INTERNATIONAL MONETARY FUND

A Medium-Scale DSGE Model for the Integrated Policy Framework

Tobias Adrian, Vitor Gaspar and Francis Vitek

WP/22/15

2022
JAN

WORKING PAPER

 WP/22/15

IMF Working Paper
Monetary and Capital Markets Department, and Fiscal Affairs Department

A Medium-Scale DSGE Model for the Integrated Policy Framework
Prepared by Tobias Adrian, Vitor Gaspar and Francis Vitek*

Authorized for distribution by Tobias Adrian and Vitor Gaspar
January 2022

ABSTRACT: This paper jointly analyzes the optimal conduct of monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, and capital flow management. This policy analysis is based on an estimated medium-scale dynamic stochastic general equilibrium (DSGE) model of the world economy, featuring a range of nominal and real rigidities, extensive macrofinancial linkages with endogenous risk, and diverse spillover transmission channels. In the pursuit of inflation and output stabilization objectives, it is optimal to adjust all policies in response to domestic and global financial cycle upturns and downturns when feasible—including foreign exchange intervention and capital flow management under some conditions—to widely varying degrees depending on the structural characteristics of the economy. The framework is applied empirically to four small open advanced and emerging market economies.

JEL Classification Numbers:	E3, E5, E6
Keywords:	Monetary Policy, Foreign Exchange Intervention, Fiscal Policy, Macroprudential Policy, Capital Flow Management, Dynamic Stochastic General Equilibrium Model, Small Open Economy
Author's E-Mail Addresses:	TAdrian@imf.org, VGaspar@imf.org, FVitek@imf.org

* This paper was prepared as part of the IPF workstream at the IMF. The authors gratefully acknowledge helpful comments and suggestions from the IPF team, in particular from Emine Boz, Christopher Erceg, Gita Gopinath, Marcin Kolasa and Jesper Lindé.

Contents

I. Introduction

International financial integration has increasingly exposed small open advanced and emerging market economies to volatile global capital flows. To cope with recurrent capital inflow and outflow surges—often associated with domestic or global financial cycle upturns and downturns—policymakers in some of these economies have occasionally responded with eclectic policy mix adjustments. In particular, to maintain macroeconomic and financial stability amid volatile capital flows, they have occasionally deployed some combination of monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, or capital flow management measures. As discussed in IMF (2020), analyzing such high dimensional policy responses requires an integrated policy framework (IPF).

This paper jointly analyzes the optimal conduct of monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, and capital flow management for four small open advanced and emerging market economies. In the spirit of the inflation targeting literature, we jointly optimize simple instrument rules governing the decentralized conduct of these policies to minimize an intertemporal loss function quadratically penalizing the deviations of inflation from target and output from potential, subject to our representation of the world economy. We then examine how the policy mix should be adjusted in response to domestic and global financial cycle upturns and downturns, with and without policy space constraints. We represent the world economy with an estimated medium-scale heteroskedastic linearized DSGE model of a pair of economies that are asymmetric in size. This framework features multiple distortions—associated with nominal rigidities and financial frictions—and internalizes extensive interactions among the policies under consideration. We consider a diverse set of small open advanced and emerging market economies that have experienced volatile capital flows, comprising Korea, South Africa, Switzerland, and Thailand. Given our focus on the global financial cycle, we represent the rest of the world with the United States.

Our DSGE model features a range of nominal and real rigidities, extensive macrofinancial linkages with endogenous risk, and diverse spillover transmission channels. The specification of nominal and real rigidities builds on the seminal work of Christiano, Eichenbaum and Evans (2005), Smets and Wouters (2003), and Monacelli (2005). This allows our model to account for the empirical evidence concerning the monetary transmission mechanism in a small open economy, while generating reasonably accurate forecasts of inflation and output growth, as documented in Vitek (2008). To integrate the other policies under consideration, we extend this conventional framework in multiple directions. To integrate fiscal policy, we add a fiscal sector and credit constraints. The credit constraints endow our model with empirically plausible fiscal multipliers, following the theoretical fiscal policy analysis literature. To integrate macroprudential policy, we add housing and banking sectors together with financial accelerator and endogenous risk mechanisms, building on Adrian and Vitek (2020). The endogenous risk mechanism captures the negative correlation between the conditional mean and variance of output growth emphasized by the growth at risk literature introduced by Adrian, Boyarchenko and Giannone (2019). To integrate foreign exchange intervention, we make explicit the balance sheet of the central bank, and drive a wedge into the uncovered interest parity condition spanning the globally integrated interbank market with a foreign currency liquidity regulation cost, motivated by Gabaix and Maggiori (2015). By altering the currency composition of the balance sheet of the central bank, sterilized foreign exchange intervention influences the exchange rate by inducing the banking sector to substitute between domestic and foreign currency denominated interbank funding, with the latter costing an exposure dependent premium. Finally, we integrate capital flow management by treating domestic and external mortgage and corporate debt as imperfect substitutes, and levying capital control taxes on cross-border borrowing. This is analogous to treating domestic and foreign output goods as imperfect substitutes, and levying tariffs on imports, as is standard in the theoretical trade policy analysis literature.

