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Comparing Monetary Policy Tools in an Estimated DSGE model with International Financial Markets

Sacha Gelfer Christopher G. Gibbs

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Abstract

We evaluate the dynamics of conventional and unconventional monetary policy using an estimated two-region dynamic stochastic general equilibrium (DSGE) model. In addition to traditional nominal frictions the open-economy model also includes financial frictions, international portfolio balance effects, and correlated global financial shocks. We find that both conventional and unconventional monetary policy is effective in stimulating output and inflation. However, the type of expansionary monetary policy used has heterogeneous effects on domestic investment, imports, exports and hours worked. Further, including a financial accelerator to the DSGE model significantly dampens the impact of aggregate investment that is expected to occur with quantitative easing. This is because unconventional monetary policy in the model is associated with an expansion in banking deposits and a minimal impact on loan demand, thus creating a fall in the loan to deposit ratio as was seen after the global financial crisis. Using historical decompositions, we find that unconventional monetary policy had a significant positive impact on output and hours worked during the global financial crisis and the preceding years after, but becomes negligible after 2014. Yet, its impact on equity and bond markets remained 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 of the world has changed substantially over the last twenty years. Starting with Japan in the late 1990's and followed by nearly all advanced economies in 2008 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 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]

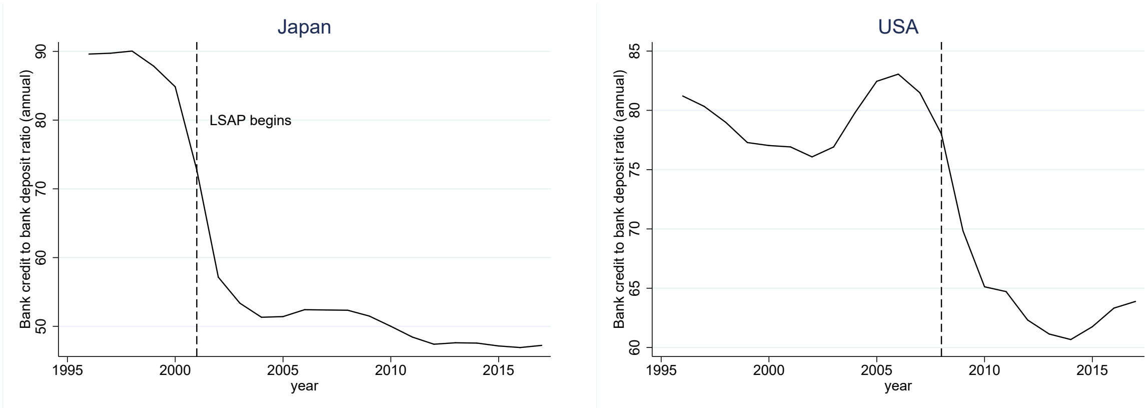
The onset of the global pandemic and its economic effects have put unconventional monetary policy tools front and center once again. However, the effectiveness of these two unconventional policies as a substitute for conventional monetary policy (CMP) is widely debated. To shed light on this important 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 theory 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 portfolios without actually affecting output or inflation so long as the LSAP does not signal future monetary policy actions or so long as it does not actually alter the behavior of fiscal policy. Moreover they argue that any direct real effects of portfolio rebalancing are likely small.

Financial studies show (Bowman et al. (2015), Rodnyansky and Darmouni (2017), Chakraborty et al. (2020)) that LSAPs change the composition of assets held by the banking sector but did not affect lending and hence aggregate investment significantly. Proponents of the irrelevance hypothesis for LSAPs often point to the fact that deposits and reserve in banks throughout the world have increased substantially due to LSAP policies. To illustrate

[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

the claim, Figure 1 shows data from the World Bank on bank credit to 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.

Despite this, recent empirical papers have shown a significant positive impact on the real economy following an LSAP implementation. Most recently, Kolasa and Wesolowski (2020) and Sims and Wu (2021) have shown significant positive effects on output, inflation, bank lending and investment after such an LSAP and suggest that unconventional monetary policy is a close substitute for conventional monetary policy.[2] In this paper, we are able to build and estimate a model that equates with both results.

We put forward a quantitative open-economy macroeconomic model that includes long and short-term domestic and foreign debt and a financial accelerator mechanism to study unconventional policies. We show that this model predicts both powerful effects of LSAP policy and a significant fall in the loan or credit to deposit ratio in the economy. LSAP policy stimulates the economy largely through trade. Purchases of long-term debt decrease long-term bond yields and depreciates the domestic currency, increasing net exports and domestic consumption. LSAPs effect on aggregate investment is negative away from the effective zero lower bound because it tends to put upward pressure on short-term rates, which

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

partly rationalizes the intuition that changes in the composition of household portfolios is ineffective. When interest rates are constrained by the effective zero lower bound, however, investment responds positively after an LSAP implementation.

Conventional monetary policy (CMP) in the model produces the standard positive effect on output, consumption, the exchange rate, and investment, where the effect on the latter is large. The difference in responses between CMP and LSAPs on investment is due to the financial accelerator. LSAPs cause banking deposits to expand, which at the effective lower bound does not affect the rate at which entrepreneurs borrow to invest. Removing the financial accelerator leads to direct purchases of capital in response to LSAPs and a large response in investment. Through the financial accelerator, LSAPs indeed cause money to pile up in banks consistent with Figure 1 while also still stimulating the macroeconomy.

Related Literature & Paper Design

Unconventional monetary policy tools were recently evaluated in a calibrated closed-economy dynamic stochastic general equilibrium (DSGE) model in Sims and Wu (2021). We extend their analysis in two important ways. First, we conduct the policy analysis in an open-economy DSGE model, 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 Kabacca (2020)). Second, we conduct the policy analysis on an estimated DSGE 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.

In this paper, we combine two New-Keynesian DSGE models. The first is an open-economy DSGE model created by Alpanda and Kabacca (2020) that incorporates large-scale asset purchases by inserting short term and long-term bond holdings into the household utility equation. The second is a DSGE model created by Del Negro et al. (2013) and used in Gelfer (2019) that incorporates financial frictions in the form of a micro-founded financial accelerator. The combination of these two models create a two-country open-economy DSGE model with a financial market with risky assets, and risk free domestic and foreign short-term and long-term bond markets. The inclusion of the two regions allows for international spillovers in terms of economic shocks, exchange rate and trade effects, and global unconventional monetary policy. The inclusion of the financial market and multiple bond markets allows for analysis to be done on large-scale asset purchases in both the US and global bond markets and US and global equity markets. In all, we estimate the DSGE model using 36 quarterly data series from 7 different countries and the European Union.

Most of the paper focuses on the heterogenous effects conventional and unconventional monetary policies have on the real economy and financial markets. Conventional monetary policy (CMP) in our model involves the central bank setting the short-term interest rate (policy rate) according to a Taylor type rule. Unconventional monetary policy include LSAP and forward guidance. LSAP in our model entails the central bank purchasing (or selling) long-term government bonds, financed by the creation (or destruction) of short-term bonds. LSAP policies can be undertaken whether conventional policy is constrained by the zero lower bound (ZLB) or not. Forward guidance in our model involves a credible commitment of cutting the desired short term policy rate implied by the Taylor rule some k periods in the future.

We find that conventional and unconventional monetary policies stimulates output, inflation and financial markets away from the ZLB. The effects of unconventional monetary policy are amplified when conducted at the ZLB or with a credible stable policy rate commitment. However, the transmission channels of conventional and unconventional monetary policy are very different. We find that unconventional policy raises output by stimulating consumption, depreciating the domestic currency and thus increasing net exports. The unconventional policy effect on investment is negative away from the ZLB and marginally positive at the ZLB or with a stable policy rate commitment. While conventional policy raises output by stimulating consumption (to a relatively lesser degree), depreciating the domestic currency (to a relatively lesser degree) and stimulating investment.

Investment being stimulated to a greater degree from a CMP shock compared to an LSAP shock is generated by the financial accelerator of the DSGE model. This is because unconventional monetary policy in the model is associated with an expansion in banking deposits and a minimal impact on loan demand, thus creating a fall in the loan to deposit ratio. While a model with no financial accelerator assumes households own the capital and instead of an increase in banking deposits after an LSAP shock, there is an increase in capital purchases and thus, a substantial increase in investment.

In order to check the robustness of these results we follow Jorda (2005) and use local projection estimates of the impulse responses to CMP shocks and LSAP shocks using the same data set used in estimating the DSGE model. However, to identify the monetary policy shocks, we use the shocks estimated by Swanson (2021). Swanson extracts three orthogonal shocks that capture conventional monetary policy, LSAPs, and forward guidance. We observe that the relative impact of output, the policy rate, the risk spread, investment and asset price growth reaction to CMP and LSAP shocks are consistent with the structural DSGE results.

When we conduct parameter sensitivity analysis we find that unconventional monetary policy is most efficient at stimulating output when the substitution between short-term and long-term bonds and the substitution between short-term domestic and foreign bonds is inelastic, home pricing rigidities are high, wage rigidities are low and when the share of global connectivity in traded goods and bonds is high. While CMP is most efficient at stimulating output when the share of global connectivity in goods and bonds is low and is not sensitive to portfolio substitution or portfolio share parameters.

In addition, this paper evaluates international policy coordination. We find that when unconventional monetary policy is globally coordinated, the effects of output and inflation are muted compared to just a domestic unconventional monetary policy intervention and the negative effect on domestic investment is no longer. This is contrary to globally coordinated CMP shocks when the output effect is magnified compared to domestic CMP only. This is because domestic conventional monetary policy 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 when CMP is conducted.

Finally, examining historical shock decompositions we find that conventional monetary policy was able to generate a positive effect on the real US economy and US financial markets during the onset of the global financial crisis. This effect starts to fade around 2010 and unconventional monetary policy begins to have significant positive impact on output and hours worked during the global financial crisis and the preceding years after, but becomes negligible after 2014. However, its positive impact on equity markets and bond markets remained through 2019 even after its impact on the real economy was non-existent. Further, unconventional monetary policy is seen as a main driver to the significant fall in the model's loan-to-deposit ratio.

The execution and findings of our paper touch on two important strands of literature relating to unconventional monetary policy analysis. These include literature on quantitative structural analyses of unconventional monetary policy and the quantitative effects unconventional monetary policy has on international trade and financial markets. The recent modeling frameworks to study unconventional monetary policy include 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).

The contribution this paper makes to the existing literature on quantitative structural analyses is twofold. First, many of these papers' models are either closed-economy models, exhibit no private credit, no financial sector inside the model or all of the above. The movement of exchange rates, loans, equity prices and bond spreads in response to unconventional monetary policy effects output, labor, investment and inflation; and is a transmission mechanism that is missing in most model-based studies of unconventional policies. Second, the model of this paper is estimated using traditional macroeconomic datasets and non-traditional datasets, including US and global stock prices, bond spreads, interest rate futures, short and long term bond supply and international public bond holding shares. This allows for a more robust level of key structural parameter estimates and a more in-depth and structural analysis of the effects of unconventional policies in equity and bond markets.

This paper also fits in with other recent papers that evaluate the quantitative effects unconventional monetary policy has on international trade, international finance and domestic financial markets. These include Rogers et al. (2018), Glick and Leduc (2018), Fratzscher et al. (2018), Inoue and Rossi (2019) and Swanson (2021). This paper's conclusions align with many of the empirical findings regarding international economic spillovers, impact of unconventional monetary policy on exchange rates and the impact on financial markets as seen in the forementioned papers. However, this paper does so using a micro-founded structural model.

The remainder of the paper is organized as follows. Section 2 lays out the open-economy DSGE model, and 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. Further, the section examines parameter sensitivity and global connectivity to the effects generated by the policy intervention. It also presents local projection estimates of the impulse responses to monetary policy that coincide with the dynamics that are generated by the DSGE model. Section 5 studies coordinated global monetary policy and it also presents historical shock decompositions for various macro-financial variables. Section 6 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 Kabacca (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 to these standard nominal and real frictions, the model incorporates financial frictions with the inclusion of financial intermediaries that play the role in allocating 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. Further, household in each country can hold domestic and foreign government bonds of both short and long-term duration, however, there exists imperfect substitutability among the four types of risk-free bonds. We include the option for households to hold both domestic and foreign bonds of both durations because it is pivotal to our analysis of the macroeconomic effects of unconventional monetary policy. Further, it provides a channel for us to discuss the impact of synchronized global monetary policy.

In the remainder of this section, we focus on the households' optimization problem, the financial sector, fiscal and monetary authorities as well as key market clearing conditions that connect the two countries. The discussion of these agents will allow us to highlight the portfolio balance effects and the associated transmission mechanism of conventional and unconventional monetary shocks to the domestic and the foreign economies. In particular, the policy effects to the short and long-term interest rates, risk premium, asset prices and the exchange rate, which are key in generating the theoretical and empirical results of this paper. The description of the more standard features of the model, such as production, employment, and importers are relegated to Appendix A. 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. 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 Kabacca (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 in regards to the 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[3] , $R_{L,t}$.

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

Household j's budget constraint is:

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

[3] 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.

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

$$\tag{8}$$

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

$$\tag{10}$$

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

$$\tag{12}$$

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

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.

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

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

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 $\hat{rer}_t$ is the real exchange rate ($\hat{rer}_t = \hat{e}_t\hat{P}^*_t/\hat{P}_t$) 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 will effect 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.[4] 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, $Loan_{t-1}$.

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

[4]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 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 and households 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.[5]

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

[5]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 $t-k$.

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[6]

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 $\varepsilon_{tax,t}$ 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;

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

where $\gamma_{b,t}$ is exogenous and follows an AR(1) process. A negative shock to $\gamma_{b,t}$ results in a

[6] Like Chen et al. (2012) and Alpanda and Kabacca (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.

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.[7]

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

[7]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 $\gamma_{b,t}$ shock is equivalent to a large scale asset purchase of long-term bonds by the central bank conducted by increasing the monetary base.

portfolio.

