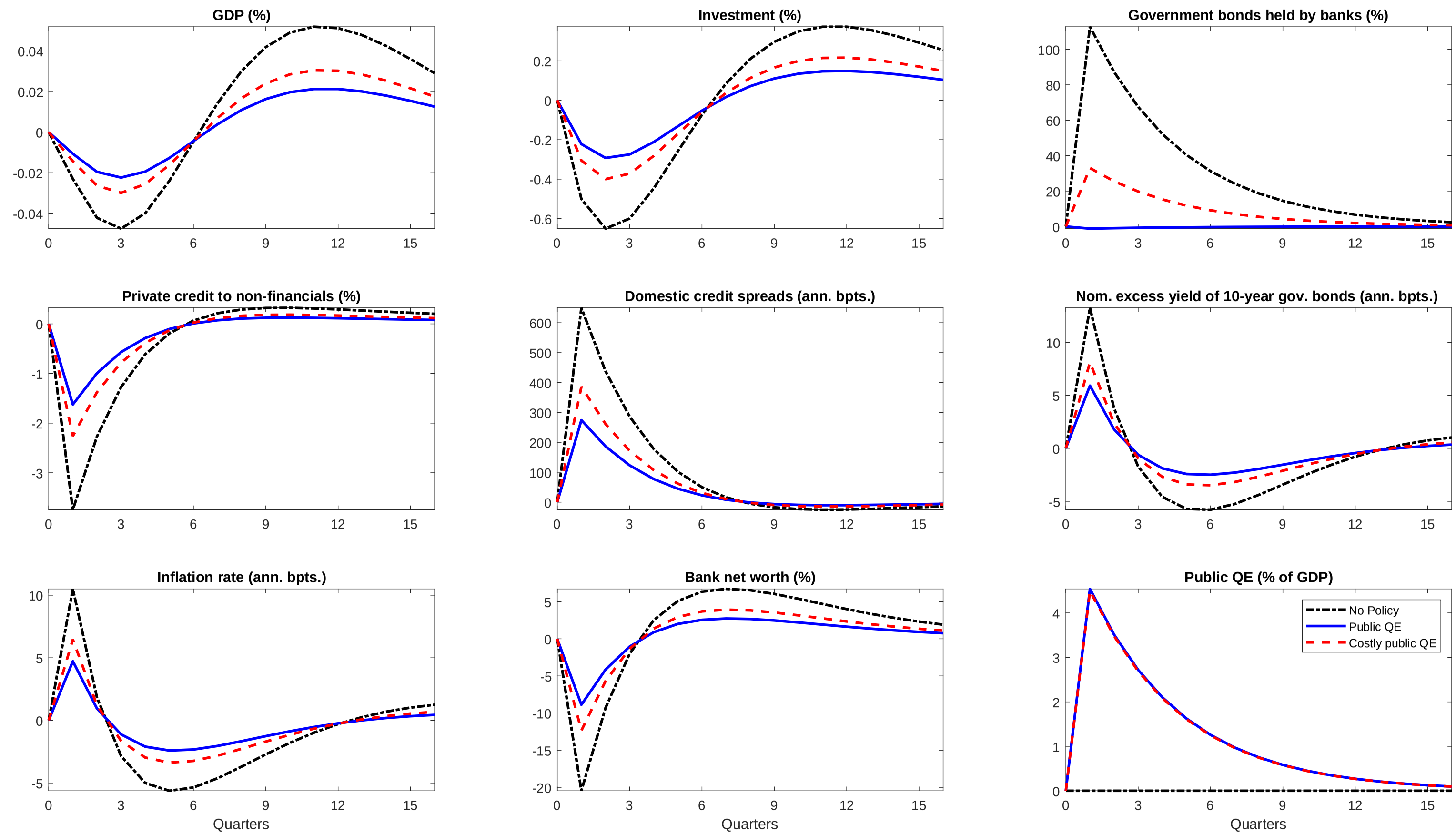

Figure 6: Deviations from the steady state. The solid lines are the case of a public asset purchases policy programme that reaches 4.5% of GDP at the peak in response to a concomitant bond sell-off shock. The dashed lines differ from this case by assuming that there are efficiency costs to the intermediation of government bonds by the central bank. Nominal excess yield is over the US short–term rate.

