Measuring the Effects of Large-Scale Asset Purchases: The Role of International Financial Markets and the Financial Accelerator

Sacha Gelfer* Christopher G. Gibbs†

Revised September 2022

Abstract

We build and estimate a two-country structural macroeconomic model with meaningful household portfolio decisions over foreign and domestic bond holdings and financial intermediation to investigate the efficacy of large-scale asset purchases (LSAP) by a central bank. Financial intermediation between financial assets and the real economy means that asset purchases do not directly lead to increased real investment. Instead, asset purchases result in an accumulation of deposits at banks without a corresponding rise in loans to the real economy. In contrast to conventional monetary policy (CMP), positive effects of asset purchases primarily work through consumption and exports via changes in real exchange rates. We find that this is in accordance with local projection analysis performed using identified LSAP and CMP shocks. Further, historical decomposition of US data reveals that unconventional monetary policies supported real economic activity when interest rates where zero (2009-2015), but not after. However, their effect on financial markets remained significant through 2019.

Keywords: Unconventional Monetary Policy, Quantitative Easing, International Bond Portfolio, DSGE, Financial accelerator
JEL: E44, E5, E52, E63, F41, F42

*Bentley University, Waltham, MA, USA. E-mail address: sgelfer@bentley.edu
†The University of Sydney, Camperdown, NSW. E-mail address: christopher.gibbs@sydney.edu.au

1 Introduction

The conduct of monetary policy in most advanced economies has changed substantially over the last twenty years. Starting with Japan in the late 1990's and followed by many advanced economies in the wake of the Global Financial Crisis (GFC), the effective zero lower bound on nominal interest rates has prevented central banks from implementing conventional monetary policy (CMP) through movements in short-term interest rates to manage inflation and output fluctuations. Instead, central banks have largely relied on forward guidance (FG) policies and large scale asset purchases (LSAP) policies, also known as quantitative easing.[1]

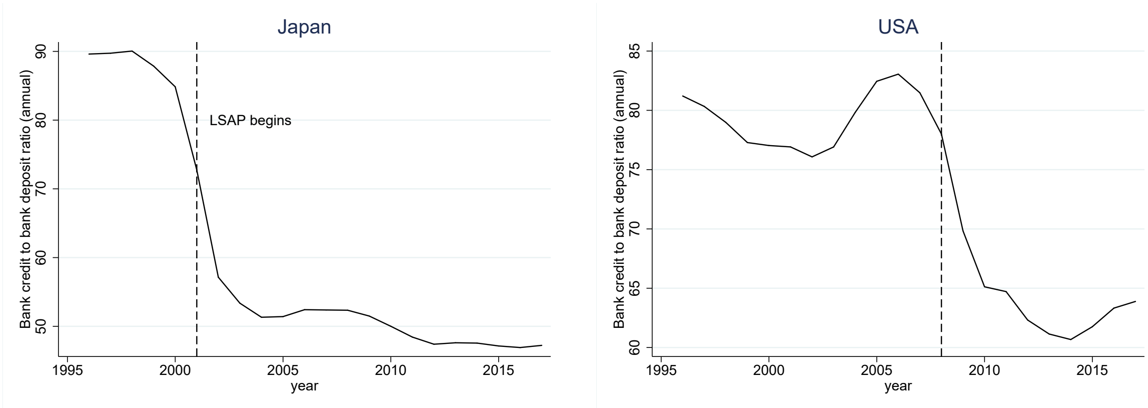
The onset of the global pandemic and its economic effects have put unconventional monetary policy tools front and center once again. However, the effectiveness of these two unconventional policies as a substitute for CMP is widely debated. To shed light on this important question, this paper builds and estimates a structural model and evaluates the macroeconomic and financial market effects of global conventional and unconventional monetary policies that have taken place over the last two decades.

Early theoretical work by Eggertsson and Woodford (2003), which predates most advanced economies hitting the effective zero lower bound, showed that in a standard New Keynesian framework, FG was a powerful tool to manage the economy whereas LSAPs are largely irrelevant. The intuition of their result is that at the effective zero lower bound a LSAP policy just alters the composition of the agent's portfolio without affecting output or inflation so long as the LSAP does not signal future monetary policy actions or does not actually alter the behavior of fiscal policy. Moreover, they argue that any direct real effects of portfolio rebalancing are likely small.

Evidence from financial studies such as Bowman et al. (2015), Rodnyansky and Darmouni (2017), and Chakraborty et al. (2020) largely support the irrelevance hypothesis finding changes to portfolio composition and increased bank reserves but little to no changes to real investment. In addition, proponents of the irrelevance hypothesis for LSAPs often point to the fact that deposits and reserves in banks throughout the world have increased substantially due to LSAP policies. Figure 1 shows data from the World Bank on bank credit to bank

[1] See Kuttner (2018) for an overview of the tools used since the global financial crisis.

Figure 1: Bank credit to bank deposit ratios



Notes: World Bank

deposits from all financial institutions that accept transferable deposits for the United States and Japan. The first adoption of an LSAP policy is indicated by the vertical lines. Following an LSAP policy, it does appear that money accumulates in the banking sector.

However, recent empirical papers focusing on macroeconomic data have shown a significant positive impact on the real economy due to LSAP policies. For example, Kolasa and Wesolowski (2020) and Sims and Wu (2021) show significant positive effects on output, inflation, bank lending and investment to LSAP policies and suggest that unconventional monetary policy is a close substitute for conventional monetary policy.[2] In this paper, we build and estimate a model that bridges the gap between these two conflicting results.

We put forward a quantitative open-economy macroeconomic model that includes long and short-term domestic and foreign debt. The model's basic structure follows Alpanda and Kabaca (2020), which we modify to include financial frictions in the form of a micro-founded financial accelerator following Del Negro et al. (2013) and Gelfer (2019). The model features two regions - the United States and a composite region of seven major economies including the European Union - that allows us to capture international spillovers in terms of economic shocks, exchange rate and trade effects, and unilateral or coordinated global unconventional monetary policy.

The estimated model succeeds at reconciling the evidence for the irrelevance results with

[2]See Papadamou et al. (2020) and Fabo et al. (2021) for a complete review of the empirical unconventional monetary policy literature.

those findings of large macroeconomic effects of LSAP policies with trade and the financial accelerator playing key roles. LSAPs increase output, consumption, and inflation, while having modest or no effect on real investment. We find that LSAP policy stimulates the economy largely through trade. Purchases of long-term debt decrease long-term bond yields and depreciate the domestic currency, increasing net exports and domestic consumption. The effect on aggregate investment though is negative away from the effective zero lower bound because it puts upward pressure on short-term rates. This occurs because LSAPs increase inflation, which necessitates a rise in the policy rate. When interest rates are constrained by the effective zero lower bound, however, investment responds positively after a LSAP.

Conventional monetary policy (CMP) in the model produces the standard positive effect on output, consumption, the exchange rate, and a large effect on investment. The difference in the response of investment between CMP and LSAPs is due to the financial accelerator. In its absence, LSAPs result directly in investment in new capital. In its presence, the investment decision is moderated through entrepreneurs' net worth and the interest rate at which they can borrow. Away from the zero lower bound, an LSAP policy increases short-term rates, which moderates any positive effect on net worth and raises borrowing costs leading to a slight fall in investment. At the zero lower bound, the rate at which entrepreneurs borrow to invest is unaffected by the policy because *of* the zero lower bound, leaving any change in investment to operate through changes in net worth, which are estimated to be small. Importantly, the model distinguishes between LSAPs and FG policy, the latter of which is key for generating large movements in net worth. Therefore, through the modeled financial accelerator, LSAPs cause money to pile up in banks while CMP does not. This is consistent with Figure 1.

Without a strong investment channel to LSAP policies, the transmission mechanism is largely through trade. LSAPs cause global portfolio rebalancing that leads to a depreciation of the home country's currency increasing net exports and consumption of domestically produced goods. The policy therefore takes on a beggar-thy-neighbor aspect, where domestic activity is supported at the expense of the rest of the world. This too is in contrast to CMP, where the policy stimulates aggregate demand in general leading to higher demand for all goods and services with only small offsetting effects on the terms of trade. This finding is relevant to policymakers since most advanced economies were constrained by the zero lower bound at the same time in the 2010s, which lead many central banks to employs LSAP policies contemporaneously.

To assess the external validity of the model's differing mechanisms for LSAPs and CMP, we follow Jorda (2005) and use local projection estimates of the impulse responses to CMP and LSAP shocks. To identify the different types of monetary policies in the data, we use the monetary policy shocks estimated by Swanson (2021). Swanson extracts three orthogonal shocks that capture conventional monetary policy, LSAPs, and forward guidance. The local projection results align with structural model's prediction for the policy and trade variables of interest. Expansionary LSAP shocks lead to an increase in the short-term interest rate, a depreciation of the exchange rate, and a small rise in net exports. Expansionary CMP shocks predict the opposite. There is a decrease in the short-term interest rate, an appreciation of the exchange rate, and a slight fall in net exports.

Finally, we use the estimated model to investigate how LSAP policies perform across two margins that have become increasingly important following the global pandemic: the degree financial integration and openness to trade and the coordination of LSAP policy interventions. The global pandemic has caused many countries to rethink their reliance on global supply chains and political turmoil has led to a retrenchment in global financial openness.[3] We show that LSAPs are most effective at stimulating output when the share of global connectivity in traded goods and bonds is high. In contrast, CMP is most effective when the share of global connectivity in goods and bonds is low.

We find that when unconventional monetary policy is globally coordinated, the effects of output and inflation are muted compared to when policy is conducted unilaterally. However, the effect on investment is increased when policy is coordinated. This is contrary to globally coordinated CMP shocks where the output effect is magnified compared to domestic unilateral CMP. This is because domestic CMP has a much smaller effect on the real exchange rate and net exports than does a domestic LSAP purchase, so the loss in net exports that occurs when monetary policy is coordinated is much smaller for CMP.

[3]For example, the war in Ukraine has led to large financial sanctions affecting many countries' access to capital.

Related Literature. There is a growing literature that assesses the effects of unconventional monetary policy in structural models such as Chen et al. (2012), Gertler and Karadi (2013), Carlstrom et al. (2017), Hohberger et al. (2019), Kolasa and Wesolowski (2020) and Sims and Wu (2021). We extend the analysis in these earlier works in two important ways. First, we conduct the policy analysis in an open-economy model. This is warranted given the empirical evidence that unconventional monetary policy can have significant effects on foreign exchange rates (see Rogers et al. (2018), Glick and Leduc (2018) and Inoue and Rossi (2019)) and create significant international economic spillovers (see Neely (2015), Fratzscher et al. (2018), and Alpanda and Kabaca (2020)). Second, we conduct the policy analysis on an estimated model that uses real-world data on global equity markets, global bond markets, global government bond supply and global private bond holdings. This allows us to address the importance that past policy intervention has had on the real economy and financial markets for both the US and the rest of the world.

The remainder of the paper is organized as follows. Section 2 describes our structural model. Section 3 describes the data used to estimate and calibrate the model along with the prior and posterior estimates of the model. Section 4 compares the dynamics associated with conventional and unconventional monetary policy interventions. It also presents the local projection estimates of the impact of monetary policy, which we use as an external validity check. Section 5 conducts historical decompositions using the model to assess the relative contribution of LSAP policies to the evolution of macroeconomic and financial data. Section 6 studies how LSAP policy changes when trade and financial openness is varied as well as when policy is conducted unilaterally or coordinated globally. Section 7 concludes and offers thoughts on future extensions.

2 Model

In this section, we augment a two-country, open-economy DSGE model that includes rigidities and portfolio balance effects developed by Alpanda and Kabaca (2020) with a private credit market and financial accelerator along the lines of Bernanke, Gertler and Gilchrist (1999), Christensen and Dib (2008) and Del Negro et al. (2013). Each country in the model includes households, financial intermediaries, entrepreneurs, capital producers, intermediate and wholesale domestic firms, importers, as well as fiscal and monetary policy rules.

The model features various nominal and real rigidities including domestic price, import price and wage stickiness, indexation of prices and wages, habit formation in consumption, adjustment costs in investment, and costs of capital utilization. These features are included in standard closed and open-economy New-Keynesian DSGE models (Smets and Wouters, (2003, 2007), Adolfson et al., (2007) Justiniano and Preston, (2010)). In addition, the model incorporates financial frictions with the inclusion of financial intermediaries that allocate household deposits in the form of risky loans to entrepreneurs who rent and purchase capital to domestic good producers and capital producers. Shocks to the financial sector are assumed to be correlated across countries. Household in each country can hold domestic and foreign government bonds of both short and long-term duration subject to imperfect substitutability among the four types of risk-free bonds. The international bond portfolios held by households provides a channel for us to discuss the impact of synchronized global monetary policy.

We focus our discussion on the households' optimization problem, the financial sector, fiscal and monetary policy, and the trade aspects of the model. These features are important for understanding the transmission of CMP and LSAPs. The description of the more standard features of the model, such as production and employment, are relegated to Appendix A1. We describe the agents in the domestic economy below, but the foreign economy is analogous in our set-up. When variables from the foreign economy are introduced, we denote them with an $(^*)$ superscript.

2.1 Households

Households supply household-specific labor to employment agencies. Households maximize a CRRA utility function over an infinite horizon with additively separable utility in consumption, assets, deposits and leisure. Households are subject to an exogenous preference shock that can be viewed as a shock in the consumer's consumption and saving decisions. In addition, households are subject to bond demand shocks that alter their preference for domestic to foreign bond ratio and short to long-term bond duration ratio.

There is a continuum of households indexed by j. The objective function for household j is given by:

$$E_t \sum_{s=0}^{\infty} \beta^s \left[e_{b,t+s}\, log(c_{t+s}(j) - hc_{t+s-1}) + \xi_a log(a_{t+s}(j)) + \xi_d log(dep_{t+s}(j)) - \frac{\xi_L (L_{t+s}(j))^{1+\nu_l}}{1+\nu_l} \right] \quad (1)$$

where $c_t(j)$ is real consumption, $a_t(j)$ is the bond portfolio, $dep_t(j)$ are real deposits held with the financial intermediary and $L_t(j)$ is supply of a household differentiated type of labor. β is the time discount parameter, h is an identical parameter across households that captures consumption persistence and ξ_a, ξ_d, and ξ_L are parameters that determine the relative importance of the bond portfolio, liquid deposits and labor in the utility function, respectively. All parameters not indexed by j are assumed to be identical across all households. Households face a stochastic shock $e_{b,t}$ that can be viewed as a utility preference shock for consumption goods.

As in Alpanda and Kabaca (2020) we assume imperfect substitution inside the asset portfolio for government bonds in order to capture the liquidity benefits generated by these assets, as well as financial institutions' portfolio preferences across the different types of government bonds. We impose imperfect substitution over different maturities and currencies using a nested CES structure. The bond portfolio in the utility function, a_t, is a CES aggregate of consisting of short-term government bonds, $a_{S,t}$, and long-term government bonds, $a_{L,t}$:

$$a_t(j) = \left[\gamma_{a,t}^{\frac{1}{\lambda_a}} a_{S,t}(j)^{\frac{\lambda_a - 1}{\lambda_a}} + (1-\gamma_{a,t})^{\frac{1}{\lambda_a}} a_{L,t}(j)^{\frac{\lambda_a - 1}{\lambda_a}} \right]^{\frac{\lambda_a}{\lambda_a - 1}} \quad (2)$$

where $\gamma_{a,t}$ determines the share of short-term bonds in the aggregate portfolio, and λ_a is the elasticity of substitution between short and long-term bonds. $\gamma_{a,t}$ is an exogenous process, centered around γ_a, and can be thought of as a preference demand shock for short term bonds.

In addition to duration diversification, the bond portfolio is also subject to a subportfolio for short-term domestic bonds, $B_{H,S,t}$ and foreign bonds, $B_{F,S,t}$. The CES aggregator for this subportfolio is given by:

$$a_{S,t}(j) = \left[\gamma_{S,t}^{\frac{1}{\lambda_S}} \left(\frac{B_{H,S,t}(j)}{P_t} \right)^{\frac{\lambda_S - 1}{\lambda_S}} + (1 - \gamma_{S,t})^{\frac{1}{\lambda_S}} \left(\frac{e_t B_{F,S,t}(j)}{P_t} \right)^{\frac{\lambda_S - 1}{\lambda_S}} \right]^{\frac{\lambda_S}{\lambda_S - 1}} \tag{3}$$

where $\gamma_{S,t}$ determines the share of short-term domestic bonds in the subaggregate portfolio, and λ_s is the elasticity of substitution between domestic and foreign short-term bonds. $\gamma_{S,t}$ is an exogenous process, centered around γ_S, and can be thought of as a preference demand shock for domestic short term bonds relative to foreign short-term bonds. P_t is the aggregate price level and e_t is the nominal exchange rate in terms of domestic currency per unit of foreign currency.

The long-term subportfolio is subject to a similar CES set-up between long-term domestic government bonds, $q_{L,t}B_{H,L,t}$ and long-term foreign government bonds, $q_L^* B_{F,L,t}$.

$$a_{L,t}(j) = \left[\gamma_{L,t}^{\frac{1}{\lambda_L}} \left(\frac{q_{L,t} B_{H,L,t}(j)}{P_t} \right)^{\frac{\lambda_L - 1}{\lambda_L}} + (1 - \gamma_{L,t})^{\frac{1}{\lambda_L}} \left(\frac{e_t q_{L,t}^* B_{F,L,t}(j)}{P_t} \right)^{\frac{\lambda_L - 1}{\lambda_L}} \right]^{\frac{\lambda_L}{\lambda_L - 1}} \tag{4}$$

where $\gamma_{L,t}$ and λ_L govern the share of domestic bonds in the subportfolio and the elasticity of substitution between domestic and foreign long-term bonds. $q_{L,t}$ is the relative price for domestic long-term bonds and along with κ determines the long-term yield[4] , $R_{L,t}$.

$$R_{L,t} = \frac{1}{q_{L,t}} + \kappa \tag{5}$$

Household j's budget constraint is:

$$\begin{aligned} c_t(j) + \frac{Dep_t(j)}{P_t} + \frac{B_{H,S,t}(j)}{P_t} + \frac{e_t B_{F,S,t}(j)}{P_t} + \frac{q_{L,t} B_{H,L,t}(j)}{P_t} + \frac{e_t q_{L,t}^* B_{F,L,t}(j)}{P_t} \leq \frac{W_t(j)}{P_t} L_t(j) + \\ \frac{R_{t-1}^D Dep_{t-1}(j)}{P_t} + \frac{R_{t-1} B_{H,S,t-1}(j)}{P_t} + \frac{e_t R_{t-1}^* B_{F,S,t-1}(j)}{P_t} + \frac{R_{L,t} q_{L,t} B_{H,L,t-1}(j)}{P_t} + \\ \frac{e_t R_{L,t}^* q_{L,t}^* B_{F,L,t-1}(j)}{P_t} + \frac{\Pi_{H,t}}{P_t} + \frac{\Pi_{F,t}}{P_t} - \frac{Tax_t}{P_t} + Tr_t - \frac{\kappa_w}{2} \left(\frac{W_t(j)/W_{t-1}(j)}{\pi_{t-1}^{\iota_w} \pi^{1-\iota_w}} - 1 \right)^2 \frac{W_t}{P_t} L_t \end{aligned} \tag{6}$$

[4]As in Woodford (2001), long-term bonds are modeled as perpetuities that pay a coupon payment of 1 unit in the first period after issuance, and their coupon payments decay by a factor of κ in each period after.

where $Dep_t(j)$ is the amount of nominal deposits held with the financial institution, R_t is the nominal interest rate on short-run bonds, R_t^D is the nominal interest rate financial intermediaries pay on deposits, Π_{H_t} and Π_{F_t} are the profit households get from owning the intermediate domestic firms and importers, $W_t(j)$ is the nominal wage earned, Tax_t are lump sum taxes payed to the government and Tr_t are wealth transfers to/from the entrepreneurial agents. Households supply market power heterogeneous labor services $L_t(j)$ and face quadratic adjustment costs when changing nominal wages, Rotemberg (1982). κ_w is an adjustment cost parameter, π is inflation and ι_w determines the degree of indexation of wage adjustments to past inflation. Household j chooses $\{c_t(j), dep_t(j), b_{H,S,t}(j), b_{H,L,t}(j), b_{F,S,t}(j), b_{F,L,t}(j), W_t(j), L_t(j)\}_{t=0}^{\infty}$ that maximize expected utility (1) subject to the household budget constraint.

The first order conditions for consumption, bank deposits, real short-term and long-term bonds foretell the interaction between unconventional monetary policy and aggregate demand.

$$\lambda_t = \frac{e_{b,t}}{c_t - hc_{t-1}} \tag{7}$$

(8)

$$\lambda_t = \beta E_t \left[\frac{R_t^D \lambda_{t+1}}{\pi_{t+1}} \right] + \frac{\xi_d}{dep_t} \tag{9}$$

(10)

$$\lambda_t = \beta E_t \left[\frac{R_t \lambda_{t+1}}{\pi_{t+1}} \right] + \frac{\xi_a}{a_t} \frac{\partial a_t}{\partial a_{S,t}} \frac{\partial a_{S,t}}{\partial b_{H,S,t}} \tag{11}$$

(12)

$$q_{L,t}\lambda_t = \beta E_t \left[\frac{R_{L,t+1} q_{L,t+1} \lambda_{t+1}}{\pi_{t+1}} \right] + \frac{\xi_a}{a_t} \frac{\partial a_t}{\partial a_{L,t}} \frac{\partial a_{L,t}}{\partial b_{H,L,t}} \tag{13}$$

Large-scale asset purchases of domestic long-term bonds by the monetary authority will alter marginal utility even if short-run interest rates remain constant. The change in marginal utility will directly effect consumption demand, labor supply, and loan supply (bank deposits). Further, the first order conditions for domestic and foreign short-term bonds and domestic and foreign long-term bonds can be combined respectively and log linearized to produce a short-term and long-term uncovered interest rate parity (UIP) condition.

$$\hat{R}_t - \hat{R}_t^* = E_t \hat{d}_{t+1} + \left(\frac{\pi}{\beta R} - 1 \right) \frac{1}{\lambda_s} \left[\hat{b}_{H,S,t} - (\hat{rer}_t + \hat{b}_{F,S,t}) - \frac{1}{1-\gamma_S} \hat{\gamma}_{S,t} \right] \tag{14}$$

$$\hat{R}_{L,t} - \hat{R}^*_{L,t} = \frac{\kappa}{R_L}\left(E_t[\hat{R}_{L,t+1}] - E_t[\hat{R}^*_{L,t+1}]\right) + \left(1 - \frac{\kappa}{R_L}\right)\Big\{E_t\hat{d}_{t+1} + \left(\frac{\pi}{\beta R} - 1\right)\frac{1}{\lambda_L}\left[\hat{q}_{L,t} + \hat{b}_{H,L,t} - (r\hat{e}r_t + \hat{q}^*_{L,t} + \hat{b}_{F,L,t}) - \frac{1}{1-\gamma_L}\hat{\gamma}_{L,t}\right]\Big\} \tag{15}$$

The two UIP conditions demonstrate additional aggregate demand effects of unconventional monetary policy by directly impacting the real exchange rate and thus, net export demand. In the above equations $r\hat{e}r_t$ is the real exchange rate ($r\hat{e}r_t = \hat{e}_t\hat{P}^*_t/\hat{P}_t$) and $\hat{d}_t$ is the the nominal depreciation of the domestic currency ($\hat{d}_t = \hat{e}_t - \hat{e}_{t-1}$). It is clear by the short-term UIP condition that unconventional monetary policy affects the current and expected exchange rate even if the interest rate differential between the two areas does not change. The degree of this change will depend on the substitutability of domestic and foreign short-run bonds, λ_s.

The effect of domestic unconventional monetary policy in regards to the long-term UIP condition is ambiguous. Its direction and magnitude depends on the long-term interest rate differential that will occur after large-scale asset purchases. This differential will heavily depend on the estimates of λ_a and λ^*_a, as well as the the values of λ_L, γ_L and γ^*_L. The estimates of this paper for all these parameter imply that the long-term interest rate differential would decrease after a large-scale asset purchase and that the relative change would be smaller than the decrease in domestic long-term bonds held by the public; thus, the long-term UIP condition amplifies a current depreciation and future appreciation of the domestic currency.