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

$$(e_t B_{F,S,t} - e_t R^*_{t-1} B_{F,S,t-1}) + (e_t q^*_{L,t} B_{F,L,t} - e_t R^*_{L,t} q^*_{L,t-1} B_{F,L,t-1}) \\ - (B^*_{F,S,t} - R_{t-1} B^*_{F,S,t-1}) - (q_{L,t} B^*_{F,L,t} - R_{L,t} q_{L,t-1} B^*_{F,L,t-1}) = P_{H,t} y^*_{F,t} - e_t P^*_{H,t} y_{F,t} \tag{34}$$

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

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

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 A.

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 (U.S.) 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 (U.S.) 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 (United States) and foreign (ROW) countries of the model.

3.1 Data

We use a total of 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 2. 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 Kabacca (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^*)

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

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 Kabacca (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 growth rate of each country's major stock index quarterly growth rate 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 plotting of the 31 series discussed can be found in the plots of Figure 10.

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,

[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.

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-identify 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 can be found in Table 3 and Table 4. First, 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. β and ξ_a are set to correspond to the steady state nominal interest rate of 4.1%. 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[10] 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

[10] 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.

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 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.

3.3 Prior and Posterior Estimates

The structural parameter marginal priors are in accordance to Alpanda and Kabaca (2020) and Del Negro and Schorfhiede (2013) priors. Tables 5 and 6 report the prior distributions used for each estimated parameter, the corresponding estimates for the posterior mean and the 90% posterior interval.[11] Further, like Alpnada and Kabacca (2020), we rescale the asset portfolio elasticity of substitution parameters and the price adjustment cost parameters to constrain their estimates within the unit interval to ensure a more robust estimation.

The auxiliary portfolio elasticity parameters is defined as:

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

for $j = \{a, S, L\}$. Further the auxiliary price adjustment cost parameter is defined as

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

[11] 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).

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.

The estimates for the portfolio elasticities imply that the elasticity of substitution 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 the next section.

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, κ_j^{est}, indicate very 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

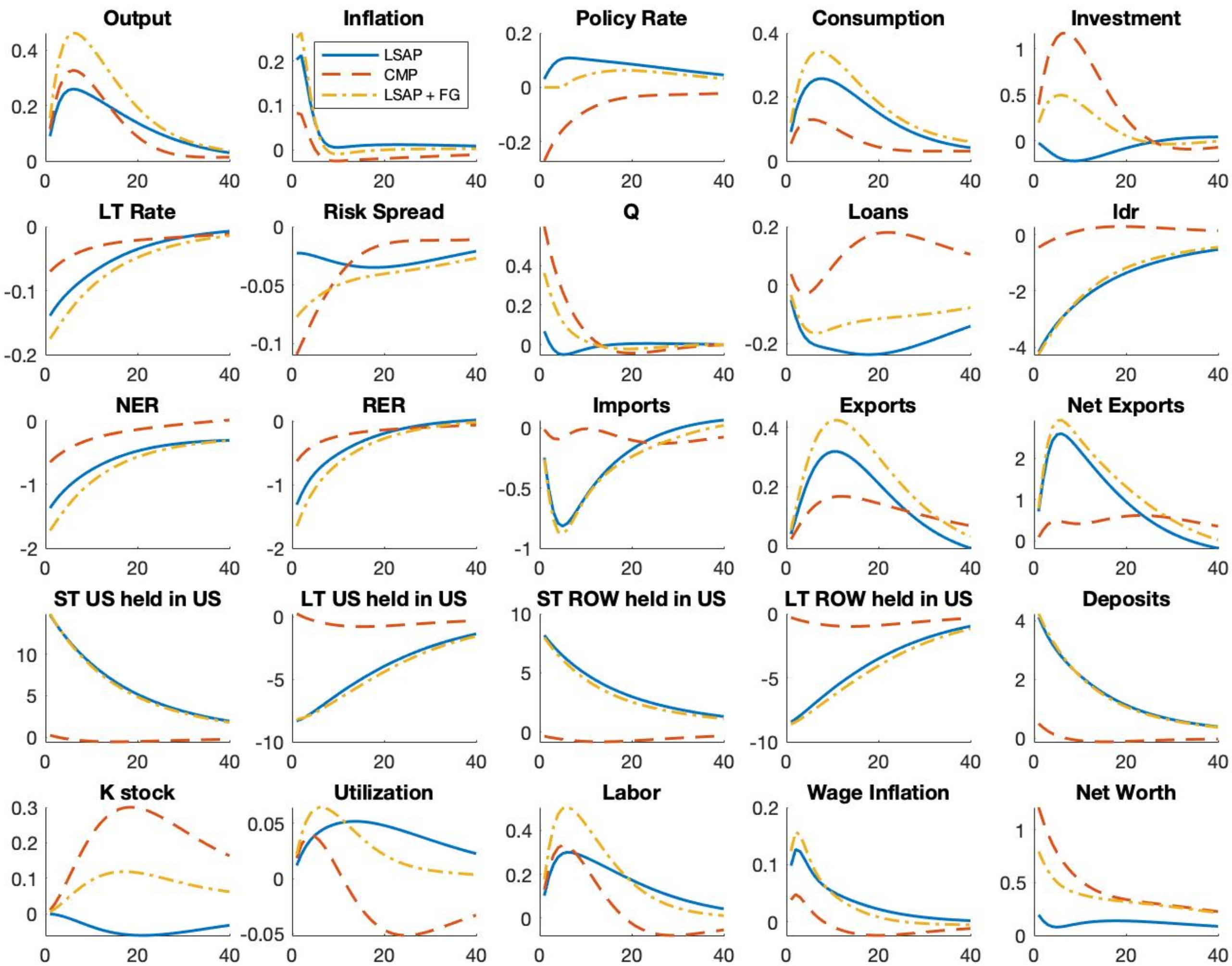
In this section, we compare and contrast exogenous changes in alternative unconventional policy tools (Large-scale Asset Purchases (LSAP) and LSAP + Forward Guidance (FG)) to conventional monetary policy (CMP). We assess the efficiency of unconventional policy interventions in affecting output, investment, inflation, foreign trade and financial market metrics. We wish to quantify the heterogeneous economic and financial effects seen with each type of monetary policy and how sensitive they are to certain structural parameters. After conducting the structural model analysis, we then evaluate the empirical robustness of our results by using local projection methods and monetary policy shocks identified by Swanson (2021).

4.1 Structural Model Analysis

We quantify how much an unconventional policy tool must be moved so as to generate similar aggregate responses to a CMP shock. The comparison is depicted in Figure 2, which plots impulse responses (IRF'S) of different macroeconomic variables to three 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 IRF of a conventional policy shock to the Taylor rule. The size of the shock is calibrated to lower the policy rate by 25 basis points. The responses

Figure 2: Monetary Policy IRF's



Notes: The solid blue line plots an LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank. The dashed red line plots the response of a shock equivalent to a 25 basis point fall in the policy rate. 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)). All 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.

of aggregate variables to this shock are consistent with 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 respond as they should with the US dollar (NER) depreciating and net exports increasing.

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 at 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 on impact. With inflation rising twice as much compared to the CMP shock. As a result the policy rate increases after the LSAP shock. As expected, the long-term interest rate declines by about 15 basis points after the shock.[12] However, investment is marginally negatively effected 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[13] as a result of the extra short-term bond supply after the shock and thus imports and exports are more impacted by the LSAP shock 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 a far longer time compared to the CMP shock.

The last policy we compare is the same LSAP shock described above with a credible commitment by the central bank to not raise the policy rate for a year after the LSAP policy intervention. In the model this is simulated by impacting the model with the LSAP shock and then searching for the appropriate anticipated monetary policy shocks that ensure that the policy rate remains unchanged for a year. This can be also thought of as an LSAP shock that occurs during a period in which the economy is at the ZLB and is most analogous to unconventional shocks that were seen during the Great Recession and its recovery.

This policy (LSAP + FG) is depicted by the dotted yellow line. The policy commitment significantly increases the efficiency of LSAP, raising the positive response of output, inflation

[12] 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).

[13] 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.

and consumption above regular LSAP and CMP. The inflation response is slightly above the response seen with regular LSAP for a few quarters but quickly converges back to the inflation dynamics seen with regular LSAP thereafter. Further, the policy rate commitment ensures that investment responds positively but is still below the positive investment impact from a CMP shock. This is because capital prices and net worth increase by a smaller amount compared to a CMP shock. As a result the risk spread decline is not as great as a CMP shock but a bit greater than a regular LSAP shock. The significant increase in deposits still creates the large decline in the loan-to-deposit ratio seen with regular LSAP. Finally, LSAP with policy commitment further depreciates the domestic currency, resulting in a bigger impact on net exports compared to the other two policy interventions.

4.2 Reduced Form Evidence

The structural estimation of the model makes quite strikingly different predictions surrounding different monetary policy interventions when the model includes a financial accelerator. In this subsection we ask what predictions would we obtain if we employ a less structured identification strategy. In other words, if we identified the relevant policy shocks using an entirely different approach, would we recover impulse responses that look like the model's predictions?

To answer this question, we follow Jorda (2005) and use local projection estimates of the impulse responses to conventional monetary policy shocks and LSAP shocks using the same data set as we did to estimate the structural model. However, to identify the monetary policy shocks, we tie our hands and simply use the shocks estimated by Swanson (2021). 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, exchange rate, and financial market data. The model is estimated on data in a 30 minute window around FOMC announcements to capture the reaction of market variables to policy announcements. Swanson argues and provides compelling evidence that his model extracts three orthogonal shocks that capture conventional monetary policy, LSAPs, and forward guidance, respectively.

We aggregate Swanson's estimated shocks to quarterly intervals by summing observations within a quarter. The idea being 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. Our local projections regression specification is

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

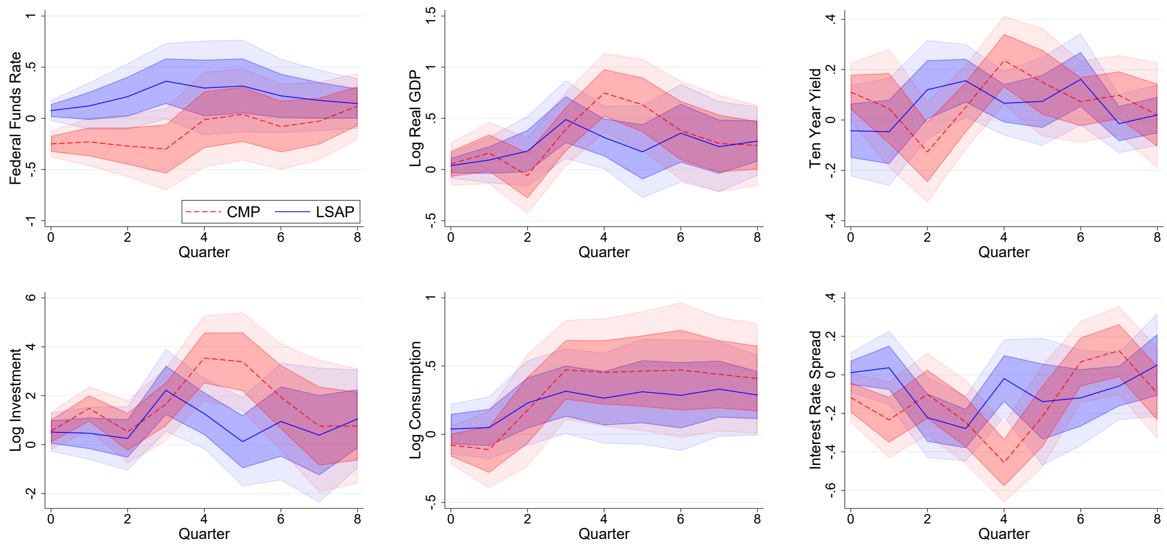
where $\Delta_h y_t = y_{t+h} - y_{t-1}$ is the variable of interest, CMP_t is the aggregated conventional monetary policy shocks, $LSAP_t$ is the aggregated LSAP shocks, FG_t is the aggregated forward guidance shocks, W_t is a vector of contemporaneous controls, X_{t-1} are lagged endogenous variables, $I(ZLB)_t$ is indicator variable for the binding zero lower bound, and β_1^h and β_2^h are the dynamic multipliers of interest for $h = 0, 1, ..., 8$.

Figure 3 plots the CMP and LSAP shocks effect on the policy rate, log real GDP, ten-year treasury yield, log investment, log consumption, and the risk spread at various horizons. The contemporaneous controls are the policy rate and the nominal exchange rate. The lagged controls are the Federal Funds Rate, nominal exchange rate, log real GDP, log price level, log consumption, log investment, household net worth, the ten-year treasury yield, and the risk spread, each appearing with two lags. We standardize the shocks to each have unit variance and scale the impulse responses so that the CMP shock lower the Federal Funds Rate by 25 basis points on impact.

The conventional monetary policy shock yields the standard predictions for expansionary monetary policy by increasing output and inflation. The congruence of CMP impulse response to standard theory gives us confidence that Swanson's shocks and our aggregation identify meaningful monetary policy interventions in the data. Comparing the CMP shocks to the LSAP shock, we find compelling similarities to the structural model with the financial accelerator. Expansionary LSAP shocks actually increase the Federal Funds Rate while only slightly decreasing the risk spread. This results in a more modest increase in output, investment, and net worth (asset prices) relative to what occurs under CMP.

Table 1 provides the individual estimates for the dynamic multipliers (β_1^h, β_2^h), of various variables of interest. The table includes tests for equality of the dynamic multipliers for the

Figure 3: 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 2017q2.

two shocks. In particular, we find compelling evidence that CMP shocks have a far greater impact on investment growth and net worth (asset prices) then do LSAP shocks after impact. One additional variable of interest is the effect of these policies on the exchange rate. Positive dynamic multipliers in Table 1 indicate appreciation of the exchange rate for expansionary policy shocks. These results imply that expansionary LSAP shocks generate a relatively larger negative impact of the US dollar compared to expansionary CMP shocks.