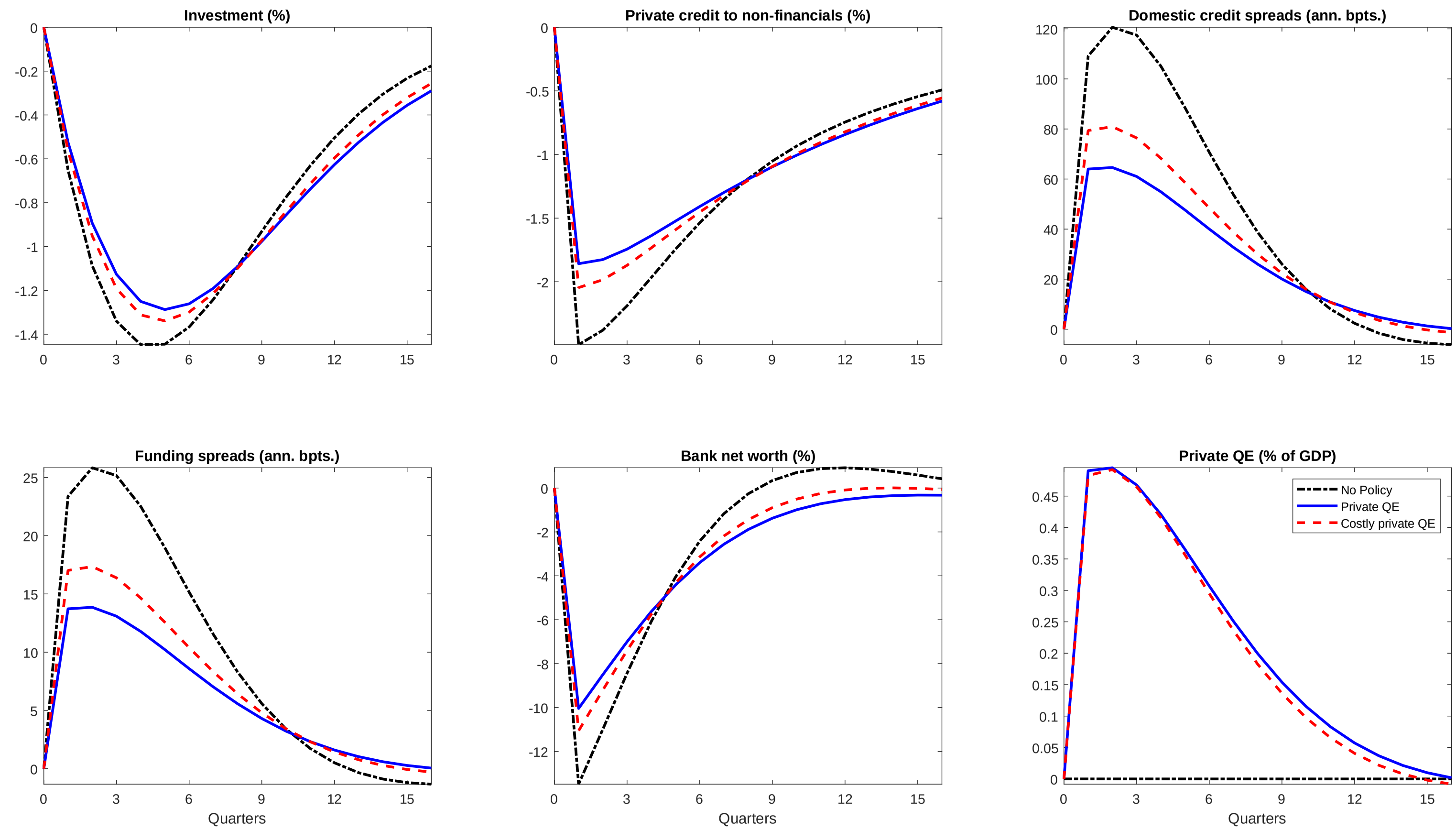

Figure 7: Deviations from the steady state. The solid lines are the case of a private asset purchases policy programme that reaches 0.5% of GDP at the peak in response to a country risk premium shock of 172 basis points in annualized terms. The dashed lines differ from this case by assuming that there are efficiency costs in intermediation of private securities by the central bank. Nominal excess yield is over the US short–term rate.

Online Appendix for "Asset purchases as a remedy for the original sin redux"-Not intended for publication[1]

Yasin Mimir[2] Enes Sunel[3]

September 20, 2021

Abstract

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

Keywords: Asset purchases, original sin redux, Bayesian estimation.
JEL Classification: E62, E63, G21

[1]A previous version of the main manuscript was circulated with the title "Quantitative Easing in Emerging-Market Economies". We would like to thank Paola Di Casola, Massimo Ferrari, Georgios Georgiadis, Gene Kindberg-Hanlon, Boris Hofmann, Serdar Kabaca, Jesper Linde, Giovanni Lombardo, Łukasz Rawdanowicz, Kasper Roszbach, and seminar participants at Norges Bank, OECD, Sveriges Riksbank, Bank of England, European Central Bank, Federal Reserve Board, World Bank, Bank for International Settlements, Bank of Canada and the Computing in Economics and Finance, 2021 meetings. The views in this paper should not be reported as representing the views of Norges Bank or the OECD or of its member countries. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank or the OECD. The usual disclaimer applies.

[2]Norges Bank, Monetary Policy Department, Bankplassen 2, 0151 Oslo, Norway, Phone: +4792082946, yasin.mimir@norges-bank.no, Personal homepage: http://www.yasinmimir.com

[3]OECD, Economics Department. 2 Rue Andre Pascal, 75775 Paris CEDEX 16, France, Phone: +33642849838, email: enessunel@gmail.com, Personal homepage: https://sites.google.com/site/enessunel/

A Model derivations

A.1 Households

Preferences of households over consumption, leisure, and real balances are represented by the lifetime utility function

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

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

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

ψ_t^c is a consumption preference shock with

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

hit by zero mean and constant variance Gaussian innovations $\varepsilon_t^{\psi^c}$. E_t is the mathematical expectation operator conditional on the information set available at t, $\beta \in (0,1)$ is the subjective discount factor, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, $h_c \in [0,1)$ governs the degree of external habit formation over aggregate consumption $\tilde{c}_{t-1}$ in the previous period, χ is the utility weight of labor and $\xi > 0$ determines the Frisch elasticity of labor supply. We also assume that the natural logarithm of real money balances provides utility flows scaled by v.

Households face the flow budget constraint,

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

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

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

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

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

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

$$\frac{v}{M_t / P_t} = \beta E_t \left[\varphi_{t+1} r_{nt} \frac{P_t}{P_{t+1}} \right]. \tag{A.8}$$

Equation (A.5) defines the Lagrange multiplier, φ_t as the marginal utility of consuming an additional unit of income. Equation (A.6) equates marginal disutility of labor to the shadow value of real wages. Finally, equations (A.7) and (A.8) represent the Euler equations for deposits, the consumption-savings margin, and money demand, respectively. External habit formation implies that $c_t = \tilde{c}_t \ \forall t$.

The CES aggregator for final consumption good reads

$$c_t = \left[\omega_t^{\frac{1}{\gamma}} (c_t^H)^{\frac{\gamma-1}{\gamma}} + (1 - \omega_t)^{\frac{1}{\gamma}} (c_t^F)^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}, \tag{A.9}$$

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

$$\log \omega_t = (1 - \rho_\omega) \bar{\omega} + \rho_\omega \log(\omega_{t-1}) + \varepsilon_t^{\omega}. \tag{A.10}$$

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

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

The expenditure minimization problem of households

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

subject to (A.49) yields the domestic consumer price index (CPI),

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

and the optimal demand frontier between home and foreign goods,

$$\frac{c_t^H}{c_t^F} = \frac{\omega_t}{1-\omega_t}\left(\frac{P_t^H}{P_t^F}\right)^{-\gamma}. \tag{A.12}$$

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

$$\log \epsilon_t = (1-\rho_\epsilon)\bar{\epsilon} + \rho_\epsilon \log(\epsilon_{t-1}) + \varepsilon_t^\epsilon. \tag{A.13}$$

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

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

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

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

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

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

A.2 Banks' net worth maximization

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

$$n_{jt+1} = R_{kt+1} q_t l_{jt} + R^g_{t+1} q^g_t b^g_{jt} - R_{t+1} d_{jt} - R^*_{t+1} b^*_{jt}, \tag{A.14}$$

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

$$R^g_{t+1} = \frac{\kappa_{gt} + (1-\delta_g) q^g_{t+1}}{q^g_t}. \tag{A.15}$$

with the natural logarithm of coupon payments following the stochastic process

$$\log \kappa_{gt} = (1-\rho_{\kappa_g}) \log \bar{\kappa_g} + \rho_{\kappa_g} \log \kappa_{gt-1} + \varepsilon^{\kappa_g}_t \tag{A.16}$$

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

The cost of foreign borrowing is defined as

$$R^*_{t+1} = \Psi_t R^*_{nt} \frac{S_{t+1}}{S_t} \frac{P_t}{P_{t+1}} \quad \forall t, \tag{A.17}$$

with US interest rates following the stochastic process

$$\log(R^*_{nt}) = (1-\rho_{R^*_n}) \log(\bar{R^*_n}) + \rho_{R^*_n} \log(R^*_{nt-1}) + \varepsilon^{R^*_n}_t \tag{A.18}$$

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

$$\psi^{rp}_t = \rho_{rp} \psi^{rp}_{t-1} + \varepsilon^{rp}_t \tag{A.19}$$

with zero mean and constant variance Gaussian innovations ε^{rp}_t also hits the country risk premium Ψ_t to capture sovereign spread fluctuations that originate from country risk. Combining equations (1) and (A.14) and re-arranging terms produce bank's net worth evolution condition (2) in the main text. Using this transition function for net worth, bankers solve the following value maximization problem,

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

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

$$+ \left[R^g_{t+1+i} - R^*_{t+1+i}\right] q^g_{t+i} b^g_{jt+i} - \left[R_{t+1+i} - R^*_{t+1+i}\right] d_{jt+i} + R^*_{t+1+i} n_{jt+i} \Big).$$

subject to the constraint (13). Since,

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

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

we have

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

producing the recursive formulation of the net worth maximization problem.