To our knowledge, this paper is the first to quantitatively analyze the optimal joint conduct of monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, and capital flow management. A vast literature has jointly analyzed the optimal conduct of subsets of these policies. Broadly speaking, the empirical optimal policy analysis literature has addressed positive issues using partial equilibrium reduced form models, while the theoretical literature has tackled normative issues using general equilibrium structural models. A branch of the theoretical optimal policy analysis literature comprises papers that derive conceptual principles guiding the optimal conduct of policy using theoretically stylized models, by analytically solving for the Ramsey optimal policy mix that supports the efficient allocation, or instrument rules that decentralize its constrained counterpart. An example of a recent paper similar in scope to ours is Basu, Boz, Gopinath, Roch and Unsal (2020), which jointly analyzes the optimal conduct of monetary policy, foreign exchange intervention, macroprudential policy and capital flow management, by solving for the Ramsey optimal policy mix that supports the constrained efficient allocation. Their paper analyzes the optimal policy mix conceptually, whereas ours does so quantitatively, using a fundamentally different theoretical framework. In particular, their model features occasionally binding borrowing constraints, whereas ours always bind. Another branch of the theoretical optimal policy analysis literature consists of papers that generate quantitative policy prescriptions using empirically congruent models, typically by numerically optimizing the response coefficients of simple instrument rules under a flexible inflation targeting regime. An example of a recent paper related to ours is Lama and Medina (2020), which jointly optimizes simple instrument rules governing the conduct of monetary policy, foreign exchange intervention, macroprudential policy and capital flow management, to minimize an intertemporal loss function quadratically penalizing the deviations of inflation from target and output from potential. Another example is Adrian, Erceg, Kolasa, Lindé and Zabczyk (2021), which examines how foreign exchange intervention and capital flow management can improve monetary policy tradeoffs and promote financial stability. Our paper contributes to this quantitative branch of the theoretical optimal policy analysis literature, expanding the range of policies considered.

Our optimal policy analysis broadly supports the observed tendency for policymakers in some small open advanced and emerging market economies to respond to recurrent capital inflow and outflow surges with eclectic policy mix adjustments. A general principle that emerges is that economies with larger international trade and financial exposures should more actively use foreign exchange intervention and capital flow management, if these policies are effective and their response thresholds are crossed. Intuitively, foreign exchange intervention tends to be more effective at stabilizing inflation and output in economies with higher trade openness due to stronger exchange rate pass-through and expenditure switching. In parallel, capital flow management tends to be more effective at stabilizing economies with larger unhedged external foreign currency denominated debt exposures due to more sensitive financial conditions and vulnerabilities, which influence growth at risk. We illustrate this general principle by simulating domestic and global financial cycle upturn and downturn scenarios using our model, conditional on our optimized policy rules. When unconstrained, monetary policy plays the primary role in stabilizing consumption price inflation and output. Foreign exchange intervention enhances monetary autonomy through a supporting role in stabilizing consumption price inflation, while its destabilizing effect on output under these scenarios is offset by fiscal policy. Finally, macroprudential policy and capital flow management have much smaller effects on the conditional means of consumption price inflation and the output gap under these scenarios, but help maintain macroeconomic stability by safeguarding financial stability, by leaning against financial developments that put growth at risk.

The organization of this paper is as follows. The next section develops the theoretical framework, while section three describes the corresponding empirical framework. These sections are necessarily technically complex given the scope of our policy analysis, and readers content to understand our results at an intuitive level without fully knowing their underpinnings can skip them. Estimation of our empirical framework, and examination of its goodness of fit, is the subject of section four. Policy analysis using this empirical framework is conducted in section five. Finally, section six concludes.

II. The Theoretical Framework

Consider a pair of structurally isomorphic open economies that are asymmetric in size and constitute the world economy. Each of these economies consists of households, firms, banks and a government, which in turn consists of a monetary authority, a fiscal authority and a macroprudential authority. Households, firms and banks optimize intertemporally, interacting with the government in an uncertain environment to determine equilibrium prices and quantities under rational expectations in globally integrated output and financial markets. All transactions in the foreign exchange market are intermediated by banks.

A. The Household Sector

There exists a continuum of households indexed by $h \in [0,1]$. Households are differentiated according to whether they are credit constrained, but are otherwise identical. Credit unconstrained households of type $Z = U$ and measure ϕ^U have access to domestic banks where they accumulate deposits, to global banks from which they secure mortgage loans, to the domestic housing market where they trade houses, and to domestic financial markets where they trade government bonds, firm stocks and bank stocks, where $0 < \phi^U < 1$. These mortgage loans are composites of domestic currency denominated mortgage loans from domestic banks, and unhedged foreign currency denominated mortgage loans from foreign banks, giving rise to a balance sheet currency mismatch. In contrast, credit constrained households of type $Z = C$ and measure ϕ^C do not have access to banks, or to the housing and financial markets, where $0 < \phi^C < 1$ and $\phi^U + \phi^C = 1$. Houses are in fixed supply at one per credit unconstrained household. Government bonds are perpetual bonds with coupon payments that decay exponentially at rate ω^G where $0 < \omega^G \leq 1$, following Woodford (2001).

In a reinterpretation of the labor market in the model of nominal wage rigidity proposed by Erceg, Henderson and Levin (2000) to incorporate involuntary unemployment along the lines of Galí (2011), each household consists of a continuum of members represented by the unit square and indexed by $(i, j) \in [0,1] \times [0,1]$. There is full risk sharing among household members, who supply indivisible differentiated intermediate labor services indexed by $i \in [0,1]$, incurring disutility from work determined by $j \in [0,1]$ if they are employed and zero otherwise. Trade specific intermediate labor services supplied by credit unconstrained and credit constrained households are perfect substitutes.

Consumption, Saving, and Residential Investment

Each infinitely lived household h has preferences defined over consumption $C_{h,s}$, housing $S^H_{h,s}H_{h,s}$, labor supply $\{L_{h,i,s}\}^1_{i=0}$, houses $S^H_{h,s+1}$, government bonds $\{S^G_{h,v,s+1}\}^s_{v=1}$ and firm stocks $\{S^F_{h,f,s+1}\}^1_{f=0}$ represented by intertemporal utility function

$$U_{h,t} = \mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} u(C_{h,s}, S^H_{h,s}H_{h,s}, \{L_{h,i,s}\}^1_{i=0}, S^H_{h,s+1}, \{S^G_{h,v,s+1}\}^s_{v=1}, \{S^F_{h,f,s+1}\}^1_{f=0}), \tag{1}$$

where E_t denotes the expectations operator conditional on information available in period t, and $0 < \beta < 1$. The intratemporal utility function is additively separable and represents external habit formation preferences in consumption and labor supply,