Table 1: Local Projection Regression Estimates

Log Investment	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8
LSAP	-0.32	-0.29	-0.16	-1.39**	-0.79	-0.08	-0.59	-0.24	-0.66
	(0.29)	(0.40)	(0.49)	(0.63)	(0.54)	(0.68)	(0.89)	(1.02)	(0.75)
CMP	-0.35	-0.93***	-0.33	-1.03*	-2.21***	-2.12***	-1.22	-0.47	-0.47
	(0.29)	(0.33)	(0.48)	(0.56)	(0.65)	(0.75)	(0.82)	(1.01)	(0.88)
R-squared	0.84	0.85	0.89	0.91	0.93	0.95	0.95	0.94	0.94
H_0: CMP=LSAP (P-value)	0.941	0.200	0.790	0.600	0.078	0.076	0.687	0.896	0.892

Risk Spread	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8
LSAP	-0.01	-0.02	0.14*	0.17***	0.01	0.09	0.07	0.04	-0.03
	(0.04)	(0.07)	(0.08)	(0.06)	(0.08)	(0.12)	(0.09)	(0.07)	(0.10)
CMP	0.07	0.15*	0.06	0.15*	0.29***	0.14	-0.04	-0.08	0.06
	(0.05)	(0.07)	(0.08)	(0.08)	(0.08)	(0.10)	(0.08)	(0.09)	(0.09)
R-squared	0.69	0.7	0.78	0.89	0.93	0.9	0.9	0.89	0.89
H_0: CMP=LSAP (P-value)	0.12	0.07	0.41	0.80	0.03	0.81	0.44	0.35	0.58

Ten Year Yield	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8
LSAP	0.03	0.03	-0.08	-0.10*	-0.04	-0.05	-0.1	0.01	-0.01
	(0.07)	(0.08)	(0.07)	(0.05)	(0.05)	(0.07)	(0.07)	(0.04)	(0.05)
CMP	-0.07	-0.03	0.08	-0.03	-0.15**	-0.09	-0.05	-0.06	-0.01
	(0.04)	(0.09)	(0.07)	(0.06)	(0.07)	(0.08)	(0.06)	(0.06)	(0.08)
R-squared	0.53	0.53	0.62	0.80	0.84	0.83	0.88	0.91	0.89
H_0: CMP=LSAP (P-value)	0.17	0.61	0.10	0.36	0.15	0.59	0.51	0.33	1.00

Nominal Exchange Rate	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8
LSAP	0.22	0.33	0.55	0.27	-0.2	0.13	0.44	-0.11	0.16
	(0.43)	(0.74)	(0.97)	(0.98)	(0.69)	(0.64)	(0.77)	(0.71)	(0.68)
CMP	0.5	0.74	1.45*	2.04***	1.18	0.88	1.14*	1.02**	0.19
	(0.39)	(0.64)	(0.76)	(0.67)	(0.81)	(0.82)	(0.64)	(0.50)	(0.54)
R-squared	0.49	0.6	0.73	0.80	0.85	0.89	0.92	0.92	0.93
H_0: CMP=LSAP (P-value)	0.63	0.68	0.52	0.20	0.20	0.46	0.47	0.11	0.98

Net Worth	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8
LSAP	0.58	-0.71	-2.48	-3.23**	-1.96	-1.55	-1.83	-0.07	0.17
	(0.97)	(1.31)	(1.50)	(1.28)	(1.31)	(1.82)	(1.48)	(1.09)	(1.49)
CMP	-1.43	-0.83	-0.93	-3.40*	-4.56***	-1.7	-0.34	-1.03	-0.93
	(1.21)	(1.58)	(1.90)	(1.89)	(1.26)	(1.63)	(1.47)	(1.58)	(1.16)
R-squared	0.49	0.61	0.7	0.83	0.92	0.92	0.93	0.93	0.95
H_0: CMP=LSAP (P-value)	0.11	0.95	0.49	0.94	0.23	0.96	0.56	0.66	0.52

In summary, the reduced form results are consistent with the structural model's dynamics discussed in the previous subsection. We see that the relative impact of output, the policy rate, the risk spread, investment and asset price growth reaction to CMP and LSAP shocks are consistent across both types of analysis. As discussed further in appendix B the addition of the financial accelerator and financial intermediaries to the structural model is key in producing these harmonized results. We find that when the DSGE model with no financial accelerator and financial intermediaries is estimated, LSAP shocks in the model have a greater impact on output and investment than do CMP shocks, illustrated in Figure 8.

4.3 Parameter Sensitivity Analysis

In this subsection, 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. Finally, we consider how the impact of unconventional and conventional monetary policies in the United States would be affected as overall trade and financial openness parameters change.

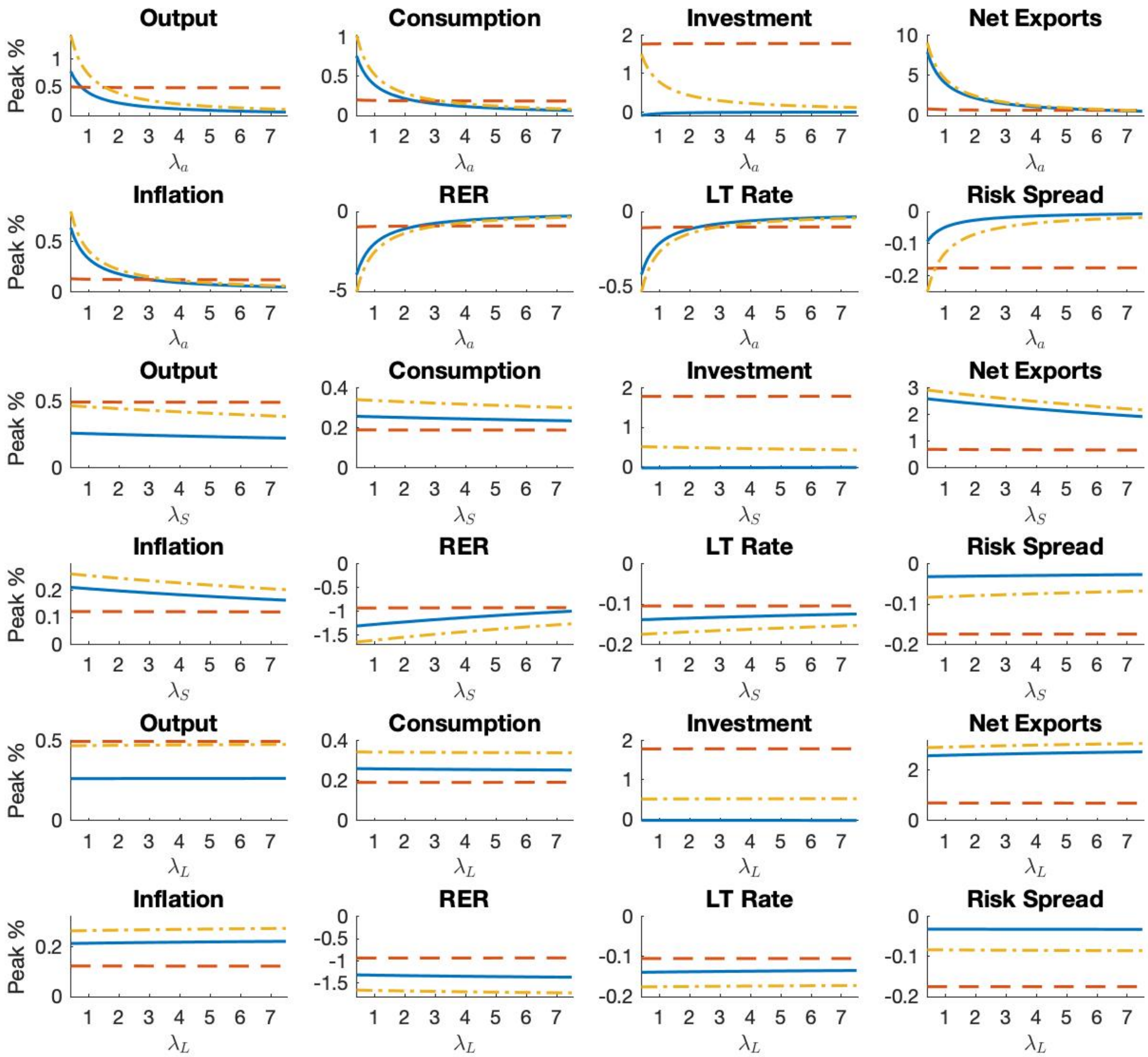
Portfolio Elasticity Sensitivity Analysis

We first analyze the sensitivity of our results to the elasticity parameters in the portfolio specification. Figure 4 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[14] 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

[14] 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 4: 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.

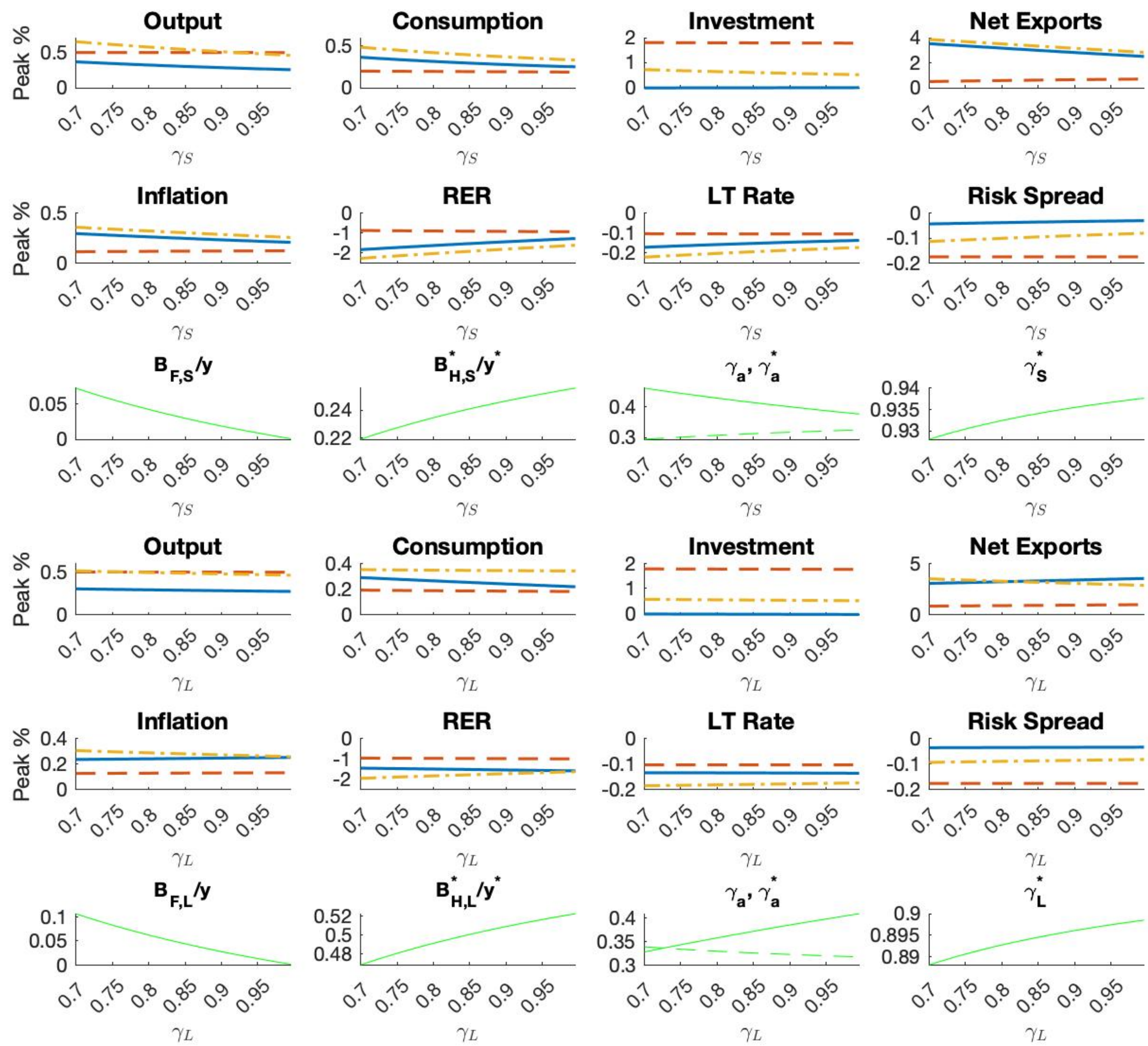
substitution of short and long-term bonds (λ_a) becomes more inelastic. Further the impact on the long-term rate and risk spread is much larger as λ_a shrinks. A LSAP + FG shock has the ability to be as efficient as a CMP shock in stimulating investment when λ_a is low. Note that a regular LSAP shock still does not greatly impact investment no matter the estimate 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.

Portfolio Share Sensitivity Analysis

Figure 5 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 5. 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 11.

Figure 5: 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 6 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.