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,

$$V_{jt} = \nu^l_t q_t l_{jt} + \nu^g_t q^g_t b^g_{jt} - \nu^*_t d_{jt} + \nu_t n_{jt}. \tag{A.20}$$

Among these recursive objects, ν^l_t and ν^g_t represent the expected marginal values of credit extended to nonfinancial firms and government, $-\nu^*_t$ 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 Lagrangian which solves the bankers' profit maximization problem reads,

$$\max_{l_{jt}, b^g_{jt}, d_{jt}} L = \nu^l_t q_t l_{jt} + \nu^g_t q^g_t b^g_t - \nu^*_t d_{jt} + \nu_t n_{jt} \tag{A.21}$$

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

where the term in square brackets incorporates the incentive compatibility constraint, (13). The first-order conditions for l_{jt}, b^g_{jt}, d_{jt}, and the Lagrange multiplier μ_t are:

$$\nu^l_t (1+\mu_t) = \lambda \mu_t, \tag{A.22}$$

$$\nu_t^g(1+\mu_t) = \lambda\mu_t\omega_g, \tag{A.23}$$

$$\nu_t^*(1+\mu_t) = \lambda\mu_t\omega_d, \tag{A.24}$$

$$\nu_t^l q_t l_{jt} + \nu_t^g q_t^g b_t^g - \nu_t^* d_{jt} + \nu_t n_{jt} - \lambda\left(q_t l_{jt} + \omega_g q_t^g b_{jt}^g - \omega_d d_{jt}\right) \geq 0 \tag{A.25}$$

respectively. We are interested in cases in which the incentive constraint of banks is always binding, which implies that $\mu_t > 0$ and (A.25) holds with equality. Combining (A.22) and (A.23) yields, $\nu_t^g = \omega_g \nu_t^l$. Combining (A.22) and (A.24) yields, $\nu_t^* = \omega_d \nu_t^l$. Re-arranging the binding version of (A.25) and using the linear conjecture leads to equation (14). The funding spread between domestic and foreign bank borrowing will always be positive (that is, $\nu_t^* > 0$) by the virtue of financial constraints always binding $\mu > 0$ and $\lambda, \omega_d > 0$ in (A.24). This also implies that the uncovered interest parity condition breaks in the model, as shown by MS and consistent with the data.

We replace V_{jt+1} in equation (12) by imposing our linear conjecture in equation (A.20) and the borrowing constraint (14) to obtain,

$$\tilde{V}_{jt} = E_t\Big\{\Xi_{t,t+1} n_{jt+1}\Big\}, \tag{A.26}$$

where $\tilde{V}_{jt}$ stands for the optimised value. Replacing the left-hand side to verify our linear conjecture on bankers' value (A.20) and using equation (2), we find that ν_t^l, ν_t^g, ν_t^* and ν_t should satisfy,

$$\nu_t^l = E_t\Big\{\Xi_{t,t+1}\left[R_{kt+1} - R_{t+1}^*\right]\Big\}, \tag{A.27}$$

$$\nu_t^g = E_t\Big\{\Xi_{t,t+1}\left[R_{t+1}^g - R_{t+1}^*\right]\Big\}, \tag{A.28}$$

$$\nu_t^* = E_t\Big\{\Xi_{t,t+1}\left[R_{t+1} - R_{t+1}^*\right]\Big\}, \tag{A.29}$$

$$\nu_t = E_t\Big\{\Xi_{t,t+1} R_{t+1}^*\Big\}, \tag{A.30}$$

with $\Xi_{t,t+1} = \Lambda_{t,t+1}\Big[1 - \theta + \theta\lambda\kappa_{t+1}\Big]$ representing the augmented stochastic discount factor of bankers, which is a weighted average defined over the likelihood of survival.

Equations (A.27) and (A.28) suggest that bankers' marginal valuation of credit to nonfinancial firms and to the government are equal to the expected discounted premiums between respective loan rates minus the benchmark cost of foreign funds. Equation (A.29) equates the marginal value of raising foreign debt to the expected discounted value of the funding premium between domestic and foreign borrowing, which is shown to be strictly greater than zero as discussed in the Online Appendix. Finally, equation (A.30) shows that marginal value of internal financing should be equal to the expected discounted opportunity cost of raising external funds. In our analytical strategy, this coincides with the cost of foreign borrowing as the reference external borrowing rate. Finally, surviving bankers' net worth n_{et+1} is derived as described in the main text as

$$n_{et+1} = \theta\Big\{\Big[(R_{kt+1} - R^*_{t+1})\kappa_t + R^*_{t+1}\Big]n_t + \Big[(R^g_{t+1} - R^*_{t+1}) - \omega_g(R_{kt+1} - R^*_{t+1})\Big]q^g_t b^g_t + \Big[\omega_d(R_{kt+1} - R^*_{t+1}) - (R_{t+1} - R^*_{t+1})\Big]d_t\Big\}. \quad \text{(A.31)}$$

Financial frictions would vanish when none of the assets are diverted, i.e. $\lambda = 0$ and bankers never have to exit, i.e. $\theta = 0$. Consequently, $\Xi_{t,t+1}$ simply collapses 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.

A.3 Capital producers

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

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

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

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

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

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

The resulting aggregate investment price index P_t^I, is given by

$$P_t^I = \left[\omega_i (P_t^H)^{1-\gamma_i} + (1-\omega_i)(P_t^F)^{1-\gamma_i}\right]^{\frac{1}{1-\gamma_i}}.$$

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

$$\max_{i_{t+i}} \sum_{i=0}^{\infty} E_0 \left[\Lambda_{t,t+1+i} \left(q_{t+i} i_{t+i} - \Phi\left(\frac{i_{t+i}}{i_{t+i-1}}\right) q_{t+i} i_{t+i} - \frac{P_{t+i}^I}{P_{t+i}} i_{t+i}\right)\right]. \tag{A.32}$$

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

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

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

$$k_{t+1} = (1-\delta_t)k_t + \exp(\psi_t^i)\left[1 - \Phi\left(\frac{i_t}{i_{t-1}}\right)\right] i_t, \tag{A.33}$$

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

$$\psi_t^i = \rho_{\psi^i} \psi_{t-1}^i + \varepsilon_t^{\psi^i} \tag{A.34}$$

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

A.4 Final goods producers

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

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

The profit maximization problem of final goods producers

$$\max_{y_t^H(i)} \; P_t^H \left[\int_0^1 y_t^H(i)^{1-\frac{1}{\epsilon_t}} di \right]^{\frac{1}{1-\frac{1}{\epsilon_t}}} - \left[\int_0^1 P_t^H(i) y_t^H(i) di \right]. \tag{A.35}$$

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

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

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

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

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

A.5 Intermediate goods producers

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

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

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

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

with zero mean and constant variance Gaussian innovations ε_t^z.