$$u(C_{h,s},S_{h,s}^{H}H_{h,s},\{L_{h,i,s}\}_{i=0}^{1},S_{h,s+1}^{H},\{S_{h,v,s+1}^{G}\}_{v=1}^{s},\{S_{h,f,s+1}^{F}\}_{f=0}^{1})=\upsilon_s^C\left[\frac{1}{1-1/\sigma}\left(C_{h,s}-\alpha^C\frac{C_{s-1}^Z}{\phi^Z}\right)^{1-1/\sigma}+\upsilon_s^D\frac{(S_{h,s}^H H_{h,s})^{1-1/\varsigma}}{1-1/\varsigma}\right.$$
$$\left.-\upsilon_s^N\int_0^1\int_{\alpha^L\frac{L_{i,s-1}^Z}{\phi^Z}}^{L_{h,i,s}}\left(j-\alpha^L\frac{L_{i,s-1}^Z}{\phi^Z}\right)^{1/\eta}djdi-\upsilon_s^H\frac{V_{h,s}^H S_{h,s+1}^H}{(1+\tau_s^C)P_s^C}-\upsilon_s^B\sum_{v=1}^{s}\frac{V_{v,s}^G S_{h,v,s+1}^G}{(1+\tau_s^C)P_s^C}-\upsilon_s^S\int_0^1\frac{V_{f,s}^F S_{h,f,s+1}^F}{(1+\tau_s^C)P_s^C}df\right], \tag{2}$$

where $0\leq\alpha^C<1$ and $0\leq\alpha^L<1$. To introduce exogenous asset risk premia that affect intertemporal substitution, we specify preference shifters υ_s^C, υ_s^H, υ_s^B and υ_s^S as functions of aggregate endogenous variables or structural shocks,

$$\upsilon_t^C=\nu_t^C-\frac{\phi_H^C}{1-\rho_H}\nu_t^H-\frac{\phi_B^C}{1-\rho_B}\tilde{\nu}_t^B-\frac{\phi_S^C}{1-\rho_S}\tilde{\nu}_t^S,\ \upsilon_s^H=\frac{\tilde{\nu}_s^B+\nu_s^H}{v(C_s^Z,C_{s-1}^Z)},$$
$$\upsilon_s^B=\frac{\tilde{\nu}_s^B}{v(C_s^Z,C_{s-1}^Z)},\ \upsilon_s^S=\frac{\tilde{\nu}_s^B+\tilde{\nu}_s^S}{v(C_s^Z,C_{s-1}^Z)},\ v(C_s^Z,C_{s-1}^Z)=\left(\frac{C_s^Z}{\phi^Z}-\alpha^C\frac{C_{s-1}^Z}{\phi^Z}\right)^{1/\sigma}, \tag{3}$$

where $\phi_H^C>0$, $\phi_B^C>0$ and $\phi_S^C>0$. To support the existence of a long run balanced growth path, we also specify preference shifters υ_s^D and υ_s^N as functions of aggregate endogenous variables or structural shocks,

$$\upsilon_s^D=\frac{\nu^D}{v(C_s^Z,C_{s-1}^Z)}(C_s)^{1/\varsigma},\ \upsilon_s^N=\frac{A_s^T}{v(C_s^Z,C_{s-1}^Z)}\frac{(L_s/\nu_s^N)^{\mu/\eta}}{w(L_s^Z,L_{s-1}^Z)},\ w(L_s^Z,L_{s-1}^Z)=\left(\frac{L_s^Z}{\phi^Z}-\alpha^L\frac{L_{s-1}^Z}{\phi^Z}\right)^{1/\eta}, \tag{4}$$

where $\mu>0$. We assume that the intratemporal utility function is strictly increasing with respect to consumption and housing, and is strictly decreasing with respect to labor supply. This implies restrictions on serially correlated private consumption demand shock ν_s^C and labor supply shock ν_s^N, given mean zero and serially correlated housing risk premium shock ν_s^H, as well as mean zero and internationally and serially correlated duration risk premium shock $\tilde{\nu}_s^B$ and equity risk premium shock $\tilde{\nu}_s^S$. Given these and other restrictions, this intratemporal utility function is strictly concave with respect to consumption, housing and labor supply if $\sigma>0$, $\varsigma>0$ and $\eta>0$.

The household enters period s with previously accumulated wealth, allocated across the values of bank deposits, mortgage loans, houses, government bonds, firm stocks and bank stocks. In particular, it holds bank deposits $B_{h,s}^{H,D}$ which pay interest at risk free deposit rate i_{s-1}^D, secures new borrowing $B_{h,s}^{H,H}$ from global banks on its $S_{h,s}^H$ mortgage loans, owns $S_{h,s}^H$ houses worth $V_{h,s}^H$, owns $\{S_{h,v,s}^G\}_{v=1}^{s-1}$ vintage specific government bonds worth $\{V_{v,s}^G\}_{v=1}^{s-1}$ which pay coupons $\{\Pi_{v,s}^G\}_{v=1}^{s-1}$, owns $\{S_{h,f,s}^F\}_{f=0}^1$ firm stocks worth $\{V_{f,s}^F\}_{f=0}^1$ which pay dividends $\{\Pi_{f,s}^F\}_{f=0}^1$, and owns $\{S_{h,b,s}^B\}_{b=0}^1$ bank stocks worth $\{V_{b,s}^B\}_{b=0}^1$ which pay dividends $\{\Pi_{b,s}^B\}_{b=0}^1$. The user cost per house $\Pi_{h,s}^H$ satisfies $\Pi_{h,s}^H=P_s^H H_{h,s}+(B_{h,s}^{H,H}-C_{h,s}^{H,H})-P_s^{I^H}I_{h,s}^H$, where P_s^H denotes the implicit rental price of housing. The coupon payment per government bond $\Pi_{v,s}^G$ satisfies $\Pi_{v,s}^G=(1+i_v^G-\omega^G)(\omega^G)^{s-v}V_{v,v}^G$, where i_v^G denotes the vintage specific yield to maturity on government bonds at issuance when $V_{v,v}^G=1$. During period s, the household receives profit income $\Pi_{h,s}^D$ from global banks, where $\Pi_{h,s}^D=\Pi_{h,s}^{D,H}+\Pi_{h,s}^{D,F}$. It also supplies differentiated intermediate labor services $\{L_{h,i,s}\}_{i=0}^1$, earning labor income at trade specific wages $\{W_{i,s}\}_{i=0}^1$. The government levies a tax on household labor income at rate τ_s^L, and remits household type specific lump sum transfer payment $T_{h,s}^Z$. These sources of funds are summed in household dynamic budget constraint:

$$B_{h,s+1}^{H,D}+S_{h,s}^H C_{h,s}^{H,H}+V_{h,s}^H S_{h,s+1}^H+\sum_{v=1}^{s}V_{v,s}^G S_{h,v,s+1}^G+\int_0^1 V_{f,s}^F S_{h,f,s+1}^F df+\int_0^1 V_{b,s}^B S_{h,b,s+1}^B db$$
$$+(1+\tau_s^C)P_s^C C_{h,s}+P_s^{I^H}S_{h,s}^H I_{h,s}^H=(1+i_{s-1}^D)B_{h,s}^{H,D}+S_{h,s}^H B_{h,s}^{H,H}+V_{h,s}^H S_{h,s}^H+\sum_{v=1}^{s-1}(\Pi_{v,s}^G+V_{v,s}^G)S_{h,v,s}^G \tag{5}$$
$$+\int_0^1(\Pi_{f,s}^F+V_{f,s}^F)S_{h,f,s}^F df+\int_0^1(\Pi_{b,s}^B+V_{b,s}^B)S_{h,b,s}^B db+\Pi_{h,s}^D+(1-\tau_s^L)\int_0^1 W_{i,s}L_{h,i,s}di+T_{h,s}^Z.$$

According to this dynamic budget constraint, at the end of period s the household reallocates its wealth across the values of bank deposits, mortgage loans, houses, government bonds, firm stocks and bank stocks. In particular, it holds bank deposits $B_{h,s+1}^{H,D}$, pays debt service cost $C_{h,s}^{H,H}$ to global banks on its $S_{h,s}^{H}$ mortgage loans, owns $S_{h,s+1}^{H}$ houses worth $V_{h,s}^{H}$, owns $\{S_{h,v,s+1}^{G}\}_{v=1}^{s}$ vintage specific government bonds worth $\{V_{v,s}^{G}\}_{v=1}^{s}$, owns $\{S_{h,f,s+1}^{F}\}_{f=0}^{1}$ firm stocks worth $\{V_{f,s}^{F}\}_{f=0}^{1}$, and owns $\{S_{h,b,s+1}^{B}\}_{b=0}^{1}$ bank stocks worth $\{V_{b,s}^{B}\}_{b=0}^{1}$. Finally, the household purchases private consumption good $C_{h,s}$ at price P_s^C, and residential investment good $I_{h,s}^{H}$ for its $S_{h,s}^{H}$ houses at price $P_s^{I^H}$. The government levies a tax on household consumption expenditures at rate τ_s^C.

The household enters period s with housing of previously accumulated quality $H_{h,s}$, which subsequently evolves according to accumulation function

$$H_{h,s+1} = (1-\delta_H)H_{h,s} + \mathcal{H}^H(I_{h,s}^H, I_{h,s-1}^H), \tag{6}$$

where $0 \le \delta_H \le 1$. Effective residential investment function $\mathcal{H}^H(I_{h,s}^H, I_{h,s-1}^H)$ incorporates convex adjustment costs in the gross growth rate of the ratio of nominal residential investment to nominal output,

$$\mathcal{H}^H(I_{h,s}^H, I_{h,s-1}^H) = \nu_s^{I^H}\left[1-\frac{\chi^H}{2}\left(\frac{P_s^{I^H}I_{h,s}^H}{P_{s-1}^{I^H}I_{h,s-1}^H}\frac{P_{s-1}^Y Y_{s-1}}{P_s^Y Y_s}-1\right)^2\right]I_{h,s}^H, \tag{7}$$

where serially correlated residential investment demand shock $\nu_s^{I^H}$ satisfies $\nu_s^{I^H} > 0$, while $\chi^H > 0$. In steady state equilibrium, these adjustment costs equal zero, and effective residential investment equals actual residential investment.

The household enters period s with previously accumulated mortgage debt $D_{h,s}^H$, which subsequently evolves according to accumulation function

$$D_{h,s+1}^H = (1-\alpha^H)D_{h,s}^H + B_{h,s}^{H,H}, \tag{8}$$

where $0 \le \alpha^H \le 1$. Adopting the collateralized borrowing variant of the financial accelerator mechanism due to Kiyotaki and Moore (1997), the household secures new mortgage borrowing from global banks to finance a fraction of the installed value of residential investment,

$$B_{h,s}^{H,H} = \phi_s^H Q_s^H I_{h,s}^H, \tag{9}$$

given by regulatory mortgage loan to value ratio limit ϕ_s^H. Its debt service cost satisfies $C_{h,s}^{H,H} = (1-\delta_s^H)(\alpha^H + i_{s-1}^{H^E})D_{h,s}^H$, reflecting an amortization payment at rate α^H and an interest payment at effective mortgage loan rate $i_{s-1}^{H^E}$ on the outstanding stock of mortgage debt, net of a writedown at mortgage loan default rate δ_s^H.