Trade and Financial Openess

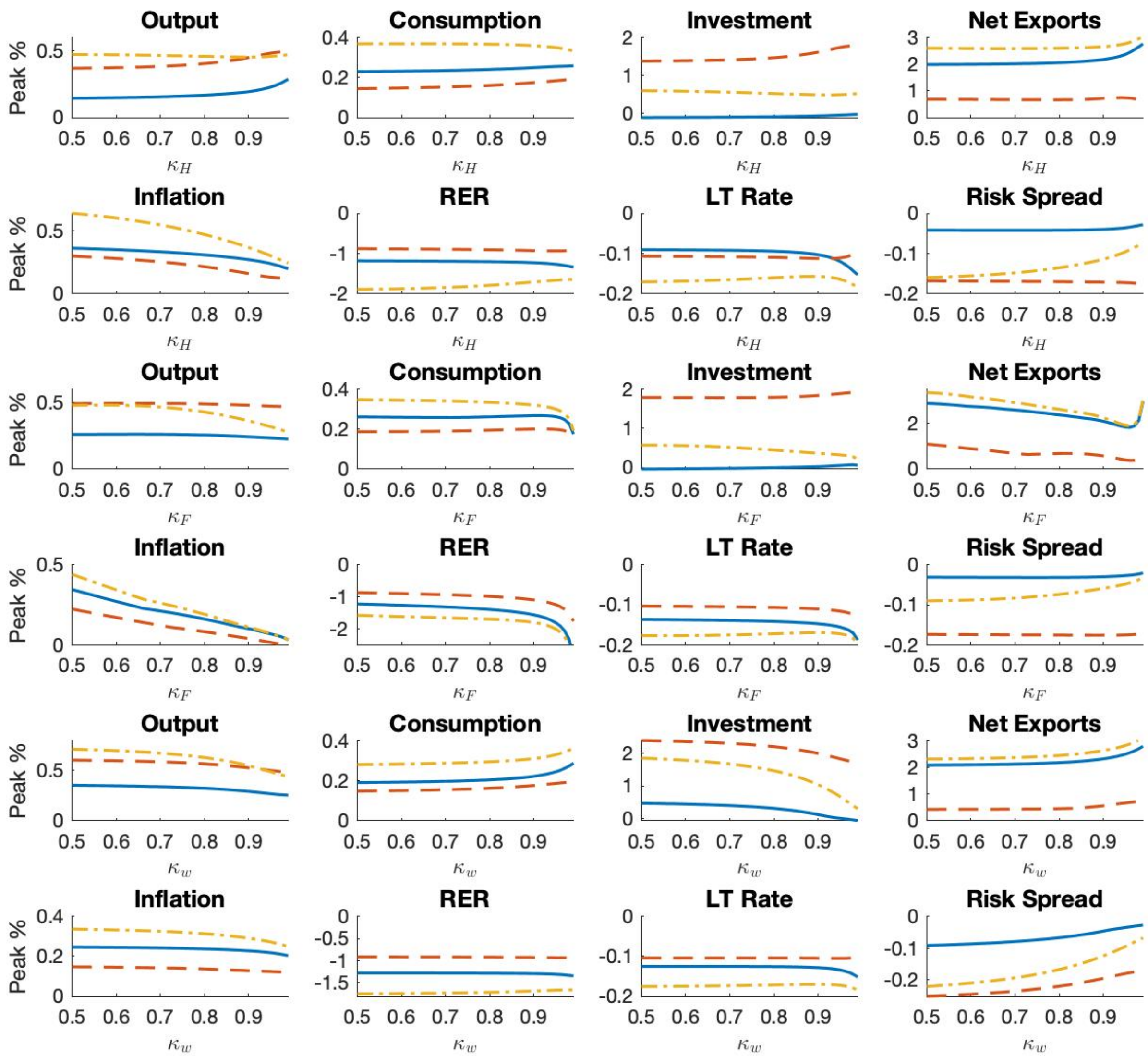
Let us now investigate how trade and financial openness impact the effects of each policy intervention in the US. We alter trade and financial openness of the two economies in two fashions. We first decrease the home good preference parameters of the US (γ_c and γ_I) to 0.7[15] In addition we decrease the short-term domestic bond preference parameters of the US and ROW (γ_S and γ_S^*) to 0.8.[16] We refer to this specification as “more open” in the proceeding analysis. In the second type of specification we set γ_c, γ_I, γ_S, γ_L, γ_S^*, γ_L^* are equal to 0.99.[17] We refer to this specification as “closed” in the proceeding analysis.

[15]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.

[16]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.

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

Figure 6: 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.

Figures 12- 14 plot the IRF's of the three policy interventions (LSAP, CMP, LSAP + FG) under the two new openness specifications along with the baseline specification of the paper. We find that the addition of the financial accelerator to the model causes LSAP and LSAP + FG shocks to increase the importance of trade and financial openness in regards to their impact on output, inflation, hours, consumption, investment, net exports and asset prices, while a more closed economy mutes the response to unconventional monetary policy. Further, Figure 13 shows that conventional monetary policy is seen to have a greater impact on these key macroeconomic variables when the economy is more closed and less of an impact when the economy is more open. This suggests that unconventional monetary policy will become more impactful as the global economy continues to become more economically and financially integrated.

5 Coordinated Policy Analysis

In this section we evaluate the economic impact of coordinated global monetary policy seen after the global financial crisis and during the global pandemic. Lastly, using historical shock decompositions, we look at the impact conventional monetary policy, unconventional monetary policy and coordinated policy has had on key macroeconomic and financial variables over the 12 years since the global financial crisis.

5.1 Coordinated Global Monetary Policy

When examining the impact of coordinated monetary policy amongst the two economies we find that there are notable differences between the economic impacts of coordinated LSAP purchases and coordinated policy rate changes (CMP). Figure 15 plots the IRF of a domestic LSAP purchase equivalent to a long-term asset purchase of 1.5% of steady state GDP by the US central bank (solid blue line) and the IRF of a global LSAP purchase equivalent to a long-term asset purchase of 1.5% of steady state GDP by both the US and the ROW simultaneously.

We can see that the coordinated LSAP purchase mutes 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 would rise less when the LSAP purchase is coordinated. This results in more of a positive impact on consumption and a positive impact on investment. Further, exports still rise even though the nominal exchange rate is unchanged because of the increase in ROW demand from the ROW unconventional monetary policy.

Many of the same effects are exhibited 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 purchase, inflation and exchange rate effects are muted and the positive impact of consumption and investment is amplified. However, unlike coordinated LSAP purchases, coordinated policy 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 does a domestic LSAP purchase, 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 outweigh the loss in net export growth.

5.2 Historical Shock Decompositions

In the previous sections we have described the key mechanisms determining the policy transmission effects of the model. The open-economy model's framework enables us to identify the source of the past fluctuations for key financial and economic variables in terms of the exogenous processes described in section 2.5. We use historical shock decompositions to describe how the model explains the evolution of the output gap, labor gap, net worth (asset prices), risk spread, loan-to-deposit ratio and the real exchange rate during and after the global financial crisis. Historical shock decompositions allow us insight on two issues. They allow us to determine the impact global macro and global finance shocks have on key variables. They also allow us to determine the immediate and lasting effects various monetary and fiscal policy interventions have had on both the real economy and financial markets.

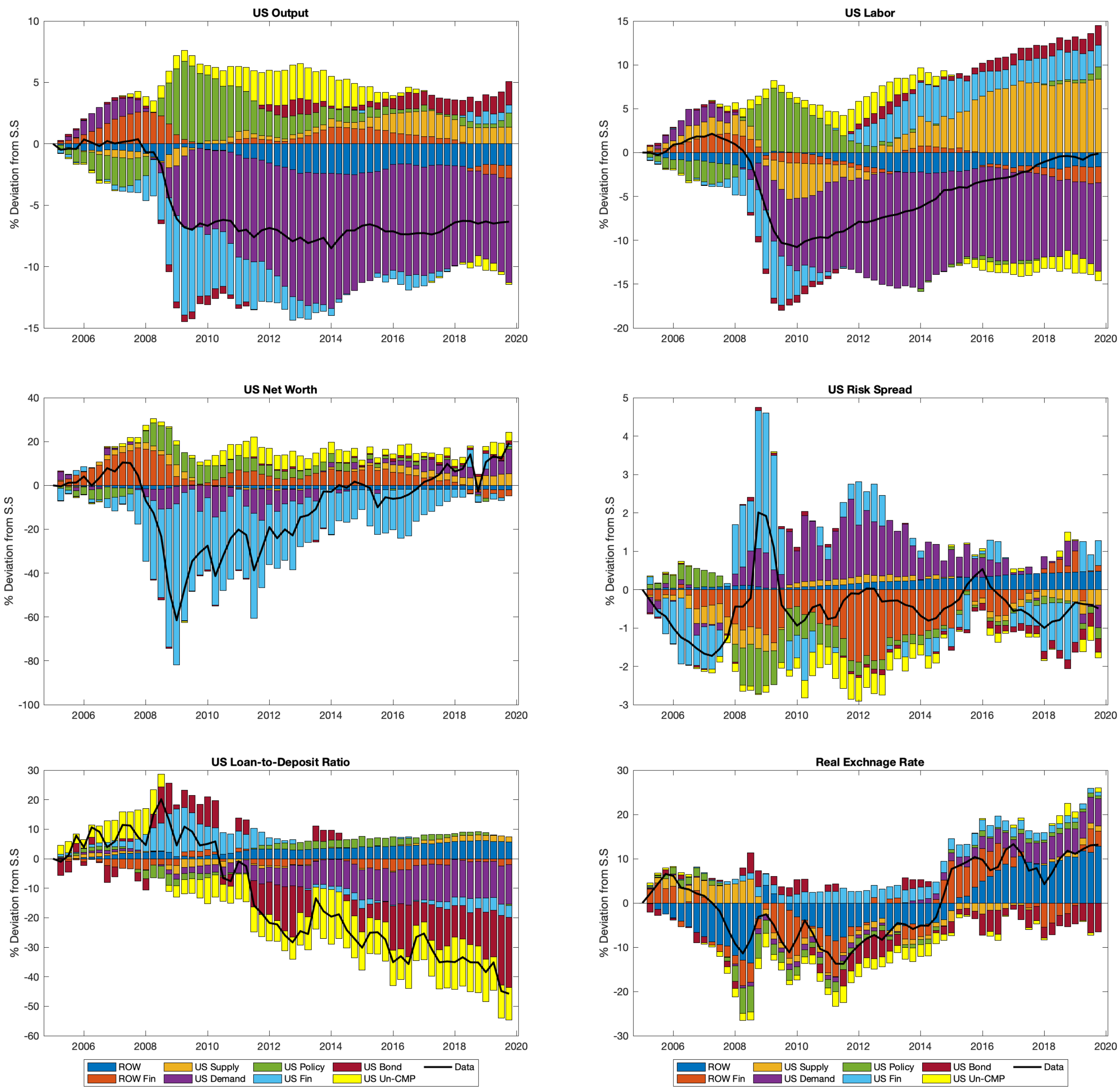
The importance of each "type" shock for the forementioned variables is quantified in Figure 7. The solid line shows the variable in deviation from its steady state value. The bars represent the contribution of each type of shock to the deviation of the variable from steady state, that is, the counterfactual 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 8 categories of shocks. *ROW* category 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.

The shock decomposition implies, the evolution of the real economy since 2008 was driven by two main forces. Disruptions in the financial sector depleted aggregate demand and employment, producing a sharp economic downturn and a sluggish recovery. The addition of credit frictions in the DSGE model allows it to capture these events, attributing an important part of the economic downturn to the net worth and spread shocks seen in the US. In the face of these large financial and demand shocks, fiscal and monetary policy played an important role in supporting the real economy by providing stimulus both 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) played an important role during the recession, lifting output and hours worked beginning in early 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 the model's Taylor Rule would predict. Hence, the model uses a series of negative CMP shocks as the primary driver of the policy rate's sharp decline by the end of 2008. As Figure 7 depicts, traditional policy intervention helped boost output, employment and asset prices, while lowering the risk spread and depreciating the US dollar.

Starting in 2010 these conventional policy effects begin to fade on the real economy and unconventional monetary policy shocks (yellow bars) begin to play a predominant role in stimulating the real economy and financial markets. 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 monetary policy effect on the real economy and the real exchange rate slows and even turns negative as the central bank balance sheet roll off period begins in 2018. However, unconventional policies have a

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.

lasting positive effect on asset prices and bond markets through 2019. Further, the model's loan-to-deposit ratio significantly declines due to unconventional policy shocks and US bond portfolio share shocks, consistent to what was empirically illustrated in Figure 1. All of this suggests that unconventional monetary policy has lasting effects on financial markets and the banking sector even after its effects on the real economy fade.

6 Conclusion

In this paper, a two-country open-economy New Keynesian dynamic stochastic general equilibrium (DSGE) model similar to the Alpanda and Kabacca (2020) is augmented with a financial accelerator and estimated using a large set of US and global macroeconomic data, equity price data, bond spreads, short and long term public bond supply, international public bond holding shares and Federal Funds Rate futures. After estimating the model we then evaluate the economic and financial market response to different types of policy interventions. These include unconventional monetary policies such as large-scale asset purchases (LSAP), forward guidance on the short-term policy rate (FG), conventional policy rate changes, globally coordinated monetary polices and domestically coordinated fiscal and monetary policy interventions.

In accordance with the unconventional monetary policy literature, we find that domestic LSAP purchases do indeed raise domestic output and inflation, however, we find that the transmission mechanism behind these increases occurs primarily through domestic consumption and export markets, while the impact on investment markets is slightly negative away from the ZLB or when there is no forward guidance policy rate commitment associated with the LSAP. LSAP's are seen to be most stimulating to output, inflation, consumption, exports, and investment when at the ZLB or when the central bank accompanies them with a stable policy rate commitment. We also see that the domestic currency depreciates by a larger amount following expansionary unconventional monetary policy compared to expansionary conventional monetary policy (CMP). All of these results are seen in both the paper's structural model analysis and an alternative local projection analysis conducted for robustness in the paper.

When evaluating the model's structural dynamics we find that unconventional monetary policy is most efficient (relative to CMP) in stimulating the economy when financial frictions in the private credit sector are low, the elasticity of substitution of short and long-term bonds is inelastic, the elasticity of substitution of domestic and foreign short-term bonds is inelastic, nominal pricing rigidities are high and nominal wage rigidities are low. Further, unlike CMP, unconventional monetary policy is seen to be more efficient at stimulating the economy as the openness of trade in goods and trade in financial markets increases. This suggests that unconventional monetary policy intervention will become more efficient as the economy continues to become more globalized.

Finally, historical shock decompositions of the model for the United States show that conventional fiscal and monetary policy played important roles in stimulating the real economy and financial markets during the onset of the Great Recession. However, their impact began to dissipate around 2010 and unconventional monetary policy played an important role in stimulating the real economy and financial markets. However, unconventional monetary policy impact on the real economy began to fade in 2015 but its positive impact on financial markets and mainly equity prices remained through the end of 2019. This historical analysis suggests that while both expansionary conventional and unconventional monetary policy stimulates the real economy and financial markets initially, unconventional monetary policy seems to have a lasting impact on financial markets well after its impact on the real economy has quelled. In contrast, conventional monetary policy effects on the real economy and financial markets seems to be more coinciding.