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

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

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

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

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

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

$$\max_{P_t^H(i)} E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j}\left[\frac{D_{t+j}^H(i)}{P_{t+j}}\right] \tag{A.36}$$

subject to the nominal profit function

$$D_{t+j}^H(i) = P_{t+j}^H(i) y_{t+j}^D(i) + S_{t+j} P_{t+j}^{H*} c_{t+j}^{H*}(i) - MC_{t+j} y_{t+j}^D(i) - P_{t+j} y_{t+j}^D \frac{\varphi^H}{2}\left[\frac{P_{t+j}^H(i)/P_{t+j-1}^H(i)}{P_{t+j-1}^H/P_{t+j-2}^H}-1\right]^2, \tag{A.37}$$

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

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

$$+\varphi^H E_t\left\{\Lambda_{t,t+1} y_{t+1}^D\left[\frac{P_{t+j+1}^H(i)/P_{t+j}^H(i)}{P_{t+j}^H/P_{t+j-1}^H}-1\right]\frac{P_{t+1}^H(i)}{P_t^H(i)^2 P_{t+j}^H/P_{t+j-1}^H}\right\}. \tag{A.38}$$

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

$$p_t^H = \frac{\epsilon_t}{\epsilon_t - 1} rmc_t - \frac{\varphi^H}{\epsilon_t - 1} \left[\frac{\pi_t^H}{\pi_{t-1}^H} - 1 \right] \frac{\pi_t^H}{\pi_{t-1}^H} + \frac{\varphi^H}{\epsilon_t - 1} E_t \left\{ \Lambda_{t,t+1} \frac{y_{t+1}^D}{y_t^D} \left[\frac{\pi_{t+1}^H}{\pi_t^H} - 1 \right] \frac{\pi_{t+1}^H}{\pi_t^H} \right\}. \quad \text{(A.39)}$$

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

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

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

which positively depends on the exogenous foreign output process,

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

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

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

$$p_t^F = \frac{\epsilon_t}{\epsilon_t - 1} s_t - \frac{\varphi^F}{\epsilon_t - 1} \left[\frac{\pi_t^F}{\pi_{t-1}^F} - 1 \right] \frac{\pi_t^F}{\pi_{t-1}^F} + \frac{\varphi^F}{\epsilon_t - 1} E_t \left\{ \Lambda_{t,t+1} \frac{y_{t+1}^F}{y_t^F} \left[\frac{\pi_{t+1}^F}{\pi_t^F} - 1 \right] \frac{\pi_{t+1}^F}{\pi_t^F} \right\} \quad \text{(A.40)}$$

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

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

$$\min_{u_t,k_t,h_t} q_{t-1}(R_{kt}-1)k_t - (q_t - q_{t-1})k_t + p^I_t \delta(u_t)k_t + w_t h_t + rmc_t \Big[y^H_t - \exp(z_t)\Big(u_t k_t\Big)^{\alpha} h_t^{1-\alpha}\Big] \quad \text{(A.41)}$$

subject to the endogenous depreciation rate function,

$$\delta_t = \delta + \frac{d}{1+\varrho} u_t^{1+\varrho}, \quad \text{(A.42)}$$

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

$$p^I_t \delta'_t k_t = \alpha\Big(\frac{y^H_t}{u_t}\Big) rmc_t, \quad \text{(A.43)}$$

$$R_{kt} = \frac{\alpha\Big(\frac{y^H_t}{k_t}\Big) rmc_t - p^I_t \delta_t + q_t}{q_{t-1}}, \quad \text{(A.44)}$$

$$w_t = (1-\alpha)\Big(\frac{y^H_t}{h_t}\Big) rmc_t. \quad \text{(A.45)}$$

A.6 De-anchored inflation expectations

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

$$p^H_t = \frac{\epsilon_t}{\epsilon_t - 1} rmc_t - \frac{\varphi^H}{\epsilon_t - 1}\left[\frac{\pi^H_t}{\left(\pi^H_{t-1}\right)^{\alpha_H}\left(\pi^H\right)^{1-\alpha_H}} - 1\right]\frac{\pi^H_t}{\left(\pi^H_{t-1}\right)^{\alpha_H}\left(\pi^H\right)^{1-\alpha_H}}$$

$$+\frac{\varphi^H}{\epsilon_t - 1} E_t\left\{\Lambda_{t,t+1}\frac{y^D_{t+1}}{y^D_t}\left[\frac{\pi^H_{t+1}}{\left(\pi^H_t\right)^{\alpha_H}\left(\pi^H\right)^{1-\alpha_H}} - 1\right]\frac{\pi^H_{t+1}}{\left(\pi^H_t\right)^{\alpha_H}\left(\pi^H\right)^{1-\alpha_H}}\right\} \quad \text{(A.46)}$$

$$p^F_t = \frac{\epsilon_t}{\epsilon_t - 1} s_t - \frac{\varphi^F}{\epsilon_t - 1}\left[\frac{\pi^F_t}{\left(\pi^F_{t-1}\right)^{\alpha_F}\left(\pi^F\right)^{1-\alpha_F}} - 1\right]\frac{\pi^F_t}{\left(\pi^F_{t-1}\right)^{\alpha_F}\left(\pi^F\right)^{1-\alpha_F}}$$

$$+\frac{\varphi^F}{\epsilon_t - 1} E_t\left\{\Lambda_{t,t+1}\frac{y^F_{t+1}}{y^F_t}\left[\frac{\pi^F_{t+1}}{\left(\pi^F_t\right)^{\alpha_F}\left(\pi^F\right)^{1-\alpha_F}} - 1\right]\frac{\pi^F_{t+1}}{\left(\pi^F_t\right)^{\alpha_F}\left(\pi^F\right)^{1-\alpha_F}}\right\} \quad \text{(A.47)}$$

instead of (A.39) and (A.40) in the baseline analysis. In this formulation, π^H and π^F are steady-state (target) home-goods and foreign-goods inflation rates, and α^H and α^F are home-goods and foreign-goods inflation indexation parameters, respectively.

A.7 Government

Government expenditures follow the exogenous process

$$\log(g_t) = (1-\rho_g)\log\bar{g} + \rho_g \log(g_{t-1}) + \varepsilon_t^g, \tag{A.48}$$

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

$$g_t = \left[\omega_t^{\frac{1}{\gamma}} (g_t^H)^{\frac{\gamma-1}{\gamma}} + (1-\omega_t)^{\frac{1}{\gamma}} (g_t^F)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}} \tag{A.49}$$

$$\frac{g_t^H}{g_t^F} = \frac{\omega_t}{1-\omega_t}\left(\frac{P_t^H}{P_t^F}\right)^{-\gamma}. \tag{A.50}$$

A.8 Resource constraints

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

$$y_t^H = c_t^H + c_t^{H*} + i_t^H + g_t^H + \frac{\varphi^H}{2} y_t^D \left[\frac{\pi_t^H}{\pi_{t-1}^H} - 1\right]^2 \tag{A.51}$$

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

$$y_t^F = c_t^F + i_t^F + g_t^F + \frac{\varphi^F}{2} y_t^F \left[\frac{\pi_t^F}{\pi_{t-1}^F} - 1\right]^2. \tag{A.52}$$

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

$$y_t = c_t + i_t + g_t + p_t^H c_t^{H*} - p_t^F y_t^F. \tag{A.53}$$

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

$$-(b_t^* + b_t^{g*}) + R_t^* b_{t-1}^* + R_t^g b_{t-1}^{g*} = p_t^H c_t^{H*} - p_t^F y_t^F. \tag{A.54}$$

B Definition of competitive equilibrium

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

i) Given exogenous processes, initial conditions, government policies, and prices; the allocations solve the utility maximization problem of households (A.2)-(A.4), the net worth maximization problem of bankers (12)-(13), and the profit maximization problems of capital producers (A.32), final goods producers (A.35), and intermediate goods producers (A.36)-(A.37) and (A.41)-(A.42).

ii) Home and foreign goods, physical capital, security claims, government bonds, domestic deposits, money, and labor markets clear. Short-term assets issued by the central bank adjust by Walras' Law to finance asset purchases. Resource constraints for home and foreign goods, (A.51) and (A.52) and GDP and balance of payments identities (A.53) and (A.54) hold.