2.2 Entrepreneurs and Financial Intermediaries

There exists a continuum of finite lived entrepreneurs indexed by e who are able to borrow from the perfectly competitive financial intermediary sector who obtain deposits from the households.[5] At the end of period $t-1$, entrepreneurs buy physical capital $Q_{t-1}\bar{K}_{t-1}$ using their own nominal net worth NW_{t-1} and a loan from the financial intermediary, $Loan_{t-1}$.

$$Q_{t-1}\bar{K}_{t-1}(e) = Loan_{t-1}(e) + NW_{t-1}(e) \tag{16}$$

[5] All interactions between entrepreneurs, intermediate firms and the financial intermediary are assumed to take placed in the closed-economy.

In period t the entrepreneur is then subject to a stochastic productivity shock $w_t(e)$ that increases or decreases the entrepreneur's physical capital stock. The productivity shock is drawn from the lognormal cumulative distribution $F(w)$ with mean $m_{w,t-1}$ and variance $\sigma^2_{w,t-1}$. The distribution is assumed to be known at $t-1$ and $m_{w,t-1}$ is such that $E[w_t(e)] = 1$. The standard deviation σ_w will follow an exogenous process and can be considered as a financing shock as it will either increase or decrease the riskiness of loans. Entrepreneurs then choose the optimal utilization rate u_t that maximizes their time t profit.

$$\max_{u_t(e)} \quad \left[R^k_t u_t(e) - P_t a(u_t(e))\right] w_t(e)\bar{K}_{t-1}(e) \tag{17}$$

where R^k_t is the rental rate of utilized capital paid by the intermediate firms and $a()$ is the cost of capital utilization payed in final good output, with $a(u) = 0$, $a'() > 0$ and $a''() > 0$.

Entrepreneurs at the end of period t sell the non-depreciated physical capital to the capital producers resulting in the following period t revenue for entrepreneur e:

$$w_t(e)\tilde{R}^k_t(e)Q_{t-1}\bar{K}_{t-1}(e) \tag{18}$$

where

$$\tilde{R}^k_t(e) = \frac{R^k_t u_t(e) + (1-\tau)Q_t - P_t a(u_t(e))}{Q_{t-1}} \tag{19}$$

Entrepreneurs and the financial intermediary agree upon a loan contract that consists of the size of the loan $Loan_t$, the interest rate of the loan R^c_t and the default threshold of the loan $\bar{w}_t$ below which entrepreneurs cannot pay back the loan and are obligated to turn over their time t revenues to the financial intermediary. However, the financial intermediary is only able to recover a $(1-\mu)$ fraction of the defaulted revenue due to bankruptcy costs.

$$\bar{w}_t(e)\tilde{R}^k_t Q_{t-1}\bar{K}_{t-1}(e) = R^c_t(e)Loan_{t-1}(e) \tag{20}$$

The financial intermediary only pays deposit holders an interest payment if the deposits are given in the form of a loan. The interest payment paid on deposits lent out is equal to the domestic risk free interest rate R_t. As a result the interest rate paid on deposits, R^D_t, is equal to:

$$R_t^D = ldr_t R_t + (1 - ldr_t) \tag{21}$$

where ldr_t is equal to the loans to deposit ratio ($Loans_t/Dep_t$). This creates a wedge between R_t and R_t^D dependent upon loan demand and deposit supply, both of which are impacted by conventional and unconventional monetary policy intervention.

The financial intermediary abides by a zero profit condition since they operate in a perfectly competitive environment given by:

$$\begin{aligned}[1 - F_{t-1}(\bar{w}_t(e))]R_t^c(e)Loan_{t-1}(e) + (1 - \mu)\int_0^{\bar{w}_t(e)} wdF_{t-1}(w)\tilde{R}_t^k Q_{t-1}\bar{K}_{t-1}(e) \\ = R_{t-1}Loans_{t-1}(e)\end{aligned} \tag{22}$$

where the first term on the left equals the expected revenue payed back to the financial intermediary, the second term equals the expected revenue the financial intermediary receives when a entrepreneur defaults and the term right of the equality is the associated cost of deposits lent out by the financial intermediary. The optimal contract maximizes expected entrepreneur profits subject to the banks' zero profit condition and is laid out in more detail in online appendix.

The aggregate equity, V_t, of entrepreneurs operating in the economy evolves according to

$$V_t = \tilde{R}_t^k Q_{t-1}\bar{K}_{t-1} - \left(R_{t-1} + \mu G_{t-1}(\bar{w}_t)\tilde{R}_t^k \tfrac{Q_{t-1}\bar{K}_{t-1}}{Q_{t-1}\bar{K}_{t-1} - N_{t-1}}\right)(Q_{t-1}\bar{K}_{t-1} - NW_{t-1}) \tag{23}$$

where the first term on the right is the time t revenue of entrepreneurs minus the interest and principle payments entrepreneurs borrowed from the banking sector. Notice that the agreed upon contract interest rate of the loan will be higher than the risk less rate, R_{t-1}. This external finance premium will be a function of bankruptcy costs and exogenous entrepreneur risk. At the end of each period a fraction $1 - \gamma$ of entrepreneurs exit the economy and are replaced by new entrepreneurs. Exiting entrepreneurs transfer some fraction of their net worth to households and the remaining net worth is transferred to newly born entrepreneurs symbolized as Tr_t. Aggregate net worth, NW_t, is subject to net worth shocks and evolves in accordance to:

$$NW_t = \gamma V_t + Tr_t + e_{NW,t} \tag{24}$$

The sector is characterized by two key log-linearized equations, the first being the spread of the return on capital over the risk free rate:

$$\hat{S}_t \equiv E_t\left[\hat{\tilde{R}}^k_{t+1} - \hat{R}_t\right] = \chi\left(\hat{Q}_t + \hat{\bar{K}}_t - N\hat{W}_t\right) + \hat{e}_{Fin,t} \tag{25}$$

where χ is the elasticity of the spread with respect to the capital to net worth ratio and $\hat{e}_{Fin,t}$ is a finance shock that effects the riskiness of entrepreneurs and thus the riskiness of banks being paid back in full.

The second key equation contains the evolutional behavior of entrepreneur net worth:

$$N\hat{W}_t = \delta_{\tilde{R}^k}(\hat{\tilde{R}}^k_t - \hat{\pi}_t) - \delta_R(\hat{R}_{t-1} - \hat{\pi}_t) + \delta_{qK}(\hat{Q}_{t-1} + \hat{\bar{K}}_{t-1}) + \delta_n N\hat{W}_{t-1} - \delta_\sigma \hat{e}^{Fin}_{t-1} + \hat{e}^{NW}_t \tag{26}$$

where the δ coefficients are functions of the steady state values of the loan default rate, entrepreneur survival rate, the steady state variance of the entrepreneurial risk shocks, the steady state level of revenue lost in bankruptcy, and the steady state ratio of capital to net worth. The value of χ, which will be estimated, will determine the steady state level of the variance of the exogenous risk shock, the steady state value of the percentage of revenue lost in bankruptcy and the steady state level of leverage. Therefore, the value of χ will determine the values of the δ coefficients.[6]

2.3 Monetary and Fiscal Policy

The *monetary authority* follows the following linearized Taylor rule to set the short-term nominal interest rate that adjusts due to deviations of inflation and output from their steady

[6]For a comprehensive look at the functional forms of all the δ coefficients used in coding the model, one must look at the working appendix of Del Negro and Schorfheide available at http://economics.sas.upenn.edu/ schorf/research.htm.

state levels.

$$\hat{R}_t = \rho \hat{R}_{t-1} + (1-\rho)\left[r_\pi \hat{\pi}_t + r_y \hat{y}_t + r_d \hat{d}_t\right] + \hat{\varepsilon}_{r,t} + \sum_{k=1}^{5} \hat{e}^r_{k,t-k} \tag{27}$$

where π_t is the inflation rate expressed in deviation way from the central bank's objective of π, y_t is the output gap, $\hat{\varepsilon}^r_t$ is a standard unanticipated monetary policy shock, and $\hat{e}^r_{k,t-k}$ are anticipated monetary policy shocks (forward guidance) known to agents at time $t-k$. In other words, agents may be informed of credible future deviations from the interest-rate feedback rule.

The consolidated government budget constraint is given by

$$\frac{P_{h,t}}{P_t} g_t + \frac{R_{t-1}}{\pi_t} b_{S,t-1} + \frac{R_{L,t}}{\pi_t} q_{L,t} b_{L,t-1} = \frac{Tax_t}{P_t} + b_{S,t} + q_{L,t} b_{L,t} \tag{28}$$

where g_t denotes real government expenditures, $P_{h,t}$ denotes the price of domestically-produced goods, and $b_{S,t}$ and $b_{L,t}$ represent real short and long-term government bonds held by the general public.[7]

Lump-sum taxes adjust with the level of output and government debt:

$$\frac{Tax_t}{P_t} = \frac{tax}{y} \left(\frac{y_t}{y}\right)^{\tau_y} \left(\frac{b_{S,t-1} + q_{L,t-1} b_{L,t-1}}{b_S + q_L b_L}\right)^{\tau_b} e_{tax,t} \tag{29}$$

where $\frac{tax}{y}$ captures the steady-state level of taxes relative to output, τ_y and τ_b determine the short-run responses of taxes to output and government debt, respectively, and $e_{tax,t}$ is a tax shock.

Lastly, large-scale asset purchases are modeled through the way in which the monetary and fiscal authorities set the relative supply of short-term and long-term bonds available to the public;

$$\gamma_{b,t} = \frac{q_{L,t} b_{L,t}}{b_{S,t}} \tag{30}$$

[7] Like Chen et al. (2012) and Alpanda and Kabaca (2020) we do not model the balance sheet of the central bank and its holdings of government bonds. This implies that the monetary base created by the monetary authority and the short-term bonds issued by the fiscal authority are perfectly substitutable, creating the above "consolidated" budget constraint for both authorities.

where $\gamma_{b,t}$ is exogenous and follows an AR(1) process. A negative shock to $\gamma_{b,t}$ results in a decrease in the supply of long-term government bonds available to the public and an increase in the supply of short-term bonds held by the public. Since the monetary base and short-term bonds are close to perfect substitutes when short-term interest rates are zero or when the central bank pays interest on bank reserves, a negative $\gamma_{b,t}$ shock is equivalent to a large scale asset purchase of long-term bonds by the central bank conducted by increasing the monetary base.

2.4 Market Clearing

The model is completed and connects the domestic and foreign economies with the following market clearing equations. Domestic production and imported products are aggregated by final goods producers, who operate in a perfectly-competitive setting. The real domestically-produced final goods, y_t, are used in the form of home consumption ($c_{H,t}$), home investment ($I_{H,t}$), government purchases (g_t) or exported, resulting in the following resource constraint:

$$y_t = c_{H,t} + I_{H,t} + g_t + y^*_{F,t} + a(u_t)\bar{K}_{t-1} \tag{31}$$

where $a(u_t)\bar{K}_{t-1}$ denotes the amount of output affected by capital utilization while $y^*_{F,t}$ also denotes the foreign country's imports; hence the domestic country's exports.

Aggregated consumption and investment are made of home and imported consumption ($c_{F,t}$) and imported investment ($I_{F,t}$) which together equal imported final goods in the domestic country ($y_{F,t}$).

$$y_{F,t} = c_{F,t} + I_{F,t} \tag{32}$$

Like assets, final consumption and investment goods are constructed as a CES aggregate of their respective home and foreign components respectively. Further, the market clearing conditions for bonds issued by the home economy are given by:

$$b_{S,t} = \frac{B_{H,S,t}}{P_t} + \frac{B^*_{F,S,t}}{P_t} \quad \& \quad q_{L,t}b_{L,t} = \frac{q_{L,t}B_{H,L,t}}{P_t} + \frac{q_{L,t}B^*_{F,L,t}}{P_t} \tag{33}$$

where $B^*_{F,S,t}$ and $B^*_{F,L,t}$ are short and long-term domestic bonds held in the foreign asset portfolio.

The two-country DSGE model is connected through the following balance of payments identity:

$$\begin{aligned}&(e_tB_{F,S,t} - e_tR^*_{t-1}B_{F,S,t-1}) + (e_tq^*_{L,t}B_{F,L,t} - e_tR^*_{L,t}q^*_{L,t-1}B_{F,L,t-1})\\&\quad - (B^*_{F,S,t} - R_{t-1}B^*_{F,S,t-1}) - (q_{L,t}B^*_{F,L,t} - R_{L,t}q_{L,t-1}B^*_{F,L,t-1}) = P_{H,t}y^*_{F,t} - e_tP^*_{H,t}y_{F,t}\end{aligned} \tag{34}$$

where the right hand side denotes the current account balance for the domestic country, and the left hand side captures the cross-border bond holdings, net of interest payments.

The loan market clearing condition is equal to

$$Q_t\bar{K}_t = NW_t + ldr_tDep_t \tag{35}$$

where the value of capital must be equal to entrepreneurial net worth and the fraction of deposits lent out by the financial intermediary. The model also includes intermediate firms, capital producers, importers and a monopolistic competitive labor market. The details of each along with the log linearized equations of the model can be found in Appendix A1.

2.5 Exogenous Processes

The model is complete with 15 exogenous shocks to each country. Three country specific i.i.d. pricing shocks to wages, domestic prices, and import prices, three AR(1) bond demand shocks, two AR(1) demand shocks to investment and consumption, four policy shocks to government purchases, taxes, monetary policy rate and a quantitative easing (bond supply available to the public ratio) shock. Further, there are three AR(1) shocks that are assumed to be correlated across countries, a stationary productivity shock and two finance shocks, one to net worth and a financial risk shock that directly affects the loan spread.

The correlated shocks are assumed to be identified in the same way as Alpanda and Aysun (2014) where shocks to the domestic country (US) have a contemporaneous effect on the level of both the domestic and foreign country's shocks while a financial or productivity shock innovation in the foreign country has a contemporaneous effect on the foreign country, but only a lagged effect on the domestic country's shock levels. In addition, the domestic country (US) is subject to five anticipated monetary policy shocks in the monetary policy interest rate setting rule that are identified off of Federal Funds Rate market expectations as in Del Negro et al. (2013).

3 Estimation

The solved linearized model is both calibrated and estimated using traditional state-space Bayesian estimation techniques as in An and Schorfheide (2007). In this section, we discuss the calibrated parameters and steady states, the data used to estimate the remaining parameters of the model, as well as the prior and posterior results of the estimated parameters for both the domestic (US) and foreign (ROW) countries of the model.

3.1 Data

We use 36 quarterly data series for the period 1999Q1 to 2019Q4 as observables in our estimation. The aggregate ROW series are constructed using the weighted average of data from Australia, Canada, China, the Euro Area, Japan, Switzerland, and the United Kingdom. The series for the ROW economy are constructed as the weighted average of data series from these countries where each country's relative weight in the ROW total is listed in Table A1. The relative weights were obtained using the average real GDP of these countries as a share of the ROW total for the sample period, and the same weights were applied for all series and all periods. Financial series from China are not included in the ROW calculation, instead the country weights are rescaled for the remaining six countries.

The observable variables used in the estimation include 19 series that are also used in Alpanda and Kabaca (2020). These include output (y, y^*), consumption (c, c^*), investment

(I, I^*), labor (L, L^*)[8], home-goods inflation (π_H, π_H^*), imported-goods inflation (π_F, π_F^*), wage inflation (π_w, π_w^*), short-term interest rate (R, R^*), long-term interest rate (R_L, R_L^*) as well as the depreciation rate of the US dollar against the ROW currency (d). Except for the inflation rates, interest rates and the depreciation rate, all data are log-differenced and demeaned prior to estimation.

In addition, eight bond supply observables are used in the estimation. These include short-term bond supply as a percentage of GDP ($\frac{b_S}{y}$, $\frac{b_S^*}{y^*}$), long-term bond supply as a percentage of GDP ($\frac{q_L b_L}{y}$, $\frac{q_L^* b_L^*}{y^*}$) for both the US and the ROW economies, international short-term bond holdings as a percentage of GDP ($\frac{b_{F,S}}{y}$, $\frac{b_{F,S}^*}{y^*}$) and international long-term bond holdings as a percentage of GDP ($\frac{q_L^* b_{F,L}}{y}$, $\frac{q_L b_{F,L}^*}{y^*}$).[9] We deviate from Alpanda and Kabaca (2020) estimation in two ways, first we use bond supply as a percentage of quarterly GDP rather than bond supply growth and we add international bond holdings to our observables. This allows for better identified estimates of elasticity of asset substitution parameters and an empirically matched time path for international bond holdings for both the US and ROW inside the model.

For the US, short-term bond supply series were constructed as the sum of the monetary base and government bonds with a maturity of less than one year at issuance. US government short and long-term bond supply series exclude the Federal Reserve holdings of government bonds. For the ROW bond supply data, all outstanding government bonds (minus those held by each country's central bank) are converted into US dollars and the summation from these are used to obtain a measure for the ROW's total short and long-term bond supplies.

With the addition of the financial accelerator in the model, there are four financial variables used in the estimation. These include net worth growth (NW, NW^*) and the private sector risk spread (S, S^*). Net worth growth is calculated using the quarterly growth rate of each country's major stock index and the risk spread is the interest rate difference between BAA bonds and treasuries for the US and BBB (Bloomberg index) bonds and a country's respective treasuries for the remaining six countries for the ROW. A complete

[8]Labor growth is hourly growth where available and the growth in total employment for countries when labor hours data were missing.

[9]The data on bond holdings are only available at year end from the Treasury International Capital (TIC) database, therefore, the known data are connected to Q4 for each year in our sample and all other quarters are assumed to be missing in our Bayesian estimation procedure.

plotting of the 31 series discussed can be found in the plots of Figure A11.

Finally, given the existence of the ZLB over our sample window and the desire to analyze the monetary policy of forward guidance, we identify the anticipated monetary policy shocks, following Del Negro and Schorfheide (2013) and augment the measurement equations with the following expectations for the US Policy Rate (R_t):

$$\text{Federal Funds Rate}^{Exp}_{t,t+1} = 400R + \Lambda_R G(\theta)^1 S_t \tag{36}$$

$$\vdots \tag{37}$$

$$\text{Federal Funds Rate}^{Exp}_{t,t+5} = 400R + \Lambda_R G(\theta)^5 S_t \tag{38}$$

where Federal Funds Rate$^{Exp}_{t,t+k}$ is the market's time t expectations (OIS data) for the policy rate k quarters ahead Λ_R is the row of Λ in the observable equation corresponding to the policy rate, $G(\theta)$ is the transitional matrix of the DSGE model and S_t is the state vector of the state-space model. The data sources, as well as other details regarding the construction of the ROW aggregates, can be found in the online appendix.

3.2 Calibrated Parameters

We calibrate certain under-identified parameters to values seen in the literature and important steady-state levels and ratios for many variables based on sample data from 1999-2019. A complete list of calibrated parameters, steady states and steady state ratios is found in Table A2 and Table A3.

The relative size of the ROW economy to the US economy is calibrated to 1.97 based on the average yearly ratio of the seven countries' GDP in real US dollars to real GDP for the US over the sample period. The steady state GDP share g/y of government purchases is calibrated to the average proportion of government purchases of US GDP and ROW GDP over the sample period. A domestic price mark-up of 1.25, a depreciation rate of 0.025, a capital share of production of 0.34 and a calibrated steady state risk premium implies a steady state share of investment to GDP (I/y) of 0.185 for both countries. This is just below the average share of investment to ROW GDP (0.205) and above the average share of investment to US GDP (0.175) over the sample period. The steady state share of exports to US GDP (y_F^*/y) is calibrated to 0.119 to match the data. These steady state component shares along with the implied steady state share of imports to US GDP (y_F/y) from the balance of trade equation imply a steady state share of consumption to GDP (c/y) of 0.618 for the US and 0.577 for the ROW.

The home-bias parameters γ_c and γ_I are calibrated to 0.845 to match the import share to US GDP found in the data over the sample period, while in the ROW, the corresponding parameters, γ_c^* and γ_I^* are set to 0.921 given the relative size of 1.97 of the ROW economy relative to the US. The tax level parameters in the two countries, (tax/y) are set to ensure that each government's budget constraint is satisfied given the bond ratios and interest rates at the steady state.

Steady state inflation (π) is calibrated to be equal to 2% on an annual basis and the nominal short and long-term interest rates (R, R_L) are calibrated to equal 4.1% on annual basis in both countries to correspond with a 2.1% annual real interest rate. The steady state risk spread (S) is set to 2.3% for both countries, just below the sample data for the US and above the sample data for the ROW. A discussion about other calibrated parameters including those involving the portfolio share parameters can be found in Appendix A2.

3.3 Prior and Posterior Estimates

The structural parameter marginal priors follow Alpanda and Kabaca (2020) and Del Negro and Schorfhiede (2013) priors. Tables A4 and A5 report the prior distributions used for each estimated parameter, the corresponding estimates for the posterior mean and the 90% posterior interval.[10]

The estimates for the portfolio elasticities[11] imply that the elasticity of substitution

[10] We construct the posterior distribution estimates using a standard Metropolis-Hastings algorithm, using a single chain of 1,000,000 draws with a 25% initial burn-in phase. Convergence is then confirmed by the convergence diagnostic test of Geweke (1999).

[11] Like Alpnada and Kabaca (2020), we rescale the asset portfolio elasticity of substitution parameters to constrain their estimates within the unit interval to ensure a more robust estimation.

The auxiliary portfolio elasticity parameters for $j = \{a, S, L\}$ is defined as:

$$\lambda_j = \frac{\lambda_j^{est}}{1 - \lambda_j^{est}} \tag{39}$$

between short and long-term bonds (λ_a and λ_a^*) for both the US and the ROW are similar, 1.65 and 1.8 respectively. The elasticity of substitution between short-term domestic and foreign bonds (λ_S and λ_S^*) are found to be fairly inelastic for both the US and ROW with estimates centered around 0.39 and 0.55 respectively. Finally, the elasticity of substitution between long-term domestic and foreign bonds (λ_L and λ_L^*) show a notable difference between the US and ROW. The US is estimated to have an elasticity of 0.71, while the ROW has an elasticity estimate of 2.8.

The ROW estimate for λ_a^* are λ_L^* are in line with the Alpnada and Kabaca (2020) estimate for the ROW. However, the remaining four portfolio elasticity parameters are estimated to be notably different. For example, the short-term, long-term portfolio elasticity of substitution for the US (λ_a) is significantly higher and the short-term domestic and foreign bonds elasticity for the ROW (λ_S^*) is significantly lower than the Alpnada and Kabaca (2020) estimates. Further, the additional foreign bond holding data series used in this paper allow the posterior estimates for λ_S are λ_L to significantly leave their prior distributions while they do not in Alpnada and Kabaca (2020). Given the importance of the portfolio elasticity parameter estimates in regards to their impact on the dynamics of unconventional monetary policy, we conduct parameter sensitivity analysis around all six of these parameters in Appendix A4.

The posterior estimates for the other structural parameters are in line with estimates in the related DSGE literature. Habit consumption, has a posterior mean around 0.85 for both the US and ROW, helping to capture the high levels of persistence seen in the consumption data. The utilization costs, investment adjustment costs and labor utility parameters are estimated in similar ranges for both the US and the ROW. The estimates for η_c indicates that the elasticity of substitution between domestic and imported consumption goods is around 1.3 in the US and 0.74 in the ROW. The corresponding figures for the investment good are 1.0 and 0.85 in the US and the ROW, respectively.

The estimates for the price and wage adjustment cost parameters[12], κ_j^{est}, indicate very

[12]The auxiliary price adjustment cost parameter is defined as

$$\kappa_j = \frac{(\Theta_j - 1)\kappa_j^{est}}{(1-\kappa_j^{est})(1-\beta\kappa_j^{est})} \tag{40}$$

for $j = \{w, H, F\}$. This makes the price and wage adjustment cost estimates comparable to the literature which uses Calvo (1983) type price and wage setting.

high levels of home price and wage stickiness and relatively lower levels of import price stickiness for the US. The Taylor rules are persistent with a mean estimate of ρ around 0.92 in both economies, while the estimates for the inflation gap and output gap coefficients are estimated at levels found in the DSGE literature. We find some, but minimal, evidence that the ROW economy sets its short-term interest rate around the nominal exchange rate with an estimate of r_d around -0.02. Finally, the shock processes are estimated to be fairly persistent and the global correlation for the financial shocks (net worth and risk) is estimated to be about 0.65, which is just below the 0.8 correlation we see in the data used for estimation for stock price growth between the US and ROW economies.

