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Working Papers
No. 15/2022 (391)

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Warsaw 2022

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Quantitative Easing in the US and Financial Cycles in Emerging Markets

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Abstract: Large international capital movements tend to be associated with strong fluctuations in asset prices and credit, contributing to domestic financial cycles and posing challenges for stabilization policies, especially in emerging market economies. In this paper we argue that these challenges are particularly severe if the global financial cycle is driven by quantitative easing (QE) in the US, and when the local banking sector has large holdings of government bonds, like in many Latin American (LA) countries. We first investigate empirically the impact of a typical round of QE by the US Fed on LA economies, finding a persistent expansion in credit to households and house prices as well as a significant loss of price competitiveness in this group of economies. We next develop a quantitative macroeconomic model of a small open economy with segmented asset markets and banks, which accounts for these observations. In this framework, foreign QE creates tensions between macroeconomic and financial stability as a contractionary impact of exchange rate appreciation is accompanied by booming credit and house prices. As a consequence, conventional monetary policy accommodation aimed at stabilizing output and inflation would further exacerbate domestic financial cycle. We show that an effective way of resolving this trade-off is to impose a time-varying tax on capital inflows. Combining foreign exchange interventions with tightening of local credit policies can also restore macroeconomic and financial stability, but at the expense of a large redistribution of wealth between borrowers and savers.

Keywords: quantitative easing, global financial cycle, domestic credit, exchange rate interventions, capital controls, macroprudential policy

JEL codes: E44, E58, F41, F42, F44

Acknowledgments: This paper benefited from discussions with M. Gradzewicz, J. Lindé, B. Maćkowiak, I. Presno, R. Priftis and S. Schmitt-Grohe. The authors also acknowledge comments from participants at the IAAE Annual Meeting in Rotterdam, CEF Conference in Tokyo, 3rd Warsaw Money-Macro-Finance Conference, CBMMW in Santiago de Chile, and Warsaw Economic Seminar (all held virtually). The views expressed herein are those of the authors and not of the institutions they are affiliated with.

1 Introduction

It is widely acknowledged that large capital inflows may drive domestic financial cycle (DFC), contributing to economic and financial instability, and seriously constraining monetary policy, especially in emerging market (EM) economies, see e.g. BIS (2012), Reinhart and Reinhart (2009) or Rey (2015). It is also well-documented that quantitative easing (QE) introduced by the US Federal Reserve in response to the Great Recession of 2007-2009 was the crucial factor in steering the global financial cycle (GFC), that resulted in a massive wave of cross-border capital flows and impacted asset prices worldwide. From the perspective of EM economies, a distinctive feature of this episode was that, unlike before, the post-crisis capital inflows were not driven by recipient countries' economic fundamentals (like better growth prospects, financial liberalization etc.) or conventional monetary policy adjustments abroad, but were instead a byproduct of unconventional (and possibly distortionary) actions taken by foreign central banks. Many EM countries, notably in Latin America (LA), implemented various measures aimed at counteracting the impact of the resulting global financial cycle, such as currency interventions and macroprudential policy tightening.[1]

This paper investigates the tensions between GFC and DFC created by the US QE for a central bank in an EM economy, as well as additional non-standard measures that may help resolve them. On the one hand, in the GFC context, exchange rate appreciation caused by capital inflows is conducive to a severe loss in international competitiveness, calling for monetary accommodation. As argued by Rajan (2016), unlike in the case of standard monetary easing abroad, the demand switching effect through the exchange rate induced by large-scale asset purchases (LSAP) abroad is likely to dominate the effect of easier financial conditions on domestic demand in EM economies. Data from LA countries are consistent with this view. As can be seen in Figure 1, the current account balance clearly deteriorated in this region during the time of US QE, and this was despite GDP growth being similar to the pre-crisis period. On the other hand, in the DFC context, QE eases credit conditions, which may justify some monetary contraction. The special feature of asset purchase programs is that, unlike conventional monetary easing, they target the longer part of the yield curve, and hence are more important for the costs of long-term financing, such as housing loans. The transmission is likely to be particularly strong when the banking sector exposure to government bond holdings is large, which is clearly the case in most LA countries.[2] Indeed, after QE was introduced in the US, credit to households (Figure 2), which consists mainly

[1] Among others, the central bank of Chile intervened in the currency market, capital controls were applied in Brazil, while maximum loan-to-value policy was modified in Brazil and Colombia.

[2] When the first round of large-scale asset purchases started in the US in 2009, the share of claims on government in total claims of the banking sector stood at about 44% in Mexico, 43% in Brazil, 20% in Uruguay and 17% in Colombia. By comparison, the median of this share among 25 small open economies was 10%. Source: IMF Monetary and Financial Statistics.

of mortgage debt, and house prices (Figure 3) continued to soar in this region. During the same period, household indebtedness in the US was on a decline while house price growth was only moderate.

To verify the presence of these dilemmas more formally, we use the series of surprise changes in large-scale asset purchases by the Fed estimated by Swanson (2020), and run local projections as in Jordà (2005) on a panel of LA economies. We find that, despite measures undertaken by these countries to curb capital inflows, QE in the US led to a persistent appreciation of LA currencies as well as growth in credit to households and house prices, which however did not result in a significant expansion in output. We interpret this evidence as indicating that US QE creaes tensions between macroeconomic and financial stability that cannot be easily resolved by using standard monetary policy alone. We next develop a quantitative macroeconomic framework that features such tensions, and use it to show that they can be mitigated, at least to some extent, by an appropriate selection of policy tools, including those that were adopted by LA economies. The model object is a small open economy, linked financially to the rest of the world by trade in long-term bonds, which are in turn imperfect substitutes of short-term bonds. As shown by Kolasa and Wesołowski (2020), such a form of international asset market segmentation is strongly supported by the data for EM economies, and generates realistic international capital flows, comovement in the term premia and exchange rate adjustments in response to QE in developed countries. Another important feature of our model is the presence of banks, operating similarly as in Gertler and Karadi (2013), and collateral constraints in the housing market. The role of banks is to intermediate funds between savers and the government and private borrowers. They provide transmission from long-term bond prices to the cost of credit, which is additionally amplified by endogenous responses of house prices.

The model, calibrated to LA data, successfully replicates a number of empirical findings concerning both domestic and global financial cycles triggered by US QE. It generates a large inflow of capital to EM economies, loss of international competitiveness, as well as a boom in house prices and mortgage loans. Two key mechanisms are at play. One is the no-arbitrage condition associated with international trade in long-term bonds, which postulates equalization of returns on domestic and foreign bonds. Since QE abroad generates a deep fall in foreign long-term rates, which is not matched by an equal drop in domestic rates under standard monetary accommodation, local currency strongly appreciates, consistently with evidence from local projections. The side effect is a sharp deterioration of small economy's international competitiveness. The second mechanism operates through internal arbitrage between bank assets. An increase in bond prices depresses the cost of loans, leading to a boom in credit and asset prices, also in line with econometric evidence.

As the model features pecuniary and aggregate demand externalities, the described scenario generates challenges for policy in the EM economy, calling for the use of non-standard measures that could complement conventional monetary policy. We consider three types of measures discussed in the literature, and used in LA economies in response to US QE: foreign exchange (FX) interventions, loan-to-value (LTV) cap on domestic borrowing, and capital controls in form of taxes on long-term bond returns earned by non-residents. As we show in our model simulations, an attempt to avoid the loss in international competitiveness by using FX interventions necessarily leads to a stronger drop in local long-term rates, which amplifies the domestic financial cycle. Constraining the latter can be achieved by applying domestic macroprudential instruments such as tightening of the LTV ratio. However, when used alone, this policy is neither very efficient in reducing capital inflow nor in limiting exchange rate appreciation, and hence it does not address the problem of international competitiveness. A policy that successfully deals with both macroeconomic and financial stability, and hence provides an alternative to coordinated FX interventions and LTV tightening, is to impose capital controls. In fact, this type of non-standard measure turns out to be clearly preferred from a social welfare perspective. In particular, and in contrast to other interventions, it helps allievate wealth redistribution between borrowers and savers that is caused by foreign QE.

Our paper is related to several strands of the literature, and in particular to positive and normative analyses of international capital flows, with a special emphasis on those arising from QE. Among studies with a positive flavor, empirical papers clearly dominate, see e.g. Fratzscher et al. (2018), Ahmed and Zlate (2014), Neely (2015), Lim and Mohapatra (2016), Tillmann (2016) and Bhattarai et al. (2021). The empirical part of our study adds to this line of research by using panel local projections rather than VARs, and by explicitly controlling for non-QE monetary shocks in the US. Importantly, we estimate the effects on GDP, credit to households and house prices, arguing that the latter two are key elements of the transmission of US QE shocks to domestic credit cycle, especially when banks hold large stocks of government bonds. However, our main contribution to the positive literature on international capital flows is to offer a quantitative theoretical framework that, by incorporating both cross-border and internal borrowing, helps understand the tensions between macroeconomic and financial stability faced by many EM as a result of LSAP programs conducted by foreign monetary authorities.[3] In this way, we also highlight the importance of QE in large economies for the financial cycle in other countries.

On the normative side, we contribute to the recent literature and policy debate on optimal policy responses to international capital flows.[4] Unlike other papers in this line of research, we focus on a specific type of capital flows, namely those induced by foreign QE, and on their

[3]To our knowledge, the only structural studies looking at QE spillovers are Alpanda and Kabaca (2020) and Kolasa and Wesołowski (2020). None of them incorporates domestic credit or housing market.

[4]See e.g. the Integrated Policy Framework developed at the IMF (Adrian et al., 2021; Basu et al., 2020).

impact on the domestic credit and asset price cycle. This has important consequences for the effectiveness of the considered policy reactions. The existing theoretical papers on FX interventions suggest that they may improve macroeconomic performance (see e.g. Mertens and Hassan, 2017; Cavallino, 2019; Fanelli and Straub, 2020) by alleviating financial market imperfections as in Gabaix and Maggiori (2015).

There is also large literature stressing the benefits of countercyclical LTV adjustments for smoothing credit booms driven by asymmetric productivity, news, terms-of-trade, housing market or global liquidity shocks (Bianchi, 2011; Bianchi et al., 2016; Bielecki et al., 2019). These predictions are usually confirmed by empirical studies, see e.g. Fratzscher et al. (2019) or Gambacorta and Murcia (2019), even though less optimistic or skeptical views also exist, especially for currency interventions (e.g. Chamon et al., 2019). Our key insight is that, when faced with capital inflow induced by QE abroad, using either FX interventions or LTV policy is not enough, and they need to be combined to address the relevant imbalances. As shown by Ghosh et al. (2017), this is exactly what emerging market economies do when faced with capital inflows.

Our analysis also underlines high effectiveness of capital controls, as already stressed by a line of theoretical papers that do not consider QE as the driving force (e.g. Korinek, 2011; Ostry et al., 2012; Davis and Presno, 2017), also confirming their favorable role for the credit cycle, as empirically tested by Forbes et al. (2015). According to our paper, if capital controls are available, they are sufficient to address the impact of both GFC and DFC arising from asset purchases by foreign central banks. This result contrasts with Korinek and Sandri (2016), who find an additional role for macroprudential regulation of credit during contractionary exchange rate depreciations, and the difference exactly reflects the special feature of QE-induced capital inflows, namely their harmful effect on international competitiveness of recipient countries.

The rest of this paper is structured as follows. In Section two we discuss empirical evidence based on local projections. Section three describes the model and Section four its calibration. In Section five we present our baseline scenario that shows how QE in the US generates a financial cycle in EM economies. Section six evaluates possible non-standard policy responses. Section seven concludes.

2 Empirical evidence on GFC and DFC

In this section we show that QE conducted by the Fed impacted the GFC and DFC in LA economies, creating a dilemma between macroeconomic and financial stability, as we described in Introduction. Our general goal is to check whether the trends discussed in Figures 1-3 can be indeed attributed to the US QE. To this end, we use local projections introduced by Jordà (2005), which have become a popular tool to investigate the causal effects of policy interventions. Exogenous US QE impulses are approximated using surprise changes in LSAP by the Fed estimated by Swanson (2020), aggregated to quarterly frequency. We consider six key macroeconomic and financial indicators as dependent variables. The macroeconomic impact of the US QE on the LA economies is depicted by GDP, inflation and the short-term interest rate. To capture the impact of the US QE on international price competitiveness in LA, we use the exchange rate against the US dollar. Finally, the domestic credit cycle is represented by changes in credit to households and house prices.

More precisely, we estimate the following panel regressions:

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + \beta_h^{QE} \mathrm{d_t} \varepsilon_t + \beta_h^{nQE} (1 - \mathrm{d_t}) \varepsilon_t + \mathbf{x}_{i,t} \gamma_h + \nu_{i,t+h} \tag{1}$$

for $h = 0, 1, 2, 3, 4$, where $y_{i,t+h}$ is the dependent variable (one of the six described above) for country i in period t, ε_t is a series of asset purchase shocks, $\mathrm{d_t}$ is a dummy variable that splits the sample into the period before and after the start of LSAP, $\mathbf{x}_{i,t}$ stands for a vector of control variables, $\alpha_{i,h}$ denotes country fixed effects, $\nu_{i,t+h}$ are regression residuals, while β_h^{QE}, β_h^{nQE} and γ_h are the estimated parameters. We use quarterly data spanning the time period 2001q1-2019q2 for five LA economies: Argentina, Brazil, Chile, Colombia and Mexico. As typically done in local projections, the vector of controls in our baseline specification includes a set of lagged macroeconomic indicators and lagged shocks. We use statistical significance and standard information criteria for variable inclusion and lag length selection. To avoid possible confusion with other monetary interventions conducted by the Fed, we additionally use in the regressions shocks to the US short-term rate and forward guidance, both of which are also taken from Swanson (2020). Further details on data, estimation results and robustness checks are presented in Appendix A.1.