In conclusion, like conventional monetary policy, unconventional monetary policy is an important tool in the policymakers 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, since many unconventional monetary policy interventions were designed to stimulate the housing sector. Even given the explosion of work evaluating unconventional monetary policy that has been done since the onset of the global financial crisis much work remains.

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A Model Details and Linearized Equations

A.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 ($c_{F,t}$).

$$c_t = \left[\gamma_c^{\frac{1}{\lambda_c}} \left(c_{H,t}\right)^{\frac{\lambda_c - 1}{\lambda_c}} + (1-\gamma_c)^{\frac{1}{\lambda_c}} \left(c_{F,t}\right)^{\frac{\lambda_c - 1}{\lambda_c}}\right]^{\frac{\lambda_c}{\lambda_c - 1}} \tag{42}$$

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:

$$c_{H,t} = \left(\frac{P_{H,t}}{P_t}\right)^{-\lambda_c} \gamma_c c_t \quad \& \quad c_{F,t} = \left(\frac{P_{F,t}}{P_t}\right)^{-\lambda_c} (1-\gamma_c) c_t \tag{43}$$

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

$$P_t = \left[\gamma_c P_{H,t}^{1-\lambda_c} + (1-\gamma_c) P_{F,t}^{1-\lambda_c}\right]^{\frac{1}{1-\lambda_c}} \tag{44}$$

Final investment good aggregators are given by

$$I_t = \left[\gamma_I^{\frac{1}{\lambda_I}} \left(I_{H,t}\right)^{\frac{\lambda_I - 1}{\lambda_I}} + (1-\gamma_I)^{\frac{1}{\lambda_I}} \left(I_{F,t}\right)^{\frac{\lambda_I - 1}{\lambda_I}}\right]^{\frac{\lambda_I}{\lambda_I - 1}} \tag{45}$$

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:

$$I_{H,t} = \left(\frac{P_{H,t}}{P_{I,t}}\right)^{-\lambda_I} \gamma_I I_t \quad \& \quad I_{F,t} = \left(\frac{P_{F,t}}{P_{I,t}}\right)^{-\lambda_I} (1-\gamma_I) I_t \tag{46}$$

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

$$P_{I,t} = \left[\gamma_I P_{H,t}^{1-\lambda_I} + (1-\gamma_I) P_{F,t}^{1-\lambda_I}\right]^{\frac{1}{1-\lambda_I}} \tag{47}$$

A.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

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\Theta_{w,t}} L_t \tag{48}$$

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:

$$\hat{\pi}_{w,t} - \iota_w \hat{\pi}_{t-1} = \beta E_t[\hat{\pi}_{w,t+1} - \iota_w \hat{\pi}_t -] \frac{\Theta_w - 1}{\kappa_w} \left(\hat{w}_t - \nu_L \hat{L} - \frac{1}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{e}_{b,t}\right) + \hat{e}_{w,t} \tag{49}$$

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

$$\hat{\pi}_{w,t} - \hat{\pi}_t = \hat{w}_t - \hat{w}_{t-1} \tag{50}$$

A.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.

$$y_t = \left(\int_0^1 y_t(i)^{\Theta_{H,t}} \, di \right)^{\frac{1}{\Theta_{H,t}}} \tag{51}$$

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 $y_t(i)$:

$$y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\Theta_{H,t}} y_t \tag{52}$$

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:

$$y_t(i) = e_{a,t} K_t(i)^{\alpha} L_t(i)^{1-\alpha} - f \tag{53}$$

where f is a fixed cost of the production process, K_t is utilized capital[18] 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:

$$\frac{\Pi_{H,t}(i)}{P_t} = \frac{P_{H,t}(i)}{P_t} y_t(i) - \frac{W_t}{P_t} L_t(i) - r_t^k K_t(i) - \frac{\kappa_H}{2} \left(\frac{P_{H,t}(i)/P_{H,t-1}(i)}{\pi_{H,t-1}^{\iota_H} \pi^{1-\iota_H}} - 1 \right)^2 \frac{P_{H,t}}{P_t} y_t \tag{54}$$

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

[18]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 (52) 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

$$\hat{K}_t - \hat{L}_t = \hat{w}_t - \hat{r}_t^k \tag{55}$$

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

$$\hat{\pi}_{H,t} - \iota_H \hat{\pi}_{H,t-1} = \beta E_t[\hat{\pi}_{H,t+1} - \iota_H \hat{\pi}_{H,t}] - \frac{\Theta_H - 1}{\kappa_H}\left(\hat{p}_{H,t} + \hat{e}_{a,t} + \alpha(\hat{K}_t - \hat{L}_t) - \hat{w}_t\right) + \hat{e}_{H,t} \tag{56}$$

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

A.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:

$$y_{F,t}(m) = \left(\frac{P_{F,t}(m)}{P_{F,t}}\right)^{-\Theta_{F,t}} y_{F,t} \tag{57}$$

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

$$\frac{\Pi_{F,t}(i)}{P_t} = \frac{P_{F,t}(i)}{P_t} y_{F,t}(m) - \frac{e_t P^*_{H,t}}{P_t} y_{F,t}(m) - \frac{\kappa_F}{2}\left(\frac{P_{F,t}(m)/P_{F,t-1}(m)}{\pi_{F,t-1}^{\iota_F}\pi^{1-\iota_F}} - 1\right)^2 \frac{P_{F,t}}{P_t} y_{F,t} \quad (58)$$

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:

$$\hat{\pi}_{F,t} - \iota_F \hat{\pi}_{F,t-1} = \beta E_t[\hat{\pi}_{F,t+1} - \iota_F \hat{\pi}_{F,t}] - \frac{\Theta_F - 1}{\kappa_F}\left(\hat{p}_{F,t} - \hat{rer}_t - \hat{p}^*_{H,t}\right) + \hat{e}_{F,t} \quad (59)$$

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. ($\theta_F = \Theta_F/(\Theta_F - 1)$)

A.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:

$$\bar{K}_t = (1-\tau)\bar{K}_{t-1} + e_{I,t}\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \quad (60)$$

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:

$$\Pi_t^k = Q_t(\bar{K}_t - (1-\tau)\bar{K}_{t-1}) - P_{I,t} I_t \tag{61}$$

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:

$$\hat{I}_t - \hat{I}_{t-1} = \beta E_t[\hat{I}_{t+1} - \hat{I}_t] + \frac{1}{S''}(\hat{Q}_t - \hat{p}_{I,t}) + \hat{e}_{I,t} \tag{62}$$

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

A.6 Linearized Equations - Home Country

- Household FOC's

$$\hat{\lambda}_t = -\frac{1}{1-h}(\hat{C}_t - h\hat{C}_t - 1) + \hat{e}_{b,t} \tag{63}$$

$$\hat{R}_{L,t} = \frac{\kappa}{R_L} E_t[\hat{R}_{L,t+1}] + \left(1 - \frac{\kappa}{R_L}\right)\left(\hat{R}_t + \left(\frac{\pi}{\beta R} - 1\right)\hat{T}_t\right) \tag{64}$$

$$\hat{T}_t = \frac{1}{\lambda_a}\left(\hat{a}_{L,t} - \hat{a}_{S,t} + \frac{1}{1-\gamma_a}\hat{\gamma}_{a,t}\right) - \frac{1}{\lambda_L}\left(\hat{a}_{L,t} - (\hat{q}_{L,t} + \hat{b}_{H,L,t}) + \hat{\gamma}_{L,t}\right) + \frac{1}{\lambda_s}\left(\hat{a}_{S,t} - \hat{b}_{H,S,t} + \hat{\gamma}_{S,t}\right) \tag{65}$$

$$\begin{aligned}\hat{\lambda}_t = \frac{\beta R}{\pi}\left(E_t[\hat{\lambda}_{t+1}] + \hat{R}_t - E_t[\hat{\pi}_{t+1}]\right) + \left(1 - \frac{\beta R}{\pi}\right)\Bigg[\frac{1-\gamma_a}{\lambda_a}\left(\hat{a}_{L,t} - \hat{a}_{S,t} + \frac{1}{1-\gamma_a}\hat{\gamma}_{a,t}\right) \\ + \frac{1-\gamma_S}{\lambda_S}\left(r\hat{e}r_t + \hat{b}_{F,S,t} - \hat{b}_{H,S,t} + \frac{1}{1-\gamma_S}\hat{\gamma}_{S,t}\right) - \hat{a}_t\Bigg]\end{aligned} \tag{66}$$

$$\hat{\lambda}_t = \frac{\beta R^D}{\pi}\left(E_t[\hat{\lambda}_{t+1}] + \hat{R}_t^D - E_t[\hat{\pi}_{t+1}]\right) - \left(1 - \frac{\beta R^D}{\pi}\right) d\hat{e}p_t \tag{67}$$

- Aggregate Definitions

$$\hat{a}_t = \gamma_a \hat{a}_{S,t} + (1-\gamma_a)\hat{a}_{L,t} \tag{68}$$

$$\hat{a}_{S,t} = \gamma_S \hat{b}_{H,S,t} + (1-\gamma_S)(\hat{rer}_t + \hat{b}_{F,S,t}) \tag{69}$$

$$\hat{a}_{L,t} = \gamma_L \hat{b}_{H,L,t} + (1-\gamma_L)(\hat{rer}_t + \hat{q}^*_{L,t} + \hat{b}_{F,L,t}) \tag{70}$$

$$\hat{c}_t = \gamma_c \hat{c}_{H,t} + (1-\gamma_c)\hat{c}_{F,t} \tag{71}$$

$$\hat{I}_t = \gamma_I \hat{I}_{H,t} + (1-\gamma_I)\hat{I}_{F,t} \tag{72}$$

- UIP Equations

$$\hat{R}_t - \hat{R}^*_t = E_t\hat{d}_{t+1} + \left(\tfrac{\pi}{\beta R} - 1\right)\tfrac{1}{\lambda_s}\left[\hat{b}_{H,S,t} - (\hat{rer}_t + \hat{b}_{F,S,t}) - \tfrac{1}{1-\gamma_S}\hat{\gamma}_{S,t}\right] \tag{73}$$

$$\begin{aligned}\hat{R}_{L,t} - \hat{R}^*_{L,t} = {} & \frac{\kappa}{R_L}\left(E_t[\hat{R}_{L,t+1}] - E_t[\hat{R}^*_{L,t+1}]\right) + \left(1 - \frac{\kappa}{R_L}\right)\Big\{E_t\hat{d}_{t+1} \\ & + \left(\frac{\pi}{\beta R} - 1\right)\frac{1}{\lambda_L}\left[\hat{q}_{L,t} + \hat{b}_{H,L,t} - (\hat{rer}_t + \hat{q}^*_{L,t} + \hat{b}_{F,L,t}) - \frac{1}{1-\gamma_L}\hat{\gamma}_{L,t}\right]\Big\}\end{aligned} \tag{74}$$

- Policy Equations

$$\hat{R}_t = \rho\hat{R}_{t-1} + (1-\rho)\left[r_\pi\hat{\pi}_t + r_y\hat{y}_t + r_d\hat{d}_t\right] + \hat{\varepsilon}_{r,t} + \sum_{k=1}^{5}\hat{e}^r_{k,t-k} \tag{75}$$

$$\begin{aligned}& \frac{g}{y}(\hat{p}_{H,t} + \hat{g}_t) + \frac{R}{\pi}\frac{b_S}{y}\left(\hat{R}_{t-1} - \hat{\pi}_t + \hat{b}_{S,t-1}\right) + \frac{R_L}{\pi}\frac{q_L b_L}{y}\left(\hat{R}_{L,t} - \hat{\pi}_t + \hat{q}_{L,t} + \hat{b}_{L,t-1}\right) \\ & \quad = \frac{tax}{y}\hat{tax}_t + \frac{b_S}{y}\hat{b}_{S,t} + \frac{q_L b_L}{y}\left(\hat{q}_{L,t} + \hat{b}_{L,t}\right)\end{aligned} \tag{76}$$

$$\hat{tax}_t = \tau_Y\hat{y}_t + \tau_b\frac{\frac{b_S}{y}}{\frac{b_S}{y} + \frac{q_L b_L}{y}}\hat{b}_{S,t-1} + \tau_b\frac{\frac{q_L b_L}{y}}{\frac{b_S}{y} + \frac{q_L b_L}{y}}\left(\hat{q}_{L,t-1} + \hat{b}_{L,t-1}\right) + \hat{e}_{tax,t} \tag{77}$$

$$\frac{b_S}{y}\hat{b}_{S,t} = \frac{b_{H,S}}{y}\hat{b}_{H,S,t} + \left(\frac{b_s}{y} - \frac{b_{H,S}}{y}\right)\hat{b}^*_{F,S,t} \tag{78}$$

$$\frac{q_L b_L}{y}\hat{b}_{L,t} = \frac{q_L b_{H,L}}{y}\hat{b}_{H,L,t} + \left(\frac{q_L b_L}{y} - \frac{q_L b_{H,L}}{y}\right)\hat{b}^*_{F,L,t} \tag{79}$$

$$\hat{\gamma}_{b,t} = \hat{q}_{L,t} + \hat{b}_{L,t} - \hat{b}_{S,t} \tag{80}$$

- Capital

$$\hat{\bar{K}}_t = (1-\tau)\hat{\bar{K}}_{t-1} + \tau \hat{I}_t + S''\tau \hat{e}_{I,t} \tag{81}$$

$$\hat{I}_t - \hat{I}_{t-1} = \beta E_t[\hat{I}_{t+1} - \hat{I}_t] + \frac{1}{S''}(\hat{Q}_t - \hat{p}_{I,t}) + \hat{e}_{I,t} \tag{82}$$

$$\hat{K}_t = \hat{u}_t + \hat{\bar{K}}_{t-1} \tag{83}$$

$$\hat{u}_t = \frac{r_k}{a''(u)}\hat{r}^k_t \tag{84}$$

- New Keynesian Phillip's Curves

$$\hat{\pi}_{w,t} - \iota_w \hat{\pi}_{t-1} = \beta E_t[\hat{\pi}_{w,t+1} - \iota_w \hat{\pi}_t -] \frac{\Theta_w - 1}{\kappa_w}\left(\hat{w}_t - \nu_L \hat{L} - \frac{1}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) + \hat{e}_{b,t}\right) + \hat{e}_{w,t} \tag{85}$$

$$\hat{\pi}_{H,t} - \iota_H \hat{\pi}_{H,t-1} = \beta E_t[\hat{\pi}_{H,t+1} - \iota_H \hat{\pi}_{H,t}] - \frac{\Theta_H - 1}{\kappa_H}\left(\hat{p}_{H,t} + \hat{e}_{a,t} + \alpha(\hat{K}_t - \hat{L}_t) - \hat{w}_t\right) + \hat{e}_{H,t} \tag{86}$$

$$\hat{\pi}_{F,t} - \iota_F \hat{\pi}_{F,t-1} = \beta E_t[\hat{\pi}_{F,t+1} - \iota_F \hat{\pi}_{F,t}] - \frac{\Theta_F - 1}{\kappa_F}\left(\hat{p}_{F,t} - r\hat{e}r_t - \hat{p}^*_{H,t}\right) + \hat{e}_{F,t} \tag{87}$$