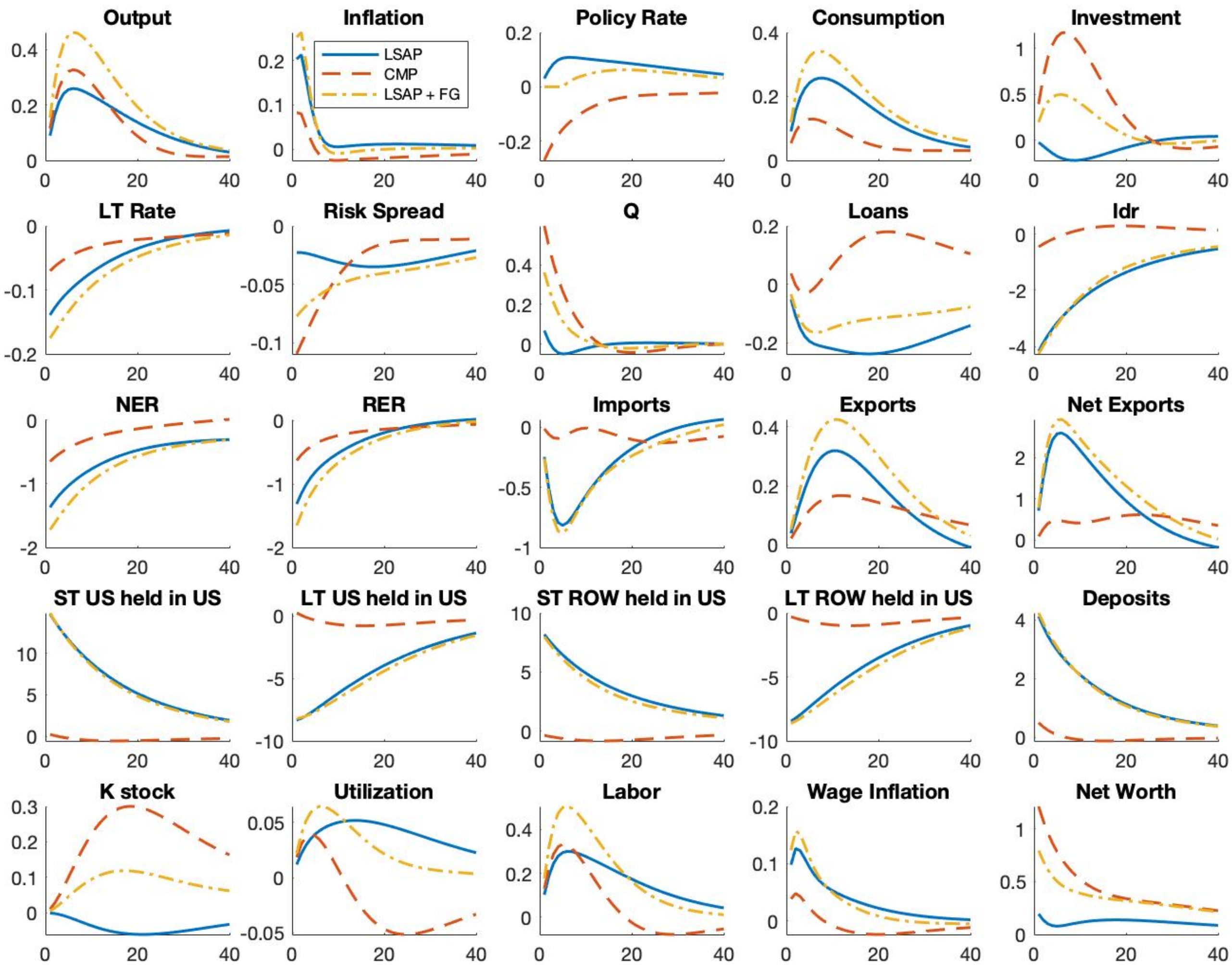
4 Comparing Monetary Policies

In this section, we compare exogenous changes in alternative unconventional policy tools (Large-scale Asset Purchases (LSAP) and LSAP + Forward Guidance (FG)) to conventional monetary policy (CMP). We assess the efficiency of unconventional policy interventions in affecting output, investment, inflation, foreign trade, and financial market metrics. We show how the inclusion of a financial accelerator changes the outcome and the transmission mechanism of both types of policy interventions.

4.1 Structural Model Analysis

Figure 2 compares the transmission of CMP and LSAP policy shocks. Aggregate macroeconomic variables are expressed as percentage deviations from the steady state, while inflation and interest rates are in annualized percentages away from steady state values. The dashed red lines depict the impulse response function (IRF) of a conventional policy shock. The size of the shock is calibrated to lower the policy rate by 25-basis points. The responses of aggregate variables to this shock are consistent with the those found in the DSGE literature. Output, hours, consumption, investment, and inflation all increase on impact. As in Del Negro et al. (2013) the CMP shock raises capital prices (Q), net worth and lowers the risk spread. As a result, the response of investment is about four times as much as output. The open-economy variables response is as expected with the US dollar (NER) depreciating and net exports increasing.

Figure 2: Monetary Policy IRF's



Notes: The solid blue line show a LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank. The dashed red line show the response of a shock equivalent to a 25-basis point fall in the policy rate. The dotted yellow line show the response of an LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank with a year's long commitment of keeping the policy rate unchanged (LSAP with Forward Guidance (FG)). All of the impulse responses are calculated using the model's posterior mean estimates and plot the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

Responses to an LSAP shock are depicted by the solid blue line. This policy intervention is scaled for an LSAP shock that is equivalent to a long-term asset purchase of 1.5% of steady state annual GDP by the central bank on impact. The purchase is initially conducted at the model's steady state. We see that the the LSAP shock has a positive impact on output, hours, consumption, and inflation, with inflation rising twice as much compared to the CMP shock for a similar change in output. The policy rate increases after the LSAP shock as a result of the rise in inflation. As expected, the long-term interest rate declines by about 15 basis points after the shock.[13] However, investment is marginally negatively affected after the LSAP shock. This is a result of capital prices and net worth only marginally increasing (and thus the risk spread only slightly decreasing) from the bond purchase. In fact, capital loans decrease, while loan supply (deposits) significantly increase, resulting in a significant decline in the loan-to-deposit ratio (ldr) after the LSAP shock.

Examining the open-economy variables after the LSAP shock, we see that the nominal exchange rate (NER) declines by more[14] because of the the increased short-term bond supply following the shock. The greater movement in the exchange rate due to an LSAP shock leads to larger movements in imports and exports compared to the CMP shock. Households hold more US and ROW short-term bonds and deposits after the shock and less long-term US and ROW bonds. The estimated persistence of the LSAP shock and the imperfect substitutability in the asset portfolio implies that the impact on output, consumption and hours worked remain positive for far longer when compared to an equivalent CMP shock.

The dash-dotted lines in Figure 2 show the effect of LSAPs at the zero lower bound (LSAP + FG). LSAP policies are usually adopted because of the zero lower bound constraint so this is a natural case to explore. We engineer this scenario by searching for a sequence of anticipated monetary policy shocks for the given LSAP shock that holds the policy rate unchanged for a year. The pegged policy rate significantly increases the power of LSAP, raising the positive response of output, inflation, and consumption above that observed for LSAP with an unconstrained short-term interest rate. Further, the peg causes investment to respond positively to the shock. This occurs by construction because the short-term interest rate does not respond to the LSAP. The lower path of interest rates then generates a large positive response to net worth leading to the increase in investment. Although, both the net worth and the investment response remain smaller than that generated by a CMP shock. The increase in investment increases demand for loans relative to the LSAP only policy but still results in a large decline in the loan-to-deposit ratio.

[13]This impact on U.S. long-term yields is well within range of the estimates in the empirical literature (Hamilton and Wu (2012), Chen et al. (2012) and Sims and Wu (2021).

[14]Rogers et al. (2014), Rogers et al. (2018), Glick and Leduc (2018), Inoue and Rossi (2019) and Kolasa and Wesolowski (2020) find a similar empirical result.

These results illustrates a key difference between LSAP policy and FG policy. It is credible low interest rate policy that boosts asset prices at the zero lower bound. LSAP policies alone have only marginal affects on net worth because while they boost bond prices at the long end, they simultaneously lower bond prices at the short end. Therefore, the net effect is small. Finally, LSAP with policy commitment to zero interest rates further depreciates the domestic currency, resulting in a bigger impact on net exports compared to the other two policy interventions.

4.1.1 Excluding the Entrepreneurs and Financial Intermediaries from the Model

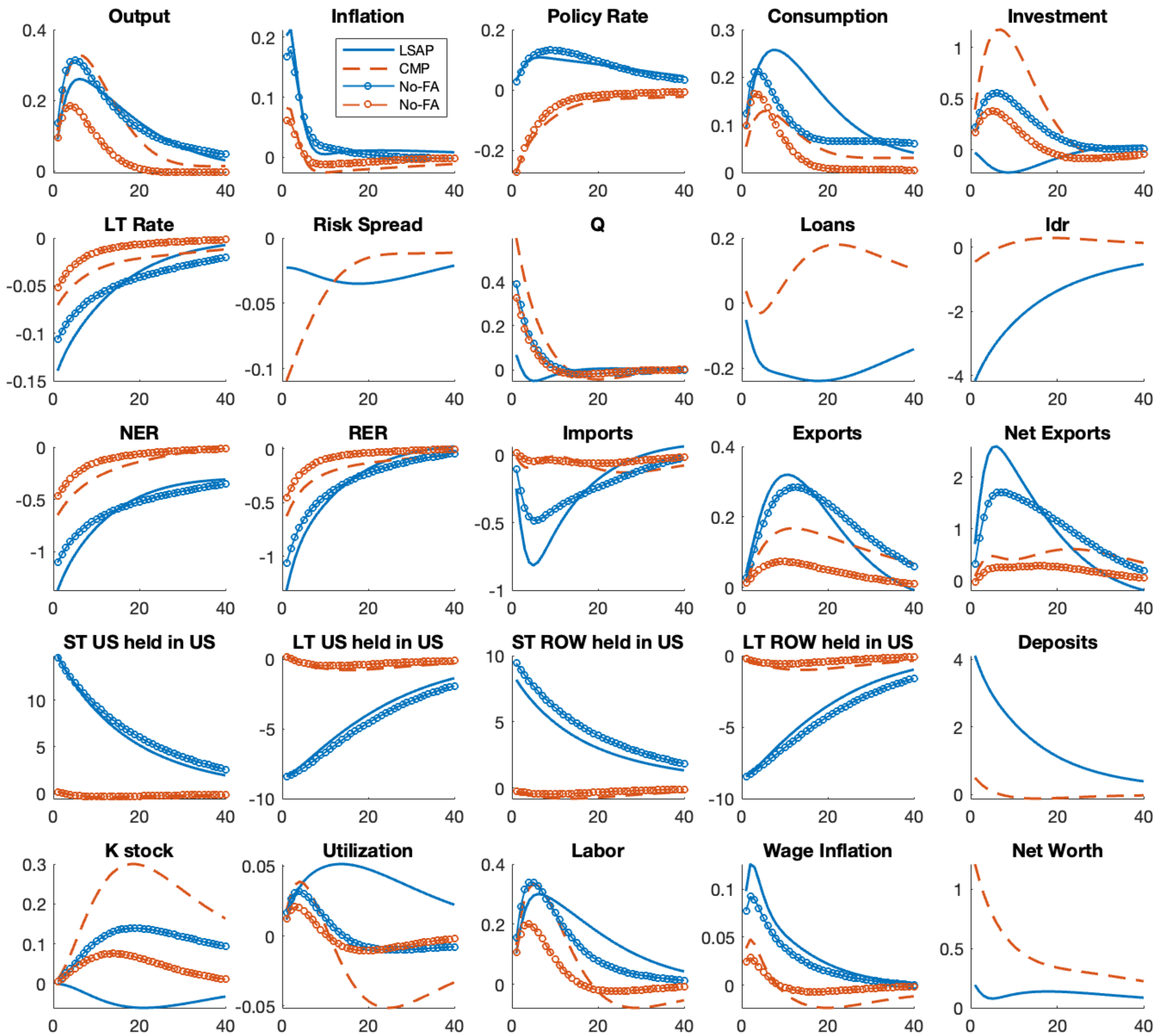
LSAP policies in the model reconcile the empirical evidence from financial studies that show weak investment responses with the sizable real effects on output and consumption documented in the macroeconomic literature. In this section, we show that it is the inclusion of the financial accelerator and financial intermediaries that delivers this result.

To illustrate, we estimate a version of the model that excludes the financial accelerator and financial intermediation assumptions. Households directly own capital and decide on the utilization rate in this model. We estimate the model using the same priors and data (minus the data on net worth growth and risk spread). We then conduct the same policy analysis as in the previous section 4.1 and compare the outcomes to the full model. We find very little difference in the posterior estimates of the shared parameters across both model specifications. Therefore, the difference we observe here should be attributed to the financial accelerator.

Figure 3 shows the comparison of the estimated IRFs for CMP and LSAPs. CMP is estimated to be less effective overall without the financial accelerator. This finding is broadly consistent with the financial accelerator literature.[15]

[15] However, this point is still debated in the literature. Foroni, Gelain and Marcellino (2022), for example, show that CMP shocks and financial frictions may not amplify output and investment responses if mixed or higher frequency data are used in the model's estimation.

Figure 3: Monetary Policy IRF's of both DSGE Models



Notes: The solid blue line show a LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank. The dashed red line show the response of a shock equivalent to a 25-basis point fall in the policy rate. The bubbled lines show each respective shock when the DSGE model does not include a Financial Accelerator (No-FA). All of the impulse responses are calculated using the models' posterior mean estimates and plot the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

LSAP shocks remain broadly similar with or without the financial accelerator except for investment. With respect to investment, there is now a significant increase in investment over and above that predicted by CMP. Bond purchases without the financial accelerator directly affect household portfolio allocations. Without intermediation in investment markets, portfolio reallocation decisions can be thought of as also including capital, which leads household to increase investment in the wake of an LSAP.

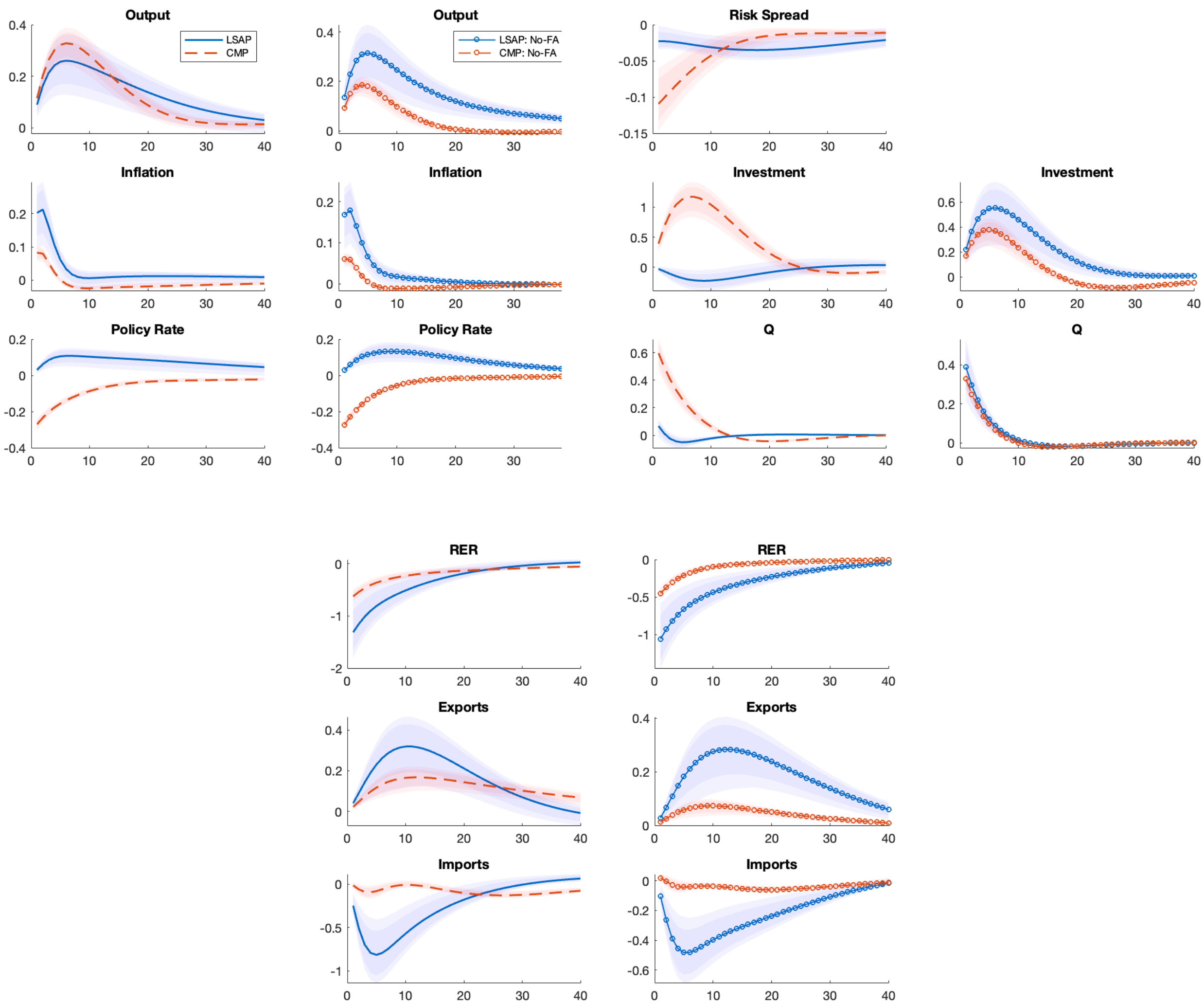
To a lesser extent there is also a different impact on net exports and consumption. The larger effect on investment crowds out some of the effect on the terms of trade and consumption. This makes an LSAP policy look more like CMP. This may explain why some studies conclude that LSAPs appear to be a close substitute for CMP. Figures 4 provides a more focused view on how the financial accelerator makes LSAPs operate differently to CMP. Output and investment have roughly the same shapes and persistence without the financial accelerator and clearly different behavior with the financial accelerator.

Finally, LSAP shocks with FG policy – in Figure A18 shown in the appendix – show a similar effect on macroeconomic variables across both specifications. The only difference observed is again in investment and net exports. The model without a financial accelerator predicts a much larger positive impact on investment and capital prices compared to the model with a financial accelerator. The model without a financial accelerator also predicts a smaller impact on exchange rate depreciation and thus net exports.

4.2 Additional evidence for LSAPs and trade

A key prediction of the model with and without the financial accelerator is that trade plays a much larger role in the transmission of LSAP policies than for CMP. In this section, we investigate the robustness of this finding using a different and less structured approach. Following Jorda (2005), we estimate local projection IRFs for LSAP and CMP shocks over the same sample period of interest but with identified shocks from an external source. Specifically, we use the shocks estimated by Swanson (2021) from high frequency data. Swanson modifies the methods of Gurkaynak et al. (2005) to separately identify conventional monetary policy shocks, LSAP shocks, and forward guidance shocks using a factor model of the yield curve, the exchange rate, and financial market data. The model is estimated on data

Figure 4: Confidence Interval IRF's around key Variables



Notes: The solid blue line show a LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank. The dashed red line show the response of a shock equivalent to a 25-basis point fall in the policy rate. The bubbled lines show each respective shock when the DSGE model does not include a Financial Accelerator (No-FA). The dark shaded bands indicate 67% confidence intervals. The lighter bands indicate 90% confidence intervals. All of the impulse responses show the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

within a 30-minute window around FOMC announcements to capture the reaction of market variables. Swanson argues and provides compelling evidence that his model extracts three orthogonal shocks that capture conventional monetary policy, LSAPs, and forward guidance, respectively.

We take Swanson's shock as data. We aggregate the shocks to a quarterly frequency by summing the individual observations within a quarter. The idea is that if there are multiple offsetting shocks in a single quarter that they will be netted out in the summation. We then include aggregated shocks directly in the local projections regressions to identify the dynamic multipliers of interest. Our local projections regression specification is

$$\Delta_h y_t = \gamma_0 + \gamma_1 I(ZLB)_t + \beta_1^h CMP_t + \beta_2^h LSAP_t + \beta_3^h FG_t + W_t \Gamma^h + X_{t-1}\Psi^h + \epsilon_{t,h} \quad (41)$$

where $\Delta_h y_t = y_{t+h} - y_{t-1}$ is the log-level variable of interest (except for interest rate variables which are taken as given), CMP_t is the aggregated conventional monetary policy shocks, $LSAP_t$ is the aggregated LSAP shocks, FG_t is the aggregated forward guidance shocks, W_t is a vector of contemporaneous controls, X_{t-1} are lagged endogenous variables, $I(ZLB)_t$ is indicator variable for the binding zero lower bound, and β_1^h and β_2^h are the dynamic multipliers of interest for $h = 0, 1, ..., 11$.

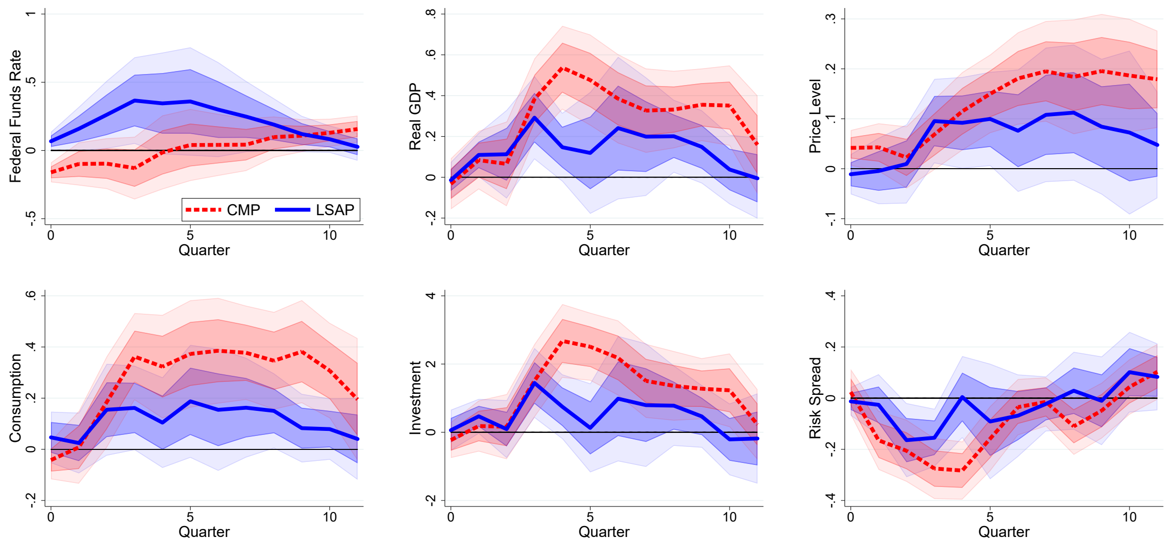
The sample of interest is relatively short: 1999q2 to 2019q2. It contains both a period at the ZLB and periods away from it. We include $I(ZLB)_t$ dummy and the FG shock to attempt to control for the effect of the ZLB. However, the majority of the variation in the LSAP shocks occurs during the ZLB period so we cannot cleanly identify LSAP shocks with and without the ZLB as in the structural model. Our estimates are therefore best thought of as a weighted average of the two types of IRFs identified by the structural model.[16]

Figure 5 plots the local projection estimates for LSAP and CMP shocks on the short-term interest rate, output, the price level, consumption, investment, and the risk spread. We normalize the size of the shock so that the average effect on output is the same for the two shock over the first four quarters.[17] A table reporting the full estimates is in the appendix.

[16]For completeness, we provide the state-dependent estimates for the LSAP shocks in the appendix. The state-dependent IRFs qualitatively show the same patterns as the structural model with the financial accelerator. However, the confidence intervals on the estimates are wide.

[17]We use one lag each of output, short and long term interest rates, consumption, investment, net worth,

Figure 5: Local Projections Impulse Responses



Notes: Local projection impulse response estimates for conventional monetary policy shocks (CMP) and large-scale asset purchase shocks (LSAP). The dark shaded bands indicate 67% confidence intervals. The lighter bands indicate 90% confidence intervals. The sample is 1999q2 to 2019q2.