Figure 4 presents the baseline results in form of the responses of each of the six variables of interest to one standard deviation QE shock in the US. The right column panels document the effects of US QE on the global and domestic financial cycle. Starting with the former, we confirm the earlier evidence from event studies of appreciation pressures on emerging market currencies following US QE. Our results extend these previous findings to longer horizons, showing the significant size and high persistence of exchange rate reaction. The maximum impact of an average innovation to LSAP in the US amounts to 3% currency appreciation against the US dollar, and it takes a year for this effect to materialize. This estimate may actually underestimate the full pressure on EM exchange rates (at least on impact) as we do not control for FX interventions conducted by central banks of LA economies, due to challenges associated with their measurement (missing information on interventions, uncertainty whether they were expected or not). As for the DFC evidence, we find the significant and persistent impact of US QE on credit to households and house prices in LA countries, amounting at its peak to around 0.6% in both cases. Again, as we do not account in the local projections for endogenous reaction of local macroprudential policies, the obtained responses are likely to underestimate the impact of foreign QE on the domestic credit cycle. The panels in the first column of Figure 4 present the macroeconomic effects. Our estimates suggest that, in response to US QE, central banks in LA countries decreased their policy rates. Despite easier domestic and global financial conditions, as well as non-standard policies implemented in some economies in the region to limit appreciation in their currencies, output and inflation in the region did not respond significantly, and the former actually fell on impact.

Summing up, the evidence presented in this section clearly confirms that asset purchases by the US Fed create a dilemma between macroeconomic and financial stability in LA, as we formulated it in Introduction. Our next step will be to develop a structural model that will reflect this dilemma, and use it to study possible options for policy makers facing it. Importantly, the model will also allow us to disentangle the effects of the external QE shock and of the endogenous response of domestic policy, including non-standard monetary and macroprudential measures.

3 Theoretical model

We develop our theoretical framework by relying on the small open economy paradigm. The model economy is populated by two types of households that differ in their rate of time preference, which separates them into borrowers and savers. The fiscal authority issues debt in form of short-term and long-term bonds denominated in local currency, of which only the latter are traded internationally. The financial flows from savers to borrowers and to the government are intermediated by a banking sector that faces an agency problem, and credit to borrowers is additionally limited by the value of their housing collateral. Monopolistically competitive firms produce output, which they sell to domestic and foreign markets subject to a price setting rigidity. In addition to standard monetary and fiscal rules, prices and allocations in this economy can be influenced by the following non-standard policy measures: exchange rate interventions, taxes on international capital flows, and limits on domestic credit expansion.

In the rest of this section we describe the problems facing each type of agents. As it is standard in the literature, we use asterisks to denote variables describing prices and allocations determined by agents populating the foreign economy, and variables without time subscripts indicate the steady state values. A full list of equations defining the equilibrium in our model can be found in the Appendix.

3.1 Savers

A representative saver maximizes her expected lifetime utility over consumption c_t^s, housing h_t^s and labor supply n_t^s

$$U_0^s = \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_s^t \left[\frac{(c_t^s)^{1-\sigma}}{1-\sigma} + A_h \log(h_t^s) - \frac{(n_t^s)^{1+\varphi}}{1+\varphi} \right] \right\} \tag{2}$$

where $0 < \beta_s < 1$ is savers' discount factor, $\sigma > 0$ is the inverse elasticity of intertemporal substitution, $\varphi > 0$ is the inverse Frisch elasticity of labor supply, and $A_h > 0$ is the weight of housing in utility. As it is now common in structural models with mortgages (see, e.g., Garriga et al., 2017), we assume that housing demand of savers is rigid and fixed at its steady state value, i.e. $h_t^s = h^s$. This prevents the model from generating counterfactually large trade in housing between borrowers and savers.

Since savers are relatively patient, they own all firms in the economy, earning a flow of dividends Div_t. They also have access to one-period nominal deposits D_t offered by financial intermediaries that pay one-period gross nominal interest rate R_t. The budget constraint of savers can be then written as

$$P_t c_t^s + P_{h,t}[h_t^s - (1-\delta_h)h_{t-1}^s] + D_t + T_t \leq W_t n_t^s + R_{t-1}D_{t-1} + Div_t \tag{3}$$

where δ_h is the housing depreciation rate, P_t is the price of consumption goods, $P_{h,t}$ is the price of housing, W_t is the nominal wage, and T_t denotes lump sum taxes.

3.2 Borrowers

Borrowers' utility is defined similarly to that of savers

$$U_0^b = \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_b^t \left[\frac{(c_t^b)^{1-\sigma}}{1-\sigma} + A_h \log(h_t^b) - \frac{(n_t^b)^{1+\varphi}}{1+\varphi} \right] \right\} \tag{4}$$

except that their discount factor is lower, i.e. $0 < \beta_b < \beta_s$, and their housing demand is not rigid.

Borrowers have access to nominal loans L_t offered by financial intermediaries at gross interest R_t^b so that their period budget constraint is

$$P_t c_t^b + P_{h,t}[h_t^b - (1-\delta_h)h_{t-1}^b] + R_{t-1}^b L_{t-1} + T_t \leq W_t n_t^b + L_t \tag{5}$$

Additionally, borrowers face a collateral constraint

$$L_t \leq m_t \mathbb{E}_t \left\{ P_{h,t+1} h_{b,t} \right\} \tag{6}$$

where m_t can be interpreted as a loan-to-value (LTV) ratio, which we assume to be fully controlled by the macroprudential regulator.

3.3 Banks

Banks channel funds obtained from savers to borrowers and to the government. Consolidated public sector debt takes the form of short-term (one-period) bonds and central bank reserves B_t, and long-term bonds $B_{L,t}$ traded at price $P_{L,t}$. Following Woodford (2001), we model long-term debt securities as perpetuities that pay an exponentially decaying coupon κ^s every period $s+1$ ($s \geq 0$) after the issuance, where $\kappa \in (0;1]$. Banks' balance sheet can then be written as

$$L_t + B_t + P_{L,t} B_{L,t} = N_t + D_t \tag{7}$$

where N_t is banks' net worth.

Each bank survives into the next period with probability ϑ and maximizes the expected value of terminal net worth

$$V_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} (1-\vartheta)\vartheta^t \Lambda_t^s N_t \tag{8}$$

Exiting banks pay out their retained earnings to their owners, and hence discount them with Λ_t^s, which denotes savers' marginal utility of nominal income. Banks are also subject to an agency problem, i.e. they can divert a fraction ϖ^L of their loans and a fraction ϖ^B of their long-term bond holdings. This friction does not apply to short-term government bonds or central bank reserves. Thus, these assets are perfect substitutes with deposits, and all of them pay interest at a short-term rate R_t that is fully controlled by the monetary authority. Each bank then faces the following incentive compatibility constraint

$$V_t \geq \varpi^L L_t + \varpi^B B_{L,t} \tag{9}$$

Each period exiting banks are replaced with the same number of entrants, which are equipped by savers with real startup funds x. The aggregate law of motion for net worth in the banking sector can hence be written as

$$N_t = \vartheta \left(R_{t-1}^b L_{t-1} + R_{L,t} P_{L,t} B_{L,t-1} + R_{t-1} B_{t-1} - R_{t-1} D_{t-1} \right) + P_t x$$

where $R_{L,t} \equiv P_{L,t}^{-1} + \kappa$ is the gross yield to maturity on long-term bonds.

3.4 Firms

To introduce imperfect substitutability between domestic and imported goods and imperfect exchange rate pass through, we consider three stages of production. At the final stage, perfectly competitive final goods producers combine homogeneous home-made and imported goods $y_{H,t}$ and $y_{F,t}$ according to

$$\tilde{y}_t = \left(\eta^{\frac{1}{\nu}} y_{H,t}^{\frac{\nu-1}{\nu}} + (1-\eta)^{\frac{1}{\nu}} y_{F,t}^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}} \tag{10}$$

where $\eta \in (0;1)$ is the home-bias parameter and $\nu > 0$ is the elasticity of substitution between domestic and imported goods.

At the middle stage of production homogeneous goods are produced by perfectly competitive aggregators that use a continuum of intermediate inputs indexed by i

$$y_{j,t} = \left(\int_0^1 y_{j,t}(i)^{\frac{1}{\mu}} di\right)^{\mu} \tag{11}$$

for $j = \{H, H^*, F\}$, where index H^*indicates exports and $\mu > 1$ controls the degree of substitution between individual input varieties.

Intermediate inputs are either produced by monopolistically competitive firms that operate a linear production function in labor

$$y_{H,t}(i) + y_{H,t}^*(i) = n_t(i) - \phi \tag{12}$$

where ϕ is a fixed cost of production, or are imported and rebranded by monopolistically competitive importers.

All intermediate goods firms set their prices in the currency of destination markets according to the Calvo scheme. More specifically, every period producers face a constant probability $1-\theta_H$ of price reoptimization for the domestic market and probability $1-\theta_H^*$ of price reset for exports. Similarly, importers update their prices with a fixed probability $1-\theta_F$. Firms that cannot reoptimize index their prices to the steady state inflation. Since all firms are owned by domestic savers, their problem at the time of price reset is to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} (\theta_H)^t \Lambda_t^s \left(P_{H,0}(i)\, \pi^t - W_t\right) y_{H,t}(i) \tag{13}$$

$$\mathbb{E}_0 \sum_{t=0}^{\infty} (\theta_H^*)^t \Lambda_t^s \left(S_t P_{H,0}^*(i)\, (\pi^*)^t - W_t\right) y_{H,t}^*(i) \tag{14}$$

$$\mathbb{E}_0 \sum_{t=0}^{\infty} (\theta_F)^t \Lambda_t^s \left(P_{F,0}\left(i\right) \left(\pi\right)^t - S_t P_t^* \right) y_{F,t}(i) \tag{15}$$

where S_t is the nominal exchange rate expressed as units of domestic currency per unit of foreign currency, $P_{H,t}(i)$ is the price set by intermediate producer i for the domestic market, $P^*_{H,t}(i)$ is the price set for the foreign market, $P_{F,t}(i)$ is the price set by importers, while $\pi_t \equiv P_t/P_{t-1}$ and $\pi_t^* \equiv P_t^*/P_{t-1}^*$ are the domestic and foreign inflation rates for final goods. This maximization problem is subject to the demand schedules solving aggregators' optimization problem described above.

3.5 Government

The fiscal authority finances fixed real purchases of final goods g with lump sum taxes levied on households T_t, taxes imposed on non-residents buying domestic long-term bonds, central bank profit Π_t^m, and net debt issuance. The budget constraint of the fiscal authority can hence be written as

$$B_t^g + P_{L,t} B_{L,t}^g + T_t + \tau_t P_{L,t} R_{L,t} B_{L,t-1}^* + \Pi_t^m = R_{t-1} B_{t-1}^g + P_{L,t} R_{L,t} B_{L,t-1}^g + P_t g_t \tag{16}$$

where $B_{L,t}^g$ and B_t^g denote the supply of, respectively, long-term and short-term government bonds, $B_{L,t}^*$ denotes domestic bonds held by foreign agents, and τ_t is the tax rate on gross return on the latter. We assume that the real value of short-term bonds $b_t^g \equiv B_t^g/P_t$ is held constant while long-term government debt evolves such that the fiscal budget constraint (16) holds under the following rule for taxes

$$\frac{T_t}{P_t} = g + \Phi \left(\frac{P_{L,t-1} b_{L,t-1}^g}{P_L b_L^g} \right)^{\gamma_b} \tag{17}$$

where $\gamma_b > 0$ controls the speed at which taxes adjust to restore real government debt to its long-term level, and Φ is a positive constant such that in the steady state the rule is consistent with the government budget constraint.

Conventional monetary policy is implemented by the central bank that follows a standard Taylor-like feedback rule

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\gamma_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\gamma_\pi} \left(\frac{y_t}{y} \right)^{\gamma_y} \right]^{1-\gamma_r} \tag{18}$$

where $\gamma_r \in (0;1)$ controls the degree of interest rate smoothing, while γ_π and γ_y reflect, respectively, the strength of interest rate response to deviations of inflation from the target and to the output gap, with aggregate output y_t as defined in the next section.

The central bank can also directly intervene in the foreign exchange market by buying foreign long-term bonds $F_{L,t}$ with newly created reserve money B_t^m. Its balance sheet constraint is hence

$$P_{L,t}^* S_t F_{L,t} = B_t^m \tag{19}$$

and profits transferred to the fiscal authority are

$$\Pi_t^m = (P_{L,t}^* R_{L,t}^* S_t - P_{L,t-1}^* S_{t-1}) F_{L,t-1} - (R_{t-1} - 1) B_{t-1}^m \tag{20}$$

The characterization of government reactions is complemented by feedback rules describing the evolution of the tax rate on international capital flows τ_t, foreign reserves accumulated by the central bank $F_{L,t}$, and the LTV ratio m_t. In our baseline scenario we do not assume any policy reactions other than those implied by the fiscal and monetary rules (17) and (18), i.e. $F_{L,t} = \tau_t = 0$ and $m_t = m$. Otherwise, adjustments in these non-standard instruments are defined while presenting the policy scenarios.