- Producers

$$\hat{y}_t = \phi \hat{e}_{a,t} + \phi\alpha \hat{K}_t + \phi(1-\alpha)\hat{L}_t \tag{88}$$

$$\hat{K}_t - \hat{L}_t = \hat{w}_t - \hat{r}^k_t \tag{89}$$

- Entrepreneurs and Financial Sector

$$E_t\left[\hat{\bar{R}}^k_{t+1} - \hat{R}_t\right] = \chi\left(\hat{Q}_t + \hat{\bar{K}}_t - N\hat{W}_t\right) + \hat{e}_{Fin,t} \tag{90}$$

$$\hat{S}_t = E_t\left[\hat{\bar{R}}^k_{t+1} - \hat{R}_t\right] \tag{91}$$

$$N\hat{W}_t = \delta_{\bar{R}^k}(\hat{\bar{R}}^k_t - \hat{\pi}_t) - \delta_R(\hat{R}_{t-1} - \hat{\pi}_t) + \delta_{qK}(\hat{Q}_{t-1} + \hat{\bar{K}}_{t-1}) + \delta_n N\hat{W}_{t-1} - \delta_\sigma \hat{e}^{Fin}_{t-1} + \hat{e}^{NW}_t \tag{92}$$

$$\hat{\bar{R}}_t^k - \hat{\pi}_t = \frac{1-\tau}{1-\tau+r^k}\hat{Q}_t + \frac{r^k}{1-\tau+r^k}\hat{r}_t^k - \hat{Q}_{t-1} \tag{93}$$

$$\frac{R^D}{ldr}\hat{R}_t^D = R\left(\hat{R}_t + l\hat{d}r_t\right) - l\hat{d}r_t \tag{94}$$

$$\left(\frac{\bar{K}}{NW} - 1\right) lo\hat{a}ns_t = \frac{\bar{K}}{NW}\left(\hat{Q}_t - \hat{\bar{K}}_t\right) - N\hat{W}_t \tag{95}$$

- Balance of Payments

$$\begin{aligned}
&\frac{b_{F,S}}{y}\left[\left(r\hat{e}r + \hat{b}_{F,S,t}\right) - \frac{R^*}{\pi^*}\left(r\hat{e}r_t + \hat{R}^*_{t-1} + \hat{b}_{F,S,t-1} - \hat{\pi}^*_t\right)\right]...\\
&\quad + \frac{q_L^* b_{F,L}}{y}\left[\left(r\hat{e}r + \hat{q}^*_{L,t} + \hat{b}_{F,L,t}\right) - \frac{R_L^*}{\pi^*}\left(r\hat{e}r_t + \hat{R}^*_{L,t} + \hat{q}^*_{L,t} + \hat{b}_{F,L,t-1} - \hat{\pi}^*_t\right)\right]...\\
&\quad - \frac{b^*_{F,S}}{y}\left[\hat{b}^*_{F,S,t} - \frac{R}{\pi}\left(\hat{R}_{t-1} + \hat{b}^*_{F,S,t-1} - \hat{\pi}_t\right)\right]...\\
&\quad - \frac{q_L b^*_{F,L}}{y}\left[\left(\hat{q}_{L,t} + \hat{b}^*_{F,L,t}\right) - \frac{R_L}{\pi}\left(\hat{R}_{L,t} + \hat{q}_{L,t} + \hat{b}^*_{F,L,t-1} - \hat{\pi}_t\right)\right]...\\
&\quad = \frac{y_F^*}{y}\left(\hat{p}_{H,t} + y^*_{F,t}\right) - \frac{y_F}{y}\left(r\hat{e}r_t + \hat{p}^*_{H,t} + y_{F,t}\right)
\end{aligned} \tag{96}$$

- Definitions

$$\hat{R}_{L,t} = -\left(1 - \frac{\kappa}{R_L}\right)\hat{q}_{L,t} \tag{97}$$

$$r\hat{e}r_t - r\hat{e}r_{t-1} = \hat{d}_t + \hat{\pi}^*_t - \hat{\pi}_t \tag{98}$$

$$0 = \gamma_c \hat{p}_{H,t} + (1-\gamma_c)\hat{p}_{F,t} \tag{99}$$

$$\hat{p}_{I,t} = \gamma_I \hat{p}_{H,t} + (1-\gamma_I)\hat{p}_{F,t} \tag{100}$$

$$\hat{\pi}_{H,t} - \hat{\pi}_t = \hat{p}_{H,t} - \hat{p}_{H,t-1} \tag{101}$$

$$\hat{\pi}_{F,t} - \hat{\pi}_t = \hat{p}_{F,t} - \hat{p}_{F,t-1} \tag{102}$$

$$\hat{\pi}_{w,t} - \hat{\pi}_t = \hat{w}_t - \hat{w}_{t-1} \tag{103}$$

$$\hat{c}_{H,t} - \hat{c}_{F,t} = \eta_c\left(\hat{p}_{F,t} - \hat{p}_{H,t}\right) \tag{104}$$

$$\hat{I}_{H,t} - \hat{I}_{F,t} = \eta_I\left(\hat{p}_{F,t} - \hat{p}_{H,t}\right) \tag{105}$$

$$\hat{y}_t = \frac{c}{y}\gamma_c \hat{c}_{H,t} + \frac{I}{y}\gamma_I \hat{I}_{H,t} \frac{g}{y}\hat{g}_t + \frac{y_F^*}{y}\hat{y}_{F,t}^* + r_k \frac{\bar{K}}{y}\hat{u}_t \tag{106}$$

$$\hat{y}_{F,t} = \frac{c}{y}\frac{y}{y_F}(1-\gamma_c)\hat{c}_{F,t} + \frac{I}{y}\frac{y}{y_F}(1-\gamma_I)\hat{I}_{F,t} \tag{107}$$

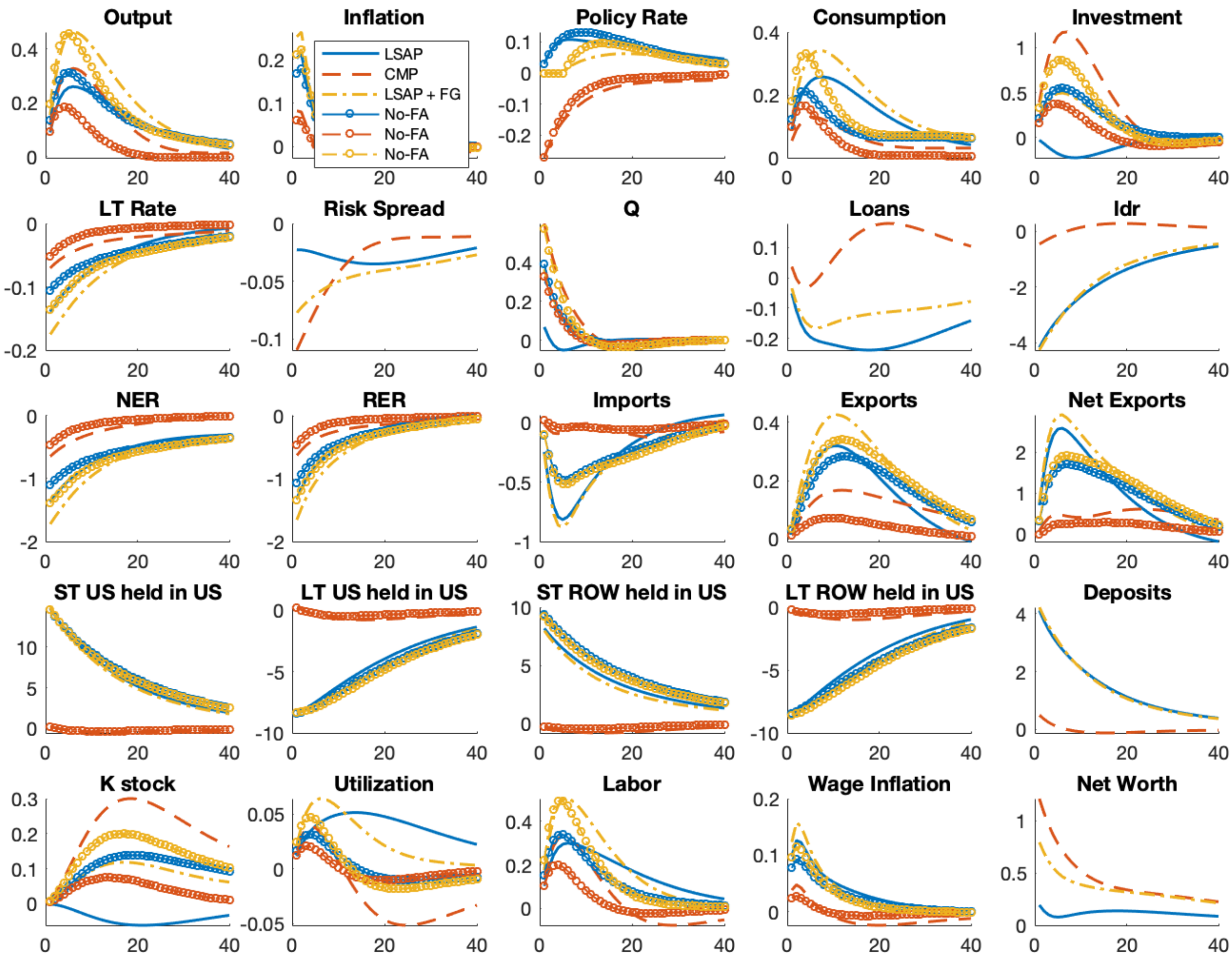
$$\hat{ldr}_t = \hat{loans}_t - \hat{dep}_t \tag{108}$$

B Excluding the Entrepreneurs and Financial Intermediaries from the Model

The inclusion of the financial accelerator and financial intermediaries in the DSGE model is key in producing many of the main results of the paper. To formally illustrate this point we estimate an additional specification of the DSGE model with no entrepreneur sector or financial intermediate sector. Instead, households simply own the capital and decide on the utilization rate of capital and how much new capital to purchase each period. We estimate the model using the same priors and data (minus the data on net worth growth and risk spread) and find remarkable similar structural posterior estimates across both model specifications.

We then conduct the same policy analysis as we did in section 4.1 for both models, ensuring that each policy intervention is equivalent across both specifications. The policy responses are plotted in Figures 8, where each policy intervention is plotted for the model with the financial accelerator (no bubbles) and without the financial accelerator (bubbled lines).

Figure 8: Monetary Policy IRF's of both DSGE Models



Notes: The solid blue line plots an LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank. The dashed red line plots the response of a shock equivalent to a 25 basis point fall in the policy rate. 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 lines plot each 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.

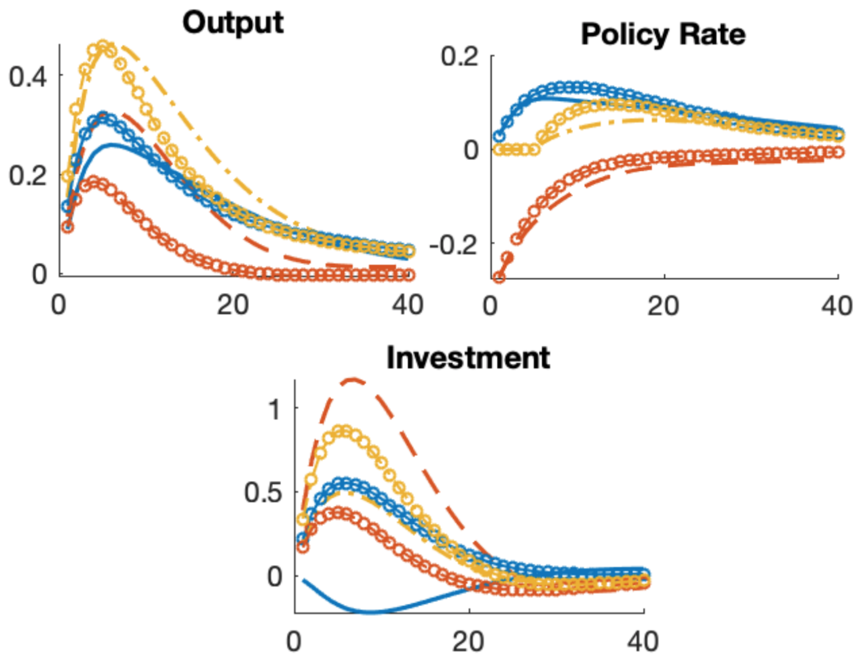
CMP shocks, associated with a 25 basis point decline in both specifications, exhibit a greater expansionary impact on output, investment and hours worked in the model with a financial accelerator compared to the model without one. This finding is consistent with the financial accelerator literature.