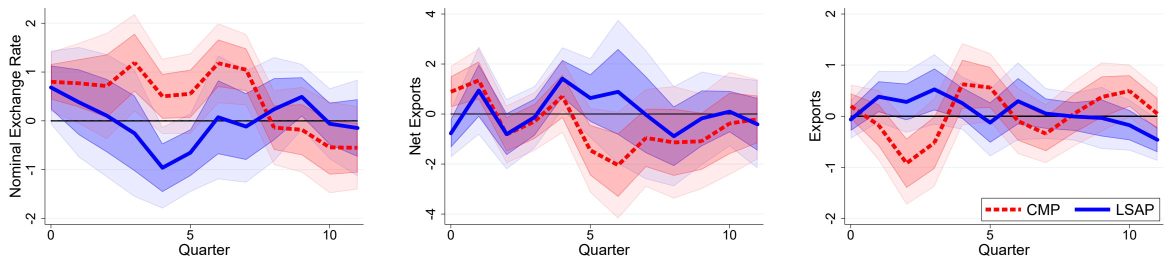
The LSAP shock increases the short-term interest rate, increases output, increases the price level, increases consumption, and marginally increases investment. The aggregated CMP shock lowers the short-term interest rate and increases output, the price level, consumption and investment. Therefore, both shocks deliver responses that are consistent with the structural model. In particular, the opposite movements in the short-term interest rate give us confidence that Swanson's shocks are identifying the correct variation in the data that we wish to study. Both shocks lower the risk spread with a larger response observed for the CMP shocks, which is consistent with the predictions of the model with the financial accelerator.

Figure 6 plots the local projections for LSAP and CMP shocks on the nominal exchange rate, net exports, and real exports from the US.[18] We find that LSAPs lead to a statically significant depreciation of the currency the year following the shock. This corresponds with an increase in exports and a statistically significant rise in net exports four quarters after the shock. CMP on the other hand does not produce IRFs with signs that correspond to the

net exports, exports, imports, the price level, and the nominal exchange rate as controls. We also include the contemporaneous policy rate and contemporaneous foreign exchange rate as controls.

[18]For the trade variables, we include the world short-term interest rate and its lag plus lagged imported inflation as controls in addition to the same controls used in the Figure 5.

Figure 6: Local Projections Impulse Responses - Trade



Notes: Local projection impulse response estimates for conventional monetary policy shocks (CMP) and large-scale asset purchase shocks (LSAP). The dark shaded bands indicate 67% confidence intervals. The lighter bands indicate 90% confidence intervals. The sample is 1999q2 to 2019q2.

shocks identified by the model. The nominal exchange rate increases in this case leading to a fall in exports and eventual fall in net exports.

Overall, the local projections estimates are broadly in-line with the predictions of the structural model. LSAP shock transmission appears to operate through trade much more so than CMP. While CMP appears to operate much more through investment than the LSAP shock.

5 Assessing the impact of LSAP

LSAP and FG policies were implemented during and following the financial crisis to support the economy as a substitute for CMP during the zero lower bound period. In this section, we use a historical shock decomposition obtained from the estimated model to assess the extent to which these policies contributed to fluctuations in the output gap, labor gap, net worth (asset prices), risk spread, loan-to-deposit ratio and the real exchange rate during and after this period.

The importance of each "type" of shock to each variables is quantified in Figure 7. The solid line shows the variable in deviation from its steady state value. The bars represent the contribution of each type of shock to the deviation of the variable from steady state. That is the counterfactual values each variable obtained by setting all other shocks to zero. By construction, for each quarter the bars sum to the value on the solid line.

We examine eight categories of shocks. *ROW* includes all ROW shocks with the exception of those affecting foreign financial asset and bond portfolios. *ROW Fin* includes shocks to

ROW net worth, ROW risk spread and ROW bond portfolio shares. *US Supply* includes US price and wage mark-up shocks and US productivity shocks. *US Demand* includes US consumption and US investment shocks. *US Policy* includes US CMP, tax and fiscal purchase shocks. *US Fin* includes US net worth and US risk spread shocks, *US Bond* includes US bond portfolio share shocks and *US Un-CMP* includes US LSAP and Forward Guidance shocks.

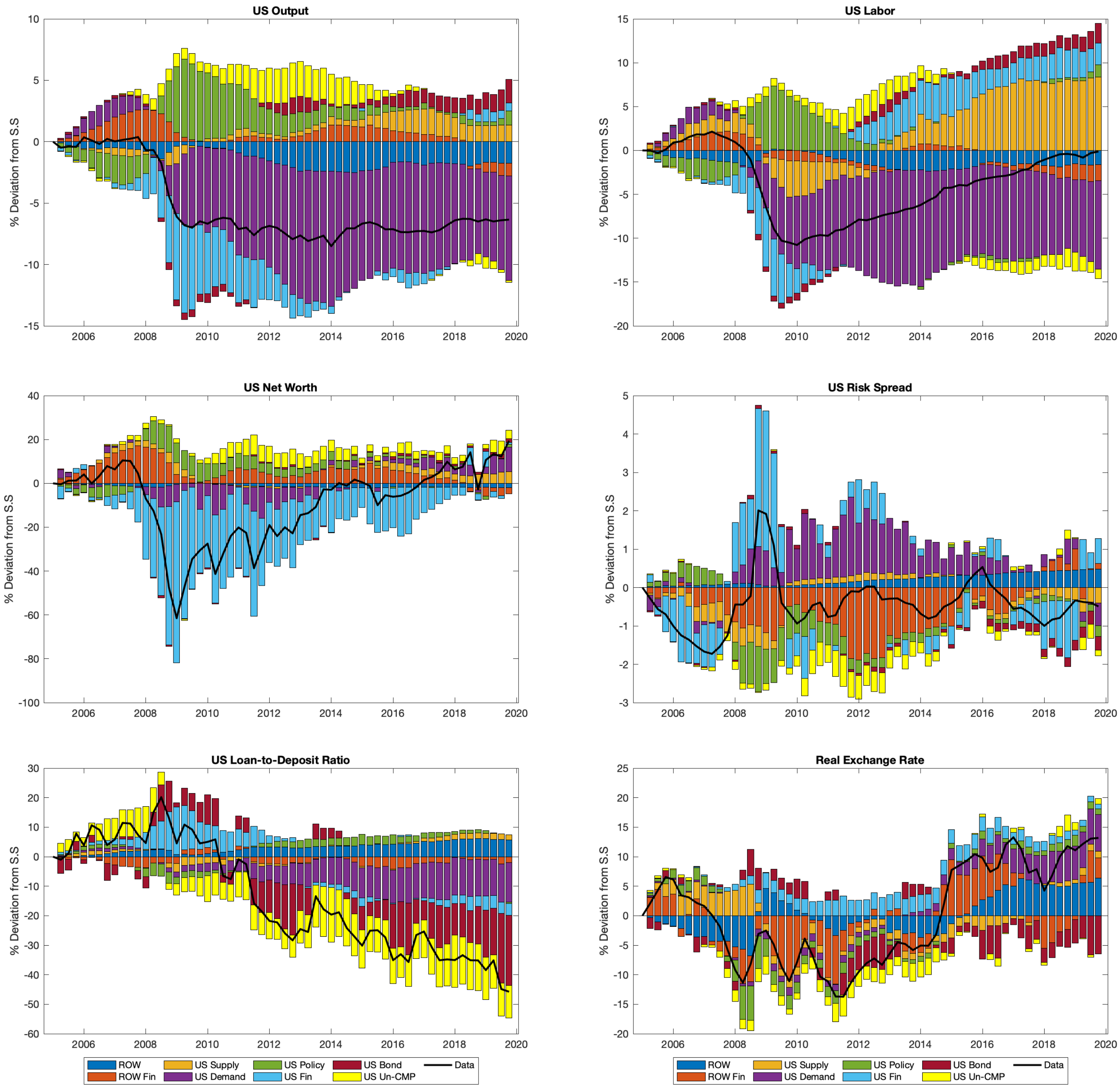
The shock decomposition implies the evolution of the real economy since 2008 was driven by two main forces: disruptions in the financial sector and weak aggregate demand. The two combine to produce an initial sharp economic downturn followed by a sluggish recovery. The credit frictions in the model are key to capturing these events with financial shocks driving significant variation in real activity early in the crisis and continued disruptions to net worth well into the recovery.

In the face of these large financial and demand shocks, fiscal and monetary policy played an important role in supporting the real economy by conventional measures at the onset of the financial crisis and by the use of large-scale asset purchases and forward guidance afterwards. Conventional fiscal and monetary policy shocks (green bars) lifted output and hours worked beginning in 2008 by sharply reducing the policy rate and increasing government purchases. The reduction in the policy rate observed in the recession was much larger than that implied by monetary policy rule indicating significant additional support in 2008 in the form of monetary policy shocks. As shown in Figure 7, traditional policy intervention helped boost output, employment and asset prices, while lowering the risk spread and depreciating the US dollar.[19]

Starting in 2010 the effects of conventional policy on the real economy start to fade and unconventional monetary policy shocks (yellow bars) begin to play a predominant role in supporting the real economy and financial markets. We find that the output gap and employment would have been between 1% and 2.8% lower in the absence of these polices. In addition, the risk spread, the loan-to-deposit ratio and the real exchange rate decline as a result of the unconventional monetary policies. Starting in 2015, we see that unconventional

[19]Historical decompositions for consumption and exports are shown in the appendix Figure A21. CMP also supported consumption and exports during this time.

Figure 7: Historical Decompositions



Notes: The figures plot the historical shock contributions for US output, labor, net worth, risk spread, loan-to-deposit ratio and the real exchange rate after 2005. The shocks are grouped into eight categories. ROW include all ROW shocks not including financial and bond portfolio share shocks in the ROW. ROW Fin include shocks to ROW net worth, ROW risk spread and ROW bond portfolio shares. US Supply includes US price and wage mark-up shocks and US productivity shocks. US Demand include US consumption and US investment shocks. US Policy include US CMP, tax and fiscal purchase shocks. US Fin include US net worth and US risk spread shocks, US Bond includes US bond portfolio share shocks and US Un-CMP include US LSAP and Forward Guidance shocks.

monetary policy's effect on the real economy and the real exchange rate slowed and even turns negative as the central bank balance sheet roll-off period begins in 2018. Unconventional policies have a lasting positive effect on asset prices and bond markets through 2019. However, their affect on real activity turns slightly negative.

We can also use the model to assess the fall in the credit-to-deposit ratios following the introduction of LSAPs shown in Figure 1. The model does not use private sector credit, loans, or deposits as observable data. Therefore, the model infers an implied loan-to-deposit ratio from the variation in other macroeconomic and financial data through the financial accelerator. The model predicts a significant decline in the loan-to-deposit ratio that is qualitatively similar to what occurred in the data discussed in the introduction. The principal drivers of the decline are LSAP policies and US bond portfolio shocks as hypothesized. The effect of these shocks persists through 2019 suggesting a long lasting effect on financial markets and the banking sector well after the policy's real effects have faded.

6 Determinants of LSAP policy effectiveness

The estimated structural model reveals trade and international financial markets play a significant role in the transmission of LSAP policies to the real economy. In this section, we explore two dimensions that affect these transmission channels motivated by developments during the global pandemic. First, we explore how the effectiveness of LSAPs may change when trade frictions and financial openness change. Second, we explore effectiveness of coordinated or simultaneous LSAP policy by the US and the ROW.

6.1 Trade and Financial Openness

We alter trade and financial openness of the two economies in two ways to assess LSAPs dependence on these frictions. We first consider the effect of more trade and financial openness relative to our baseline model. We decrease the home good preference parameters of the US (γ_c and γ_I) to 0.7 and we decrease the short-term domestic bond preference parameters of the US and ROW (γ_S and γ_S^*) to 0.8.[20] We refer to this specification as "more open" in the proceeding analysis. In the second specification, we consider the effect of more closed

[20]This results in a decrease of the home good preference parameters of the ROW (γ_c^* and γ_I^*) to 0.843 , as we keep the same steady state trade balance. The reduction of γ_S also results in changes to other calibrated steady state parameters in the model. These steady state parameters are recalibrated appropriately.

economy relative to our baseline. We set γ_c, γ_I, γ_S, γ_L, γ_S^*, γ_L^* are equal to 0.99.[21] We refer to this specification as "closed" in the proceeding analysis.

Figure 8 plots the IRFs for LSAP policies under the baseline specification and the two new openness specifications. The LSAP+FG case is shown in the appendix in Figure A20. The effect of openness in this cases is similar to those shown in Figure 8 for LSAP+FG with any qualitative differences looking broadly similar to the difference observed in Figure 2. We find that LSAP and LSAP + FG shocks when mediated through the financial accelerator depend greatly on the degree of trade and financial openness. A more open economy increases the impact of these policies on output, inflation, hours, consumption, investment, net exports and asset prices, while a more closed economy mutes the response to the same policy. Without free trade and free flows of capital internationally, LSAP policies are much less effective.

We find that the opposite is true, however, for CMP. Figure A19 - available in the appendix - shows that the ordering of the impacts is flipped for CMP. The closed specification has the largest impact on real activity. The open specification has the smallest impact. However, we find that both LSAP and CMP have much less impact on inflation in a more closed world. To the extent that economies are becoming more closed following the pandemic, this result suggest larger sacrifice ratios to lower inflation for both LSAP policy and CMP.

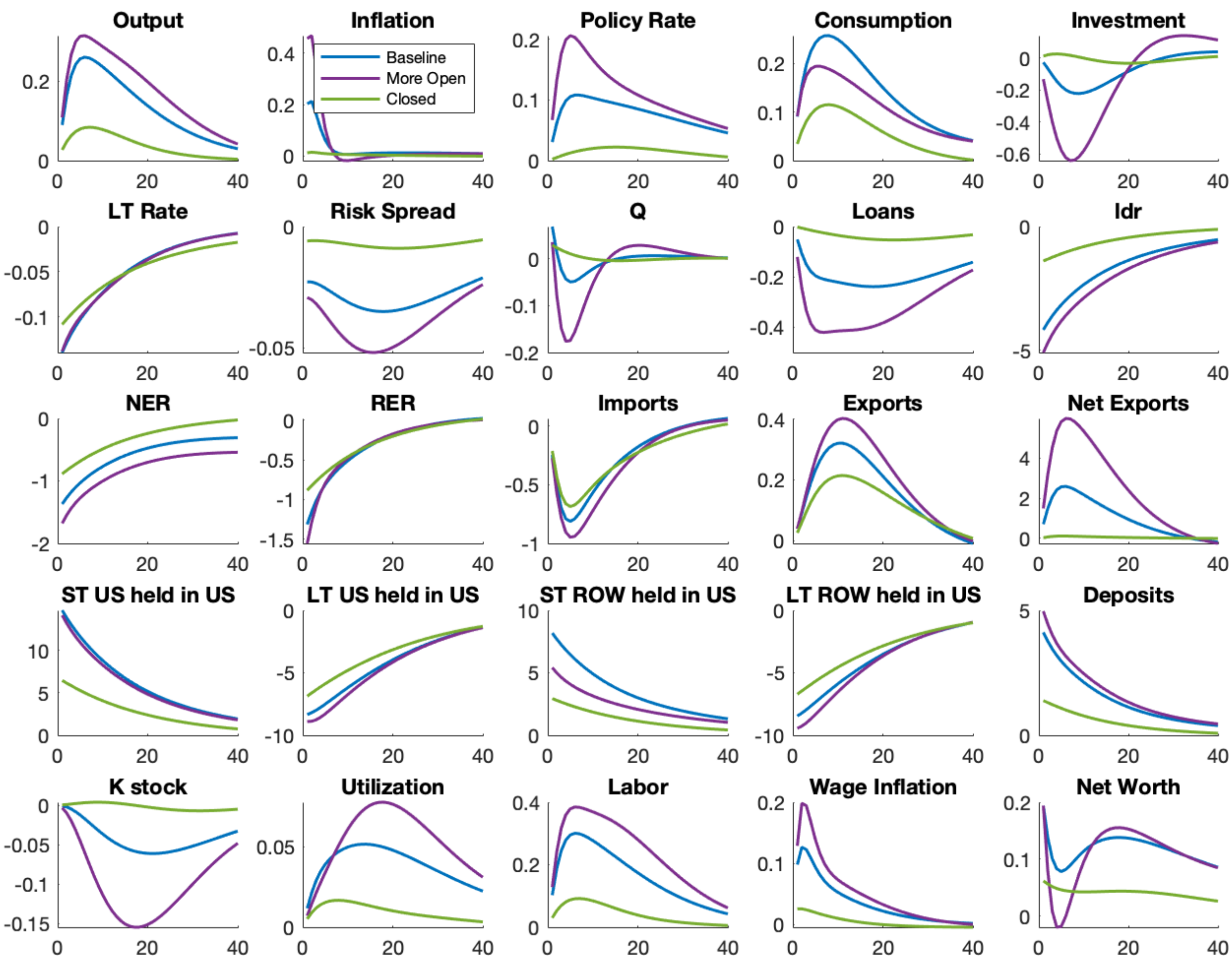
6.2 Coordinated Global Monetary Policy

The Global Financial Crisis and the Pandemic caused many countries to use unconventional policies. In this section, we explore how the impacts of LSAPs and CMP change when conducted simultaneously in the US and the ROW economy. Figure 9 plots the IRF of to a unilateral domestic LSAP policy equivalent to a long-term asset purchase of 1.5% of steady state GDP by the US (solid blue line), which we compare to coordinated LSAP purchases of the same size conducted simultaneously by the US and the ROW economy.

Coordinated LSAP purchases mute the response of US output, hours worked and inflation. This occurs mainly through the trade channel as the nominal and real exchange rates are not as affected now that monetary policy is coordinated. However, the long-term interest rate in the US falls more and the policy rate rises less when the LSAP purchase

[21] Calibrated steady state values that are dependent on these values are also recalibrated appropriately.

Figure 8: Trade and Financial Openness - LSAP shock

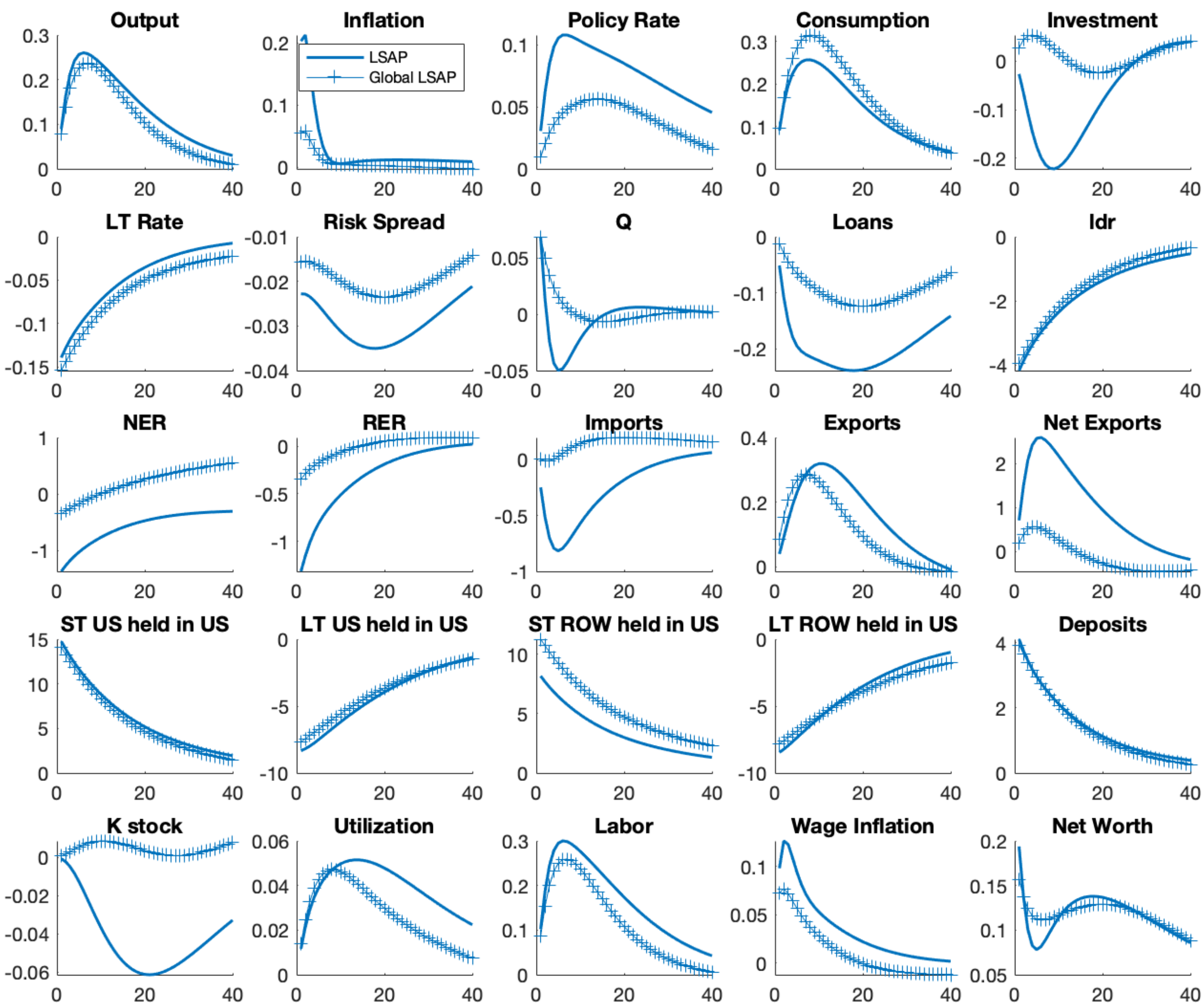


Notes: The solid blue line show a LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank using the baseline parameters of this paper. The solid purple line show the same LSAP shock in a more open economy (γ_c, $\gamma_I = .7$, γ_s, $\gamma_s^* = .8$), The solid green line show the same LSAP shock in a closed economy (γ_c, γ_I, γ_s, γ_s^*, γ_L, $\gamma_L^* = .99$). All of the impulse responses show the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

is coordinated. This generates a larger impact on consumption and investment than in the unilateral case. Further, exports rise even though the nominal exchange rate is unchanged because of the increase in ROW demand from the ROW policy.

Many of the same effects are exhibited in Figure 10, when we compare a domestic CMP shock to a coordinated CMP shock that is equivalent to a 25-basis point decline in both the US and ROW policy rates simultaneously. Like with the coordinated LSAP purchases, inflation and exchange rate effects are muted and the positive impact of consumption and investment is amplified. However, unlike coordinated LSAP purchases, coordinated policy

Figure 9: Coordinated LSAP shocks

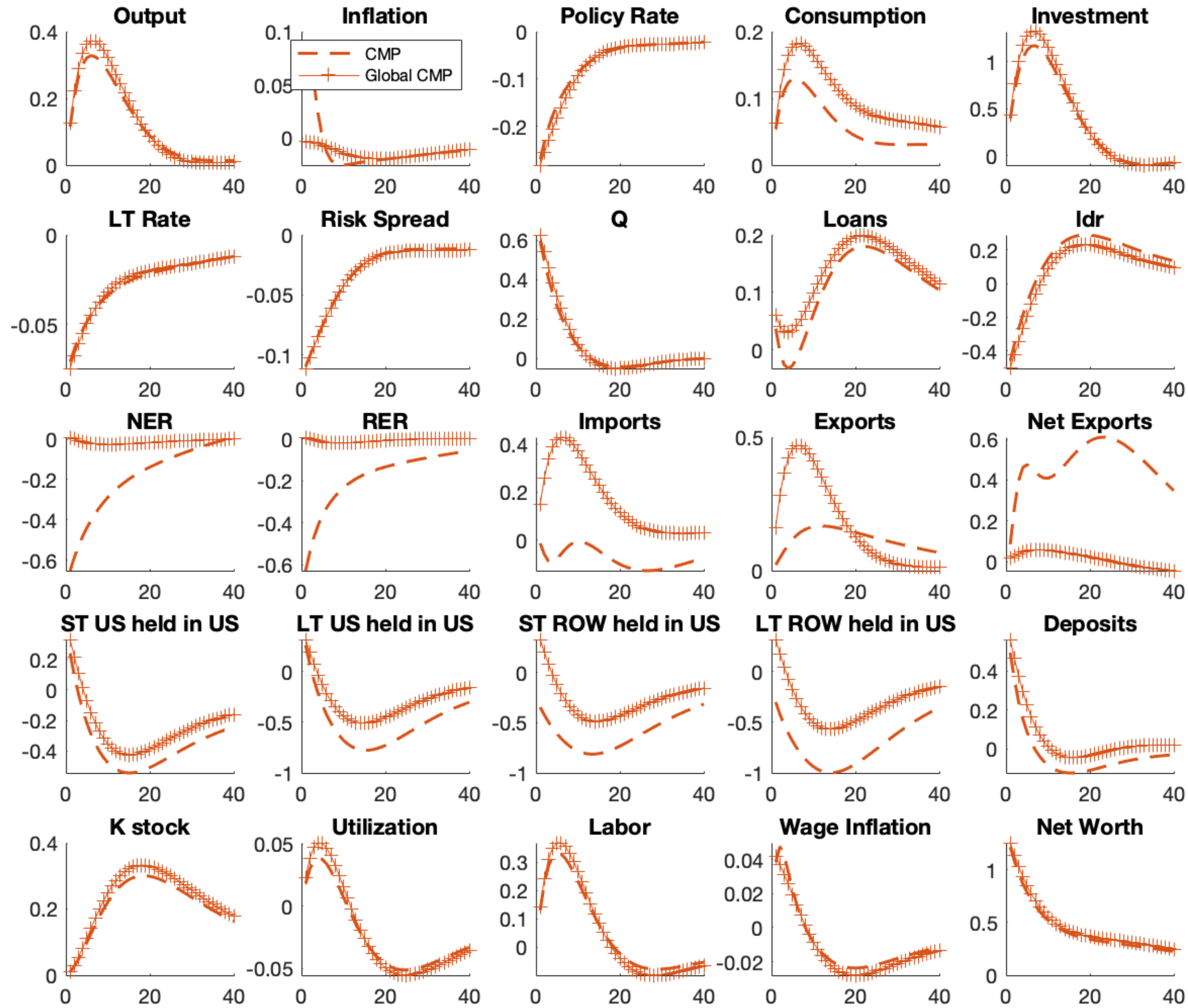


Notes: The solid blue line show a LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank. The marked blue line show the same LSAP shock in both the US and the ROW. All of the impulse responses show the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

rate cuts increase the positive impact on output and hours worked in the US. This is because domestic conventional monetary policy has a much smaller effect on net exports than a domestic LSAP purchases, so the loss in net exports that occurs when monetary policy is coordinated is much smaller when conventional monetary policy is conducted. As a result, the increase in consumption and investment outweighs the loss in net export growth.