Credit Unconstrained Households

In period t, the credit unconstrained household chooses state contingent sequences for consumption $\{C_{h,s}\}_{s=t}^{\infty}$, residential investment $\{I_{h,s}^H\}_{s=t}^{\infty}$, housing quality $\{H_{h,s+1}\}_{s=t}^{\infty}$, labor force participation $\{\{N_{h,i,s}\}_{i=0}^{1}\}_{s=t}^{\infty}$, bank deposits $\{A_{h,s+1}^D\}_{s=t}^{\infty}$, mortgage debt $\{D_{h,s+1}^H\}_{s=t}^{\infty}$, houses $\{S_{h,s+1}^H\}_{s=t}^{\infty}$, government bonds $\{\{S_{h,v,s+1}^G\}_{v=1}^{s}\}_{s=t}^{\infty}$, firm stocks $\{\{S_{h,f,s+1}^F\}_{f=0}^{1}\}_{s=t}^{\infty}$ and bank stocks $\{\{S_{h,b,s+1}^B\}_{b=0}^{1}\}_{s=t}^{\infty}$ to maximize intertemporal utility function (1) subject to dynamic budget constraint (5), housing quality accumulation function (6), mortgage debt accumulation function (8), and terminal nonnegativity constraints $H_{h,T+1} \ge 0$, $A_{h,T+1}^D \ge 0$, $D_{h,T+1}^H \ge 0$, $S_{h,T+1}^H \ge 0$, $S_{h,v,T+1}^G \ge 0$, $S_{h,f,T+1}^F \ge 0$ and $S_{h,b,T+1}^B \ge 0$ for $T \to \infty$. In equilibrium, the solutions to this utility maximization problem satisfy intertemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} (1+i_t^D) = 1, \tag{10}$$

which equates the expected discounted value of the gross real return on bank deposits to one. They also satisfy intertemporal optimality condition

$$\frac{Q_{h,t}^H}{P_t^{I^H}} \mathcal{H}_1^H(h,t) + \phi_t^H (1+R_{h,t}^H) \frac{Q_t^H}{P_t^{I^H}} + \mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} \frac{P_{t+1}^{I^H}}{P_t^{I^H}} \frac{Q_{h,t+1}^H}{P_{t+1}^{I^H}} \mathcal{H}_2^H(h,t+1) = 1, \tag{11}$$

which equates the expected discounted value of an additional unit of residential investment to its price. Here $Q_{h,s}^H$ denotes the shadow price of housing, which is proportional to the Lagrange multiplier on the period s housing quality accumulation function, while $R_{h,s}^H$ denotes the shadow price of mortgage debt, which is proportional to the Lagrange multiplier on the period s mortgage debt accumulation function. In addition, they satisfy intertemporal optimality condition

$$\frac{Q_{h,t}^H}{P_t^{I^H}} = \mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} \frac{P_{t+1}^{I^H}}{P_t^{I^H}} \left[\frac{P_{t+1}^H}{P_{t+1}^{I^H}} + (1-\delta_H) \frac{Q_{h,t+1}^H}{P_{t+1}^{I^H}} \right], \tag{12}$$

which equates the relative shadow price of housing to the expected discounted value of its future value net of depreciation plus the future relative implicit rental price of housing. Furthermore, they satisfy intratemporal optimality condition

$$\frac{u_{S^H H}(h,t)}{u_C(h,t)} = \frac{1}{1+\tau_t^C} \frac{P_t^H}{P_t^C}, \tag{13}$$

which equates the marginal rate of substitution between housing and consumption to the relative implicit rental price of housing. They also satisfy intertemporal optimality condition

$$R_{h,t}^H = \mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} \left[(1-\alpha^H) R_{h,t+1}^H - (1-\delta_{t+1}^H)(\alpha^H + i_t^{H^E}) \right], \tag{14}$$

which equates the shadow price of mortgage debt to the expected discounted value of its amortized future value minus the marginal cost of future mortgage debt service. In addition, they satisfy intratemporal optimality condition

$$-\frac{u_{L_i}(h,i,t)}{u_C(h,t)} = \frac{1-\tau_t^L}{1+\tau_t^C} \frac{W_{i,t}}{P_t^C}, \tag{15}$$

which equates the marginal rate of substitution between leisure and consumption for the marginal trade specific labor force participant to the corresponding after tax real wage. They also satisfy intratemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} \left[\frac{\Pi_{h,t+1}^H + V_{h,t+1}^H}{V_{h,t}^H} - (1+i_t^D) \right] = \frac{u_C(t)}{u_C(h,t)} (\tilde{\nu}_t^B + \nu_t^H), \tag{16}$$

which equates the expected discounted values of the gross real risk adjusted returns on houses and bank deposits. In addition, they satisfy intratemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} \left[\frac{\Pi_{v,t+1}^G + V_{v,t+1}^G}{V_{v,t}^G} - (1+i_t^D) \right] = \frac{u_C(t)}{u_C(h,t)} \tilde{\nu}_t^B, \tag{17}$$

which equates the expected discounted values of the gross real risk adjusted returns on government bonds and bank deposits. Furthermore, they satisfy intratemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} \left[\frac{\Pi_{f,t+1}^F + V_{f,t+1}^F}{V_{f,t}^F} - (1+i_t^D) \right] = \frac{u_C(t)}{u_C(h,t)} (\tilde{v}_t^B + \tilde{v}_t^S), \tag{18}$$

which equates the expected discounted values of the gross real risk adjusted returns on firm stocks and bank deposits. Finally, they satisfy intratemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,t+1)}{u_C(h,t)} \frac{1+\tau_t^C}{1+\tau_{t+1}^C} \frac{P_t^C}{P_{t+1}^C} \left[\frac{\Pi_{b,t+1}^B + V_{b,t+1}^B}{V_{b,t}^B} - (1+i_t^D) \right] = 0, \tag{19}$$

which equates the expected discounted values of the gross real returns on bank stocks and bank deposits.