C Data sources and targeted moment definitions

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

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

Output velocity of money. Monetary aggregate M1 are collected from the OECD. Velocity is computed by taking the GDP-to-M1 ratio.

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

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

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

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

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

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

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

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

D System priors used in the Bayesian estimation

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

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

E References

Andrle, Michal and Jaromir Benes, "System Priors; Formulating Priors about DSGE Models' Properties," IMF Working Papers 13/257, International Monetary Fund December 2013.

Arslanalp, Serkan and Takahiro Tsuda, "Tracking Global Demand for Emerging Market Sovereign Debt," 2014. IMF Working Paper No. 14/39.

Ehlers, Torsten and Agustin Víllar, "The Role of Banks," *BIS Papers*, 2015, *83*, 9–39.

Gertler, Mark, Simon Gilchrist, and Fabio Natalucci, "External Constraints on Monetary Policy and the Financial Accelerator," *Journal of Money, Credit, and Banking*, 2007, *39(2/3)*, 295–330.

IMF, "Bridge to Recovery," *Global Financial Stability Report*, 2020. October.

Negro, Marco Del and Frank Schorfheide, "Forming priors for DSGE models (and how it affects the assessment of nominal rigidities)," *Journal of Monetary Economics*, October 2008, *55* (7), 1191–1208.

Rotemberg, Julio J., "Sticky Prices in the United States," *Journal of Political Economy*, 1982, *90*, 1187–1211.

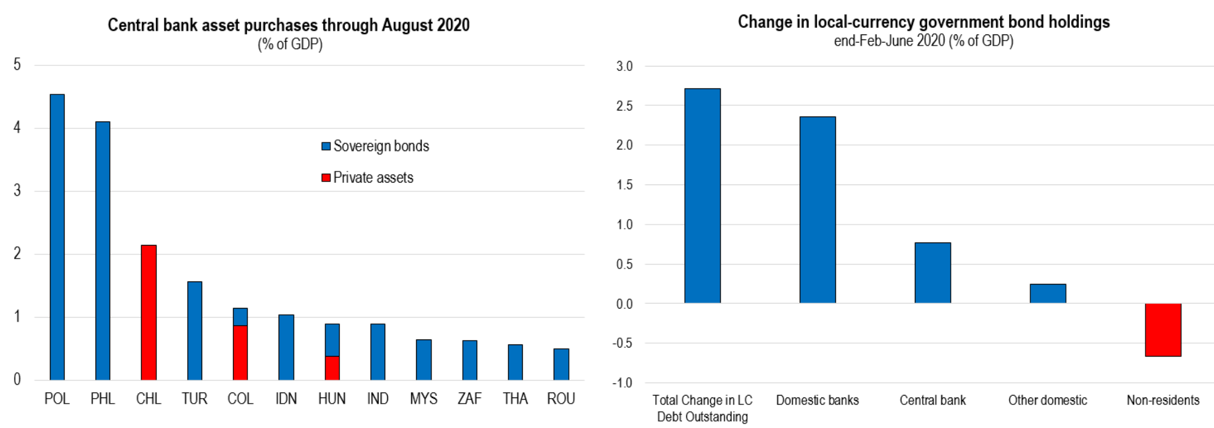

Figure E.1: Assets on the left panel correspond to bank bonds for the case of Chile and Colombia. Private asset purchases are in mortgage bonds for the case of Hungary. The rest of purchases are in secondary market sovereign bonds. The right panel shows averages across 9 countries that are reported by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