Overall, we find that coordinated LSAP policies are somewhat less effective at supporting real activity than coordinated CMP. However, both types of policy have a much smaller effect

Figure 10: Coordinated CMP shocks



Notes: The dashed red line show a CMP shock equivalent to a 25-basis point decline in the US policy rate. The marked red line plots the same CMP shock in both economies, equivalent to a 25-basis point decline in both the US and ROW policy rates. All of the impulse responses show the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

on inflation for any given movement in output. This offer a explanation for why coordinated policies of all types following the financial crisis failed to deliver inflation.

7 Conclusion

In accordance with the unconventional monetary policy literature, we find that domestic large-scale asset purchases raise domestic output and inflation in much the same way as conventional monetary policy but that the transmission mechanism is different. Asset purchases rely more heavily on trade to support domestic real activity. We find that asset purchases have a significant affect on the terms of trade by depreciating the domestic currency. This depreciation shifts consumption toward domestically produced goods and increases net exports.

Large-scale asset purchase's reliance on trade to support real economic activity contrasts with conventional policy that works primarily through stimulating investment. Investment under LSAP policies is negative away from the zero lower bound or positive but small at the zero lower bound because of the financial accelerator. We show that incorporating the financial accelerator in the model is critical to explaining evidence in financial studies that LSAPs have a negligible affect on investment. It also provides an explanation for the stylized fact that credit-to-deposit ratios in countries that introduce LSAPs tend to greatly decrease.

Finally, we show that LSAP policy's reliance on trade to transmit to the real economy means that the degree of trade and financial openness is critical to the effectiveness of the policy. Global retrenchment in trade and financial integration weakens the power of LSAP policies. In addition, the reliance on trade means that coordinated policy, where many countries engage in LSAP policies simultaneously, also weakens its real effects.

Conventional and unconventional monetary policies are important tools in the policymaker's tool kit, however, the heterogeneous effects that both have on goods markets, investment, trade and financial markets must be considered. This paper attempts to provide an avenue to do just that. Future extensions include, introducing a private bond market into the model, evaluating endogenous unconventional monetary policy rules, and adding a housing sector to the model.

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A1 Model Details and Linearized Equations

A1.1 Final-Good Aggregators

There are two types of final-goods aggregators, one for consumption and one for investment. Consumption aggregators are perfectly competitive and produce the final consumption good as a CES aggregate of home consumption ($c_{H,t}$) and imported consumption ($c_{F,t}$).

$$c_t = \left[\gamma_c^{\frac{1}{\lambda_c}} \left(c_{H,t}\right)^{\frac{\lambda_c-1}{\lambda_c}} + (1-\gamma_c)^{\frac{1}{\lambda_c}} \left(c_{F,t}\right)^{\frac{\lambda_c-1}{\lambda_c}}\right]^{\frac{\lambda_c}{\lambda_c-1}} \tag{A42}$$

where γ_c denotes the share of domestic consumption goods, and λ_c is the elasticity of substitution between home and foreign consumption. Derived demand for home and imported consumption is given by:

$$c_{H,t} = \left(\frac{P_{H,t}}{P_t}\right)^{-\lambda_c} \gamma_c c_t \quad \& \quad c_{F,t} = \left(\frac{P_{F,t}}{P_t}\right)^{-\lambda_c} (1-\gamma_c) c_t \tag{A43}$$

where $P_{H,t}$ and $P_{F,t}$ are the prices of home and imported goods, respectively. The aggregate price index, P_t, for consumption goods is given by

$$P_t = \left[\gamma_c P_{H,t}^{1-\lambda_c} + (1-\gamma_c) P_{F,t}^{1-\lambda_c}\right]^{\frac{1}{1-\lambda_c}} \tag{A44}$$

Final investment good aggregators are given by

$$I_t = \left[\gamma_I^{\frac{1}{\lambda_I}} \left(I_{H,t}\right)^{\frac{\lambda_I-1}{\lambda_I}} + (1-\gamma_I)^{\frac{1}{\lambda_I}} \left(I_{F,t}\right)^{\frac{\lambda_I-1}{\lambda_I}}\right]^{\frac{\lambda_I}{\lambda_I-1}} \tag{A45}$$

where γ_I denotes the share of domestic investment goods, and λ_I is the elasticity of substitution between home and foreign investment. Derived demand for home and imported investment is given by:

$$I_{H,t} = \left(\frac{P_{H,t}}{P_{I,t}}\right)^{-\lambda_I} \gamma_I I_t \quad \& \quad I_{F,t} = \left(\frac{P_{F,t}}{P_{I,t}}\right)^{-\lambda_I} (1-\gamma_I) I_t \tag{A46}$$

where $P_{I,t}$ is the aggregate price of investment and is given by: .

$$P_{I,t} = \left[\gamma_I P_{H,t}^{1-\lambda_I} + (1-\gamma_I) P_{F,t}^{1-\lambda_I} \right]^{\frac{1}{1-\lambda_I}} \tag{A47}$$

A1.2 Labor Market

Labor services supplied are heterogeneous across households, and are combined into an aggregated labor level by perfectly-competitive labor intermediaries, labor services are then rented out to goods producers. The labor demand curve each household (j) faces is

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\Theta_{w,t}} L_t \tag{A48}$$

where W_t is the nominal wage rate and $\Theta_{w,t}$ is a time-varying elasticity of substitution between the differentiated labor services. Wage cost-push shocks $e_{w,t}$ are centered around the markup of wages over the marginal rate of substitution, θ_w. ($\theta_w = \Theta_w/(\Theta_w - 1)$)

The optimality conditions of households with respect to labor and wages can be combined to derive a log-linearized New Keynesian Phillips curve for wages given by:

$$\hat{\pi}_{w,t} - \iota_w \hat{\pi}_{t-1} = \beta E_t[\hat{\pi}_{w,t+1} - \iota_w \hat{\pi}_t -] \frac{\Theta_w - 1}{\kappa_w} \left(\hat{w}_t - \nu_L \hat{L} - \frac{1}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{e}_{b,t} \right) + \hat{e}_{w,t} \tag{A49}$$

where nominal wage inflation $\hat{\pi}_{w,t}$ and the real wage $\hat{w}_t$ are defined as:

$$\hat{\pi}_{w,t} - \hat{\pi}_t = \hat{w}_t - \hat{w}_{t-1} \tag{A50}$$

A1.3 Domestic Firms

Home final good producers operate in a perfectly competitive market. They buy intermediate goods $y_t(i)$, package them into final output y_t. The final good of the economy is a

CES production function of a continuum of intermediate goods indexed by i.

$$y_t = \left(\int_0^1 y_t(i)^{\Theta_{H,t}}\, di\right)^{\frac{1}{\Theta_{H,t}}} \tag{A51}$$

The parameter $\Theta_{H,t}$ is a time-varying elasticity of substitution between the differentiated goods and gauges the monopoly power an intermediate firm has in selling its specific good i. The first order condition of the final good producers profit maximization problem leads to the following demand for good $y_t(i)$:

$$y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\Theta_{H,t}} y_t \tag{A52}$$

where $P_{H,t}$ is the home price level. Home price cost-push shocks $e_{H,t}$ are centered around the markup of home prices over marginal cost in the home country, denoted as θ_H. ($\theta_H = \Theta_H/(\Theta_H - 1)$)

Intermediate good producers are the first stage of production. Intermediate firms use utilized capital and labor packaged by the employment agencies to produce differentiated intermediate goods that they sell to the final goods producers. A continuum of these firms indexed by i exist and use the following production process:

$$y_t(i) = e_{a,t} K_t(i)^{\alpha} L_t(i)^{1-\alpha} - f \tag{A53}$$

where f is a fixed cost of the production process, K_t is utilized capital[22] and $e_{a,t}$ is a stationary stochastic productivity shock that alters the production process worldwide. Firms hire labor and rent capital in perfectly competitive markets and pay identical wages and rental rates. The intermediate firms' profit at time t is given by:

$$\frac{\Pi_{H,t}(i)}{P_t} = \frac{P_{H,t}(i)}{P_t} y_t(i) - \frac{W_t}{P_t} L_t(i) - r_t^k K_t(i) - \frac{\kappa_H}{2}\left(\frac{P_{H,t}(i)/P_{H,t-1}(i)}{\pi_{H,t-1}^{\iota_H}\pi^{1-\iota_H}} - 1\right)^2 \frac{P_{H,t}}{P_t} y_t \tag{A54}$$

where, similar to wage stickiness, price stickiness is introduced via quadratic adjustment costs with level parameter κ_H, and ι_H captures the extent to which price adjustments are

[22]Utilized capital, K_t, is equal to the capital stock times the utilization rate. $K_t = u_t \bar{K}_{t-1}$

indexed to past inflation. A domestic firm's objective is to choose the quantity of labor, capital and the price of its output each period, to maximize the present value of profits subject to the demand function it is facing (A52) with respect to its individual output. The first-order conditions of the firm with respect to labor and capital can be combined and linearized to relate the capital-labor ratio as

$$\hat{K}_t - \hat{L}_t = \hat{w}_t - \hat{r}_t^k \tag{A55}$$

The first-order condition with respect to price yields the linearized New Keynesian Phillips curve for domestic prices as:

$$\hat{\pi}_{H,t} - \iota_H \hat{\pi}_{H,t-1} = \beta E_t[\hat{\pi}_{H,t+1} - \iota_H \hat{\pi}_{H,t}] - \frac{\Theta_H - 1}{\kappa_H} \left(\hat{p}_{H,t} + \hat{e}_{a,t} + \alpha(\hat{K}_t - \hat{L}_t) - \hat{w}_t \right) + \hat{e}_{H,t} \tag{A56}$$

where $p_{H,t}$ is the relative price of home goods. ($p_{H,t} = \frac{P_{H,t}}{P_t}$).

A1.4 Importers

A unit measure of importers indexed by m, import foreign goods from abroad, differentiate them and markup their price, and then sell these heterogeneous goods to perfectly competitive import aggregators, who aggregate these imported goods using a CES aggregator. The demand curve facing each importer is given by:

$$y_{F,t}(m) = \left(\frac{P_{F,t}(m)}{P_{F,t}} \right)^{-\Theta_{F,t}} y_{F,t} \tag{A57}$$

where $y_{F,t}$ is the aggregate level of imports and $\Theta_{F,t}$ is a time-varying elasticity of substitution between the differentiated import goods. Import cost-push shocks $e_{F,t}$ are centered around the markup of import good prices over its import price, θ_F. ($\theta_F = \Theta_F/(\Theta_F - 1)$)

Importers maximize the present value of profits subject to the demand function they are facing from the aggregators. The importer's profits at time t are given by

$$\frac{\Pi_{F,t}(i)}{P_t} = \frac{P_{F,t}(i)}{P_t} y_{F,t}(m) - \frac{e_t P^*_{H,t}}{P_t} y_{F,t}(m) - \frac{\kappa_F}{2}\left(\frac{P_{F,t}(m)/P_{F,t-1}(m)}{\pi^{\iota_F}_{F,t-1}\pi^{1-\iota_F}} - 1\right)^2 \frac{P_{F,t}}{P_t} y_{F,t} \quad \text{(A58)}$$

where κ_F and ι_F are the price adjustment cost and indexation parameters. Import price frictions ensure there is not perfect import price/exchange rate pass through.

The first-order condition of importers with respect to price yields the following linearized import-price New Keynesian Phillips curve:

$$\hat{\pi}_{F,t} - \iota_F \hat{\pi}_{F,t-1} = \beta E_t[\hat{\pi}_{F,t+1} - \iota_F \hat{\pi}_{F,t}] - \frac{\Theta_F - 1}{\kappa_F}\left(\hat{p}_{F,t} - r\hat{e}r_t - \hat{p}^*_{H,t}\right) + \hat{e}_{F,t} \quad \text{(A59)}$$

where $p_{F,t}$ is the relative price of import goods, ($p_{F,t} = \frac{P_{F,t}}{P_t}$) and rer_t is the real exchange rate. Import price cost-push shocks $\epsilon_{F,t}$ are centered around the markup of import good prices over its import price, denoted as θ_F. ($\theta_F = \Theta_F/(\Theta_F - 1)$)

A1.5 Capital Producers

Capital goods are produced in a perfectly competitive sector of the economy by purchasing aggregated investment and transforming it into new capital. In addition to producing new capital, capital producers also buy and sell capital from entrepreneurs at price Q_t. At the end of time t capital producers purchase non-depreciated $t-1$ physical capital from entrepreneurs and investment goods from the aggregated good producers and convert them to the time t capital stock. The time t physical capital stock is then purchased by entrepreneurs and used in time $t+1$ production. The physical capital stock evolves according to:

$$\bar{K}_t = (1-\tau)\bar{K}_{t-1} + e_{I,t}\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \quad \text{(A60)}$$

where τ is the depreciation rate and I_t is the investment good purchased.

Capital producers face a stochastic exogenous AR(1) process $e_{I,t}$ that alters the ability of producers to turn investment purchases into physical capital. In addition, capital producers face investment adjustment costs represented by the function S. Where $S(1) = S'(1) = 0$,

$S'() > 0$ and $S''() > 0$.

Capital producers profit is defined as:

$$\Pi_t^k = Q_t(\bar{K}_t - (1-\tau)\bar{K}_{t-1}) - P_{I,t}I_t \tag{A61}$$

where $P_{I,t}$ is the price of investment. The capital producers maximize future profits by choosing an Investment level subject to the households' discount factor and the capital accumulation equation. The first-order condition with respect to investment yields the following linearized investment demand equation:

$$\hat{I}_t - \hat{I}_{t-1} = \beta E_t[\hat{I}_{t+1} - \hat{I}_t] + \frac{1}{S''}(\hat{Q}_t - \hat{p}_{I,t}) + \hat{e}_{I,t} \tag{A62}$$

where $p_{I,t}$ is the relative price of investment goods, ($p_{I,t} = \frac{P_{I,t}}{P_t}$).

A1.6 Linearized Equations - Home Country

- Household FOC's

$$\hat{\lambda}_t = -\frac{1}{1-h}(\hat{C}_t - h\hat{C}_t - 1) + \hat{e}_{b,t} \tag{A63}$$

$$\hat{R}_{L,t} = \frac{\kappa}{R_L}E_t[\hat{R}_{L,t+1}] + \left(1 - \frac{\kappa}{R_L}\right)\left(\hat{R}_t + \left(\frac{\pi}{\beta R} - 1\right)\hat{T}_t\right) \tag{A64}$$

$$\hat{T}_t = \frac{1}{\lambda_a}\left(\hat{a}_{L,t} - \hat{a}_{S,t} + \frac{1}{1-\gamma_a}\hat{\gamma}_{a,t}\right) - \frac{1}{\lambda_L}\left(\hat{a}_{L,t} - (\hat{q}_{L,t} + \hat{b}_{H,L,t}) + \hat{\gamma}_{L,t}\right) + \frac{1}{\lambda_s}\left(\hat{a}_{S,t} - \hat{b}_{H,S,t} + \hat{\gamma}_{S,t}\right) \tag{A65}$$

$$\begin{aligned}\hat{\lambda}_t = {} & \frac{\beta R}{\pi}\left(E_t[\hat{\lambda}_{t+1}] + \hat{R}_t - E_t[\hat{\pi}_{t+1}]\right) + \left(1 - \frac{\beta R}{\pi}\right)\left[\frac{1-\gamma_a}{\lambda_a}\left(\hat{a}_{L,t} - \hat{a}_{S,t} + \frac{1}{1-\gamma_a}\hat{\gamma}_{a,t}\right)\right. \\ & \left. + \frac{1-\gamma_S}{\lambda_S}\left(\hat{rer}_t + \hat{b}_{F,S,t} - \hat{b}_{H,S,t} + \frac{1}{1-\gamma_S}\hat{\gamma}_{S,t}\right) - \hat{a}_t\right]\end{aligned} \tag{A66}$$

$$\hat{\lambda}_t = \frac{\beta R^D}{\pi}\left(E_t[\hat{\lambda}_{t+1}] + \hat{R}_t^D - E_t[\hat{\pi}_{t+1}]\right) - \left(1 - \frac{\beta R^D}{\pi}\right)\hat{dep}_t \tag{A67}$$

- Aggregate Definitions

$$\hat{a}_t = \gamma_a \hat{a}_{S,t} + (1-\gamma_a)\hat{a}_{L,t} \tag{A68}$$

$$\hat{a}_{S,t} = \gamma_S \hat{b}_{H,S,t} + (1-\gamma_S)(r\hat{e}r_t + \hat{b}_{F,S,t}) \tag{A69}$$

$$\hat{a}_{L,t} = \gamma_L \hat{b}_{H,L,t} + (1-\gamma_L)(r\hat{e}r_t + \hat{q}^*_{L,t} + \hat{b}_{F,L,t}) \tag{A70}$$

$$\hat{c}_t = \gamma_c \hat{c}_{H,t} + (1-\gamma_c)\hat{c}_{F,t} \tag{A71}$$

$$\hat{I}_t = \gamma_I \hat{I}_{H,t} + (1-\gamma_I)\hat{I}_{F,t} \tag{A72}$$

- UIP Equations

$$\hat{R}_t - \hat{R}^*_t = E_t\hat{d}_{t+1} + \left(\tfrac{\pi}{\beta R} - 1\right)\tfrac{1}{\lambda_s}\left[\hat{b}_{H,S,t} - (r\hat{e}r_t + \hat{b}_{F,S,t}) - \tfrac{1}{1-\gamma_S}\hat{\gamma}_{S,t}\right] \tag{A73}$$

$$\begin{aligned}\hat{R}_{L,t} - \hat{R}^*_{L,t} = {} & \frac{\kappa}{R_L}\left(E_t[\hat{R}_{L,t+1}] - E_t[\hat{R}^*_{L,t+1}]\right) + \left(1 - \frac{\kappa}{R_L}\right)\Big\{E_t\hat{d}_{t+1} \\ & + \left(\frac{\pi}{\beta R} - 1\right)\frac{1}{\lambda_L}\left[\hat{q}_{L,t} + \hat{b}_{H,L,t} - (r\hat{e}r_t + \hat{q}^*_{L,t} + \hat{b}_{F,L,t}) - \frac{1}{1-\gamma_L}\hat{\gamma}_{L,t}\right]\Big\}\end{aligned} \tag{A74}$$

- Policy Equations

$$\hat{R}_t = \rho\hat{R}_{t-1} + (1-\rho)\left[r_\pi\hat{\pi}_t + r_y\hat{y}_t + r_d\hat{d}_t\right] + \hat{\varepsilon}_{r,t} + \sum_{k=1}^{5}\hat{e}^r_{k,t-k} \tag{A75}$$

$$\begin{aligned}&\frac{g}{y}(\hat{p}_{H,t} + \hat{g}_t) + \frac{R}{\pi}\frac{b_S}{y}\left(\hat{R}_{t-1} - \hat{\pi}_t + \hat{b}_{S,t-1}\right) + \frac{R_L}{\pi}\frac{q_L b_L}{y}\left(\hat{R}_{L,t} - \hat{\pi}_t + \hat{q}_{L,t} + \hat{b}_{L,t-1}\right) \\ &\quad = \frac{tax}{y}t\hat{a}x_t + \frac{b_S}{y}\hat{b}_{S,t} + \frac{q_L b_L}{y}\left(\hat{q}_{L,t} + \hat{b}_{L,t}\right)\end{aligned} \tag{A76}$$

$$t\hat{a}x_t = \tau_Y\hat{y}_t + \tau_b\frac{\frac{b_S}{y}}{\frac{b_S}{y} + \frac{q_L b_L}{y}}\hat{b}_{S,t-1} + \tau_b\frac{\frac{q_L b_L}{y}}{\frac{b_S}{y} + \frac{q_L b_L}{y}}\left(\hat{q}_{L,t-1} + \hat{b}_{L,t-1}\right) + \hat{e}_{tax,t} \tag{A77}$$

$$\frac{b_S}{y}\hat{b}_{S,t} = \frac{b_{H,S}}{y}\hat{b}_{H,S,t} + \left(\frac{b_s}{y} - \frac{b_{H,S}}{y}\right)\hat{b}^*_{F,S,t} \tag{A78}$$

$$\frac{q_L b_L}{y}\hat{b}_{L,t} = \frac{q_L b_{H,L}}{y}\hat{b}_{H,L,t} + \left(\frac{q_L b_L}{y} - \frac{q_L b_{H,L}}{y}\right)\hat{b}^*_{F,L,t} \tag{A79}$$

$$\hat{\gamma}_{b,t} = \hat{q}_{L,t} + \hat{b}_{L,t} - \hat{b}_{S,t} \tag{A80}$$

- Capital

$$\hat{\bar{K}}_t = (1-\tau)\hat{\bar{K}}_{t-1} + \tau \hat{I}_t + S''\tau \hat{e}_{I,t} \tag{A81}$$

$$\hat{I}_t - \hat{I}_{t-1} = \beta E_t[\hat{I}_{t+1} - \hat{I}_t] + \frac{1}{S''}(\hat{Q}_t - \hat{p}_{I,t}) + \hat{e}_{I,t} \tag{A82}$$

$$\hat{K}_t = \hat{u}_t + \hat{\bar{K}}_{t-1} \tag{A83}$$

$$\hat{u}_t = \frac{r_k}{a''(u)}\hat{r}_t^k \tag{A84}$$

- New Keynesian Phillip's Curves

$$\hat{\pi}_{w,t} - \iota_w \hat{\pi}_{t-1} = \beta E_t[\hat{\pi}_{w,t+1} - \iota_w \hat{\pi}_t -] \frac{\Theta_w - 1}{\kappa_w}\left(\hat{w}_t - \nu_L \hat{L} - \frac{1}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{e}_{b,t}\right) + \hat{e}_{w,t} \tag{A85}$$

$$\hat{\pi}_{H,t} - \iota_H \hat{\pi}_{H,t-1} = \beta E_t[\hat{\pi}_{H,t+1} - \iota_H \hat{\pi}_{H,t}] - \frac{\Theta_H - 1}{\kappa_H}\left(\hat{p}_{H,t} + \hat{e}_{a,t} + \alpha(\hat{K}_t - \hat{L}_t) - \hat{w}_t\right) + \hat{e}_{H,t} \tag{A86}$$

$$\hat{\pi}_{F,t} - \iota_F \hat{\pi}_{F,t-1} = \beta E_t[\hat{\pi}_{F,t+1} - \iota_F \hat{\pi}_{F,t}] - \frac{\Theta_F - 1}{\kappa_F}\left(\hat{p}_{F,t} - r\hat{e}r_t - \hat{p}^*_{H,t}\right) + \hat{e}_{F,t} \tag{A87}$$