3.6 Market clearing

If we denote the share of borrowers as ω_b and normalize the total mass of households to unity, the equilibrium on the goods market can be written as

$$\tilde{y}_t = \omega_b c_t^b + (1 - \omega_b) c_t^s + g \tag{21}$$

and housing market clearing requires

$$h = \omega_b h_t^b + (1 - \omega_b) h_t^s \tag{22}$$

The aggregate resource constraint is

$$y_t \equiv y_{H,t} \Delta_{H,t} + \frac{1 - \omega}{\omega} y_{H,t}^* \Delta_{H,t}^* = \omega_b n_t^b + (1 - \omega_b) n_t^s - \phi \tag{23}$$

where, for $j = \{H, H^*\}$

$$\Delta_{j,t} = \int_0^1 \left(\frac{P_{j,t}(i)}{P_{j,t}} \right)^{\frac{\mu}{1-\mu}} di \tag{24}$$

are the measures of price dispersion resulting from staggered pricing by intermediate goods producing firms.

Since only banks can purchase short-term government bonds and hold central bank reserves, the associated market clearing condition is

$$B_t = B_t^g + B_t^m \tag{25}$$

while that describing the long-term bond market is

$$B_{L,t} + B^*_{L,t} = B^g_{L,t} \tag{26}$$

Together with the budget constraints of all agents in the economy, all these market clearing conditions imply the following law of motion for the economy's total foreign debt, including foreign reserve holdings by the central bank

$$P_{L,t}B^*_{L,t} - S_t P^*_{L,t} F_{L,t} = (1-\tau_t) R_{L,t} P_{L,t} B^*_{L,t-1} - R^*_{L,t} P^*_{L,t} S_t F_{L,t-1} + P_{F,t} y_{F,t} - S_t P^*_{H,t} y^*_{H,t} \tag{27}$$

3.7 Rest of the world

Given our small open economy assumption, foreign allocations and prices are exogenous to home agents and the rest of the world is treated as a closed economy. To generate quantitative easing in the foreign economy, we introduce into it market segmentation between short-term and long-term bonds in a parsimonious way. In the essence, and compared to a standard New Keynesian setup, this economy features an additional type of households, who are financially restricted in that they can trade only in long-term bonds. This, together with adjustment costs associated with transactions in bonds, makes bonds of different maturity imperfect substitutes. As a result, quantitative easing, modeled as an exogenous change in the maturity composition of consolidated public debt, has real effects. Since such defined framework is essentially a simplified version of Chen et al. (2012), we do not describe it in detail here. A full list of conditions defining its equilibrium can be found in the Appendix.

Our small open economy is linked to the rest of the world via trade and financial linkages. When buying foreign goods, domestic importers face an exogenous price P^*_t, while the demand for exports is given by a standard formula

$$y^*_{H,t} = \eta^* \left(\frac{P^*_{H,t}}{P^*_t} \right)^{-\nu^*} y^*_t \tag{28}$$

Since long-term bonds issued by the small economy can be traded by foreign agents subject to capital flow taxation, we have the following long-term UIP condition

$$\mathbb{E}_t \left\{ \Lambda^*_{t,t+1} (1-\tau_{t+1}) R_{L,t+1} \frac{P_{L,t+1}}{P_{L,t}} \frac{S_t}{S_{t+1}} \right\} = \mathbb{E}_t \left\{ \Lambda^*_{t,t+1} R^*_{L,t+1} \frac{P^*_{L,t+1}}{P^*_{L,t}} \right\} \tag{29}$$

where $\Lambda^*_{t,t+1}$ is foreign investors' stochastic discount factor for nominal payoffs expressed in foreign country's currency.

4 Calibration and solution

We calibrate our small open economy model to mimic LA characteristics. We set the parameters to match some key steady state values observed in the data or take them directly from the literature. Table 1 shows the calibrated parameters whereas Table 2 presents the targeted steady state proportions. The time period is one quarter.

In our model, the key transmission channel hinges on housing credit, banking sector frictions and bond holdings. We target mortgages to (annual) GDP in the steady state at 0.16 , which falls in the middle of the range of household debt to GDP in LA.[5] In order to meet this goal, we set the share of borrowers equal one quarter. By calibrating the housing preference parameter at 0.09 we aim at reaching the housing stock to GDP ratio in the steady state (about 1.25 annually), in line with the data on household real wealth to GDP in Brazil and Chile as reported by Suisse (2018). At the same time, we keep the depreciation rate of housing stock at a standard level of 0.005 and the steady state LTV ratio at a conventional level of 0.8. Without loss of generality, the fixed housing stock is set to normalize steady state real house prices to unity.

Based on the World Bank and the International Monetary Fund Quarterly Public Sector Debt data, the share of sovereign bonds in quarterly GDP is calibrated at 1.5, while the share of long term bonds is set to 0.8.[6] In order to meet the steady state share of foreign investors in the domestic bond market of 15 percent[7] as well as bank leverage of 6, which is standard in the literature and in line with the Basel Committee recommendations, we set both bank run-away parameters to 0.26 and the survival probability to 0.95. Since long-term bonds are modeled as perpetuities, we need to specify their coupons. We do it to match the duration of long-term bonds in LA equal to 8 years.[8]

The discount factor of savers is set to a conventional value of 0.995 while that of borrowers is calibrated at 0.985 so that the relative impatience of this type of agents is similar to that used by Campbell and Hercowitz (2009). The price stickiness parameters are calibrated such that they imply the average price duration of about five quarters for domestic sales and half of that for international trade. These values ensure reasonable slope of the Phillips curve and degree of exchange rate pass-through.

The remaining parameters are either well-established in the literature or do not have important effects on our results. The steady state government spending in both countries is set to 0.2 of GDP, roughly in line with the long-run averages observed in the data. The long-run inflation rate is calibrated at 2% annually. The elasticity of intertemporal substitution,

[5] Average value for Brazil, Chile, Colombia, Argentina and Mexico 2008. BIS data.

[6] The data refers to the average share in Brazil, Colombia, Argentina and Mexico in years 2011-2018.

[7] Average value for Brazil, Mexico and Peru in 2009q1. Credit Suisse data.

[8] Average modified duration for Chile and Mexico in 2008. OECD data.

the Frisch elasticity of labor supply, price markups, and interest rate rule coefficients are all set to standard values used in the DSGE literature. In the baseline parametrization, we assume that the central bank does not directly respond to exchange rate movements.

To link the small economy to the rest of the world, we calibrate its home bias parameter at 0.75 to capture the average share of imports in GDP in LA, corrected for the import content of exports estimated by the OECD.[9] The elasticity of substitution between domestically produced goods and imports is set to 1.5, which can be seen as a compromise between the micro and macro estimates found in the literature. The same value is used to describe the price elasticity of exports.

The foreign closed economy is aimed to reflect the key features of the US. Since this block of our model essentially serves to generate the paths of bond prices, inflation and output in the rest of the world in response to its QE, while parametrizing it we draw heavily from Chen et al. (2012), who estimate a very similar closed economy framework to study the effects of QE in the US. The full list of assumed parameter values for the large economy can be found in the Appendix. As a double check, we additionally make sure that the obtained reactions in the large economy of those variables that are key from the small economy's perspective are consistent with the existing empirical evidence on the effects of QE.

We solve the model in a perfect foresight mode. This means that, even though QE is not anticipated in advance, once it is announced, the whole future path of asset purchases is perfectly known to all agents. This formulation allows us to preserve all non-linearities in our model, including the possibly binding effective lower bound on the nominal interest rate and an occasionally binding collateral constraint. To smooth out the initial responses of borrowers, we replace the collateral constraint by a smooth penalty function advocated by Den Haan and De Wind (2012). The advantage of this approach is that we can parametrize the penalty function such that it gets arbitrarily close to a kinked constraint, and that it preserves its key features in deterministic simulations even for parametrizations that are reasonably smooth around the kink, see Brzoza-Brzezina et al. (2015).

5 QE-driven financial cycles

We first use our model to generate a scenario that mimics one round of quantitative easing in the large foreign economy, and investigate how it affects the small country. Figure 5 presents the results. The panels in the first row present the response of the foreign economy. The sequence of central bank asset purchases are constructed such that they lower the share of long-term debt in total public sector liabilities by around 4 percentage points within one year, in line with a typical round of QE in the US. After a year, QE is gradually withdrawn,

[9] 0.75 is very close to the average in Chile and Mexico and somewhat larger than in Colombia and Brazil.

at the pace implying a half-life equal to about three years.[10] We also assume that the large economy faces a binding zero lower bound constraint until the sequence of asset purchases is completed so that the foreign short-term interest rate is fixed over the period of one year.

As the foreign central bank reduces the supply of long-term bonds, it squeezes the transaction costs of foreign unrestricted households. Consequently, the term premium in the large economy decreases, driving down the long-term interest rate by around 15 bps. This reaction is a bit larger than obtained by Chen et al. (2012), who consider the effects of LSAP II in the US in a model with bond market segmentation, but closer to empirical studies that usually report a stronger response of bond yields. The increase in foreign output of about 0.08% at peak is also in line with Chen et al. (2012).

Due to trade and financial linkages, developments in the large economy generate reactions in the small economy, which we depict in the remaining panels of Figure 5. There are two key mechanisms at play. The first one, associated with the global financial cycle, hinges on international asset market segmentation in the model that allows only for cross-border trade in long-term bonds.[11] Since foreign households arbitrage between returns on domestic and foreign assets (see equation 29), a drop in the return on foreign long-term bonds induces an inflow of capital to the small economy. This generates appreciation of its currency by 0.8% on impact and a fall in the long-term rate by 10 bps.

The second mechanism relates to the domestic financial cycle. When the return on domestic long-term bonds goes down, banks arbitrage out returns from bonds and mortgage loans, inducing a drop in the lending rate in the small economy. This, together with a boom in house prices that relaxes the collateral constraint, translates into expansion in credit to households by 0.5%. Higher borrowing fuels domestic demand that increases by 0.2%.

In the simulation, the exchange rate appreciation that undermines international competitiveness of the small economy is large enough to generate a contraction in its output and a fall in inflation, despite a boom in domestic spending, thus reflecting the concerns expressed by Rajan (2016).[12] In response, the central bank lowers the short-term interest rate in order to preserve macroeconomic stability. This further increases the demand for credit and house prices, exacerbating the domestic financial cycle.

At this point it is straightforward to see that, if the central bank in the small economy attempted to limit capital inflow and reduce appreciation of the exchange rate with conventional monetary policy, it would need to lower the short-term interest rate much more. In this way, it would generate a deeper fall also in the domestic long-term rate, hence reducing the

[10] The simulated reactions reported in this section do not depend qualitatively on the assumed pace of exit from QE, but become substantially stronger if the asset purchases are more persistent.

[11] See Kolasa and Wesołowski (2020) for a detailed explanation of the theoretical implications of the assumed bond market segmentation and empirical evidence validating it.

[12] It is worth noting that our model generates this outcome without exaggerating the magnitude of exchange rate appreciation, see local projection evidence in Section 2.

incentive of foreign agents to buy small economy's bonds. This intervention, however, would lead to an even stronger boom in credit and asset prices. We thus have the manifestation of the Tinbergen rule – one policy tool, i.e. the short-term interest rate in the small economy, cannot simultaneously ensure both macroeconomic (internal and external) and financial stability. It needs to be stressed that this conclusion does not depend on whether the interest rate in the small economy follows the standard feedback rule 18 as in our simulations, or is instead chosen optimally according to some welfare criterion. More generally, a trade-off between domestic and external imbalances is well-known for policymakers in many emerging market economies (see e.g. BIS, 2012). What makes it particularly challenging in the context of foreign QE, and potentially different from other forces driving capital flows to emerging markets, is that it generates a sharp deterioration in the recipient country's international competitiveness.

6 Non-standard policy measures

In this section we investigate how the policy trade-off in small open economies resulting from foreign QE-driven DFC and GFC, can be alleviated with complementary policy tools. We focus on instruments that address international or domestic borrowing more directly, and which have already been used by emerging market economies (including LA) to combat large capital inflows and their disruptive consequences. These are: foreign exchange (FX) interventions, capital controls and caps on domestic borrowing. All of these non-standard measures have been identified in the theoretical literature as potentially useful in correcting externalities associated with capital flows.

Ideally, one could design rules for each of the three instruments, optimizing their parameters according to some welfare criterion. While giving useful insights, this approach would require a fully stochastic framework and global solution methods to appropriately account for key non-linearities, including the interaction between the US QE and effective lower bound on the federal funds rate. Given the model size, this is not computationally feasible, so we follow a different strategy that nevertheless allows us to assess if a given non-standard measure implemented by the small economy can help it resolve the trade-off between macroeconomic and financial stability. More specifically, we use the baseline scenario developed in the previous section and see how it is modified when additional policy instruments are deployed one at a time, each time assigning to them one specific stabilization objective that can be considered their natural target. These targets are: the nominal exchange rate for FX interventions, net foreign assets position for capital controls, and domestic credit for caps on borrowing. Following this strategy allows us to easily see how pursuing a particular stabilization objective with a particular instrument affects other macroeconomic developments, and hence whether its use goes towards improving the macro-financial tradeoff created by foreing QE. Importantly, while running the simulations we are able to preserve all model non-linearities, including the effective lower bound and occasionally binding collateral constraint.