Credit Constrained Households

In period t, the credit constrained household chooses state contingent sequences for consumption $\{C_{h,s}\}_{s=t}^{\infty}$ and labor force participation $\{\{N_{h,i,s}\}_{i=0}^{1}\}_{s=t}^{\infty}$ to maximize intertemporal utility function (1) subject to dynamic budget constraint (5) and the applicable access restrictions. In equilibrium, the solutions to this utility maximization problem satisfy household static budget constraint

$$(1+\tau_t^C)P_t^C C_{h,t} = (1-\tau_t^L)\int_0^1 W_{i,t} L_{h,i,t} di + T_{h,t}^C, \tag{20}$$

which equates consumption expenditures to disposable labor income plus transfers. They also satisfy intratemporal optimality condition

$$-\frac{u_{L_i}(h,i,t)}{u_C(h,t)} = \frac{1-\tau_t^L}{1+\tau_t^C} \frac{W_{i,t}}{P_t^C}, \tag{21}$$

which equates the marginal rate of substitution between leisure and consumption for the marginal trade specific labor force participant to the corresponding after tax real wage.

Labor Supply

The unemployment rate u_t^L measures the share of the labor force N_t in unemployment U_t, that is $u_t^L = U_t / N_t$, where unemployment equals the labor force less employment L_t, that is $U_t = N_t - L_t$. The labor force satisfies $N_t = \int_0^1 N_{i,t} di$.

There exist a large number of perfectly competitive firms which combine differentiated intermediate labor services $\{L_{i,t}\}_{i=0}^{1}$ supplied by trade unions of workers to produce final labor service L_t according to constant elasticity of substitution production function:

$$L_t = \left[\int_0^1 (L_{i,t})^{\frac{\theta_t^L - 1}{\theta_t^L}} di \right]^{\frac{\theta_t^L}{\theta_t^L - 1}}. \tag{22}$$

The representative final labor service firm maximizes profits from production of the final labor service with respect to inputs of intermediate labor services, implying demand functions:

$$L_{i,t} = \left(\frac{W_{i,t}}{W_t} \right)^{-\theta_t^L} L_t. \tag{23}$$

Since the production function exhibits constant returns to scale, in equilibrium the final labor service firm generates zero profit, implying aggregate wage index:

$$W_t = \left[\int_0^1 (W_{i,t})^{1-\theta_t^L} di \right]^{\frac{1}{1-\theta_t^L}}. \tag{24}$$

Serially uncorrelated wage markup shock ϑ_t^L satisfies $\vartheta_t^L = \theta_t^L / (\theta_t^L - 1)$, where the wage elasticity of demand for intermediate labor services θ_t^L satisfies $\theta_t^L > 1$.

In an extension of the model of nominal wage rigidity proposed by Erceg, Henderson and Levin (2000) along the lines of Smets and Wouters (2003), each period a randomly selected fraction $1-\omega^L$ of trade unions adjust their wage optimally, where $0 \le \omega^L < 1$. The remaining fraction ω^L of trade unions adjust their wage to account for past wage inflation, as well as past consumption price inflation and trend productivity growth, according to partial indexation rule

$$W_{i,t} = \left[\left(\frac{W_{t-1}}{W_{t-2}} \right)^{1-\mu^L} \left(\frac{P_{t-1}^C A_{t-1}^T}{P_{t-2}^C A_{t-2}^T} \right)^{\mu^L} \right]^{\gamma^L} \left[\left(\frac{\bar{W}_{t-1}}{\bar{W}_{t-2}} \right)^{1-\mu^L} \left(\frac{\bar{P}_{t-1}^C \bar{A}_{t-1}}{\bar{P}_{t-2}^C \bar{A}_{t-2}} \right)^{\mu^L} \right]^{1-\gamma^L} W_{i,t-1}, \tag{25}$$

where $0 \le \gamma^L \le 1$ and $0 \le \mu^L \le 1$. Under this specification, although trade unions adjust their wage every period, they infrequently do so optimally, and the interval between optimal wage adjustments is a random variable.

If trade union i can adjust its wage optimally in period t, then it does so to maximize intertemporal utility function (1) subject to dynamic budget constraint (5), intermediate labor service demand function (23), and the assumed form of nominal wage rigidity. Since all trade unions that adjust their wage optimally in period t solve an identical utility maximization problem, in equilibrium they all choose a common wage W_t^* given by necessary first order condition:

$$\frac{W_t^*}{W_t} = -\frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^L)^{s-t} \frac{\beta^{s-t} u_C(h,s)}{u_C(h,t)} \vartheta_s^L \frac{u_{L_i}(h,i,s)}{u_C(h,s)} \left\{ \left[\left(\frac{W_{t-1}}{W_{s-1}} \right)^{1-\mu^L} \left(\frac{P_{t-1}^C A_{t-1}^T}{P_{s-1}^C A_{s-1}^T} \right)^{\mu^L} \right]^{\gamma^L} \left[\left(\frac{\bar{W}_{t-1}}{\bar{W}_{s-1}} \right)^{1-\mu^L} \left(\frac{\bar{P}_{t-1}^C \bar{A}_{t-1}}{\bar{P}_{s-1}^C \bar{A}_{s-1}} \right)^{\mu^L} \right]^{1-\gamma^L} \frac{W_s}{W_t} \right\}^{\theta_s^L} \left(\frac{W_t^*}{W_t} \right)^{-\theta_s^L} L_{h,s}}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^L)^{s-t} \frac{\beta^{s-t} u_C(h,s)}{u_C(h,t)} (\theta_s^L - 1) \frac{1-\tau_s^L}{1+\tau_s^C} \frac{W_s}{P_s^C} \left\{ \left[\left(\frac{W_{t-1}}{W_{s-1}} \right)^{1-\mu^L} \left(\frac{P_{t-1}^C A_{t-1}^T}{P_{s-1}^C A_{s-1}^T} \right)^{\mu^L} \right]^{\gamma^L} \left[\left(\frac{\bar{W}_{t-1}}{\bar{W}_{s-1}} \right)^{1-\mu^L} \left(\frac{\bar{P}_{t-1}^C \bar{A}_{t-1}}{\bar{P}_{s-1}^C \bar{A}_{s-1}} \right)^{\mu^L} \right]^{1-\gamma^L} \frac{W_s}{W_t} \right\}^{\theta_s^L - 1} \left(\frac{W_t^*}{W_t} \right)^{-\theta_s^L} L_{h,s}}. \tag{26}$$