- Producers

$$\hat{y}_t = \phi \hat{e}_{a,t} + \phi\alpha \hat{K}_t + \phi(1-\alpha)\hat{L}_t \tag{A88}$$

$$\hat{K}_t - \hat{L}_t = \hat{w}_t - \hat{r}_t^k \tag{A89}$$

- Entrepreneurs and Financial Sector

$$E_t\left[\hat{\bar{R}}^k_{t+1} - \hat{R}_t\right] = \chi\left(\hat{Q}_t + \hat{\bar{K}}_t - N\hat{W}_t\right) + \hat{e}_{Fin,t} \tag{A90}$$

$$\hat{S}_t = E_t\left[\hat{\bar{R}}^k_{t+1} - \hat{R}_t\right] \tag{A91}$$

$$N\hat{W}_t = \delta_{\bar{R}^k}(\hat{\bar{R}}^k_t - \hat{\pi}_t) - \delta_R(\hat{R}_{t-1} - \hat{\pi}_t) + \delta_{qK}(\hat{Q}_{t-1} + \hat{\bar{K}}_{t-1}) + \delta_n N\hat{W}_{t-1} - \delta_\sigma \hat{e}^{Fin}_{t-1} + \hat{e}^{NW}_t \tag{A92}$$

$$\hat{\bar{R}}_t^k - \hat{\pi}_t = \frac{1-\tau}{1-\tau+r^k}\hat{Q}_t + \frac{r^k}{1-\tau+r^k}\hat{r}_t^k - \hat{Q}_{t-1} \tag{A93}$$

$$\frac{R^D}{ldr}\hat{R}_t^D = R\left(\hat{R}_t + l\hat{d}r_t\right) - l\hat{d}r_t \tag{A94}$$

$$\left(\frac{\bar{K}}{NW} - 1\right) lo\hat{a}ns_t = \frac{\bar{K}}{NW}\left(\hat{Q}_t - \hat{\bar{K}}_t\right) - N\hat{W}_t \tag{A95}$$

- Balance of Payments

$$\begin{aligned}
&\frac{b_{F,S}}{y}\left[\left(r\hat{e}r + \hat{b}_{F,S,t}\right) - \frac{R^*}{\pi^*}\left(r\hat{e}r_t + \hat{R}^*_{t-1} + \hat{b}_{F,S,t-1} - \hat{\pi}^*_t\right)\right]...\\
&\quad + \frac{q_L^* b_{F,L}}{y}\left[\left(r\hat{e}r + \hat{q}^*_{L,t} + \hat{b}_{F,L,t}\right) - \frac{R_L^*}{\pi^*}\left(r\hat{e}r_t + \hat{R}^*_{L,t} + \hat{q}^*_{L,t} + \hat{b}_{F,L,t-1} - \hat{\pi}^*_t\right)\right]...\\
&\quad - \frac{b^*_{F,S}}{y}\left[\hat{b}^*_{F,S,t} - \frac{R}{\pi}\left(\hat{R}_{t-1} + \hat{b}^*_{F,S,t-1} - \hat{\pi}_t\right)\right]...\\
&\quad - \frac{q_L b^*_{F,L}}{y}\left[\left(\hat{q}_{L,t} + \hat{b}^*_{F,L,t}\right) - \frac{R_L}{\pi}\left(\hat{R}_{L,t} + \hat{q}_{L,t} + \hat{b}^*_{F,L,t-1} - \hat{\pi}_t\right)\right]...\\
&\quad = \frac{y_F^*}{y}\left(\hat{p}_{H,t} + y^*_{F,t}\right) - \frac{y_F}{y}\left(r\hat{e}r_t + \hat{p}^*_{H,t} + y_{F,t}\right)
\end{aligned} \tag{A96}$$

- Definitions

$$\hat{R}_{L,t} = -\left(1 - \frac{\kappa}{R_L}\right)\hat{q}_{L,t} \tag{A97}$$

$$r\hat{e}r_t - r\hat{e}r_{t-1} = \hat{d}_t + \hat{\pi}^*_t - \hat{\pi}_t \tag{A98}$$

$$0 = \gamma_c \hat{p}_{H,t} + (1-\gamma_c)\hat{p}_{F,t} \tag{A99}$$

$$\hat{p}_{I,t} = \gamma_I \hat{p}_{H,t} + (1-\gamma_I)\hat{p}_{F,t} \tag{A100}$$

$$\hat{\pi}_{H,t} - \hat{\pi}_t = \hat{p}_{H,t} - \hat{p}_{H,t-1} \tag{A101}$$

$$\hat{\pi}_{F,t} - \hat{\pi}_t = \hat{p}_{F,t} - \hat{p}_{F,t-1} \tag{A102}$$

$$\hat{\pi}_{w,t} - \hat{\pi}_t = \hat{w}_t - \hat{w}_{t-1} \tag{A103}$$

$$\hat{c}_{H,t} - \hat{c}_{F,t} = \eta_c\left(\hat{p}_{F,t} - \hat{p}_{H,t}\right) \tag{A104}$$

$$\hat{I}_{H,t} - \hat{I}_{F,t} = \eta_I\left(\hat{p}_{F,t} - \hat{p}_{H,t}\right) \tag{A105}$$

$$\hat{y}_t = \frac{c}{y}\gamma_c \hat{c}_{H,t} + \frac{I}{y}\gamma_I \hat{I}_{H,t}\frac{g}{y}\hat{g}_t + \frac{y_F^*}{y}\hat{y}_{F,t}^* + r_k\frac{\bar{K}}{y}\hat{u}_t \tag{A106}$$

$$\hat{y}_{F,t} = \frac{c}{y}\frac{y}{y_F}(1-\gamma_c)\hat{c}_{F,t} + \frac{I}{y}\frac{y}{y_F}(1-\gamma_I)\hat{I}_{F,t} \tag{A107}$$

$$\hat{ldr}_t = \hat{loans}_t - \hat{dep}_t \tag{A108}$$

A2 Data, Calibrated and Estimated Parameters

Table A1 presents the weight placed on each country in order to produce the ROW series while Figure A11 plots the series of data used to estimate the model for both the US and the ROW.

Table A1: Country Weights for ROW Data

Country	Economic Variables	Financial Variables
European Union (EU)	0.430	0.523
Japan (JPN)	0.198	0.241
China (CHN)	0.178	-
United Kingdom (UK)	0.085	0.103
Canada (CAN)	0.052	0.064
Australia (AUS)	0.037	0.045
Switzerland (SWZ)	0.019	0.024

Figure A11: Data Series

In addition to the calibrated parameters discussed in Section 3.2, we also calibrate certain parameters around the financial accelerator and portfolio share. Following Chen et al. (2012), the parameter for the coupon payments of long-term bonds, (κ), is calibrated to imply a duration of 30 quarters for both countries, similar to the average duration in the secondary market for 10-year US Treasury bonds. The model's steady state default rate (F) is set to 0.0075 which corresponds to Bernanke, Gertler, Gilchrist (1999) annualized default rate of 3%. The quarterly survival rate of entrepreneurs is fixed at 0.985 which corresponds to an average entrepreneur life of roughly 12 years and the steady state loan to deposit ratio is set to 0.9 for both countries.

To calibrate the portfolio share parameters for the US and the ROW, we combine the supply of short and long-term bonds in each economy, as well as data on foreign bond holdings provided by the Treasury International Capital (TIC) database of the US Treasury. For the US the short and long-term government bonds outstanding[23] relative to annual GDP are 0.202 and 0.366, respectively, over the 1999-2019 period. The corresponding government short and long-term bond supply-to-GDP ratios for the ROW economy are given by 0.256 and 0.523, when the sample of countries used to construct the ROW measure for our estimation is calculated. For bond holdings, TIC data indicates that the foreign private holdings of short and long-term US Treasuries, as a ratio to world GDP excluding the US, are given by 0.017 and 0.059, respectively, for the 1999-2019 period. TIC data also shows that US residents' holdings of short and long-term foreign government bonds, as a ratio to US GDP, are given by 0.005 and 0.030. These represent our targets for the foreign holdings of each bond.

The differences in the bond supplies and international bond holdings can then be used to construct data targets for domestic holdings of these bonds. The bond holding ratios can then be used to calibrate the portfolio share parameters in the CES aggregates. As a result, the implied share of short-term bonds in the US portfolio, (γ_a), is 0.382, while the implied shares of domestic bonds in the US short and long-term portfolios, (γ_S) and (γ_L), are 0.971 and 0.891. For the ROW portfolio, the share of short-term bonds, (γ_a^*), is calculated to equal

[23] Short and long-term bonds held by the Federal Reserve are subtracted and the monetary base is added to the short-term bond supply amount.

0.323, while the implied shares of domestic bonds in their short and long-term portfolios, (γ_S^*) and (γ_L^*), are 0.937 and 0.896.

Table A2: Calibrated Parameters and Steady-states

Description	Symbols	US	ROW
Discount rate	β, β^*	0.9857	0.9857
Depreciation rate	τ, τ^*	0.025	0.025
Capital share of production	α, α^*	0.34	0.34
Coupon rate for long-term bonds	κ, κ^*	0.9773	0.9773
Central bank policy-FX response	r_d, r_d^*	0	est
Anticipated monetary policy shock variance	$\sigma_{ant,k}$	$\sigma_r/5$	-
Degree of markup in sector	$\theta_{\{w,H,F\}}$	1.25	1.25
Fixed cost of Production	ϕ, ϕ^*	1.25	1.25
Loan to deposit steady-state ratio	ldr, ldr^*	0.9	0.9
Survival rate of entrepreneur	γ, γ^*	0.985	0.985
Loan default rate	F, F^*	0.0075	0.0075
Portfolio share-Short vs Long	γ_a, γ_a^*	0.382	0.323
Portfolio share-Short-Domestic vs Foreign	γ_S, γ_S^*	0.971	0.937
Portfolio share-Long-Domestic vs Foreign	γ_L, γ_L^*	0.891	0.896
Home Goods share-Consumption	γ_c, γ_c^*	0.845	0.921
Home Goods share-Investment	γ_I, γ_I^*	0.845	0.921
Steady-state inflation	π, π^*	1.005	1.005
Steady-state nominal interest rate	R, R^*	1.011	1.011
Steady-state long-term nominal interest rate	R_L, R_L^*	1.011	1.011
Steady-state interest rate spread	S, S^*	1.00575	1.00575

Table A3: Steady-state Ratios

Description	Symbols	US	ROW
Relative Size	$y/y^*, y^*/y$	0.508	1.97
Consumption to output	c/y, c^*/y^*	0.618	0.577
Investment to output	I/y, I^*/y^*	0.185	0.185
Government to output	g/y, g^*/y^*	0.202	0.235
Tax to output	tax/y, tax^*/y^*	0.2156	0.2536
Exports to output	y_F^*/y, y_F/y^*	0.119	0.063
Imports to output	y_F/y, y_F^*/y^*	0.124	0.060
Short-bond supply to GDP (annual)	b_S/y, b_S^*/y^*	0.202	0.256
Long-bond supply to GDP (annual)	b_L/y, b_L^*/y^*	0.366	0.523
Short-Home bond holdings to GDP (annual)	$b_{H,S}/y$, $b_{H,S}^*/y^*$	0.169	0.253
Long-Home bond holdings to GDP (annual)	$b_{H,L}/y$, $b_{H,L}^*/y^*$	0.250	0.508
Short-Foreign bond holdings to GDP (annual)	$b_{F,S}/y$, $b_{F,S}^*/y^*$	0.005	0.017
Long-Foreign bond holdings to GDP (annual)	$b_{F,L}/y$, $b_{F,L}^*/y^*$	0.030	0.059

Table A4: Prior and Posterior Estimates - Structural Parameters

			U.S. Posterior			ROW Posterior		
Parameter		Prior	Mean	5%	95%	Mean	5%	95%
Habit Consumption	h	β(0.7,0.1)	0.870	0.836	0.900	0.857	0.824	0.888
Utilization Cost	$a''(u)$	β(0.2,0.025)	0.204	0.160	0.249	0.186	0.143	0.233
Investment Adj Cost	S''	G(5,1)	5.823	4.207	7.561	6.563	5.009	8.324
CRRA Labor	ν_L	G(2,0.25)	2.031	1.638	2.467	2.247	1.744	2.829
Elasticity: ST-LT Bonds	λ_a^{est}	β(0.5,0.1)	0.622	0.508	0.739	0.644	0.549	0.742
Elasticity: Home-Foreign ST Bonds	λ_S^{est}	β(0.5,0.1)	0.282	0.199	0.373	0.357	0.261	0.463
Elasticity: Home-Foreign LT Bonds	λ_L^{est}	β(0.5,0.1)	0.416	0.319	0.516	0.737	0.630	0.834
Taylor rule: Persistence	ρ	β(0.7,0.1)	0.923	0.904	0.939	0.922	0.904	0.938
Taylor rule: Inflation	r_π	G(2,0.2)	1.825	1.568	2.104	1.920	1.652	2.200
Taylor rule: Output gap	r_y	G(0.12,0.025)	0.075	0.059	0.092	0.095	0.074	0.121
Taylor rule: NER	r_d	N(0,0.025)	-	-	-	-0.016	-0.047	0.014
Tax rule: Output	τ_y	G(1,0.2)	0.953	0.665	1.285	0.898	0.625	1.206
Tax rule: Debt	τ_b	G(1,0.2)	0.715	0.508	0.974	0.874	0.696	1.079
Elasticity: Home-Foreign Cons	η_c	G(0.9,0.1)	1.341	1.234	1.452	0.739	0.620	0.866
Elasticity: Home-Foreign Inv	η_I	G(0.9,0.1)	1.005	0.833	1.188	0.846	0.699	1.002
Wage indexation	ι_w	β(0.5,0.2)	0.163	0.114	0.211	0.101	0.065	0.132
Home price indexation	ι_H	β(0.5,0.2)	0.501	0.341	0.660	0.569	0.367	0.906
Import price indexation	ι_F	β(0.5,0.2)	0.486	0.294	0.686	0.525	0.338	0.723
Wage Adj Cost	κ_w^{est}	β(0.5,0.1)	0.967	0.961	0.971	0.980	0.970	0.992
Home price Adj Cost	κ_H^{est}	β(0.5,0.1)	0.974	0.959	0.983	0.967	0.909	0.986
Import price Adj Cost	κ_F^{est}	β(0.5,0.1)	0.697	0.642	0.751	0.922	0.891	0.947
Financial Spread Elasticity	χ	G(0.05,0.01)	0.045	0.040	0.054	0.037	0.035	0.041

Table A5: Prior and Posterior Estimates - Exogenous Shock Parameters

Parameter		Prior	U.S. Posterior			ROW Posterior		
			Mean	5%	95%	Mean	5%	95%
Shock Standard Deviations (x100)								
Wage Shock	σ_w	$IG(0.5, 0.4)$	0.229	0.198	0.263	0.173	0.150	0.200
Home Price Shock	σ_H	$IG(0.5, 0.4)$	0.214	0.187	0.246	0.226	0.190	0.284
Import Price Shock	σ_F	$IG(0.5, 0.4)$	2.435	2.057	2.887	1.719	1.471	2.015
Productivity Shock	σ_a	$IG(0.5, 0.4)$	0.486	0.424	0.560	0.331	0.289	0.378
Consumption Shock	σ_b	$IG(0.5, 0.4)$	5.327	4.452	6.289	4.181	3.521	4.991
Investment Shock	σ_I	$IG(0.5, 0.4)$	1.394	1.078	1.786	0.941	0.746	1.172
CMP Shock	σ_r	$IG(0.5, 0.4)$	0.105	0.091	0.120	0.057	0.050	0.065
Govt Shock	σ_g	$IG(0.5, 0.4)$	1.591	1.450	1.743	0.443	0.062	1.091
Tax Shock	σ_{tax}	$IG(0.5, 0.4)$	21.130	19.748	22.547	40.320	37.629	43.199
LSAP Shock	σ_{γ_b}	$IG(0.5, 0.4)$	5.111	4.550	5.736	6.363	5.648	7.190
Net worth Shock	σ_{NW}	$IG(0.5, 0.4)$	2.519	1.781	3.369	2.074	1.515	2.735
Risk Shock	σ_{Fin}	$IG(0.5, 0.4)$	0.228	0.193	0.268	0.183	0.155	0.216
ST-LT Bond Demand Shock	σ_{γ_a}	$IG(0.5, 0.4)$	11.437	9.874	13.219	9.536	8.390	10.824
ST Home Bond Demand Shock	σ_{γ_S}	$IG(0.5, 0.4)$	1.695	1.155	2.400	2.584	1.872	3.471
LT Home Bond Demand Shock	σ_{γ_L}	$IG(0.5, 0.4)$	3.366	2.355	4.662	1.973	1.486	2.588
Shock Persistence								
Productivity Shock	ρ_a	$\beta(0.5, 0.2)$	0.941	0.910	0.969	0.871	0.814	0.919
Consumption Shock	ρ_b	$\beta(0.5, 0.2)$	0.949	0.925	0.969	0.962	0.942	0.981
Investment Shock	ρ_I	$\beta(0.5, 0.2)$	0.769	0.595	0.945	0.712	0.601	0.812
Govt Shock	ρ_g	$\beta(0.5, 0.2)$	0.885	0.816	0.948	0.965	0.939	0.988
Tax Shock	ρ_{tax}	$\beta(0.5, 0.2)$	0.717	0.614	0.807	0.025	0.008	0.054
LSAP Shock	ρ_{γ_b}	$\beta(0.5, 0.2)$	0.963	0.949	0.980	0.985	0.971	0.995
Net worth Shock	ρ_{NW}	$\beta(0.5, 0.2)$	0.726	0.589	0.835	0.656	0.526	0.768
Risk Shock	ρ_{Fin}	$\beta(0.5, 0.2)$	0.828	0.772	0.878	0.805	0.756	0.851
ST-LT Bond Demand Shock	ρ_{γ_a}	$\beta(0.5, 0.2)$	0.967	0.954	0.979	0.967	0.951	0.980
ST Home Bond Demand Shock	ρ_{γ_S}	$\beta(0.5, 0.2)$	0.769	0.617	0.876	0.876	0.812	0.925
LT Bond Demand Shock	ρ_{γ_L}	$\beta(0.5, 0.2)$	0.876	0.782	0.935	0.963	0.946	0.977
Shock Correlation								
Net worth Shock Corr	ρ_{NW,NW^*}	$\beta(0.5, 0.1)$	0.654	0.575	0.719	-	-	-
Risk Shock Corr	ρ_{Fin,Fin^*}	$\beta(0.5, 0.1)$	0.698	0.635	0.753	-	-	-
Productivity Shock Corr	ρ_{a,a^*}	$\beta(0.5, 0.1)$	0.418	0.341	0.488	-	-	-

A3 Local Projection Estimates

Table A6 provides the point estimates for the local projections IRFs shown in Section 4.2 of the main text. Negative LSAP shocks correspond to asset purchases. Positive LSAP shocks correspond to asset sales. Therefore, the sign of the dynamic multipliers for LSAP shocks has the same interpretation as the sign of the dynamic multipliers for CMP shocks. In other words, a negative CMP shocks lowers the short term interest rate and corresponds to expansionary policy. Likewise, a negative LSAP shock corresponds to an asset purchase and expansionary policy.

All of the regression specifications we consider include one lag of the policy rate, output, price level, consumption, investment, risk spread, ten-year rate, net worth, nominal exchange rate, net exports, exports, and imports as controls as well as a ZLB dummy indicator and a recession dummy indicator. The US policy rate includes the nominal exchange rate as a contemporaneous control. Output, price level, consumption, investment, and the risk spread specifications include the US policy rate and the nominal exchange rate as well contemporaneous controls. The nominal exchange rate, net exports, and exports include the ROW policy rate and its lag and the lag of import prices as additional controls.

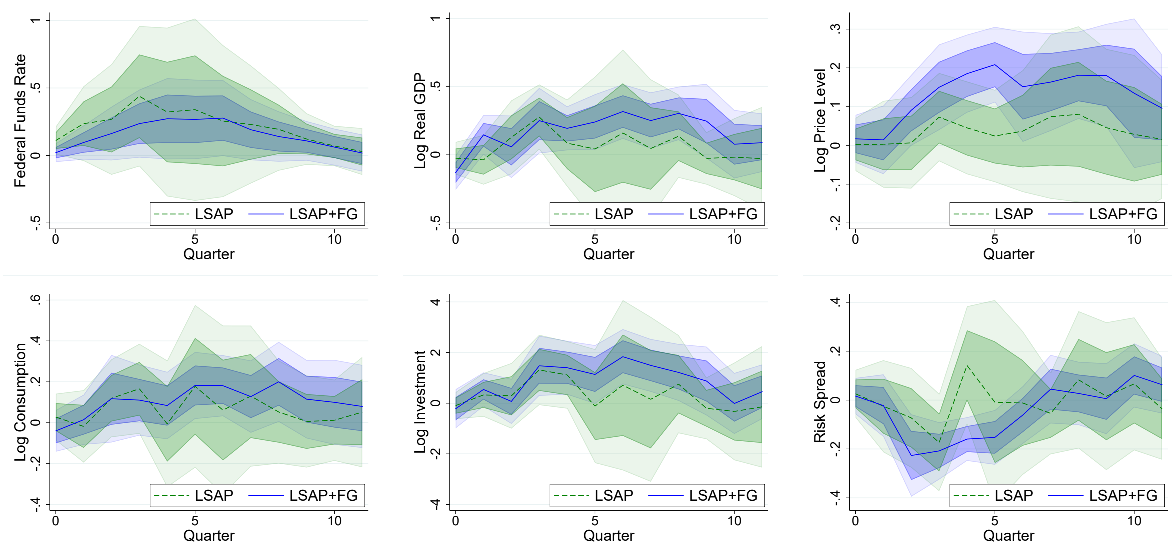
Figure A12 and A13 show the state-dependent local projection estimates. The state-dependent local projections regression specification is

$$\begin{aligned}\Delta_h y_t \;=\;& \gamma_0 + \gamma_1 I(ZLB)_t + \left(\beta_1^h CMP_t + \beta_2^h LSAP_t + \beta_3^h FG_t\right) \times I(ZLB)_t \\ & + \left(\beta_4^h CMP_t + \beta_5^h LSAP_t + \beta_6^h FG_t\right) \times (1 - I(ZLB)_t) \\ & + W_t \Gamma^h + X_{t-1}\Psi^h + \epsilon_{t,h}\end{aligned}$$

where β_1^h, β_2^h, β_4^h, and β_5^h are the dynamic multipliers of interest for $h = 0, 1, ..., 11$. The full sample is 1999q2 to 2019q2 and zero lower bound period is 2009q1 through 2015q4.

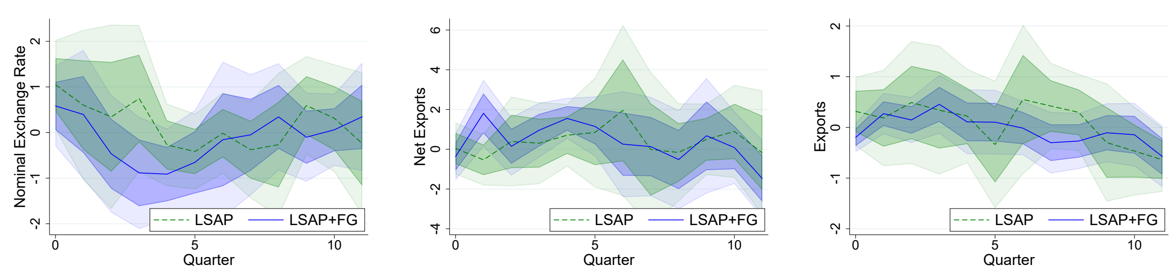
Consistent with the structural model, we find that LSAP+FG has a qualitatively larger effect on output, inflation, consumption, investment, and the risk spread. We also find qualitatively larger effects for the trade variables. Finally, consistent with the model with the financial accelerator, we cannot reject the null hypothesis of no effect on investment for LSAPs conducted outside of the zero lower bound period.