6.1 FX interventions

We start with foreign exchange (FX) interventions, which are a typical central bank instrument used to stabilize the nominal exchange rate, and a natural complement to changes in the policy rate. We assume that the monetary authority, apart from adjusting the short-term rate in response to output and inflation, also purchases foreign long-term bonds $F_{L,t}$ in quantity that ensures perfect nominal exchange rate stabilization.[13] In our setup, purchasing foreign bonds is financed with issuance of short-term domestic bonds, which is a model equivalent of sterilized FX interventions.

The outcome of such defined scenario is presented in Figure 6. The scale of interventions on the foreign exchange market needed to stabilize the nominal exchange rate is reasonable – at its peak it does not exceed 3.5% of GDP, which is roughly the size of purchases by the central bank of Chile in 2011. It is also consistent with central bank communication in the LA region, where the monetary authorities explicitly announced in the past that their FX intervention were aimed at reducing the appreciation pressure (see e.g. BIS, 2012).

In line with the long UIP condition (29), stabilizing the nominal exchange rate requires the long-term interest rate in the small economy to fall more than in the baseline scenario. This prevents capital inflow from abroad and can turn the response of output into a positive one as the country now benefits from expansion in economic activity abroad without losing its international competitiveness. Actually, the amount of FX purchases needed to keep the nominal exchange rate stable eventually leads to a capital outflow and fall in domestic demand. This means that, if the goal is to prevent a fall in output due to loss of international competitiveness, a smaller scale of the intervention would be sufficient. At the same time, however, lower long-term interest rates not only limit inflow of capital from abroad, but also translate into a more rapid expansion in domestic credit and, consequently, a sharper increase in house prices. Again, arbitrage in the banking sector is key for the transmission of high bond prices to the cost of credit.

To sum up, combining conventional monetary policy with FX interventions allows to address both internal and external dimensions of macroeconomic stability, but at the expense of amplifying the domestic financial cycle. The two policies are not good complements due to international arbitrage in bond markets. An attempt to increase the policy rate to curb the domestic financial cycle widens the long-term interest rate differential, which creates the

[13]The outcomes are the same if we define FX interventions as central bank purchases of foreign short-term bonds.

need for even bigger FX intervention to prevent exchange rate appreciation, thus annihilating the effect of tighter monetary policy on the cost of credit.

6.2 LTV policy

A natural complement to conventional monetary policy that can be used directly to limit internal credit expansion is domestically-oriented macroprudential policy. One of the popular instruments used in this context is the maximum Loan-to-Value (LTV) ratio, which in our model is represented by the policy parameter m_t. For illustrative purposes, we assume that it is adjusted such that domestic credit is perfectly stabilized at its steady state level.

As can be seen from Figure 7, to achieve this goal the LTV ratio needs to be tightened by about 0.5 percentage points. This may look like a modest intervention, but remember that in our model debt is one-period. In reality, mortgages are taken by households for many years, and changes in the LTV limit apply only to new borrowing. This means that, according to our simulations, the adjustment of this policy parameter that is required to prevent expansion in credit is actually quite sizable, but not inconceivable given the actions taken in those countries that actively use this type of macroprudential policy tools (see e.g. Richter et al., 2018). A lower LTV ratio also cuts the peak in absorption as borrowers have to reduce their consumption under tighter credit limits, and helps reduce the boom in house prices. As for other variables, however, the impact of this policy is very moderate. In particular, it is not helpful in reducing external imbalances – both net foreign assets and exchange rate appreciation are similar to the baseline scenario.

In contrast to FX interventions, which were supposed to shield the domestic economy against falling output and inflation, LTV policy can be seen as designed to address the domestic financial cycle. In this way it can create more space for the central bank to counteract contractionary forces associated with the loss of international competitiveness. This, together with the lack of significant effects on external stability, makes LTV adjustments a good complement to sterilized FX interventions, and combining these two policies can efficiently deal with both macroeconomic and financial consequences of QE-induced global and domestic financial cycles.

6.3 Tax on capital flows

Finally, we consider an outward-oriented macroprudential policy that directly addresses the capital inflow. We focus on a tax on foreign investors' returns whenever they hold small economy's assets as it seems to be a natural tool to reduce a carry trade motive of capital inflows. Among LA countries, this type of capital controls has been used during the QE period by Brazil. As in the case of other policies, and for illustrative purposes, we assume an extreme version of adjustments in the tax on foreign returns τ_t, setting it such that it perfectly stabilizes the small economy's net foreign asset position (in relation to GDP).[14]

As Figure 8 documents, such policy is very successful at stabilizing house prices, credit, and domestic demand. It also significantly reduces the exchange rate appreciation so that output in the small economy slightly expands, generating a moderate increase in inflation. According to our simulations, the required increase in taxation amounts to about 11 bps at peak. This value can be compared to the steady state quarterly yield on long-term bonds issued by the small economy (81 bps), and hence the scale of this intervention is definitely not unreasonable.

Overall, the macroprudential tax on foreign positions appropriately deals with both GFC and DFC. This outcome is intuitive as this instrument directly addresses the primary channel of QE spillovers, i.e. international arbitrage in bond prices. As capital inflow taxes shrink the difference between net returns on domestic and foreign long-term bonds for foreign agents, they effectively discourage capital inflows to the home economy. As a result, appropriate adjustments in this macroprudential instrument counteract emerging internal and external macroeconomic imbalances, and at the same time preserve financial stability.

6.4 Welfare effects

We complement our analysis of non-standard policy measures with a discussion of their welfare consequences. Since our model features two distinct types of households, which differ in average net asset positions and their composition, both QE abroad itself and possible policies aimed at mitigating its effects can have potentially important redistributive effects. As borrowers hold negative assets and are financially constrained, easier credit conditions and higher collateral value generated by foreign QE are likely to improve their welfare. In contrast, savers are likely to lose due to lower interest income and higher spending on housing.

This intuition is confirmed in Table 3, in which we show how welfare of the two types of agents, defined by formulas (2) and (4), change under asset purchases implemented in the large economy, with possible policy interventions undertaken in the small economy as described in the previous sections. All numbers are expressed as the difference from the steady state. Since we do not optimize the scale of interventions, but aim at illustrating their working, in what follows we concentrate more on their qualitative rather than quantitative effects. In this context, it is also important to note that the signs of welfare gains relative to the baseline are robust to making the non-standard interventions very small. This means

[14] Capital controls in the form considered in this paper are sometimes thought of as directed at preventing exchange rate appreciation, even though this eventually improves the trade balance, and hence the net foreign asset position. The simulation results presented below would be similar if we defined the target for this policy as exchange rate stabilization, like we did in the case of FX interventions above.

in particular that the conclusions we formulate below about welfare redistribution also apply to marginal use of these policies, and are not due to assigning to them strict stabilization objectives as we have been doing for illustrative purposes.

Preventing exchange rate appreciation using FX interventions makes redistribution of welfare from savers to borrowers even larger. This is because this policy amplifies the financial cycle, thus relaxing credit constraints faced by borrowers. The opposite effect is achieved with LTV tightening, which thus turns out to be an efficient tool to mitigate redistribution caused by foreign QE. Finally, welfare loss of savers can be almost completely prevented with appropriate adjustment in taxes on capital inflows, leaving still some benefits on the part of borrowers. This result from several general equilibrium effects: higher output and tax revenue translate into rising income of both types of households, while a higher short-term interest rate supports the financial condition of savers. Overall, our welfare analysis confirms that capital controls should be considered as the preferred response of the small open economy to large-scale asset purchase programs conducted abroad.

7 Conclusions

Capital inflows stemming from unconventional policy measures implemented by the US Fed have a substantial impact on economic and financial stability in EM economies. This paper adds to the understanding of this process by providing empirical evidence on QE spillovers to a number of macroeconomic and financial variables in LA, and by developing a structural macroeconomic model that combines a realistic description of asset market segmentation with the role of domestic credit and asset prices, amplified by financial frictions associated with collateral constraints and agency problems. In response to foreign QE, the model generates a large inflow of capital to an emerging market economy, loss of its international competitiveness, as well as a boom in house prices and mortgage loans that successfully mimic empirical evidence for LA countries. As output and inflation decline, the EM central bank faces a trade-off between macroeconomic and financial stability that cannot be resolved with conventional measures.

An attempt to avoid the loss in international competitiveness by preventing exchange rate appreciation using short-term rates or currency interventions necessarily leads to easier credit conditions, which amplifies the financial cycle. To constrain the latter, exchange rate policy should be combined by additional measures, such as tightening of the domestically-oriented macroprudential policy. An instrument that addresses both macroeconomic and financial stability issues is time-varying taxation of international capital flows. This type of non-standard policy is also clearly preferred from a social welfare perspective.

A general insight from our analysis is that capital inflows to emerging market economies induced by large scale asset purchases abroad should be treated differently from other drivers of the global financial cycle. This type of flows create more severe trade-offs for the recipient countries, strengthening the case for tighter coordination between domestic monetary and macroprudential policies, and fora more active use of the latter. However, as our analysis reveals, an appropriate selection of macroprudential policy tools is key if the goal is not only to stabilize the economy as a whole, but also to prevent substantial welfare redistribution between borrowers and savers.

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Tables and figures

Table 1: Calibrated parameters

Parameter	Value
Share of borrowers; ω_b	0.25
Inv. elasticity of intertemporal substitution; σ	2
Inv. Frisch elasticity of labor supply; φ	2
Discount factor, borrowers; β^b	0.985
Discount factor, savers; β^s	0.995
Coupon; κ	0.929
Depreciation rate of housing stock; δ_h	0.005
Preference parameter for housing; a_h	0.09
Steady-state LTV ratio; m	0.8
Steady-state housing stock; h	5.26
Bank run-away parameters; ϖ^L, ϖ^B	0.26
Bank surviving probability; ϑ	0.95
Startup funds for banks; x	0.0083
Calvo probability for domestic production; θ_H	0.8
Calvo probability for exports and imports; θ_H^*, θ_F	0.6
Price markup; μ	1.15
Elasticity of substitution btw. home and imported goods; ν	1.5
Home-bias; η	0.75
Steady-state inflation; π	1.005
Interest rate smoothing; γ_r	0.9
Interest rate response to inflation; γ_π	1.5
Interest rate response to output gap; γ_y	0.125
Tax response to long-term debt; γ_b	1.3

Table 2: Targeted steady state ratios

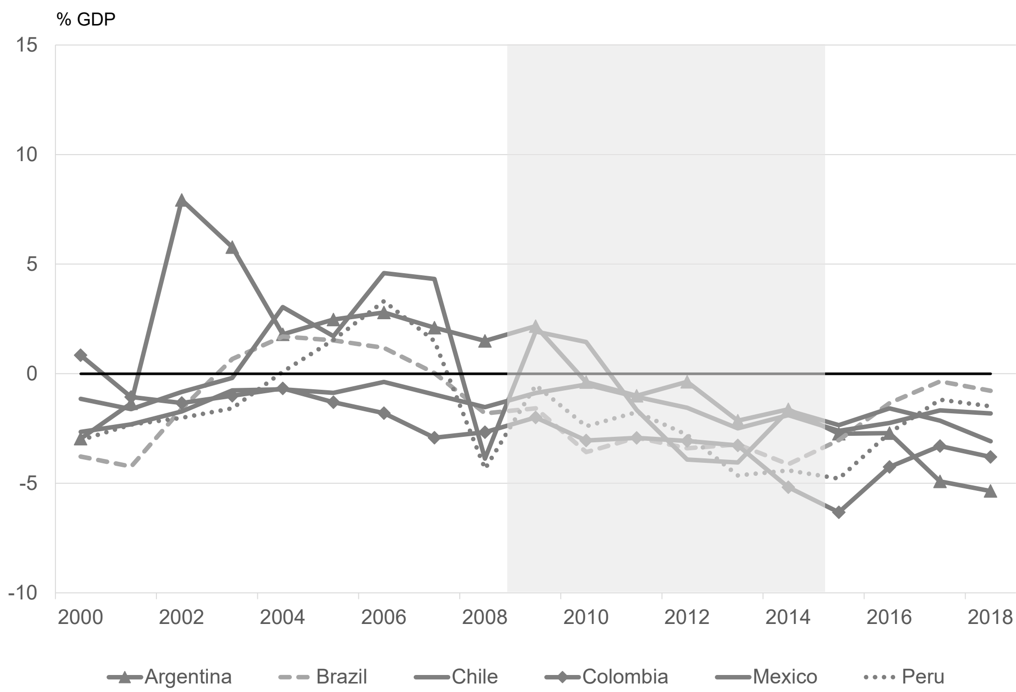
Steady state ratio	Value
Share of government spending in GDP; $\frac{g}{y}$	0.2
Ratio of government bonds to GDP; $\frac{b^g+P_L b_L^g}{y}$	1.5
Share of long-term bonds in total bonds; $\frac{P_L b_L^g}{b^g+P_L b_L^g}$	0.8
Share of residents in small economy's long-term bonds; $\frac{b_L}{b_L^g}$	0.85

Table 3: Welfare effects

	Baseline	FX interventions	LTV tightening	Capital inflow tax
Borrowers	0.023	0.108	0.013	0.005
Savers	-0.032	-0.043	-0.030	0.000