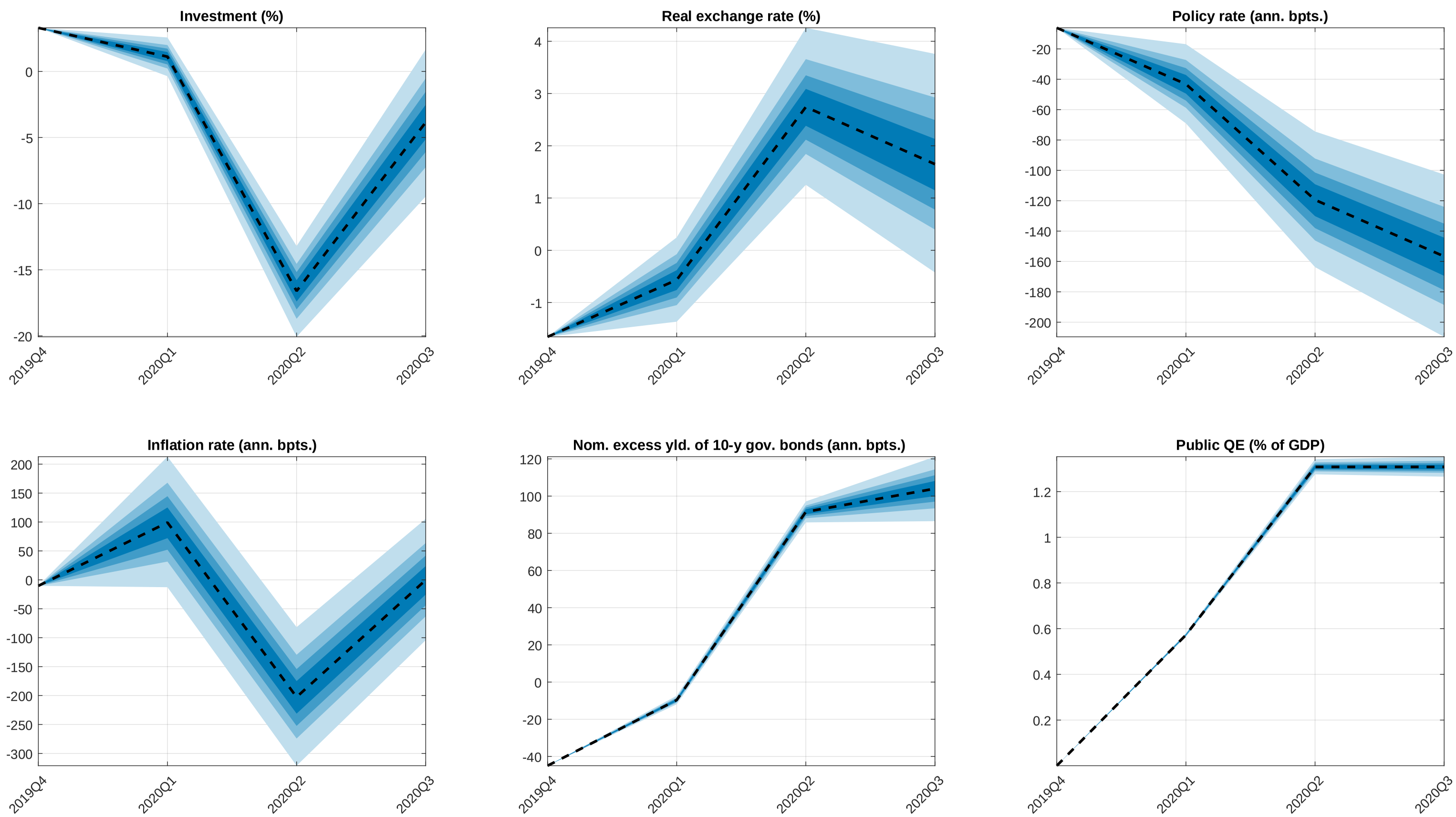

Figure E.2: Effects of adopting baseline quantitative easing policies during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline QE policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3.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

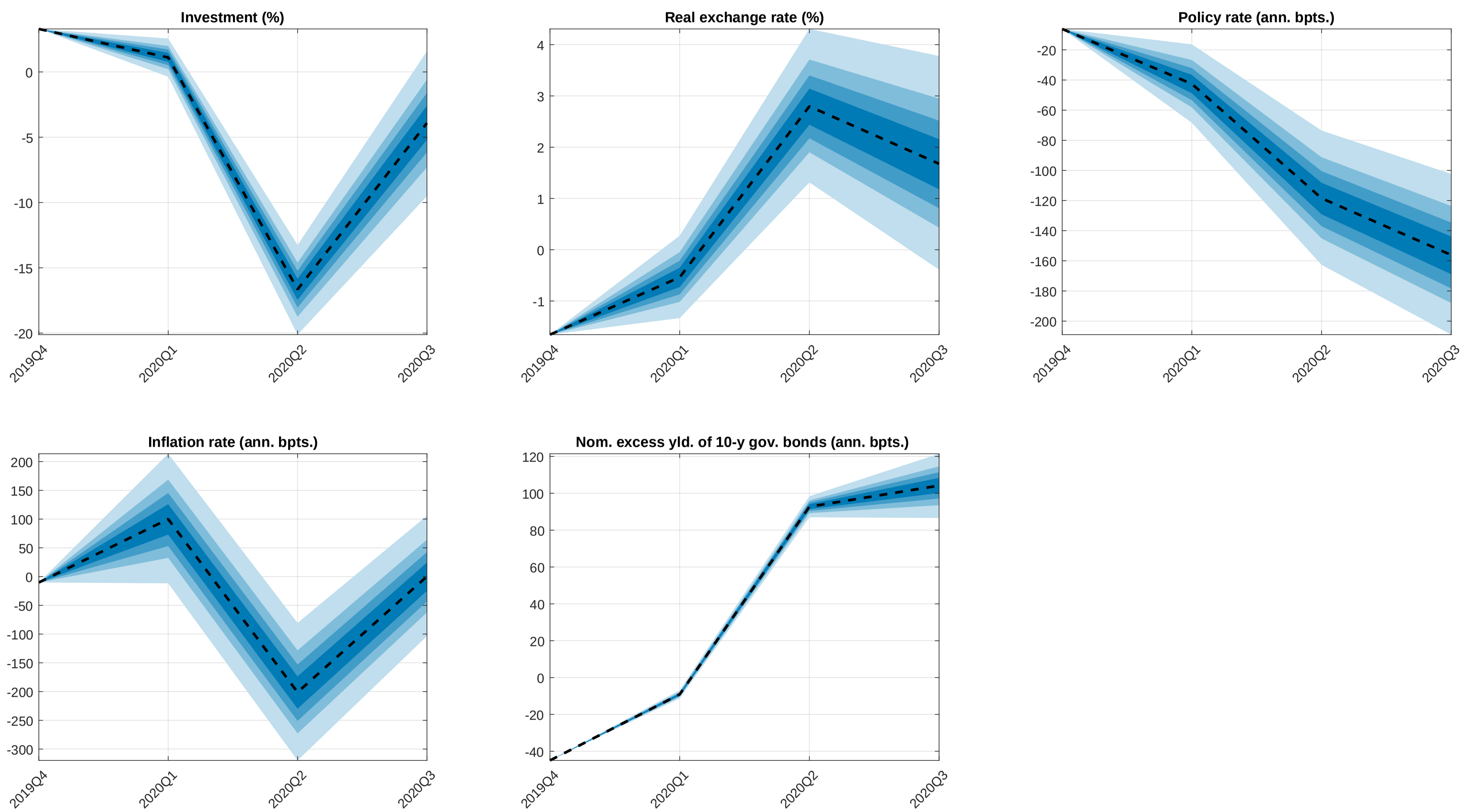

Figure E.3: Effects of adopting no quantitative easing policies during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline QE policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3.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