Figure A12: State-Dependent Local Projections Impulse Responses



Notes: Local projection impulse response estimates for state-dependent large scale asset purchase shocks during the zero lower bound period (LSAP + FG) and outside of the zero lower bound period. The dark shaded bands indicate 67% confidence intervals. The lighter bands indicate 90% confidence intervals. The full sample is 1999q2 to 2019q2 and zero lower bound period is 2009q1 through 2015q4.

Figure A13: Local Projections Impulse Responses - Trade



Notes: Local projection impulse response estimates for state-dependent large scale asset purchase shocks during the zero lower bound period (LSAP + FG) and outside of the zero lower bound period. The dark shaded bands indicate 67% confidence intervals. The lighter bands indicate 90% confidence intervals. The full sample is 1999q2 to 2019q2 and zero lower bound period is 2009q1 through 2015q4.

Table A6: Local Projection Regression Estimates

VARIABLES	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8	h = 9	h = 10	h = 11
US Policy Rate												
LSAP	-0.05	-0.12	-0.20*	-0.29*	-0.27	-0.28	-0.23	-0.19	-0.15	-0.09	-0.06	-0.02
	(0.03)	(0.07)	(0.12)	(0.15)	(0.17)	(0.18)	(0.16)	(0.12)	(0.09)	(0.06)	(0.05)	(0.05)
	[0.141]	[0.102]	[0.083]	[0.057]	[0.125]	[0.134]	[0.153]	[0.116]	[0.104]	[0.135]	[0.170]	[0.661]
CMP	0.16***	0.10	0.10	0.13	0.01	-0.04	-0.04	-0.04	-0.10	-0.11	-0.13**	-0.16***
	(0.04)	(0.09)	(0.11)	(0.14)	(0.16)	(0.16)	(0.14)	(0.11)	(0.09)	(0.07)	(0.06)	(0.06)
	[0.001]	[0.296]	[0.386]	[0.347]	[0.930]	[0.799]	[0.764]	[0.713]	[0.279]	[0.136]	[0.038]	[0.010]
Log Real GDP												
LSAP	0.02	-0.09*	-0.09	-0.23**	-0.11	-0.09	-0.19	-0.16	-0.16*	-0.12	-0.03	0.00
	(0.04)	(0.05)	(0.10)	(0.09)	(0.08)	(0.14)	(0.16)	(0.13)	(0.08)	(0.08)	(0.08)	(0.09)
	[0.664]	[0.094]	[0.386]	[0.019]	[0.147]	[0.505]	[0.251]	[0.254]	[0.064]	[0.169]	[0.710]	[0.964]
CMP	0.02	-0.08	-0.07	-0.38***	-0.54***	-0.48***	-0.38***	-0.33**	-0.33***	-0.36***	-0.35***	-0.16
	(0.07)	(0.09)	(0.12)	(0.12)	(0.12)	(0.13)	(0.13)	(0.12)	(0.11)	(0.11)	(0.12)	(0.14)
	[0.777]	[0.328]	[0.599]	[0.002]	[0.000]	[0.001]	[0.005]	[0.010]	[0.005]	[0.001]	[0.004]	[0.274]
Log Price Level												
LSAP	0.00	0.00	-0.01	-0.07*	-0.07*	-0.08*	-0.06	-0.08	-0.09	-0.07	-0.06	-0.04
	(0.02)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)	(0.06)	(0.06)	(0.06)	(0.08)	(0.05)
	[0.829]	[0.909]	[0.840]	[0.062]	[0.098]	[0.080]	[0.301]	[0.183]	[0.172]	[0.302]	[0.462]	[0.457]
CMP	-0.03	-0.04	-0.02	-0.07	-0.11**	-0.15***	-0.18***	-0.20***	-0.18***	-0.20***	-0.19***	-0.18***
	(0.02)	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)
	[0.148]	[0.139]	[0.543]	[0.110]	[0.017]	[0.002]	[0.002]	[0.002]	[0.009]	[0.006]	[0.008]	[0.003]
Log Consumption												
LSAP	-0.02	-0.02	-0.12	-0.13	-0.08	-0.15	-0.12	-0.13	-0.12*	-0.06	-0.06	-0.03
	(0.04)	(0.05)	(0.08)	(0.08)	(0.08)	(0.10)	(0.11)	(0.09)	(0.07)	(0.06)	(0.06)	(0.07)
	[0.572]	[0.729]	[0.153]	[0.104]	[0.326]	[0.159]	[0.281]	[0.166]	[0.091]	[0.304]	[0.273]	[0.673]
CMP	0.02	-0.01	-0.18*	-0.36***	-0.32***	-0.37***	-0.39***	-0.38***	-0.35***	-0.38***	-0.31***	-0.19
	(0.05)	(0.08)	(0.11)	(0.10)	(0.12)	(0.12)	(0.12)	(0.11)	(0.11)	(0.12)	(0.11)	(0.14)
	[0.684]	[0.926]	[0.088]	[0.001]	[0.009]	[0.004]	[0.003]	[0.001]	[0.004]	[0.002]	[0.008]	[0.177]
Log Investment												
LSAP	-0.04	-0.36	-0.07	-1.13**	-0.58	-0.10	-0.77	-0.62	-0.61	-0.36	0.16	0.14
	(0.27)	(0.24)	(0.39)	(0.47)	(0.44)	(0.60)	(0.85)	(0.84)	(0.55)	(0.43)	(0.49)	(0.61)
	[0.883]	[0.129]	[0.858]	[0.021]	[0.191]	[0.870]	[0.372]	[0.464]	[0.271]	[0.398]	[0.739]	[0.817]
CMP	0.22	-0.18	-0.16	-1.51**	-2.68***	-2.51***	-2.18***	-1.51**	-1.36**	-1.28**	-1.23*	-0.23
	(0.31)	(0.45)	(0.57)	(0.64)	(0.64)	(0.59)	(0.65)	(0.64)	(0.61)	(0.53)	(0.64)	(0.61)
	[0.480]	[0.683]	[0.776]	[0.021]	[0.000]	[0.000]	[0.002]	[0.023]	[0.029]	[0.020]	[0.061]	[0.715]
Risk Spread												
LSAP	-0.00	0.02	0.13*	0.12**	-0.00	0.07	0.05	0.02	-0.02	0.01	-0.08	-0.06
	(0.02)	(0.06)	(0.07)	(0.05)	(0.07)	(0.10)	(0.07)	(0.05)	(0.07)	(0.08)	(0.07)	(0.06)
	[0.994]	[0.716]	[0.061]	[0.025]	[0.964]	[0.500]	[0.478]	[0.726]	[0.750]	[0.920]	[0.283]	[0.289]
CMP	-0.01	0.17**	0.21***	0.28***	0.28***	0.16**	0.04	0.01	0.11	0.05	-0.04	-0.10
	(0.05)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.07)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)
	[0.903]	[0.019]	[0.006]	[0.000]	[0.000]	[0.041]	[0.594]	[0.798]	[0.103]	[0.454]	[0.501]	[0.118]
Nominal Exchange Rate												
LSAP	-0.53	-0.30	-0.08	0.20	0.75*	0.51	-0.06	0.09	-0.18	-0.38	0.05	0.11
	(0.34)	(0.52)	(0.58)	(0.60)	(0.39)	(0.37)	(0.59)	(0.53)	(0.50)	(0.31)	(0.34)	(0.46)
	[0.127]	[0.572]	[0.887]	[0.742]	[0.058]	[0.177]	[0.923]	[0.864]	[0.711]	[0.225]	[0.890]	[0.804]
CMP	-0.81**	-0.77	-0.71	-1.19**	-0.50	-0.56	-1.18**	-1.05**	0.14	0.18	0.54	0.55
	(0.36)	(0.49)	(0.65)	(0.59)	(0.46)	(0.49)	(0.49)	(0.43)	(0.46)	(0.52)	(0.56)	(0.51)
	[0.028]	[0.123]	[0.275]	[0.049]	[0.278]	[0.264]	[0.018]	[0.019]	[0.764]	[0.728]	[0.335]	[0.282]
Net Exports												
LSAP	0.56	-0.73	0.63	0.10	-1.10*	-0.50	-0.69	0.02	0.69	0.14	-0.08	0.32
	(0.42)	(0.82)	(0.65)	(0.57)	(0.58)	(0.74)	(1.34)	(1.19)	(0.93)	(0.87)	(0.64)	(0.82)
	[0.185]	[0.375]	[0.338]	[0.864]	[0.063]	[0.502]	[0.606]	[0.985]	[0.459]	[0.877]	[0.907]	[0.697]
CMP	-0.81	-1.34*	0.82	0.30	-0.71	1.45	2.04	0.95	1.13	1.09	0.37	0.21
	(0.56)	(0.76)	(0.69)	(0.69)	(0.87)	(1.00)	(1.27)	(1.16)	(1.34)	(1.14)	(1.22)	(0.95)
	[0.148]	[0.082]	[0.239]	[0.669]	[0.418]	[0.155]	[0.113]	[0.415]	[0.400]	[0.343]	[0.760]	[0.824]
Exports												
LSAP	0.06	-0.30	-0.22	-0.41	-0.20	0.10	-0.23	-0.04	0.00	0.03	0.14	0.36*
	(0.18)	(0.23)	(0.28)	(0.32)	(0.24)	(0.31)	(0.35)	(0.23)	(0.22)	(0.28)	(0.23)	(0.19)
	[0.752]	[0.208]	[0.437]	[0.204]	[0.406]	[0.753]	[0.518]	[0.862]	[0.986]	[0.926]	[0.555]	[0.065]
CMP	-0.21	0.18	0.92*	0.52	-0.63	-0.56	0.09	0.34	-0.05	-0.38	-0.49	-0.05
	(0.24)	(0.41)	(0.48)	(0.51)	(0.48)	(0.40)	(0.38)	(0.34)	(0.38)	(0.40)	(0.31)	(0.31)
	[0.381]	[0.668]	[0.062]	[0.316]	[0.196]	[0.165]	[0.807]	[0.321]	[0.903]	[0.354]	[0.113]	[0.874]
Observations	80	80	80	79	78	77	76	75	74	73	72	71

Notes: Local projection estimates for conventional monetary policy shocks (CMP) and large scale asset purchase shocks (LSAP). The standard error is shown in parentheses. The p-value is shown for the null hypothesis of a zero effect is shown in brackets. The sample is 1999q2 to 2019q2.

A4 Parameter Sensitivity Analysis

In this section, we conduct sensitivity analysis on some of the key parameters of the model, and examine how changes to the portfolio share and elasticity parameters effect the efficiency of unconventional monetary policy relative to conventional monetary policy for various economic variables. We also evaluate the importance that nominal price and wage frictions have across the different policy interventions.

Portfolio Elasticity Sensitivity Analysis

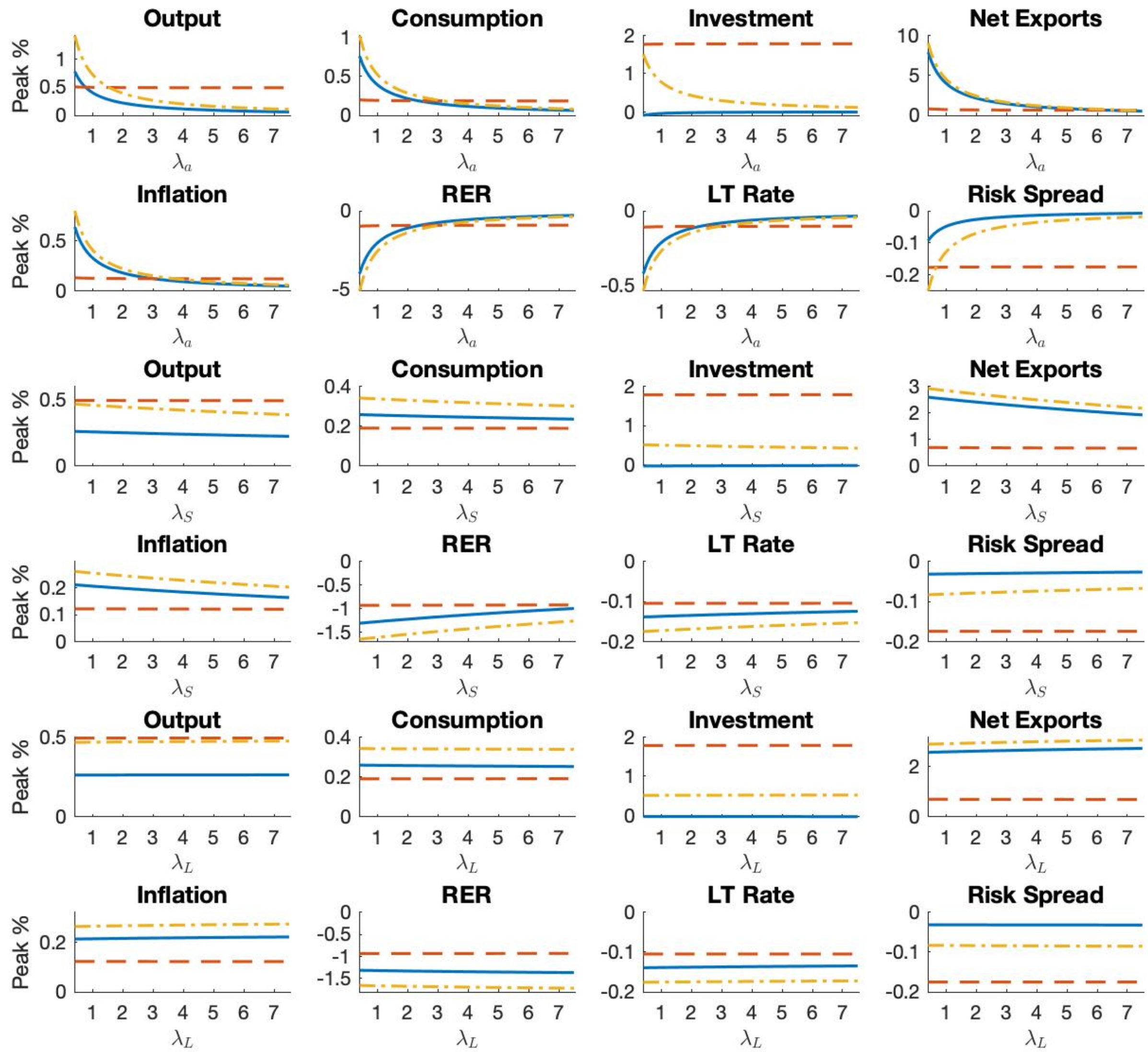
We first analyze the sensitivity of our results to the elasticity parameters in the portfolio specification. Figure A14 plots the peak response from steady state in the first eight quarters from each policy intervention discussed previously for output, investment, consumption, net exports, inflation, the real exchange rate, long-term rate and the risk spread across different estimates of the domestic portfolio elasticity parameters.

We see that the CMP shock[24] is not sensitive to any of the domestic portfolio elasticity estimates as all the dashed red lines are flat for all λ's. However, the efficacy of an LSAP shock on output, consumption, net exports and inflation significantly increases as the portfolio substitution of short and long-term bonds (λ_a) becomes more inelastic. Further the impact on the long-term rate and risk spread is much larger as λ_a shrinks. A LSAP + FG shock has the ability to be as efficient as a CMP shock in stimulating investment when λ_a is low. Note that a regular LSAP shock still does not impact investment no matter the value of λ_a.

We find similar but not as dramatic results when we examine the response sensitivity of the elasticity of substitution between domestic and foreign short-term bonds, λ_S. As λ_S increases (more substitution elasticity), LSAP and LSAP +FG shocks have less of an impact on all economic variables. Finally, we see little to no response sensitivity to the estimate of λ_L, as the peak response is consistent across all variables and all estimates of λ_L. This is also true when we examine the response sensitivity of the ROW portfolio substitution parameters, λ^*'s.

[24]The CMP shock in this section is scaled to create the same peak output response as the LSAP + FG shock of the previous section when all estimated structural parameters are at their posterior means. This is equivalent to about a 40 basis point reduction in the policy rate. This means that where the dotted yellow lines cross the dashed red lines in the output peak plots is where all structural parameters are at their posterior mean estimates.

Figure A14: Elasticity Sensitivity - Peak Responses from Different Policy Interventions

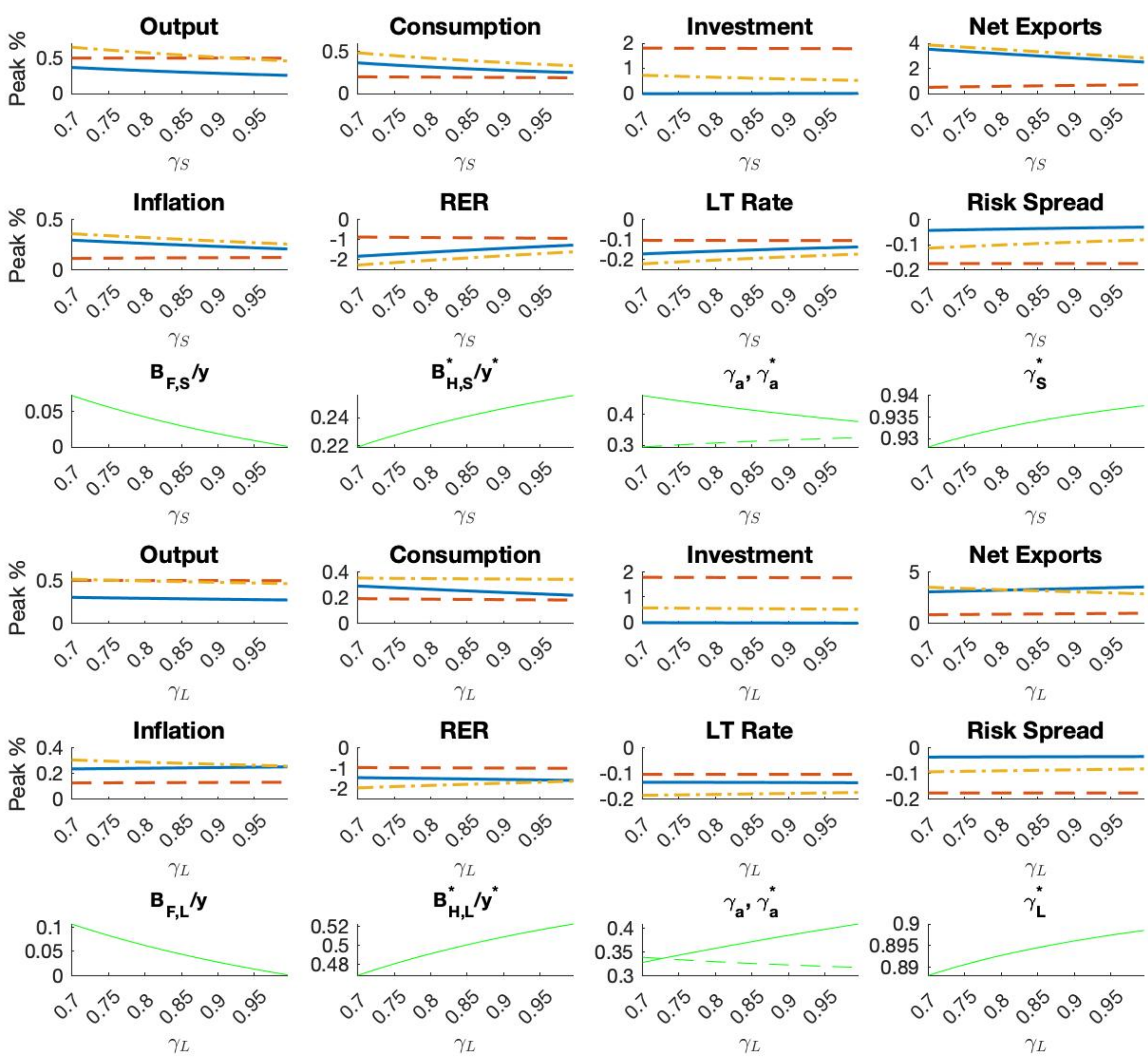


Notes: The solid blue line plots the peak response (in the first 8 quarters) of an LSAP shock across different estimates of λ. The dashed red line plots the peak response of an equivalent CMP shock across different estimates of λ. The dotted yellow line plots the peak response of an LSAP shock with policy rate commitment across different estimates of λ. All peak responses are calculated using the model's posterior mean for all other parameters not on the x-axis and plot the peak % deviation away from each variable's respected steady state value on the y-axis.

Portfolio Share Sensitivity Analysis

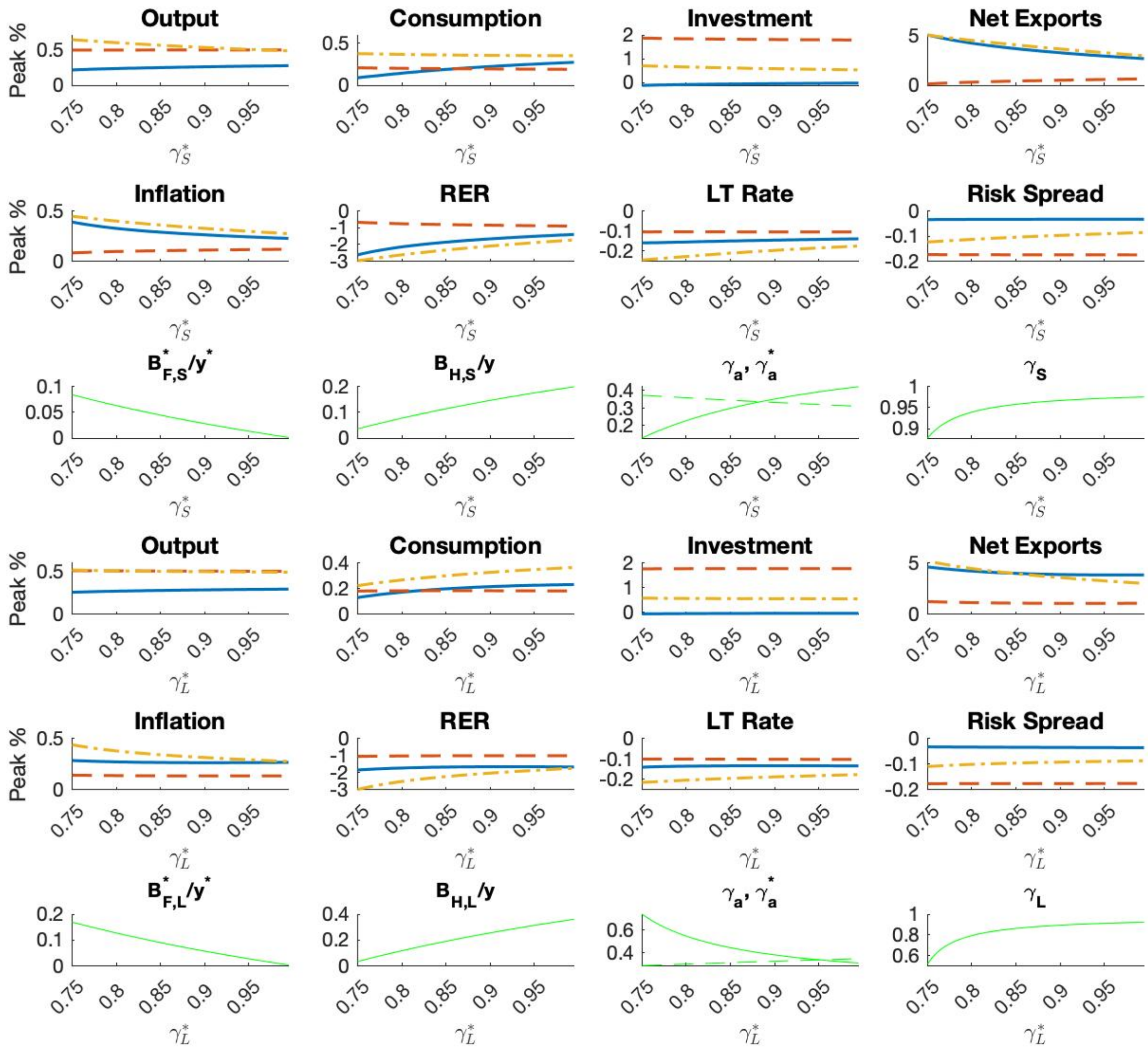
Figure A15 shows the response sensitivity as we alter the share of short-term and long-term ROW bonds in the US bond portfolio, (γ_S and γ_L). Altering, these parameters, also changes other calibrated parameters. The other calibrated parameters that are changed are plotted in the third and sixth rows of Figure A15. We see that as the share of ROW short-term bonds held by the US increases (lower γ_S) the impact of LSAP has a greater response on output, consumption, net exports and inflation. As the share of ROW long-term bonds held by the US increases (lower γ_L), the expenditure response is mostly unaffected by an LSAP shock but inflation response slightly increases. The same result is found when we examine the response sensitivity to the international portfolio share parameters, γ_S^* and γ_L^* in Figure A16.