This necessary first order condition equates the expected discounted value of the marginal utility of consumption gained from labor supply to the expected discounted value of the marginal utility cost incurred from leisure foregone. Aggregate wage index (24) equals an average of the wage set by the fraction $1-\omega^L$ of trade unions that adjust their wage optimally in period t, and the average of the wages set by the remaining fraction ω^L of trade unions that adjust their wage according to partial indexation rule (25):

$$W_t = \left\{ (1-\omega^L)(W_t^*)^{1-\theta_t^L} + \omega^L \left\{ \left[\left(\frac{W_{t-1}}{W_{t-2}} \right)^{1-\mu^L} \left(\frac{P_{t-1}^C A_{t-1}^T}{P_{t-2}^C A_{t-2}^T} \right)^{\mu^L} \right]^{\gamma^L} \left[\left(\frac{\bar{W}_{t-1}}{\bar{W}_{t-2}} \right)^{1-\mu^L} \left(\frac{\bar{P}_{t-1}^C \bar{A}_{t-1}}{\bar{P}_{t-2}^C \bar{A}_{t-2}} \right)^{\mu^L} \right]^{1-\gamma^L} W_{t-1} \right\}^{1-\theta_t^L} \right\}^{\frac{1}{1-\theta_t^L}}. \tag{27}$$

Since those trade unions able to adjust their wage optimally in period t are selected randomly from among all trade unions, the average wage set by the remaining trade unions equals the value of the aggregate wage index that prevailed during period $t-1$, rescaled to account for past wage inflation, as well as past consumption price inflation and trend productivity growth.

B. The Production Sector

The production sector supplies a final output good for absorption by domestic and foreign households, firms and governments. In doing so, firms demand the final labor service from households, obtain corporate loans from global banks, and accumulate private physical capital through business investment. These corporate loans are composites of domestic currency denominated corporate loans from domestic banks, and unhedged foreign currency denominated corporate loans from foreign banks, giving rise to a balance sheet currency mismatch.

Output Demand

There exist a large number of perfectly competitive firms which combine differentiated intermediate output goods $\{Y_{f,t}\}_{f=0}^{1}$ supplied by intermediate output good firms to produce final output good Y_t according to constant elasticity of substitution production function:

$$Y_t = \left[\int_0^1 (Y_{f,t})^{\frac{\theta_t^Y - 1}{\theta_t^Y}} df\right]^{\frac{\theta_t^Y}{\theta_t^Y - 1}}. \tag{28}$$

The representative final output good firm maximizes profits from production of the final output good with respect to inputs of intermediate output goods, implying demand functions:

$$Y_{f,t} = \left(\frac{P_{f,t}^Y}{P_t^Y}\right)^{-\theta_t^Y} Y_t. \tag{29}$$

Since the production function exhibits constant returns to scale, in equilibrium the final output good firm generates zero profit, implying aggregate output price index:

$$P_t^Y = \left[\int_0^1 (P_{f,t}^Y)^{1-\theta_t^Y} df\right]^{\frac{1}{1-\theta_t^Y}}. \tag{30}$$

Serially uncorrelated output price markup shock ϑ_t^Y satisfies $\vartheta_t^Y = \theta_t^Y / (\theta_t^Y - 1)$, where the price elasticity of demand for intermediate output goods θ_t^Y satisfies $\theta_t^Y > 1$.

Labor Demand and Business Investment

There exists a continuum of monopolistically competitive intermediate output good firms indexed by $f \in [0,1]$. Intermediate output good firms supply differentiated intermediate output goods, but are otherwise identical.

Each intermediate output good firm f sells shares to domestic credit unconstrained households at price $V_{f,t}^F$. Acting in the interests of its shareholders, it maximizes its pre-dividend stock market value, which in equilibrium equals the expected discounted value of current and future dividend payments

$$\Pi_{f,t}^F + V_{f,t}^F = \mathrm{E}_t \sum_{s=t}^{\infty} \frac{\beta^{s-t} \lambda_s^F}{\lambda_t^F} \Pi_{f,s}^F, \tag{31}$$

where $\lambda_s^F = \lambda_s^U \prod_{r=1}^{s-1} (1 + \tilde{\nu}_r^B + \tilde{\nu}_r^S)^{-1}$, while $\lambda_{h,s}$ denotes the Lagrange multiplier on the period s household dynamic budget constraint. The derivation of this result imposes a transversality condition that rules out self-fulfilling speculative asset price bubbles.

Shares entitle households to dividend payments equal to net profits $\Pi_{f,s}^F$, defined as after tax earnings, plus new corporate borrowing $B_{f,s}^{F,F}$ less debt service cost $C_{f,s}^{F,F}$, minus business investment expenditures,

$$\Pi_{f,s}^F = (1-\tau_s^K)(P_{f,s}^Y Y_{f,s} - W_s L_{f,s} - \Phi_{f,s}^F) + (B_{f,s}^{F,F} - C_{f,s}^{F,F}) - P_s^{I^K} I_{f,s}^K, \tag{32}$$

where $Y_{f,s} = \mathcal{F}(u_{f,s}^K K_{f,s}, A_s L_{f,s})$. Earnings are defined as revenues from sales of differentiated intermediate output good $Y_{f,s}$ at price $P_{f,s}^Y$ less expenditures on final labor service $L_{f,s}$, and other variable costs $\Phi_{f,s}^F$. The government levies a tax on corporate earnings at rate τ_s^K.