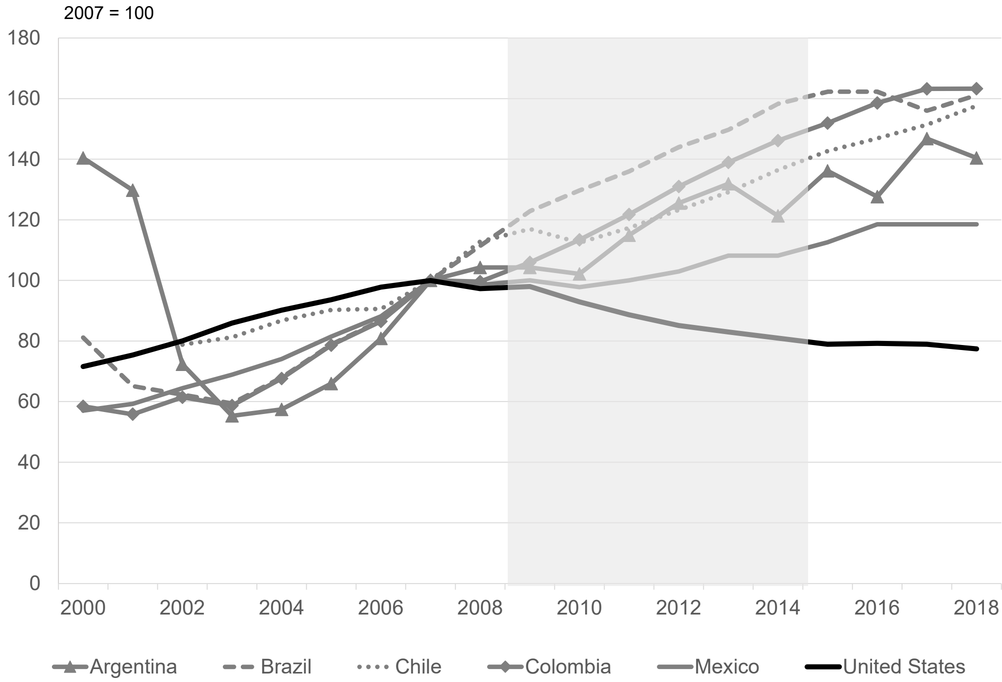
Note: All numbers are presented as deviations from agents' lifetime utility in the steady state.

Figure 1: Current account to GDP



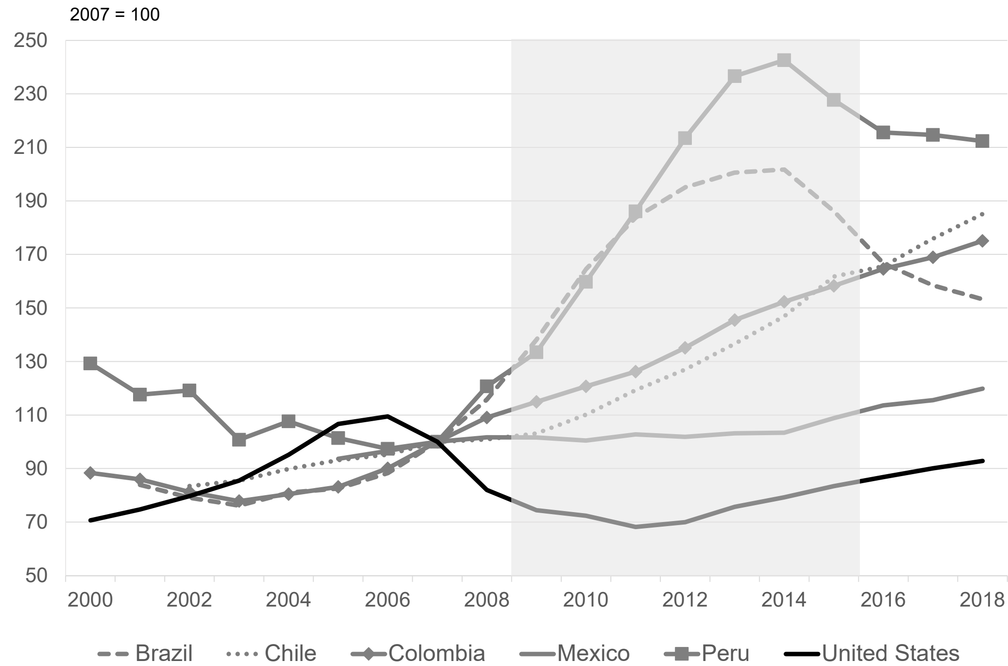
Source: International Monetary Fund. The shadow area indicates the period of net long-term government bond purchases by the US Fed.

Figure 2: Household debt to GDP



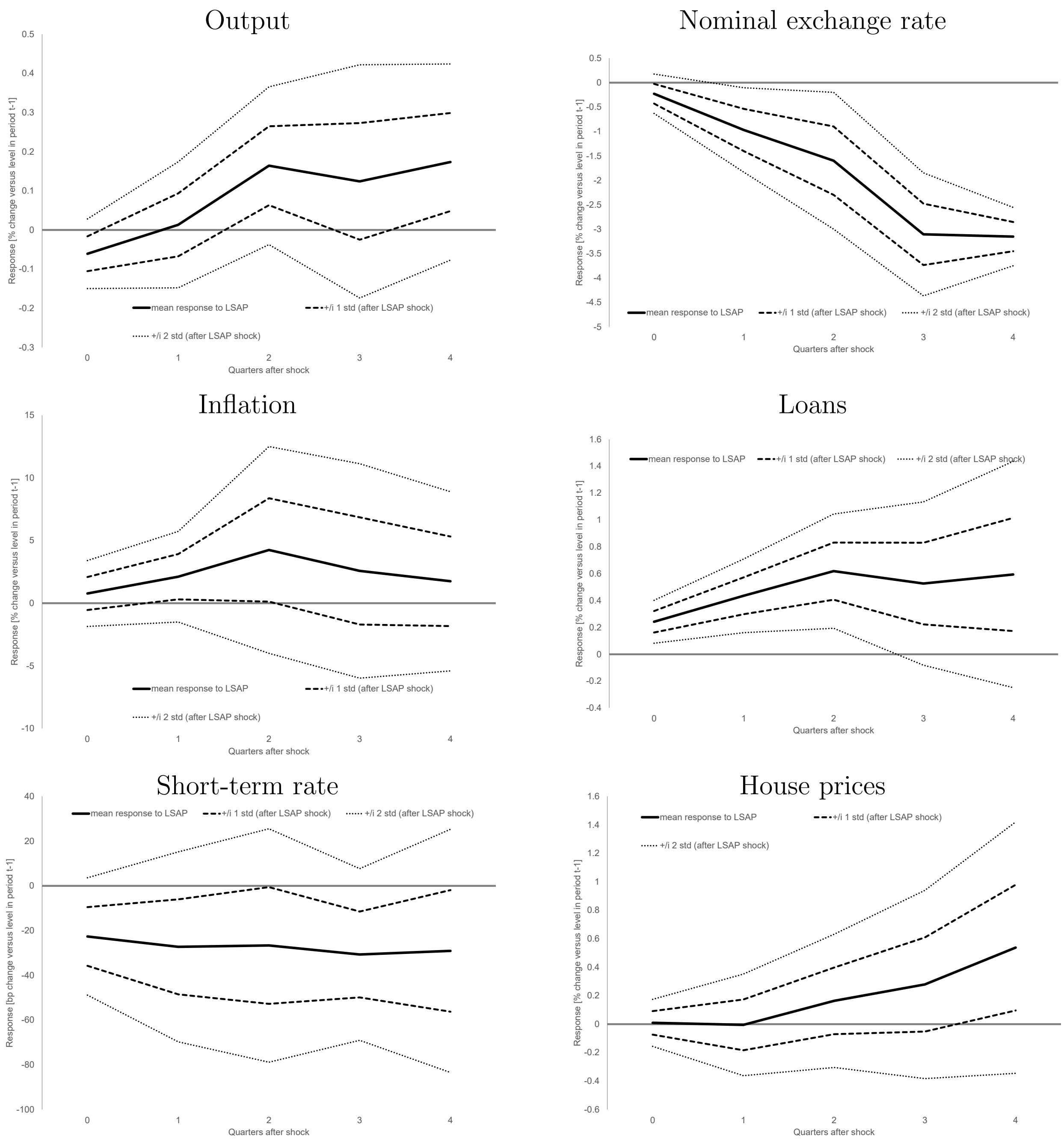
Source: Bank for International Settlements. The shadow area indicates the period of net long-term government bond purchases by the US Fed.

Figure 3: Real house prices



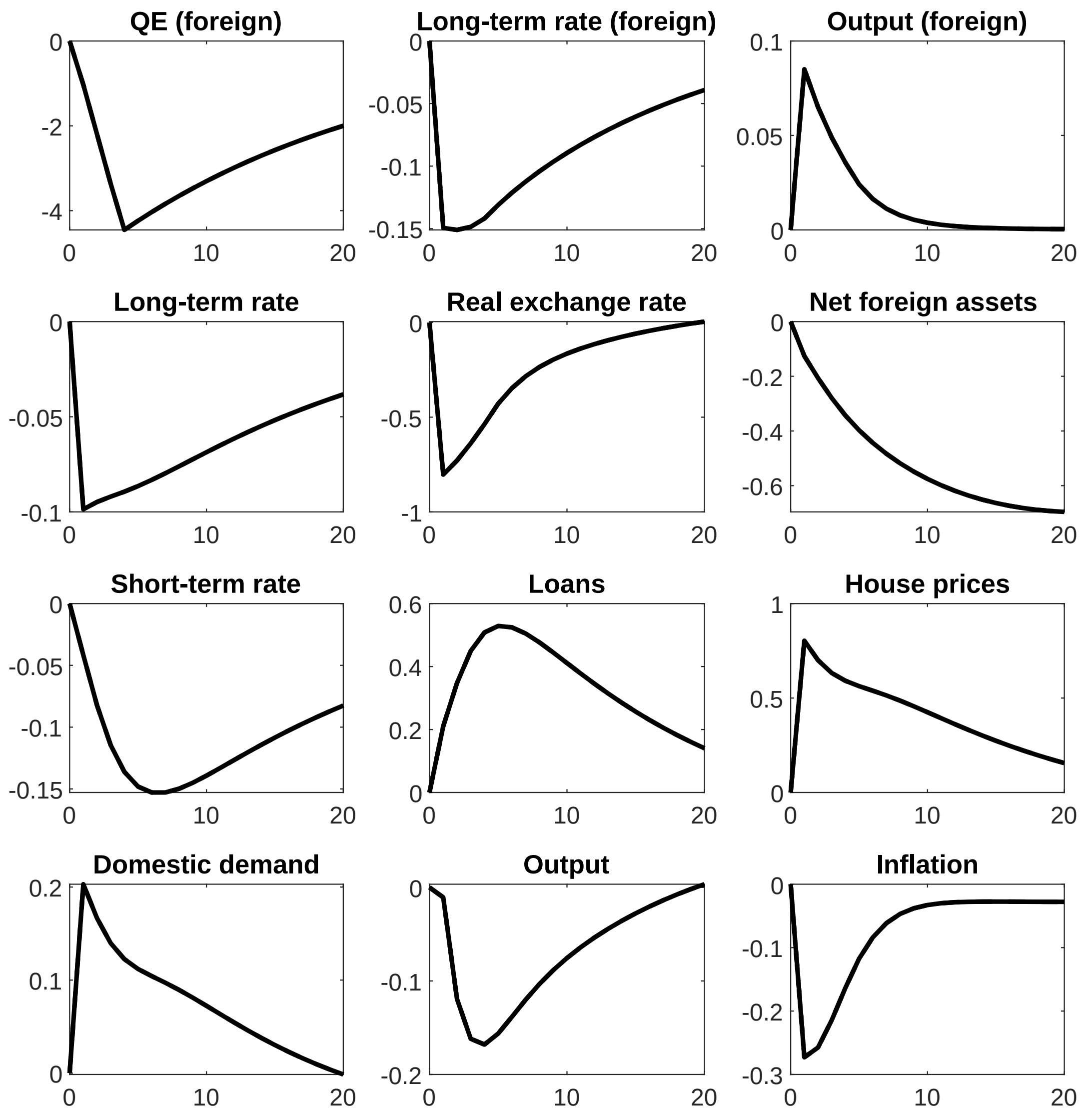
Source: Bank for International Settlements. The shadow area indicates the period of net long-term government bond purchases by the US Fed.