Figure A15: Portfolio Share Sensitivity - Peak Responses from Different Policy Interven-



Notes: The solid blue line plots the peak response (in the first 8 quarters) of an LSAP shock across different estimates of γ_S and γ_L. The dashed red line plots the peak response of an equivalent CMP shock across different estimates of γ_S and γ_L. The dotted yellow line plots the peak response of an LSAP shock with policy rate commitment across different estimates of γ_S and γ_L. All peak responses are calculated using the model's posterior mean for all other parameters not on the x-axis and plot the peak % deviation away from each variable's respected steady state value on the y-axis.

Figure A16: ROW Portfolio Share Sensitivity - Peak Responses from Different Policy Interventions



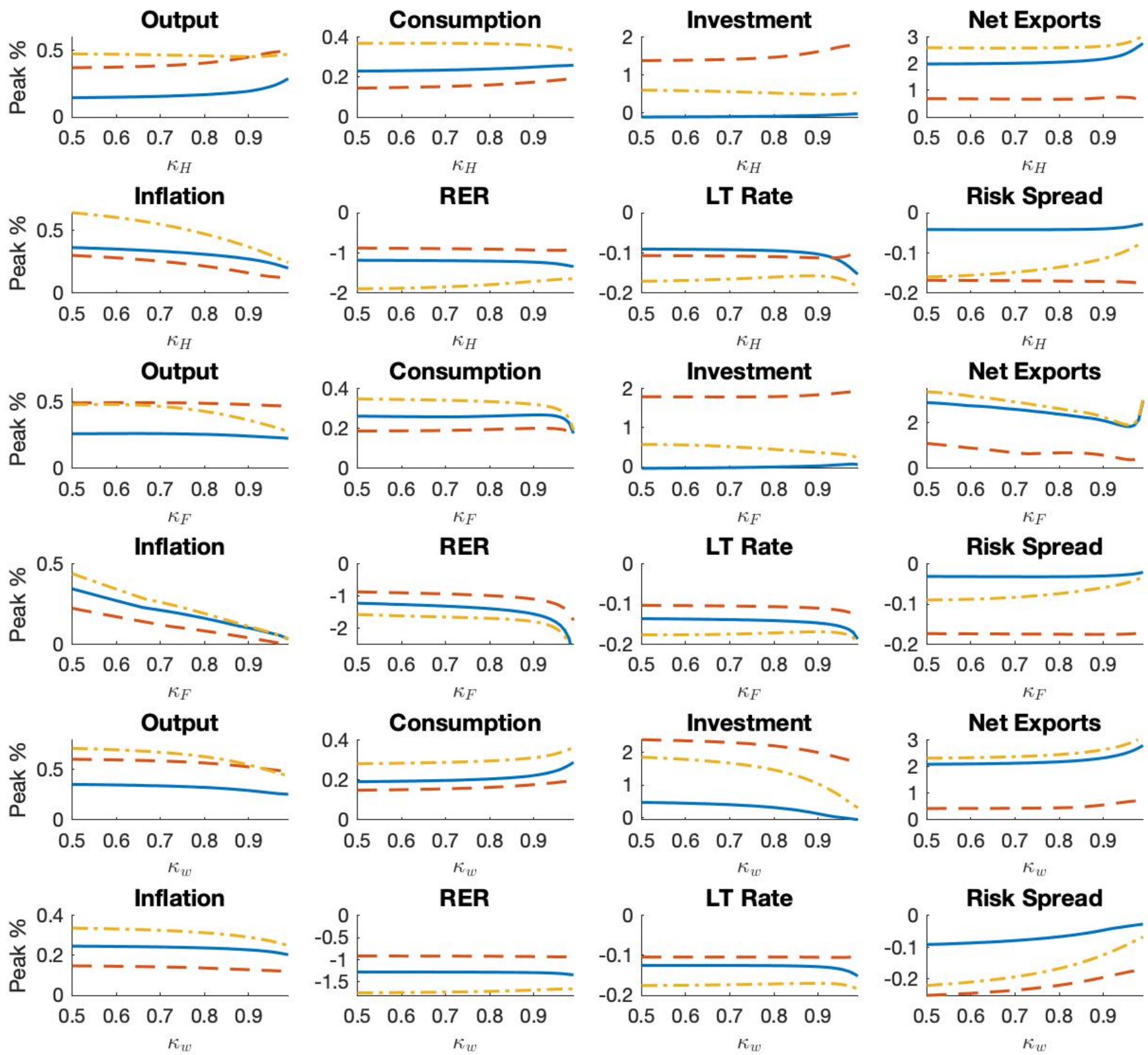
Notes: The solid blue line plots the peak response (in the first 8 quarters) of an LSAP shock across different estimates of γ_S^* and γ_L^*. The dashed red line plots the peak response of an equivalent CMP shock across different estimates of γ_S^* and γ_L^*. The dotted yellow line plots the peak response of an LSAP shock with policy rate commitment across different estimates of γ_S^* and γ_L^*. All peak responses are calculated using the model's posterior mean for all other parameters not on the x-axis and plot the peak % deviation away from each variable's respected steady state value on the y-axis.

Price and Wage Rigidity Sensitivity Analysis

Next, in Figure A17 we examine the response sensitivity as we alter the nominal price and wage frictions, κ_H, κ_F and κ_w. We see that unlike the previous sensitivity analysis, different estimates of κ_H, κ_F and κ_w will alter the effects of the CMP policy shock. As home and foreign pricing frictions decrease CMP shocks create a smaller impact on expenditures and a greater impact on inflation. When wage frictions decrease CMP shocks have more of an impact on investment and the same impact on inflation, as producers are more inclined to substitute labor for capital in production.

We also see that pricing and wage frictions have a limited impact on the output and inflation response of LSAP shocks. The one exception being foreign pricing frictions, as we see that the inflation peak response increases as foreign pricing frictions decrease. We also see that pricing and wage frictions have a significant impact on the peak response from LSAP + FG shocks. In all cases as the nominal friction increases the LSAP + FG (dotted yellow line) shock peak response gets closer to the regular LSAP (solid blue line) shock peak response. This is because as nominal frictions increase the impact on inflation is muted causing less of an endogenous policy response to a regular LSAP shock. As a result less anticipated policy shocks are needed to maintain the forward guidance policy commitment that is part of the LSAP + FG policy intervention. In summary, relative efficacy of LSAP and CMP shocks remains constant for various nominal friction parameter values.

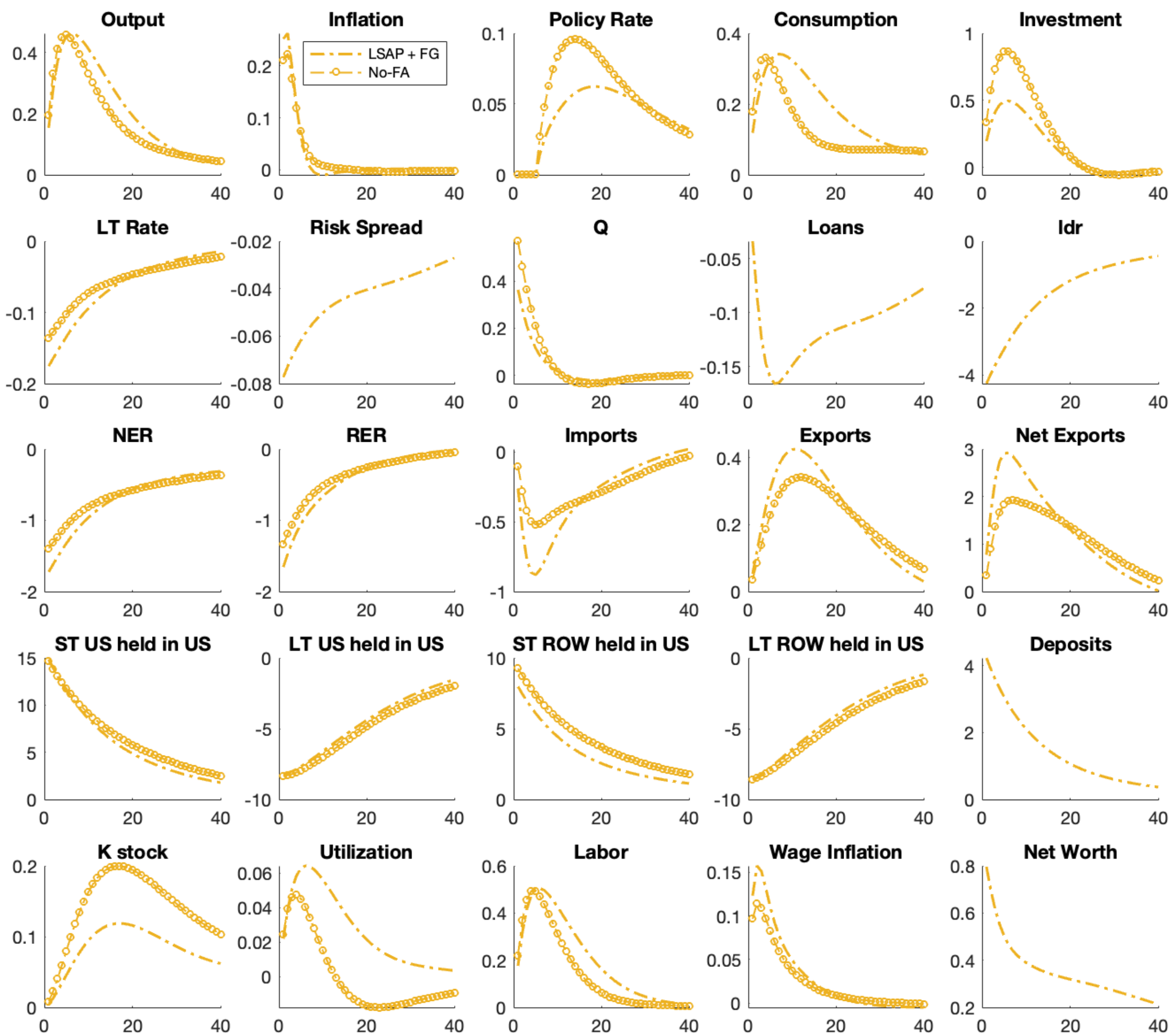
Figure A17: Price Frictions Sensitivity - Peak Responses from Different Policy Interventions



Notes: The solid blue line plots the peak response (in the first 8 quarters) of an LSAP shock across different estimates of κ_H, κ_F and κ_w. The dashed red line plots the peak response of an equivalent CMP shock across different estimates of κ_H, κ_F and κ_w. The dotted yellow line plots the peak response of an LSAP shock with policy rate commitment across different estimates of κ_H, κ_F and κ_w. All peak responses are calculated using the model's posterior mean for all other parameters not on the x-axis and plot the peak % deviation away from each variable's respected steady state value on the y-axis.

A5 Financial Accelerator and LSAP + FG

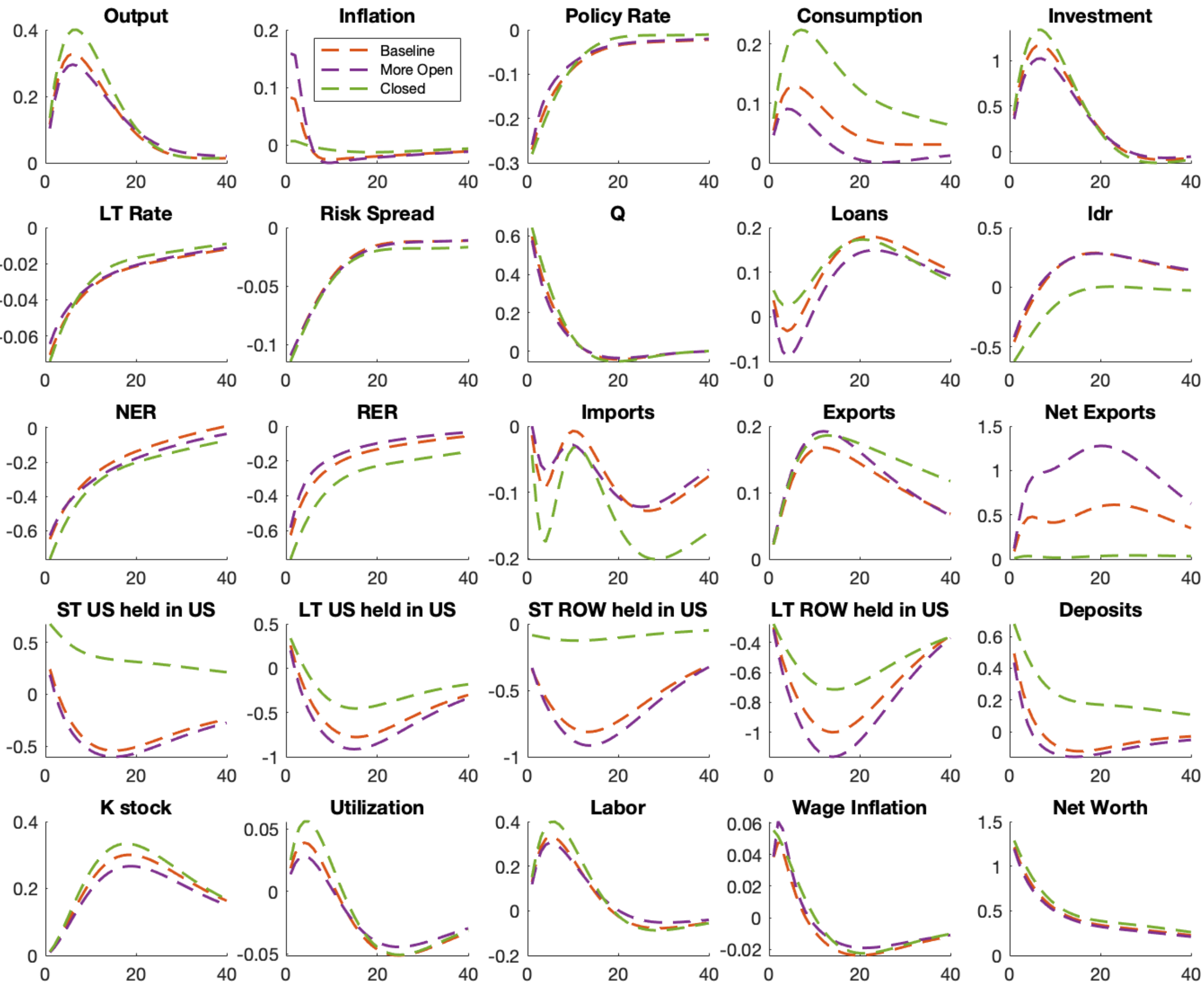
Figure A18: LSAP with Policy Forward Guidance IRF's of both DSGE Models



Notes: The dotted yellow line plots the response of an LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank with a year's long commitment of keeping the policy rate unchanged (LSAP with Forward Guidance (FG)). The bubbled line plot the respective shock when the DSGE model does not include a Financial Accelerator. All responses are calculated using the models' posterior mean estimates and plot the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

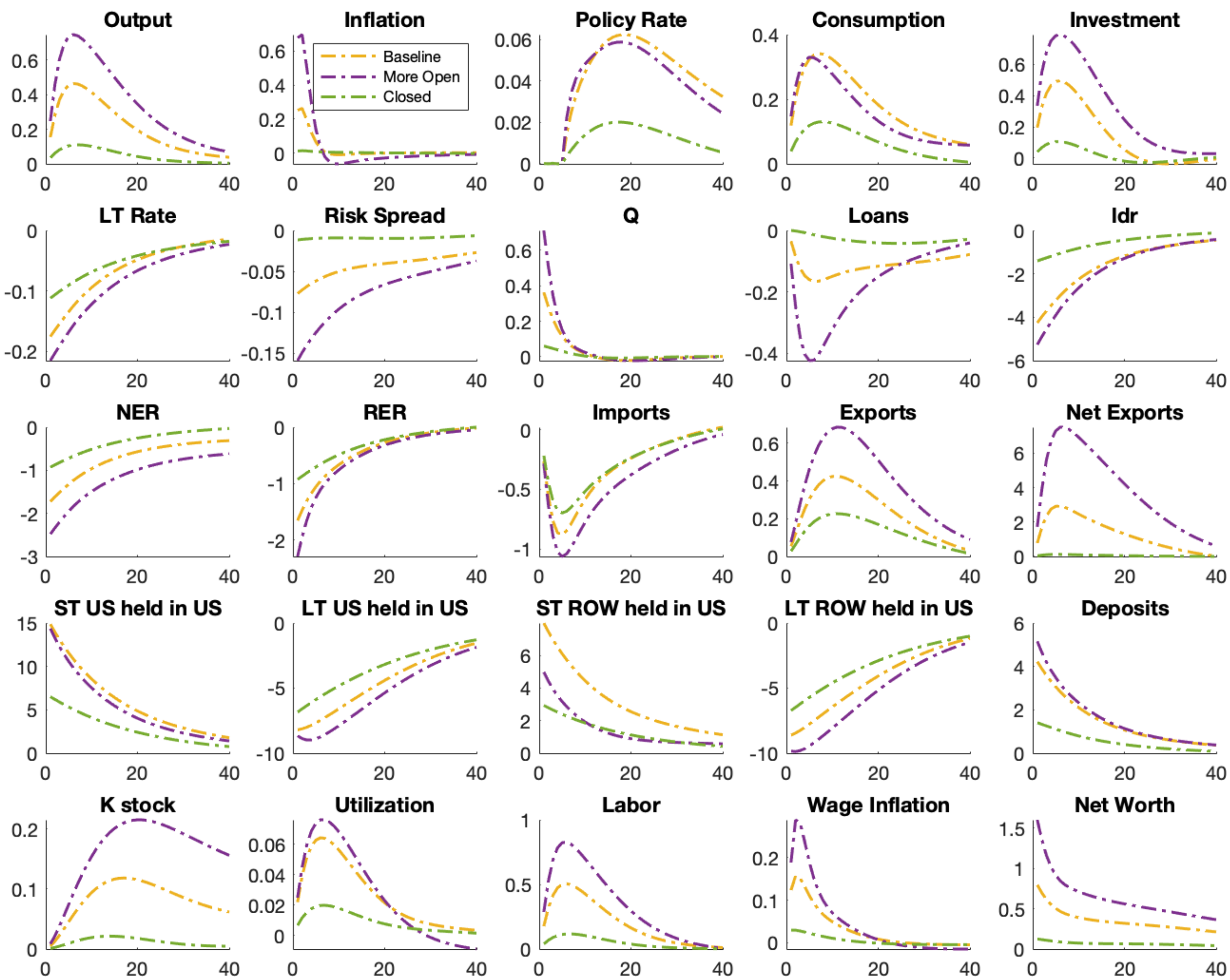
A6 Trade and Financial Openness IRF's

Figure A19: Trade and Financial Openness - CMP shock



Notes: The dashed red line plots a CMP shock equivalent to a 25 basis point reduction in the policy rate using the baseline parameters of this paper. The dashed purple line plots the same CMP shock in a more open economy (γ_c, $\gamma_I = .7$, γ_s, $\gamma_s^* = .8$), The dashed green line plots the same CMP shock in a closed economy (γ_c, γ_I, γ_s, γ_s^*, γ_L, $\gamma_L^* = .99$). All responses plot the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

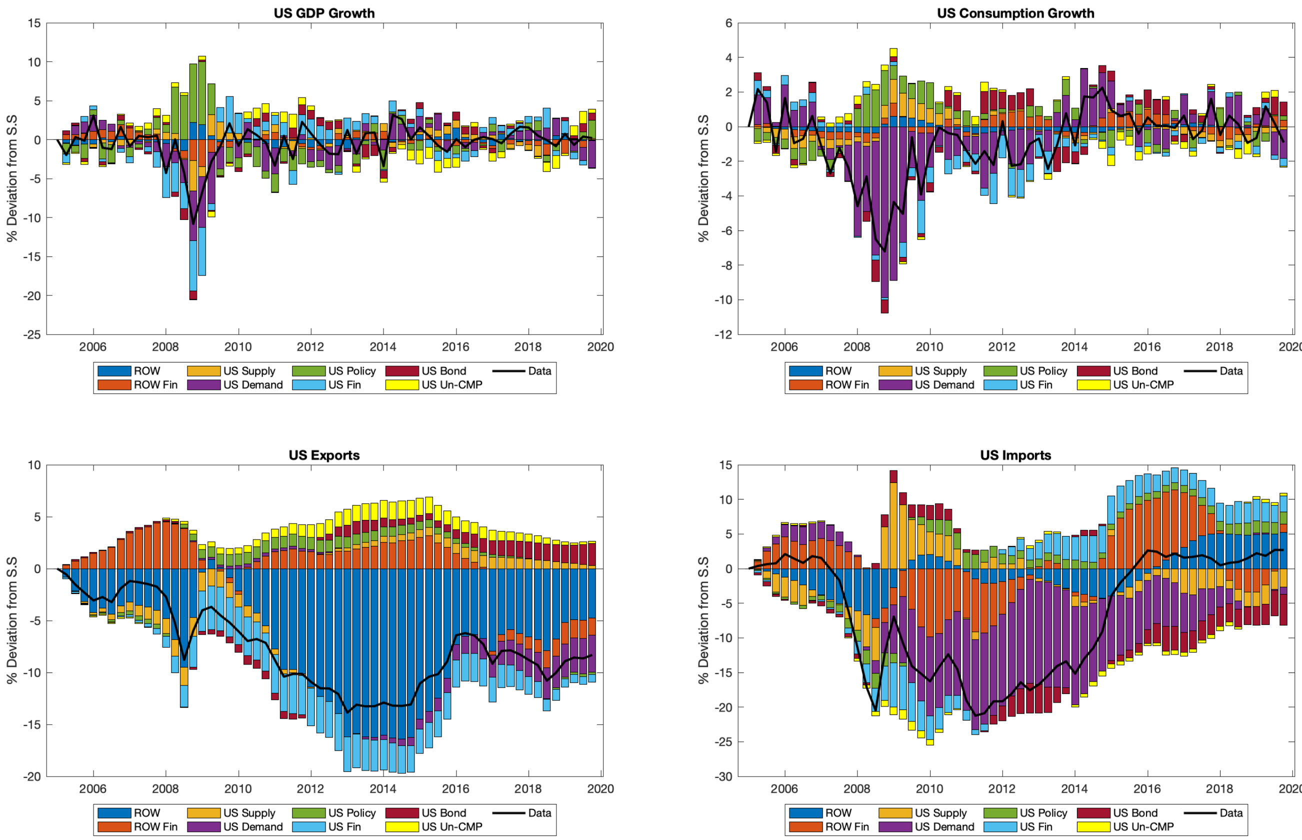
Figure A20: Trade and Financial Openness - LSAP + FG shock



Notes: The dotted yellow line plots an LSAP + FG shock equivalent to a long-term asset purchase of 1.5% of steady state GDP and year's long policy rate commitment by the central bank using the baseline parameters of this paper. The dotted purple line plots the same LSAP + FG shock in a more open economy (γ_c, $\gamma_I = .7$, γ_s, $\gamma_s^* = .8$), The dotted green line plots the same LSAP + FG shock in a closed economy (γ_c, γ_I, γ_s, γ_s^*, γ_L, $\gamma_L^* = .99$). All responses plot the % deviation away from each variable's respected steady state value on the y-axis. All interest rate and inflation rates are annualized.

A7 Additional Historical Shock Decompositions

Figure A21: Historical Decompositions



Notes: The figures plot the historical shock contributions for US GDP growth, Consumption growth, Exports, and Imports after 2005. The shocks are grouped into eight categories. ROW include all ROW shocks not including financial and bond portfolio share shocks in the ROW. ROW Fin include shocks to ROW net worth, ROW risk spread and ROW bond portfolio shares. US Supply includes US price and wage mark-up shocks and US productivity shocks. US Demand include US consumption and US investment shocks. US Policy include US CMP, tax and fiscal purchase shocks. US Fin include US net worth and US risk spread shocks, US Bond includes US bond portfolio share shocks and US Un-CMP include US LSAP and Forward Guidance shocks.