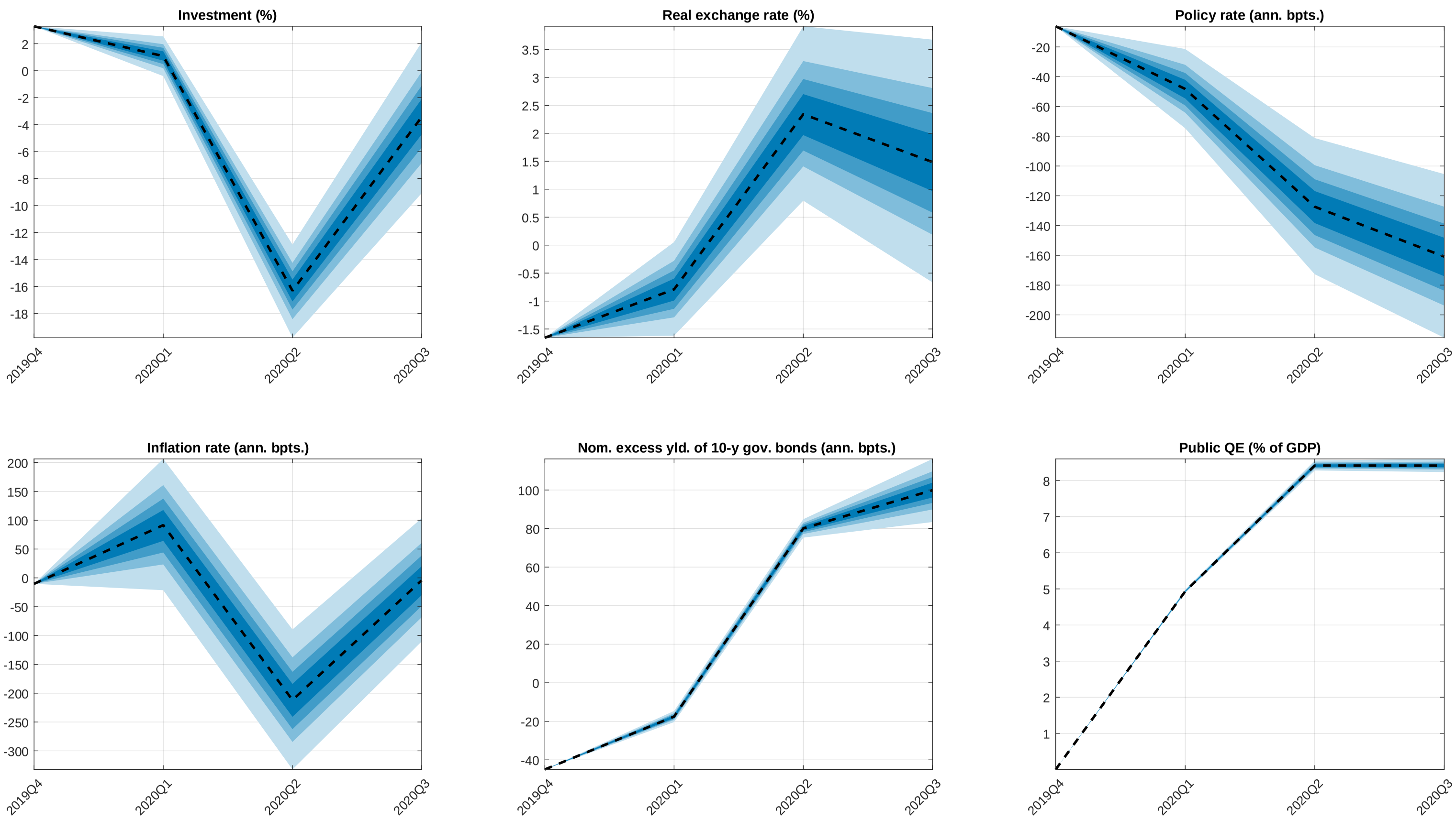

Figure E.4: Effects of adopting aggressive public bond purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline QE policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3.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

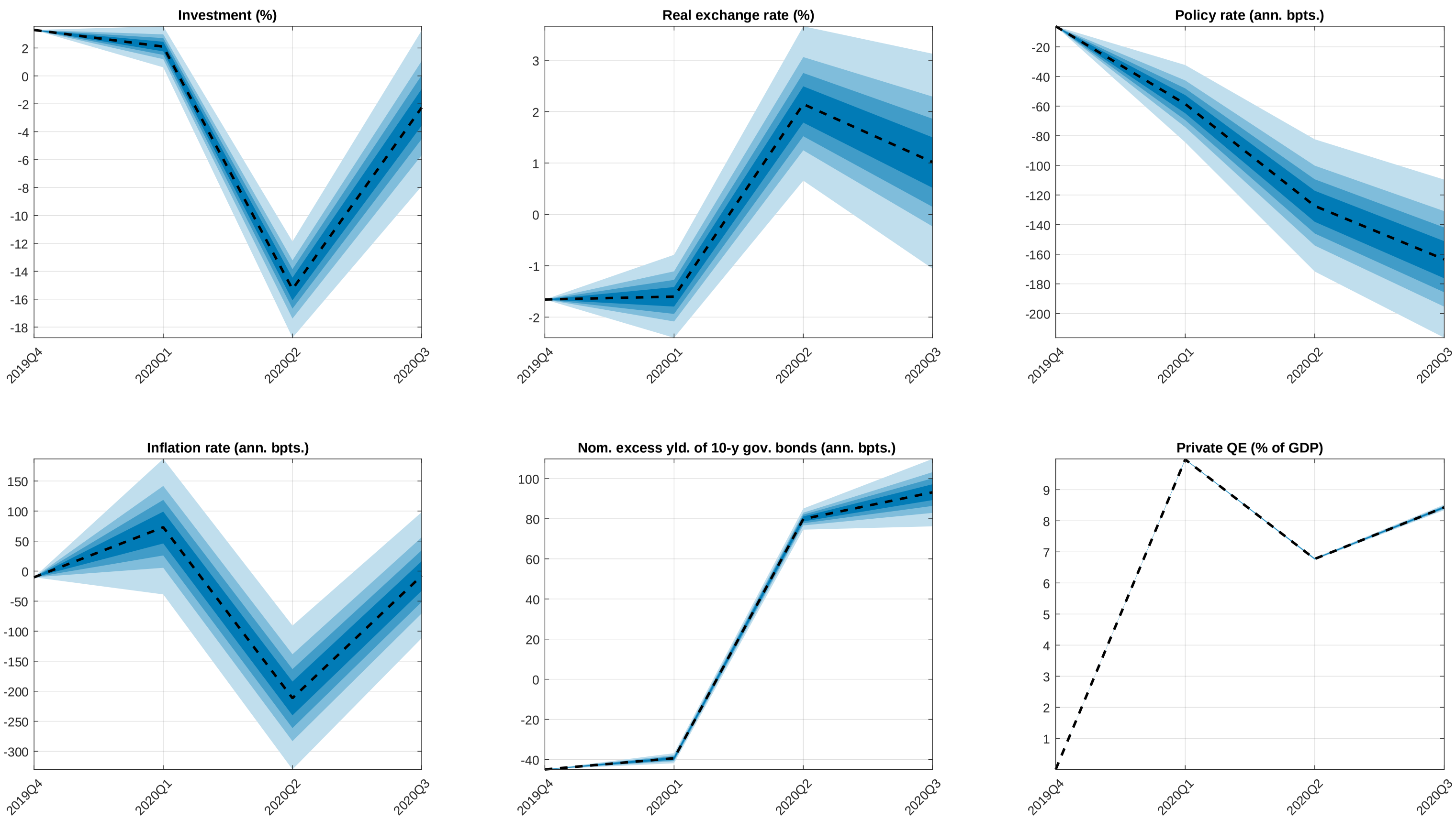

Figure E.5: Effects of adopting aggressive private security purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline QE policy regime) to match variable paths in the out-of-estimation sample of 2020Q1-2020Q3.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