Figure 4: Responses of selected variables in LA to LSAP shock in US



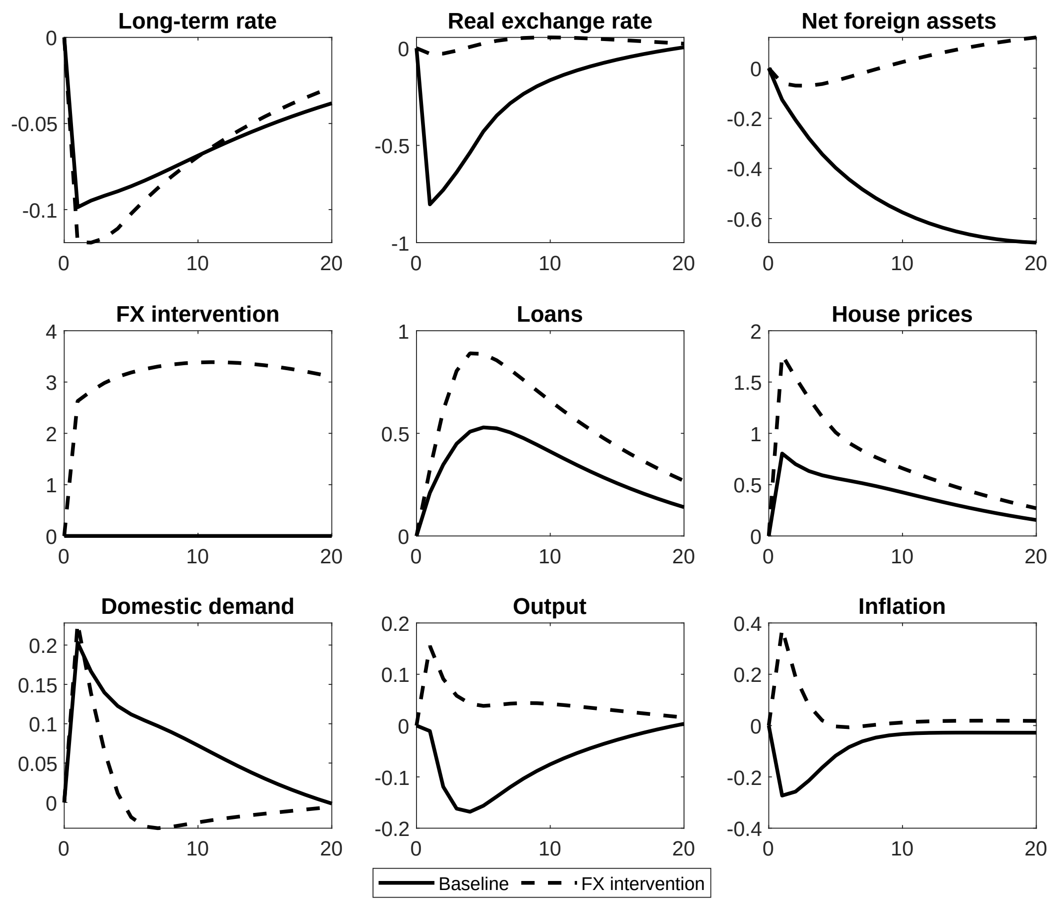
Note: Local projection panel estimation for Argentina, Brazil, Chile, Colombia and Mexico. US LSAP shocks are taken from Swanson (2020). The presented responses follow a one standard deviation US LSAP shock and refer to the period 2009q1-2019q2. A negative FX response indicates LA exchange rate appreciation against the US dollar.

Figure 5: Effects of quantitative easing in the large economy



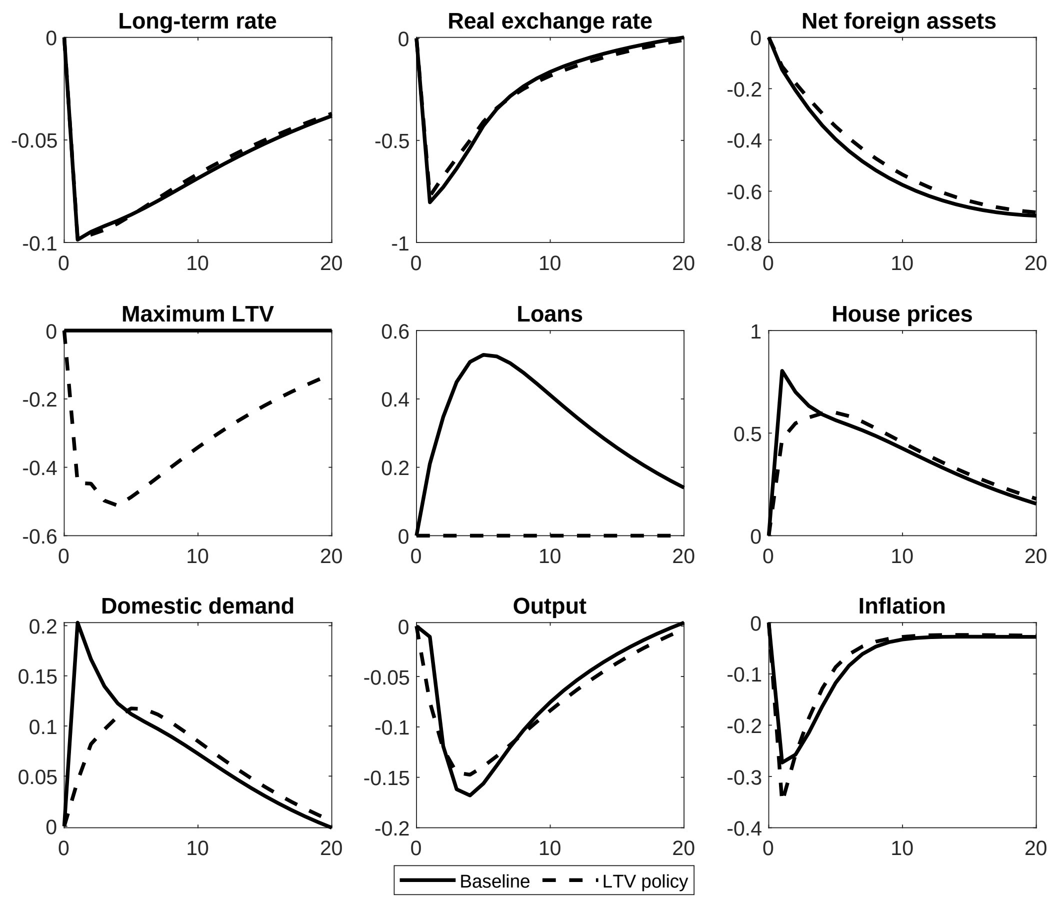
Note: All responses are in percent deviations from the steady state. The responses of the interest rates and inflation are annualized.

Figure 6: Effects of FX interventions



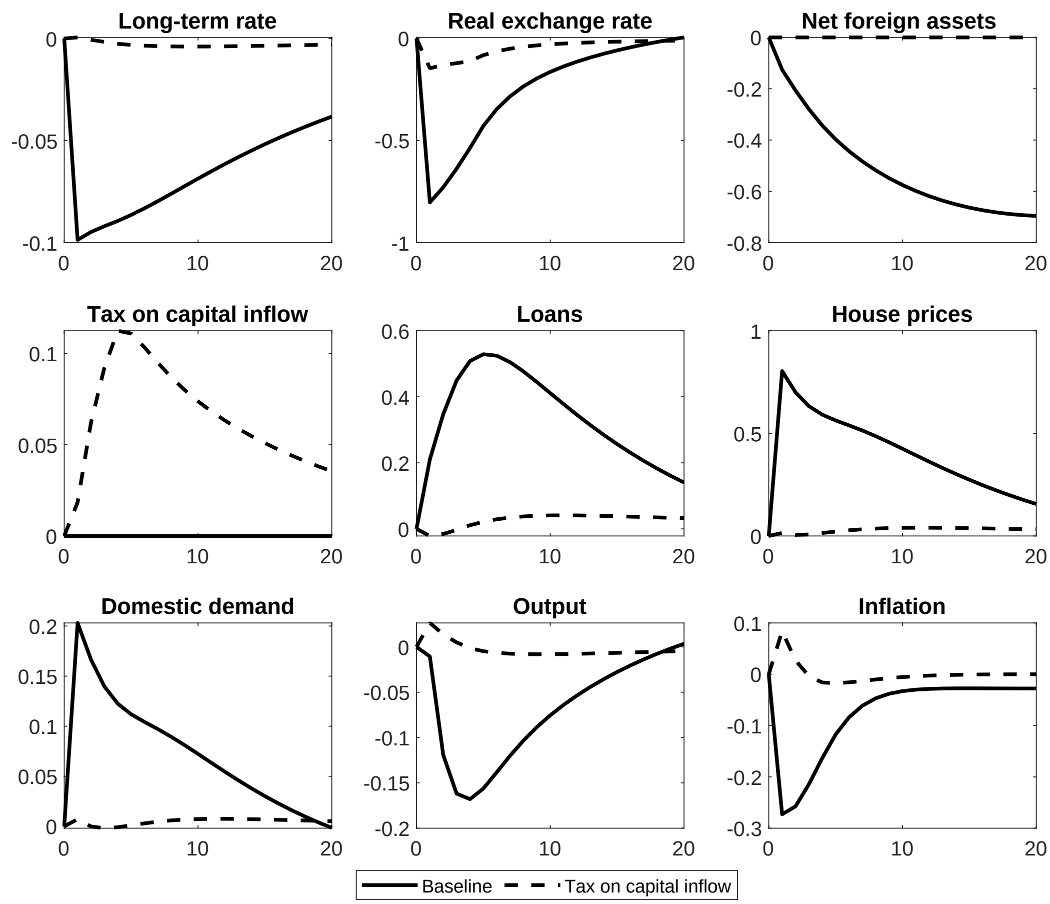
Note: This figure presents the effects of quantitative easing in the large economy, as defined in Figure 5, and assuming that the monetary authority in the small economy intervenes on the FX market by purchasing foreign long-term bonds in exchange for central bank reserves so that the nominal exchange rate is perfectly stabilized. All responses are in percent deviations from the steady state. The responses of interest and inflation rates are annualized.

Figure 7: Effects of LTV policy



Note: This figure presents the effects of quantitative easing in the large economy, as defined in Figure 5, and assuming that the macroprudential authority in the small economy adjusts the maximum LTV ratio so that credit is perfectly stabilized. All responses are in percent deviations from the steady state. The responses of interest and inflation rates are annualized.

Figure 8: Effects of taxing capital gains of foreigners



Note: This figure presents the effects of quantitative easing in the large economy, as defined in Figure 5, and assuming that the fiscal authority adjusts the tax on capital inflows in a way that perfectly stabilizes net foreign assets. All responses are in percent deviations from the steady state. The responses of interest and inflation rates are annualized.

Appendix A

A.1 Panel estimation of local projections

In this appendix we present some more details on the local projection estimates discussed in Section 2. Table A.1 reports the definitions of variables that we used in the estimated regressions and their data sources. Note that the baseline specifications do not necessarily use all of these variables as their inclusion was determined by information criteria and statistical significance. The only exception from this selection criteria are the US QE dummy and variables approximating US monetary policy shocks that are included in all regressions since they are crucial to assess correctly the impact of US QE shocks on endogenous variables. We report the outcomes for the baseline estimation and for two-three alternative specifications, which serve as robustness checks. It turns out that the latter do not change significantly our baseline results, but perform worse in terms of information criteria. By the same token, checking specifications with other controls, we found them not improving the estimation. For all sets of regressions, we also checked other specifications, using the remaining variables listed in Table A.1. However, they did not enter in a statistically significant way nor improve the model performance.

Tables A.1, A.1 and A.1 present the estimates of β_h^{QE} for typical macroeconomic variables in monetary regressions, namely GDP, CPI index and the short-term interest rate. In the baseline regressions, the control variables include two lags of the LSAP shock, the US QE period dummy, contemporary values and two lags of two non-QE monetary shocks in the US (i.e. shocks to the federal funds rate and to the forward guidance), as well as lagged first two differences of domestic GDP, CPI index and the short-term interest rate, as well as the exchange rate against the US dollar, and US GDP. The reported alternative specifications drop lagged US monetary shocks or the lagged change in the domestic endogenous variable.

Table A.1 shows the estimates of β_h^{QE} obtained in the exchange rate regressions. In the baseline, the control variables include two lags of the LSAP shock, the US QE period dummy, contemporary values and two lags of two non-QE monetary shocks in the US, two lags of first differences of domestic and US GDP and VIX, as well as contemporaneous change in VIX to control for global sentiment in financial markets. Table A.1 and A.1 present the estimates for credit to households and house prices that are associated with domestic financial cycle. In the baseline regressions, the control variables include two lags of the LSAP shock, the US QE period dummy, contemporary values and two lags of two non-QE monetary shocks in the US, as well as lagged first differences of domestic GDP, CPI index, the short-term interest rate (for house price only) and exchange rate against the US dollar. The reported alternative specifications drop lagged US monetary shocks or the lagged change in endogenous variables.

Table A.1: List of variables in local projection models

Variable Description	Data source	Data description
GDP - expenditure approach (log)	OECD	VOBARSA
CPI index (log)	OECD	CPI: 01-12 - All items; seasonal adj. TRAMO/SEATS
Short-term interest rate	OECD, Bloomberg	Per cent per annum
Exchange rate against the US dollar (log)	BIS	BIS/xru_current/
Credit to households and NPISHs (log)	BIS	Credit from all sectors at market value
House prices (log)	OECD	Country level, Index publication base
LSAP shock	Swanson (2020)	LSAP factor
Federal funds rate shock	Swanson (2020)	Federal Funds Rate factor
Forward guidance shock	Swanson (2020)	Forward guidance factor
US GDP - expenditure approach (log)	OECD	VOBARSA
VIX index	Bloomberg	N/A

Table A.2: Local projections for GDP in LA

	h=0	h=1	h=2	h=3	h=4
Baseline	0.004	-0.001	-0.011	-0.008	-0.012
	(0.003)	(0.005)	(0.007)	(0.010)	(0.008)
Without lagged monetary policy shocks	0.005	0.001	-0.010	-0.008	-0.012
	(0.004)	(0.005)	(0.005)	(0.008)	(0.006)
Without lagged GDP	0.007	0.002	-0.008	-0.007	-0.011
	(0.005)	(0.006)	(0.005)	(0.007)	(0.005)

Note: The numbers are estimates of parameter β_h^{QE} in equation (1) for GDP regressions. Standard errors in parentheses, stars indicate statistical significance: *** p<0.01, ** p<0.05, * p<0.1. A positive estimate means that an unexpected increase in asset purchases in the US (negative realization in the Swanson (2020) LSAP factor) leads a decrease in GDP in LA at horizon h.