When we examine the blue lines which depict LSAP shocks across the two specifications, we find some notable similarities and some notable differences. First, notice that the bond holdings are nearly identical across the two model specifications, this is a result of near identical portfolio elasticity estimates across the two specifications. Second, the response of the nominal and real exchange rates across both specifications are identical. As a result, the impact on exports is also quite similar across the specifications.

However, there is a stark difference in the impact on investment between the two specifications. The model with no financial accelerator predicts a large positive impact on investment from an LSAP purchase, one that is equivalent to the response of an LSAP shock with forward guidance in the model with a financial accelerator. This occurs because in the model specification with no financial accelerator the households own the capital. Thus when bond purchases are conducted by the central bank they effect the household portfolio and thus the marginal utility of consumption. This then has a direct and immediate effect on the household purchase of new capital and capital prices. This larger and positive impact on investment from an LSAP shock in the model without a financial accelerator creates a larger impact on output compared to the model with a financial accelerator, even though the policy rate response is almost identical across the two specifications.

Further, in the model without a financial accelerator, the relative impact of output and investment to CMP and LSAP shocks are no longer consistent with the reduced form analysis conducted in section 4.2. Instead, the structural model predicts that LSAP shocks have a greater impact on investment and output growth than do CMP shocks. This is evident in Figure 9, where the non-bubbled red line is above the non-bubbled blue line but the bubbled red line is below the bubbled blue line for output and investment.

Figure 9: Monetary Policy IRF's of Key Variables



Finally, LSAP shocks with commitment to not raise the policy rate (yellow lines) show a similar effect on macroeconomic variables across both specifications. The difference being 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 and smaller impact on exchange rate depreciation and thus net exports.

C Tables and Figures

Table 2: 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

Table 3: 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 4: 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 5: Prior and Posterior Estimates - Structural Parameters

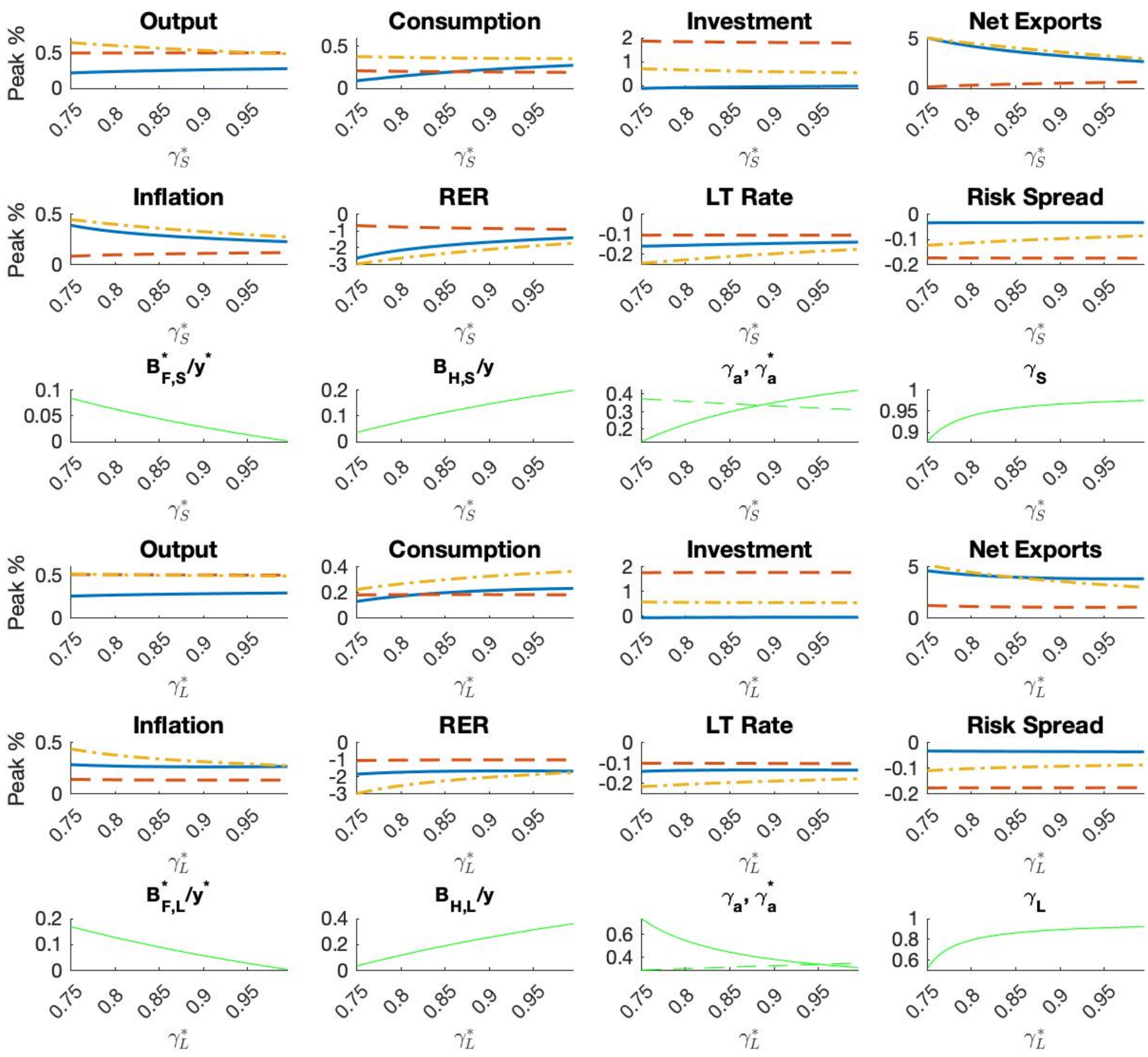
			U.S. Posterior			ROW Posterior		
Parameter		Prior	Mean	5%	95%	Mean	5%	95%
Habit Consumption	h	$\beta(0.7,0.1)$	0.870	0.836	0.900	0.857	0.824	0.888
Utilization Cost	$a''(u)$	$\beta(0.2,0.025)$	0.204	0.160	0.249	0.186	0.143	0.233
Investment Adj Cost	S''	$G(5,1)$	5.823	4.207	7.561	6.563	5.009	8.324
CRRA 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}	$\beta(0.5,0.1)$	0.622	0.508	0.739	0.644	0.549	0.742
Elasticity: Home-Foreign ST Bonds	λ_S^{est}	$\beta(0.5,0.1)$	0.282	0.199	0.373	0.357	0.261	0.463
Elasticity: Home-Foreign LT Bonds	λ_L^{est}	$\beta(0.5,0.1)$	0.416	0.319	0.516	0.737	0.630	0.834
Taylor rule: Persistence	ρ	$\beta(0.7,0.1)$	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	$\beta(0.5,0.2)$	0.163	0.114	0.211	0.101	0.065	0.132
Home price indexation	ι_H	$\beta(0.5,0.2)$	0.501	0.341	0.660	0.569	0.367	0.906
Import price indexation	ι_F	$\beta(0.5,0.2)$	0.486	0.294	0.686	0.525	0.338	0.723
Wage Adj Cost	κ_w^{est}	$\beta(0.5,0.1)$	0.967	0.961	0.971	0.980	0.970	0.992
Home price Adj Cost	κ_H^{est}	$\beta(0.5,0.1)$	0.974	0.959	0.983	0.967	0.909	0.986
Import price Adj Cost	κ_F^{est}	$\beta(0.5,0.1)$	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 6: 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	-	-	-

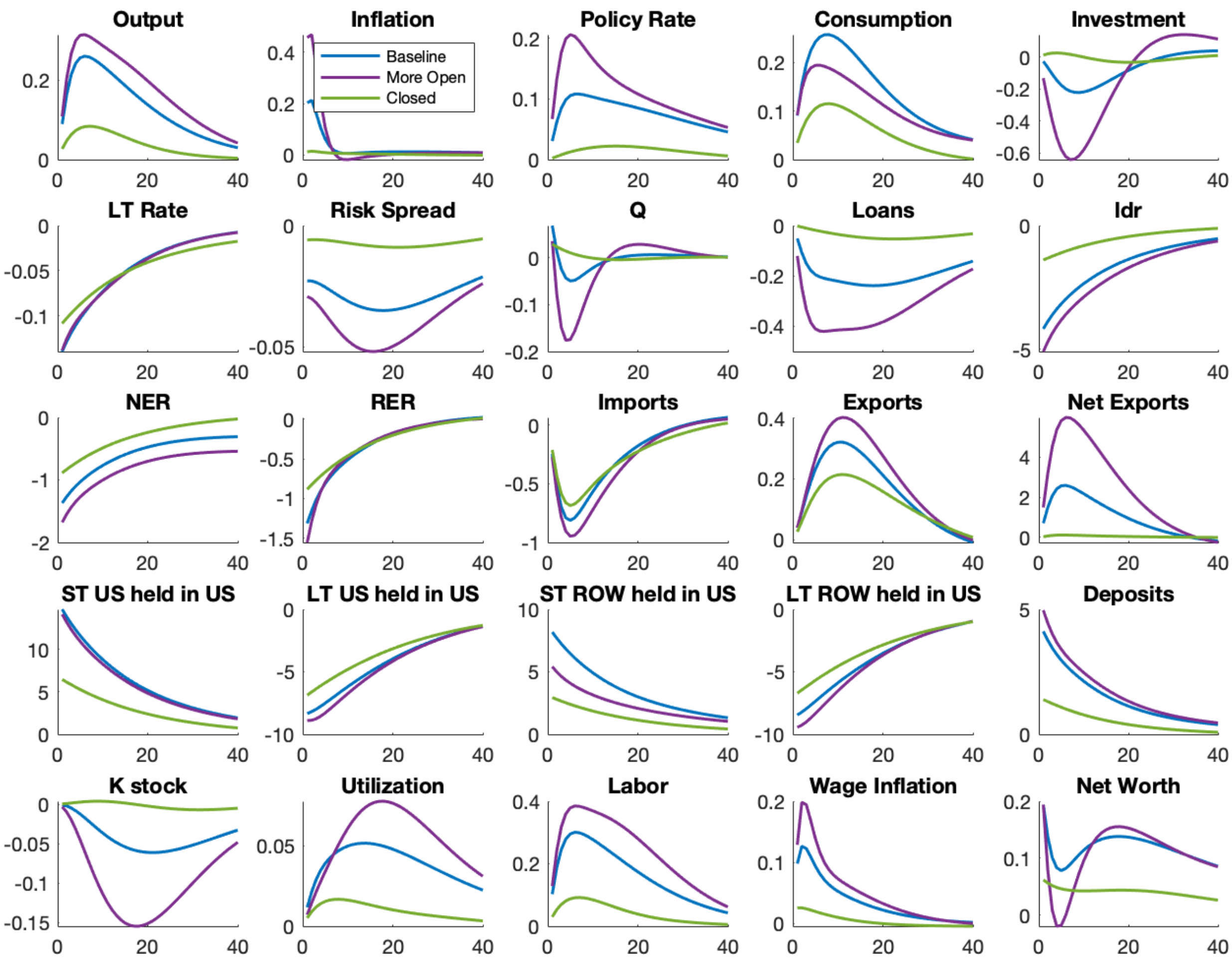
Figure 10: Data Series

Figure 11: ROW Portfolio Share Sensitivity - Peak Responses from Different Policy Interventions



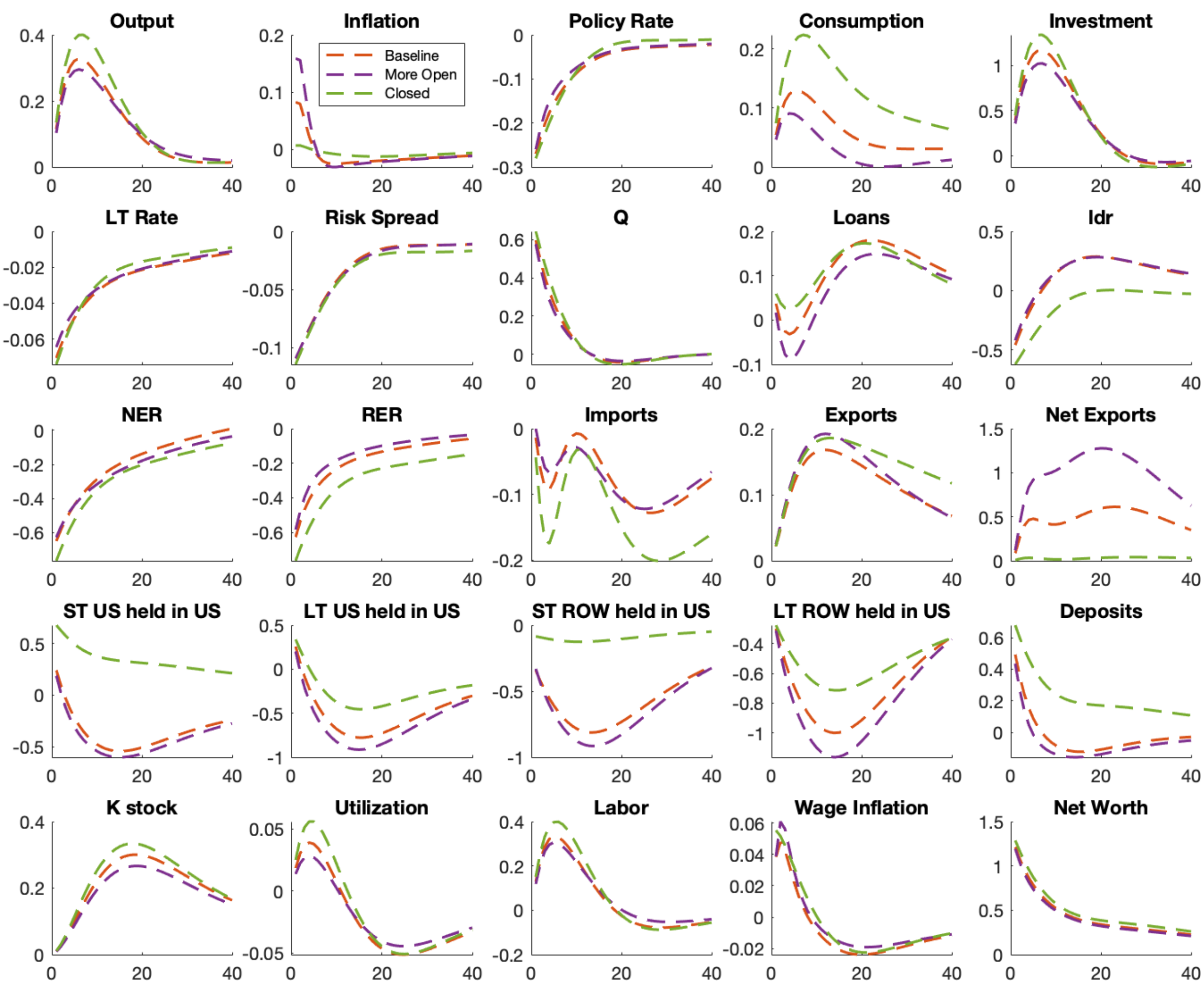
Notes: The solid blue line plots the peak response (in the first 8 quarters) of an LSAP shock across different estimates of γ_S^* and γ_L^*. The dashed red line plots the peak response of an equivalent CMP shock across different estimates of γ_S^* and γ_L^*. The dotted yellow line plots the peak response 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.