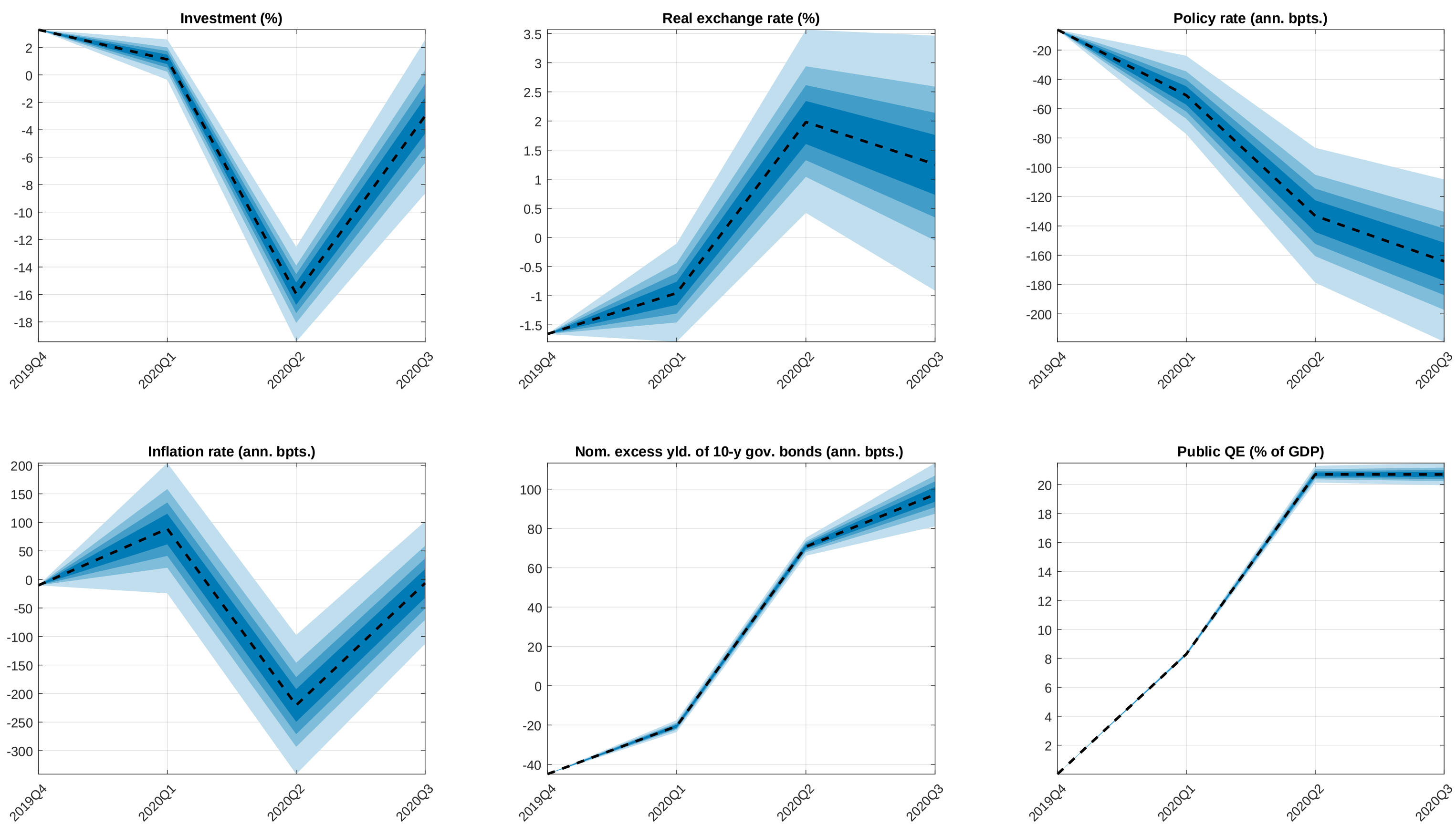

Figure E.6: Effects of adopting (advanced economy-type) aggressive public bond purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline QE policy regime) to match variable paths in the out-of-estimation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

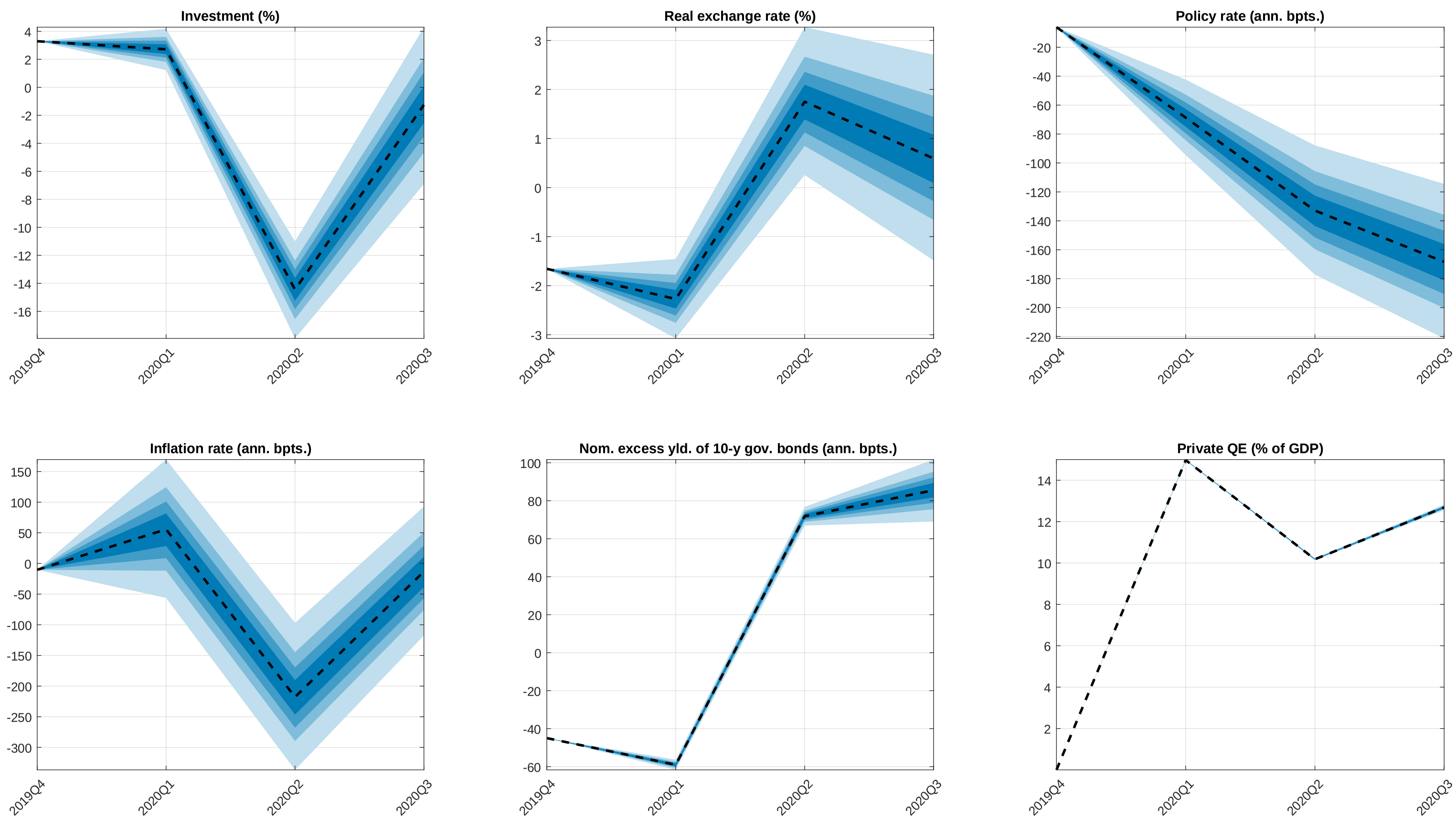

Figure E.7: Effects of adopting (advanced economy-type) aggressive private security purchases during the COVID-19 crisis under shock uncertainty. Deviations from a HP-trend. The dashed lines are the basis for filtering shocks (under the baseline QE policy regime) to match variable paths in the out-of-estimation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