Table A.3: Local projections for inflation in LA

	h=0	h=1	h=2	h=3	h=4
Baseline	-0.052	-0.141	-0.284	-0.172	-0.117
	(0.088)	(0.121)	(0.276)	(0.286)	(0.239)
Without lagged monetary policy shocks	-0.055	-0.158	-0.321	-0.211	-0.145
	(0.105)	(0.129)	(0.303)	(0.298)	(0.248)
Without lagged CPI	0.877	1.915	2.748	4.376	3.341
	(0.650)	(1.504)	(2.275)	(3.108)	(2.877)

Note: The numbers are estimates of parameter β_h^{QE} in equation (1) for CPI regressions. Standard errors in parentheses, stars indicate statistical significance: *** p<0.01, ** p<0.05, * p<0.1. A positive estimate means that an unexpected increase in asset purchases in the US (negative realization in the Swanson (2020) LSAP factor) leads a decrease in prices in LA at horizon h.

Table A.4: Local projections for short-term interest rate in LA

	h=0	h=1	h=2	h=3	h=4
Baseline	1.511	1.822	1.781	2.048	1.942
	(0.876)	(1.417)	(1.742)	(1.281)	(1.814)
Without lagged monetary policy shocks	1.456	1.955	1.865	1.978	1.743
	(0.881)	(1.461)	(1.706)	(1.254)	(1.750)
Without lagged int.rate	1.533	2.679	2.324	2.076	2.882
	(0.983)	(1.433)	(1.462)	(1.393)	(1.915)

Note: The numbers are estimates of parameter β_h^{QE} in equation (1) for short-term interest rate regressions. Standard errors in parentheses, stars indicate statistical significance: *** p<0.01, ** p<0.05, * p<0.1. A positive estimate means that an unexpected increase in asset purchases in the US (negative realization in the Swanson (2020) LSAP factor) leads a decrease in short-term interest rates in LA at horizon h.

Table A.5: Local projections for LA exchange rates against the US dollar

	h=0	h=1	h=2	h=3	h=4
Baseline	0.015	0.065*	0.107*	0.207***	0.210***
	(0.013)	(0.029)	(0.047)	(0.042)	(0.020)
Without lagged monetary policy shocks	0.014	0.064	0.119*	0.224**	0.248***
	(0.015)	(0.032)	(0.051)	(0.050)	(0.035)
Without lagged exchange rate	0.003	0.059	0.120*	0.224***	0.249***
	(0.018)	(0.034)	(0.049)	(0.046)	(0.031)
Without contemporaneous VIX	-0.006	0.040	0.087	0.185**	0.187***
	(0.013)	(0.030)	(0.047)	(0.042)	(0.021)

Note: *** p<0.01, ** p<0.05, * p<0.1. The numbers are estimates of parameter β_h^{QE} in equation (1) for the exchange rate regressions. Standard errors in parentheses, stars indicate statistical significance: *** p<0.01, ** p<0.05, * p<0.1. A positive estimate means that an unexpected increase in asset purchases in the US (negative realization in the Swanson (2020) LSAP factor) leads to LA currency appreciation at horizon h.

Table A.6: Local projections for credit to households in LA

	h=0	h=1	h=2	h=3	h=4
Baseline	-0.016**	-0.029**	-0.041**	-0.035	-0.040
	(0.005)	(0.009)	(0.014)	(0.020)	(0.028)
Without lagged monetary policy shocks	-0.014*	-0.030**	-0.041*	-0.038	-0.039
	(0.006)	(0.011)	(0.017)	(0.023)	(0.029)
Without lagged credit	-0.019**	-0.038**	-0.051**	-0.052	-0.055
	(0.006)	(0.012)	(0.018)	(0.026)	(0.033)

Note: The numbers are estimates of parameter β_h^{QE} in equation (1) for loans to households regressions. Standard errors in parentheses, stars indicate statistical significance: *** p<0.01, ** p<0.05, * p<0.1. A positive estimate means that an unexpected increase in asset purchases in the US (negative realization in the Swanson (2020) LSAP factor) leads a decrease in credit in LA at horizon h.

Table A.7: Local projections for house prices in LA

	h=0	h=1	h=2	h=3	h=4
Baseline	-0.001	0.000	-0.011	-0.019	-0.036
	(0.006)	(0.012)	(0.016)	(0.022)	(0.029)
Without lagged monetary policy shocks	0.005	0.000	-0.005	-0.011	-0.024
	(0.006)	(0.011)	(0.015)	(0.021)	(0.029)
Without lagged house prices	-0.001	-0.014	-0.032	-0.051	-0.069
	(0.016)	(0.029)	(0.039)	(0.049)	(0.063)

Note: The numbers are estimates of parameter β_h^{QE} in equation (1) for house prices regressions. Standard errors in parentheses, stars indicate statistical significance: *** p<0.01, ** p<0.05, * p<0.1. A negative estimate means that an unexpected increase in asset purchases in the US (negative realization in the Swanson (2020) LSAP factor) leads an increase in house prices in LA at horizon h.

A.2 Equilibrium conditions - small open economy

The following equations list the equilibrium conditions in the small open economy, for given allocations and prices in the large economy. Those are jointly determined by the system of equilibrium conditions described in the next section. The list of equations making up the equilibrium is complemented by the rules (or exogenous values) describing the evolution of the following three policy instruments: tax rate on international capital flows τ_t, foreign reserves $f_{L,t} \equiv F_{L,t}/P_t^*$, and the LTV ratio m_t.

A.2.1 Households

Marginal utility

$$\lambda_t^s = (c_t^s)^{-\sigma} \tag{A.1}$$

$$\lambda_t^b = (c_t^b)^{-\sigma} \tag{A.2}$$

Bond prices

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

Households' budget constraints

$$c_t^s + p_{h,t}[h_t^s - (1-\delta_h)h_{t-1}^s] + d_t + t_t = \frac{R_{t-1}}{\pi_t} d_{t-1} + w_t n_t^s + div_t \tag{A.4}$$

$$c_t^b + p_{h,t}[h_t^b - (1-\delta_h)h_{t-1}^b] + \frac{R_{L,t-1}}{\pi_t} l_{t-1}^b + t_t = l_t^b + w_t n_t^b \tag{A.5}$$

Collateral constraint and its tightness

$$l_t^b \leq m\mathbb{E}_t \left\{ p_{h,t+1}\pi_{t+1}h_t^b \right\} \tag{A.6}$$

$$\chi_t \geq 0 \tag{A.7}$$

Complementary slackness condition

$$\left(l_t^b - m\mathbb{E}_t\left\{p_{h,t+1}\pi_{t+1}h_t^b\right\}\right)\chi_t = 0 \tag{A.8}$$

Consumption-leisure choice

$$(n_t^s)^\varphi = \lambda_t^s w_t \tag{A.9}$$

$$(n_t^b)^\varphi = \lambda_t^b w_t \tag{A.10}$$

Optimal financial decisions by households

$$\lambda_t^s = \beta\mathbb{E}_t\left\{\lambda_{t+1}^s\frac{R_t}{\pi_{t+1}}\right\} \tag{A.11}$$

$$\lambda_t^b = \beta^b\mathbb{E}_t\left\{\lambda_{t+1}^b\frac{R_{L,t}}{\pi_{t+1}}\right\} + \chi_t \tag{A.12}$$

Housing demand

$$h_t^s = h^s \tag{A.13}$$

$$\lambda_t^b p_{h,t} = \frac{a_h}{h_t^b} + \beta^b(1-\delta_h)\mathbb{E}_t\left\{\lambda_{t+1}^b p_{h,t+1}\right\} + m_t\chi_t\mathbb{E}_t\left\{p_{h,t+1}\pi_{t+1}\right\} \tag{A.14}$$

Dividends

$$(1-\omega_b)div_t = p_{H,t}y_{H,t} + s_t p_{H,t}^* y_{H,t}^* - w_t\left[\omega_b n_t^b + (1-\omega_b)n_t^s\right] + (p_{F,t} - s_t)y_{F,t} + div_t^b \tag{A.15}$$

A.2.2 Financial intermediaries

Value of lending

$$V_{L,t} = \beta^s\mathbb{E}_t\left\{\frac{\lambda_{t+1}^s}{\lambda_t^s}\Omega_{t+1}\frac{R_t^b - R_t}{\pi_{t+1}}\right\} \tag{A.16}$$

Value of bond holdings

$$V_{B,t} = \beta^s\mathbb{E}_t\left\{\frac{\lambda_{t+1}^s}{\lambda_t^s}\Omega_{t+1}\frac{\frac{P_{L,t+1}}{P_{L,t}}R_{L,t+1} - R_t}{\pi_{t+1}}\right\} \tag{A.17}$$

Value of net worth

$$V_{N,t} = \beta^s\mathbb{E}_t\left\{\frac{\lambda_{t+1}^s}{\lambda_t^s}\Omega_{t+1}\frac{R_t}{\pi_{t+1}}\right\} \tag{A.18}$$

Binding incentive compatibility constraint

$$V_{L,t}l_t + V_{B,t}P_{L,t}b_{L,t} + V_{N,t}n_t = \varpi^L l_t + \varpi^B b_{L,t} \tag{A.19}$$

Marginal value of net worth

$$\Omega_t = (1-\vartheta) + \vartheta \left(V_{L,t}\frac{l_t}{n_t} + V_{B,t}\frac{P_{L,t}b_{L,t}}{n_t} + V_{N,t} \right)$$

Optimal asset portfolio

$$\frac{V_{L,t}}{\theta^L} = \frac{V_{B,t}}{\theta^B}$$

Net worth in the banking sector

$$n_t = \vartheta \left(\frac{R^b_{t-1}}{\pi_t} l_{t-1} + \frac{P_{L,t}}{P_{L,t-1}} \frac{R_{L,t}}{\pi_t} P_{L,t} b_{L,t-1} + \frac{R_{t-1}}{\pi_t} b_{t-1} - \frac{R_{t-1}}{\pi_t} d_{t-1} \right) + x$$

Net transfers to savers

$$div^b_t = (1-\vartheta) \left(\frac{R^b_{t-1}}{\pi_t} l_{t-1} + \frac{P_{L,t}}{P_{L,t-1}} \frac{R_{L,t}}{\pi_t} P_{L,t} b_{L,t-1} + \frac{R_{t-1}}{\pi_t} b_{t-1} - \frac{R_{t-1}}{\pi_t} d_{t-1} \right) - x$$

A.2.3 Firms

Final goods basket

$$\tilde{y}_t = \left[\eta^{\frac{1}{\nu}} (y_{H,t})^{\frac{\nu-1}{\nu}} + (1-\eta)^{\frac{1}{\nu}} (y_{F,t})^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \tag{A.20}$$

Optimal composition of final goods basket

$$y_{H,t} = \eta (p_{H,t})^{-\nu} \tilde{y}_t \tag{A.21}$$

$$y_{F,t} = (1-\eta)(p_{F,t})^{-\nu} \tilde{y}_t \tag{A.22}$$

Export demand

$$y^*_{H,t} = \eta^* \left(p^*_{H,t}\right)^{-\nu^*} y^*_t \tag{A.23}$$

Real price indices

$$p_{H,t}^{\frac{1}{1-\mu}} = \theta_H \left(p_{H,t-1}\frac{\pi}{\pi_t} \right)^{\frac{1}{1-\mu}} + (1-\theta_H)(\tilde{p}_{H,t})^{\frac{1}{1-\mu}} \tag{A.24}$$

$$p_{F,t}^{\frac{1}{1-\mu}} = \theta_F \left(p_{F,t-1}\frac{\pi}{\pi_t} \right)^{\frac{1}{1-\mu}} + (1-\theta_F)(\tilde{p}_{F,t})^{\frac{1}{1-\mu}} \tag{A.25}$$

$$p_{H,t}^{*\frac{1}{1-\mu}} = \theta^*_H \left(p^*_{H,t-1}\frac{\pi^*}{\pi^*_t} \right)^{\frac{1}{1-\mu}} + (1-\theta^*_H)\left(\tilde{p}^*_{H,t}\right)^{\frac{1}{1-\mu}} \tag{A.26}$$