Figure 12: Trade and Financial Openness - LSAP shock



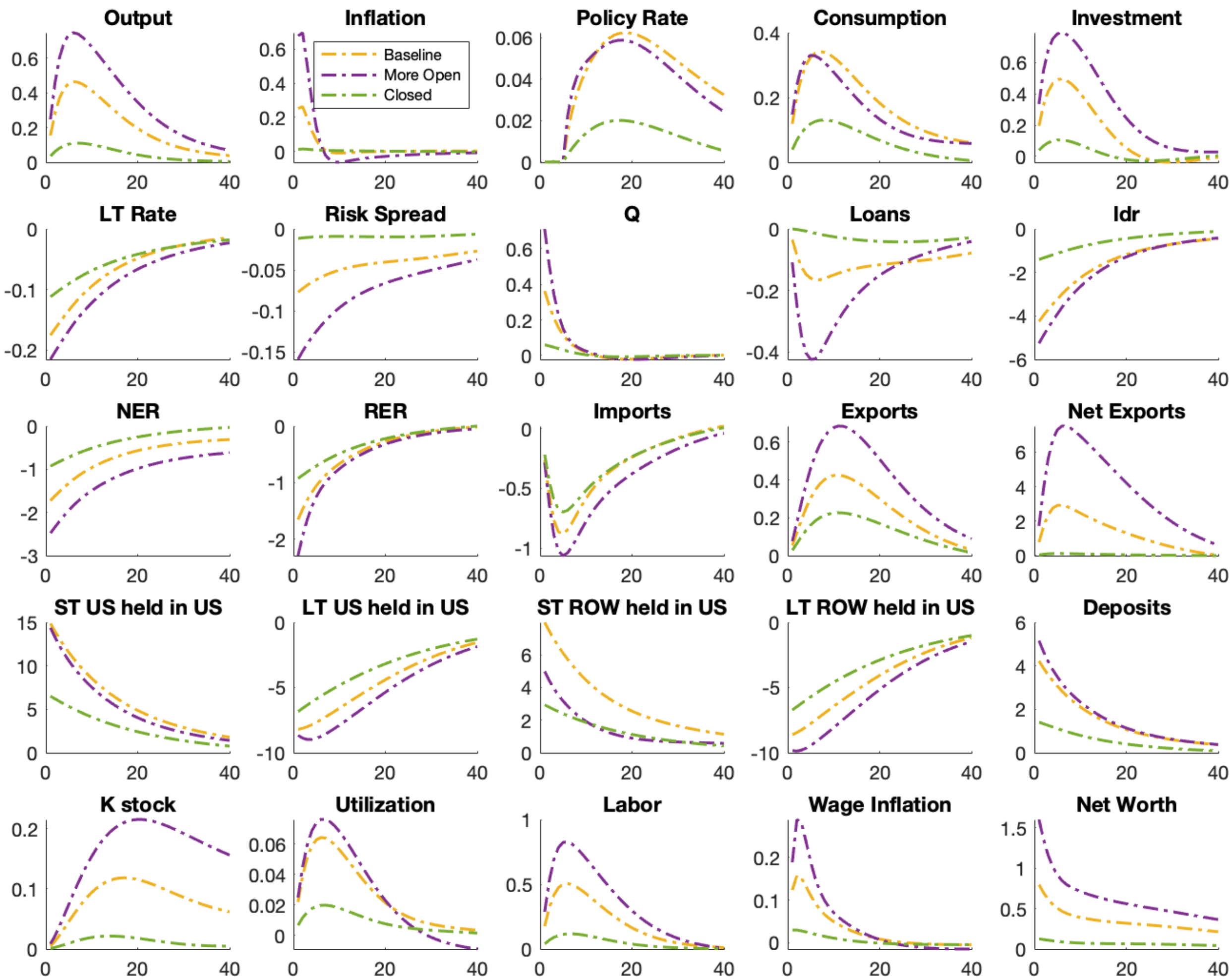
Notes: The solid blue line plots an LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank using the baseline parameters of this paper. The solid purple line plots the same LSAP shock in a more open economy (γ_c, $\gamma_I = .7$, γ_s, $\gamma_s^* = .8$), The solid green line plots the same LSAP 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 13: Trade and Financial Openness - CMP shock



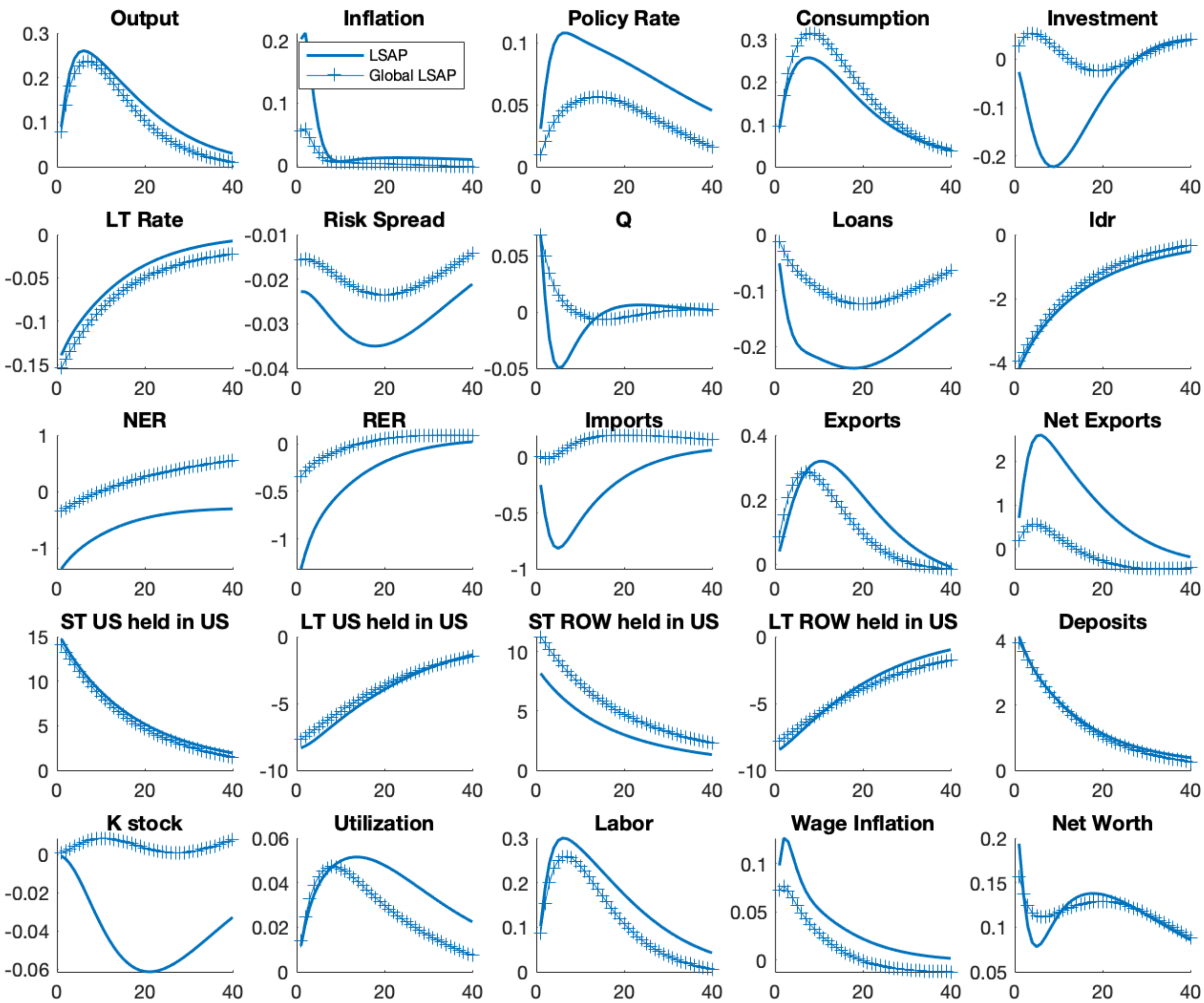
Notes: The dashed red line plots a CMP shock equivalent to a 25 basis point reduction in the policy rate using the baseline parameters of this paper. The dashed purple line plots the same CMP shock in a more open economy (γ_c, $\gamma_I = .7$, γ_s, $\gamma_s^* = .8$), The dashed green line plots the 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 14: Trade and Financial Openness - LSAP + FG shock



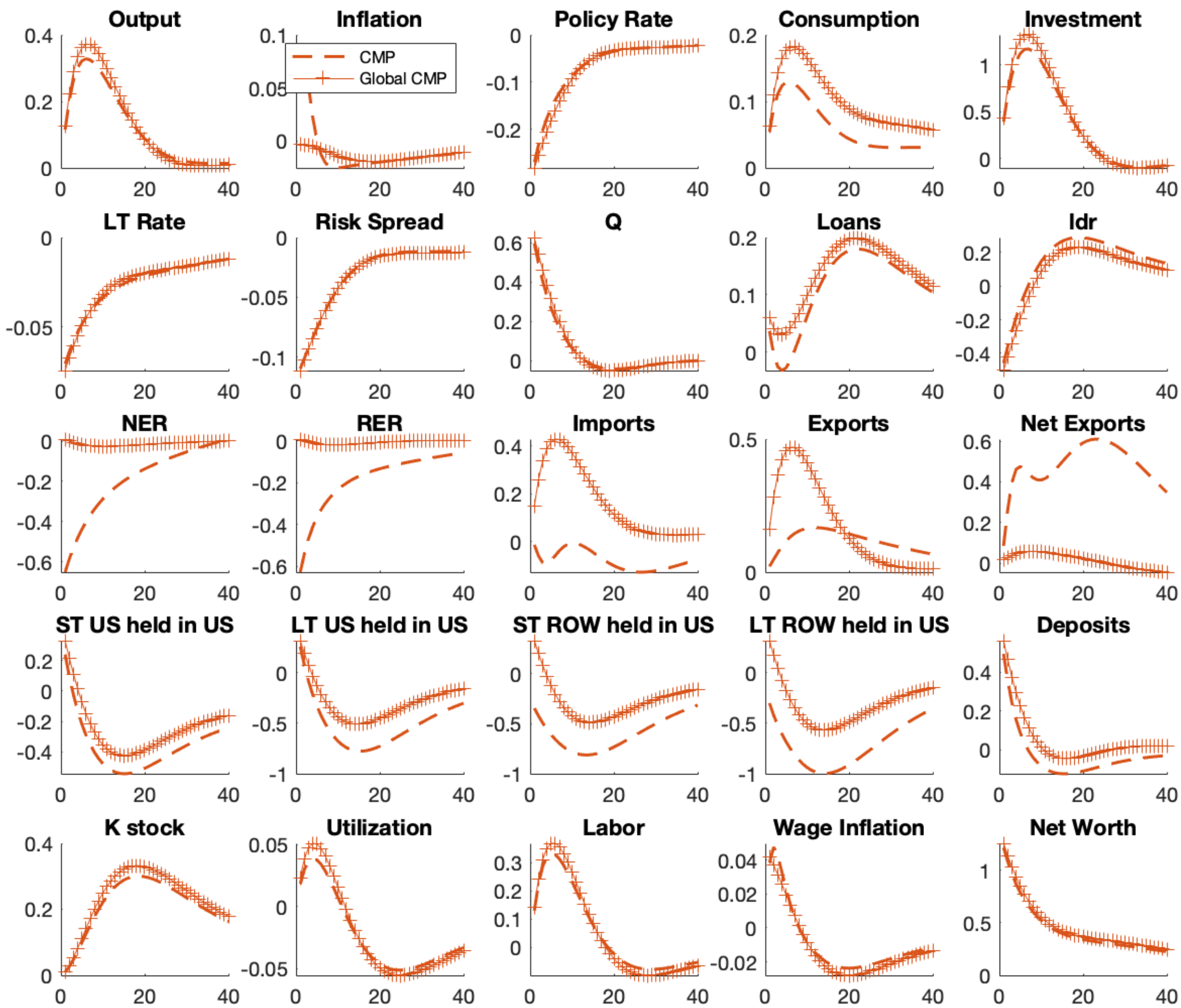
Notes: The dotted yellow line plots an LSAP + FG shock equivalent to a long-term asset purchase of 1.5% of steady state GDP and year's long policy rate commitment by the central bank using the baseline parameters of this paper. The dotted purple line plots the same LSAP + FG shock in a more open economy (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.

Figure 15: Coordinated LSAP shocks



Notes: The solid blue line plots an LSAP shock equivalent to a long-term asset purchase of 1.5% of steady state GDP by the central bank. The marked blue line plots the same LSAP shock in both the US and the ROW. 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 16: Coordinated CMP shocks



Notes: The dashed red line plots 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 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.