Optimal reset prices

$$\tilde{p}_{H,t} = \mu \frac{\Omega_{H,t}}{\Upsilon_{H,t}} \tag{A.27}$$

$$\Omega_{H,t} = \lambda_t^s w_t p_{H,t}^{\frac{\mu}{\mu-1}} y_{H,t} + \beta\theta_H \mathbb{E}_t \left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{\mu}{1-\mu}} \Omega_{H,t+1} \tag{A.28}$$

$$\Upsilon_{H,t} = \lambda_t^s p_{H,t}^{\frac{\mu}{\mu-1}} y_{H,t} + \beta\theta_H \mathbb{E}_t \left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{1}{1-\mu}} \Upsilon_{H,t+1} \tag{A.29}$$

$$\tilde{p}_{F,t} = \mu \frac{\Omega_{F,t}}{\Upsilon_{F,t}} \tag{A.30}$$

$$\Omega_{F,t} = \lambda_t^s s_t p_{F,t}^{\frac{\mu}{\mu-1}} y_{F,t} + \beta\theta_F \mathbb{E}_t \left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{\mu}{1-\mu}} \Omega_{F,t+1} \tag{A.31}$$

$$\Upsilon_{F,t} = \lambda_t^s p_{F,t}^{\frac{\mu}{\mu-1}} y_{F,t} + \beta\theta_F \mathbb{E}_t \left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{1}{1-\mu}} \Upsilon_{F,t+1} \tag{A.32}$$

$$\tilde{p}^*_{H,t} = \mu \frac{\Omega^*_{H,t}}{\Upsilon^*_{H,t}} \tag{A.33}$$

$$\Omega^*_{H,t} = \lambda_t^s w_t p_{H,t}^{*\frac{\mu}{\mu-1}} y^*_{H,t} + \beta^*\theta^*_H \mathbb{E}_t \left(\frac{\pi^*}{\pi^*_{t+1}}\right)^{\frac{\mu}{1-\mu}} \Omega^*_{H,t+1} \tag{A.34}$$

$$\Upsilon^*_{H,t} = \lambda_t^s s_t p_{H,t}^{*\frac{\mu}{\mu-1}} y^*_{H,t} + \beta^*\theta^*_H \mathbb{E}_t \left(\frac{\pi^*}{\pi^*_{t+1}}\right)^{\frac{1}{1-\mu}} \Upsilon^*_{H,t+1} \tag{A.35}$$

A.2.4 Government

Monetary policy rule

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{y_t}{y}\right)^{\gamma_y}\right]^{1-\gamma_r} \tag{A.36}$$

Consolidated government budget constraint

$$\begin{aligned} & b_t^g + b_t^m + P_{L,t} b_{L,t}^g - s_t P^*_{L,t} f_{L,t} + t_t + \tau_t P_{L,t} \frac{R_{L,t}}{\pi_t} b^*_{L,t-1} \\ = & \frac{R_{t-1}}{\pi_t} (b_{t-1}^g + b_{t-1}^m) + P_{L,t} \frac{R_{L,t}}{\pi_t} b_{L,t-1}^g - s_t P^*_{L,t} \frac{R^*_{L,t}}{\pi^*_t} f_{L,t-1} + g \end{aligned} \tag{A.37}$$

Total government debt

$$b_t^g + P_{L,t} b_{L,t}^g = b^g + P_L b_L^g \tag{A.38}$$

$$t_t = g + \Phi \left(\frac{P_{L,t-1} b_{L,t-1}^g}{P_L b_L^g}\right)^{\gamma_b} \tag{A.39}$$

Supply of short-term government bonds

$$b_t^g = b^g \tag{A.40}$$

Central bank balance sheet

$$b_t^m = s_t P_{L,t}^* f_{L,t} \tag{A.41}$$

A.2.5 Aggregation and market clearing

Housing market clearing

$$h = \omega_b h_t^b + (1-\omega_b) h_t^s \tag{A.42}$$

Credit market clearing

$$l_t = \omega_b l_t^b \tag{A.43}$$

Goods market clearing

$$\tilde{y}_t = \omega_b c_t^b + (1-\omega_b) c_t^s + g_t \tag{A.44}$$

Aggregate production function

$$y_{H,t}\Delta_{H,t} + y_{H,t}^*\Delta_{H,t}^* = \omega_b n_t^b + (1-\omega_b) n_t^s - \phi_t \tag{A.45}$$

Aggregate output

$$y_t = y_{H,t}\Delta_{H,t} + y_{H,t}^*\Delta_{H,t}^* \tag{A.46}$$

Price dispersion

$$\Delta_{H,t} = \left(\frac{p_{H,t}}{p_{H,t-1}}\right)^{\frac{\mu}{\mu-1}} \theta_H \Delta_{H,t-1} \left(\frac{\pi}{\pi_t}\right)^{\frac{\mu}{1-\mu}} + (1-\theta_H)\left(\frac{\tilde{p}_{H,t}}{p_{H,t}}\right)^{\frac{\mu}{1-\mu}} \tag{A.47}$$

$$\Delta_{H,t}^* = \left(\frac{p_{H,t}^*}{p_{H,t-1}^*}\right)^{\frac{\mu}{\mu-1}} \theta_H^* \Delta_{H,t-1}^* \left(\frac{\pi^*}{\pi_t^*}\right)^{\frac{\mu}{1-\mu}} + (1-\theta_H^*)\left(\frac{\tilde{p}_{H,t}^*}{p_{H,t}^*}\right)^{\frac{\mu}{1-\mu}} \tag{A.48}$$

Bond market clearing

$$b_t = b_t^g + b_t^m \tag{A.49}$$

$$b_{L,t} + b_{L,t}^* = b_{L,t}^g \tag{A.50}$$

Net foreign debt

$$P_{L,t} b_{L,t}^* - s_t P_{L,t}^* f_{L,t} = (1-\tau_t) P_{L,t} \frac{R_{L,t}}{\pi_t} b_{L,t-1}^* - s_t P_{L,t}^* \frac{R_{L,t}^*}{\pi_t^*} f_{L,t-1} + p_F y_F - s_t p_{H,t}^* y_{H,t}^* \tag{A.51}$$

Foreign demand for home long-term bonds

$$\mathbb{E}_t\left\{\lambda_{t+1}^*(1-\tau_{t+1})\frac{R_{L,t+1}}{\pi_{t+1}}\frac{P_{L,t+1}}{P_{L,t}}\frac{S_t}{S_{t+1}}\right\} = \mathbb{E}_t\left\{\lambda_{t+1}^*\frac{R_{L,t+1}^*}{\pi_{t+1}^*}\frac{P_{L,t+1}^*}{P_{L,t}^*}\right\} \tag{A.52}$$

A.3 Equilibrium conditions - large economy

The following equations describe the equilibrium in the large economy. The single exogenous force driving it are shocks to the composition of consolidated government debt ε_t^{L*}. Lower case letters for variables defined in the main text indicate their real counterparts. Superscripts u and r indicate unrestricted and restricted households, respectively. The former can trade both long-term bonds (subject to transaction costs) and short-term bonds, while asset holdings by the latter is restricted to long-term bonds. See Chen et al. (2012) for details and more discussion of this type of (internal) asset market segmentation.

A.3.1 Households

Marginal utility

$$\lambda_t^{r*} = (c_t^{r*})^{-\sigma^*} \tag{A.53}$$

$$\lambda_t^{u*} = (c_t^{u*})^{-\sigma^*} \tag{A.54}$$

$$\lambda_t^{*} = \omega_r^* \lambda_t^{r*} + (1-\omega_r^*)\lambda_t^{u*} \tag{A.55}$$

Bond prices

$$P_{L,t}^* = \frac{1}{R_{L,t}^* - \kappa^*} \tag{A.56}$$

Households' budget constraints

$$c_t^{r*} + P_{L,t}^* b_{L,t}^{r*} + t_t^* = P_{L,t}^* \frac{R_{L,t}^*}{\pi_t^*} b_{L,t-1}^{r*} + w_t^* n_t^{r*} + d_t^* \tag{A.57}$$

$$c_t^{u*} + b_t^{u*} + P_{L,t}^* b_{L,t}^{u*} + t_t^* = \frac{R_{t-1}^*}{\pi_t^*} b_{t-1}^{u*} + P_{L,t}^* \frac{R_{L,t}^*}{\pi_t^*} b_{L,t-1}^{u*} + w_t^* n_t^{u*} + d_t^* \tag{A.58}$$

Consumption-leisure choice

$$(n_t^{r*})^{\varphi*} = \lambda_t^{r*} w_t^* \tag{A.59}$$

$$(n_t^{u*})^{\varphi*} = \lambda_t^{u*} w_t^* \tag{A.60}$$

Optimal bond holdings

$$\lambda_t^{r*} P_{L,t}^* = \beta^{r*} \mathbb{E}_t \left\{ \lambda_{t+1}^{r*} P_{L,t+1}^* \frac{R_{L,t+1}^*}{\pi_{t+1}^*} \right\} \tag{A.61}$$

$$\lambda_t^{u*} = \beta^{u*} \mathbb{E}_t \left\{ \lambda_{t+1}^{u*} \frac{R_t^*}{\pi_{t+1}^*} \right\} \tag{A.62}$$

$$\lambda_t^{u*}(1+\zeta_t^*) P_{L,t}^* = \beta^{u*} \mathbb{E}_t \left\{ \lambda_{t+1}^{u*} P_{L,t+1}^* \frac{R_{L,t+1}^*}{\pi_{t+1}^*} \right\} \tag{A.63}$$

Transaction costs

$$\frac{1+\zeta_t^*}{1+\zeta^*} = \left(\frac{P_{L,t}^* b_{L,t}^{u*}}{P_L^* b_L^{u*}} \right)^{\xi^*} \tag{A.64}$$

A.3.2 Firms

Real price index

$$1 = \theta^* \left(\frac{\pi^*}{\pi_t^*}\right)^{\frac{1}{1-\mu^*}} + (1-\theta^*)\left(\tilde{p}_t^*\right)^{\frac{1}{1-\mu^*}} \tag{A.65}$$

Optimal reset prices

$$\tilde{p}_t^* = \mu^* \frac{\Omega_t^*}{\Upsilon_t^*} \tag{A.66}$$

$$\Omega_t^* = \lambda_t^* \frac{w_t^*}{\exp\{\varepsilon_t^{z*}\}} y_t^* + \beta^* \theta^* \mathbb{E}_t \left(\frac{\pi^*}{\pi_{t+1}^*}\right)^{\frac{\mu^*}{1-\mu^*}} \Omega_{t+1}^* \tag{A.67}$$

$$\Upsilon_t^* = \lambda_t^* y_t^* + \beta^* \theta^* \mathbb{E}_t \left(\frac{\pi^*}{\pi_{t+1}^*}\right)^{\frac{1}{1-\mu^*}} \Upsilon_{t+1}^* \tag{A.68}$$

Dividends

$$d_t^* = y_{F,t}^* - w_t^* \left[\omega_r^* n_t^{r*} + (1-\omega_r^*) n_t^{u*}\right] \tag{A.69}$$

A.3.3 Government

Monetary policy rule

$$\frac{R_t^*}{R^*} = \left(\frac{R_{t-1}^*}{R^*}\right)^{\gamma_r^*} \left[\left(\frac{\pi_t^*}{\pi^*}\right)^{\gamma_\pi^*} \left(\frac{y_t^*}{y^*}\right)^{\gamma_y^*}\right]^{1-\gamma_r^*} \tag{A.70}$$

Government budget constraint

$$b_t^{g*} + P_{L,t}^* b_{L,t}^{g*} + t_t^* = \frac{R_{t-1}^*}{\pi_t^*} b_{t-1}^{g*} + P_{L,t}^* \frac{R_{L,t}^*}{\pi_t^*} b_{L,t-1}^{g*} + g^* \tag{A.71}$$

Total government debt

$$b_t^{g*} + P_{L,t}^* b_{L,t}^{g*} = b^{g*} + P_L^* b_L^{g*} \tag{A.72}$$

Composition of government debt

$$\frac{P_{L,t}^* b_{L,t}^{g*}}{P_L^* b_L^{g*}} = \exp\{\varepsilon_t^{L*}\} \tag{A.73}$$

A.3.4 Aggregation and market clearing

Goods market clearing

$$y_t^* = \omega_r^* c_t^{r*} + (1-\omega_r^*) c_t^{u*} + g_t^* \tag{A.74}$$

Aggregate production function

$$\Delta_t^* y_t^* = \omega_r^* n_t^{r*} + (1-\omega_r^*) n_t^{u*} - \phi_t^* \tag{A.75}$$

Price dispersion

$$\Delta_t^* = \theta^* \Delta_{t-1}^* \left(\frac{\pi^*}{\pi_t^*} \right)^{\frac{\mu^*}{1-\mu^*}} + (1 - \theta^*) \left(\tilde{p}_t^* \right)^{\frac{\mu^*}{1-\mu^*}} \tag{A.76}$$

Bond market clearing

$$(1 - \omega_r^*) b_t^{u*} = b_t^{g*} \tag{A.77}$$

$$(1 - \omega_r^*) b_{L,t}^{u*} + \omega_r^* b_{L,t}^{r*} = b_{L,t}^{g*} \tag{A.78}$$

A.4 Large economy - calibration

The following table presents the calibrated parameter values in the large economy block.

Table A.8: Calibrated parameters - large economy block

Parameter	Value
Share of restricted households; ω_r^*	0.1
Inv. elasticity of intertemporal substitution; σ^*	2
Inv. Frisch elasticity of labor supply; φ^*	2
Discount factor, restricted households; β^{r*}	0.992
Discount factor, unrestricted households; β^{u*}	0.995
Coupon; κ^*	0.929
Transaction cost; ξ^*	0.015
Calvo probability; θ_F^*	0.8
Price markup; μ^*	1.15
Steady-state inflation; π^*	1.005
Interest rate smoothing; γ_r^*	0.9
Interest rate response to inflation; γ_π^*	2
Interest rate response to output gap; γ_y^*	0.125

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