The intermediate output good firm utilizes private physical capital $K_{f,s}$ at rate $u_{f,s}^K$ and rents final labor service $L_{f,s}$ to produce differentiated intermediate output good $Y_{f,s}$ according to production function:

$$\mathcal{F}(u_{f,s}^K K_{f,s}, A_s L_{f,s}) = (u_{f,s}^K K_{f,s})^{\phi^Y} (A_s L_{f,s})^{1-\phi^Y}. \tag{33}$$

This production function exhibits constant returns to scale, with $0 \le \phi^Y \le 1$. Productivity A_s depends on the ratio of the public capital stock to the aggregate labor force,

$$A_s = (\tilde{\nu}_s^A)^{\phi^A} \left(\frac{K_s^G}{N_s} \right)^{1-\phi^A}, \tag{34}$$

where internationally and serially correlated productivity shock $\tilde{\nu}_s^A$ satisfies $\tilde{\nu}_s^A > 0$, while $0 < \phi^A \le 1$. Trend productivity A_s^T exhibits partial adjustment dynamics, that is $A_s^T = (A_{s-1}^T)^{\rho^{A^T}} (A_s)^{1-\rho^{A^T}}$ where $0 \le \rho^{A^T} < 1$.

In utilizing private physical capital to produce output, the intermediate output good firm incurs a cost $\mathcal{G}^K(u_{f,s}^K, K_{f,s})$ denominated in terms of business investment:

$$\Phi_{f,s}^F = P_s^{I^K} \mathcal{G}^K(u_{f,s}^K, K_{f,s}) + F_s^F. \tag{35}$$

Following Christiano, Eichenbaum and Evans (2005), this capital utilization cost is increasing in the capital utilization rate at an increasing rate,

$$\mathcal{G}^K(u_{f,s}^K, K_{f,s}) = \mu^K \left[e^{\eta^K (u_{f,s}^K - 1)} - 1 \right] K_{f,s}, \tag{36}$$

where $\mu^K > 0$ and $\eta^K > 0$. In steady state equilibrium, the capital utilization rate equals one, and the cost of utilizing capital equals zero. Fixed cost F_s^F ensures that $\int_0^1 \Phi_{f,s}^F df = 0$.

The intermediate output good firm enters period s with previously accumulated private physical capital stock $K_{f,s}$, which subsequently evolves according to accumulation function

$$K_{f,s+1} = (1-\delta_K) K_{f,s} + \mathcal{H}^K(I_{f,s}^K, I_{f,s-1}^K), \tag{37}$$

where $0 \le \delta_K \le 1$. Motivated by Christiano, Eichenbaum and Evans (2005), effective business investment function $\mathcal{H}^K(I_{f,s}^K, I_{f,s-1}^K)$ incorporates convex adjustment costs in the gross growth rate of the ratio of nominal business investment to aggregate nominal output,

$$\mathcal{H}^K(I_{f,s}^K, I_{f,s-1}^K) = \nu_s^{I^K} \left[1 - \frac{\chi^K}{2} \left(\frac{P_s^{I^K} I_{f,s}^K}{P_{s-1}^{I^K} I_{f,s-1}^K} \frac{P_{s-1}^Y Y_{s-1}}{P_s^Y Y_s} - 1 \right)^2 \right] I_{f,s}^K, \tag{38}$$

where serially correlated business investment demand shock $\nu_s^{I^K}$ satisfies $\nu_s^{I^K} > 0$, while $\chi^K > 0$. In steady state equilibrium, these adjustment costs equal zero, and effective business investment equals actual business investment.

The intermediate output good firm enters period s with previously accumulated corporate debt $D_{f,s}^F$, which subsequently evolves according to accumulation function

$$D_{f,s+1}^F = (1-\alpha^F) D_{f,s}^F + B_{f,s}^{F,F}, \tag{39}$$

where $0 \leq \alpha^F \leq 1$. Adopting the collateralized borrowing variant of the financial accelerator mechanism due to Kiyotaki and Moore (1997), the intermediate output good firm secures new corporate borrowing from global banks to finance a fraction of the installed value of business investment,

$$B_{f,s}^{F,F} = \phi_s^F Q_s^K I_{f,s}^K, \tag{40}$$

given by regulatory corporate loan to value ratio limit ϕ_s^F. Its debt service cost satisfies $C_{f,s}^{F,F} = (1-\delta_s^F)(\alpha^F + i_{s-1}^{F^E})D_{f,s}^F$, reflecting an amortization payment at rate α^F and an interest payment at effective corporate loan rate $i_{s-1}^{F^E}$ on the outstanding stock of corporate debt, net of a writedown at corporate loan default rate δ_s^F.

In period t, the intermediate output good firm chooses state contingent sequences for employment $\{L_{f,s}\}_{s=t}^{\infty}$, the capital utilization rate $\{u_{f,s}^K\}_{s=t}^{\infty}$, business investment $\{I_{f,s}^K\}_{s=t}^{\infty}$, the private physical capital stock $\{K_{f,s+1}\}_{s=t}^{\infty}$ and corporate debt $\{D_{f,s+1}^F\}_{s=t}^{\infty}$ to maximize pre-dividend stock market value (31) subject to production function (33), private physical capital accumulation function (37), corporate debt accumulation function (39), and terminal nonnegativity constraints $K_{f,T+1} \geq 0$ and $D_{f,T+1}^F \geq 0$ for $T \to \infty$. In equilibrium, the solutions to this value maximization problem satisfy necessary first order condition

$$\mathcal{F}_{AL}(f,t)\Psi_{f,t} = (1-\tau_t^K)\frac{W_t}{P_t^Y A_t}, \tag{41}$$

which equates real marginal cost $\Psi_{f,s}^F$ to the ratio of the after tax real wage to the marginal product of labor, where $\Psi_{f,s}^F$ is proportional to the Lagrange multiplier on the period s production technology constraint. They also satisfy necessary first order condition

$$\mathcal{F}_{u^K K}(f,t)\frac{P_t^Y}{P_t^{I^K}}\Psi_{f,t} = (1-\tau_t^K)\frac{\mathcal{G}_{u^K}^K(f,t)}{K_{f,t}}, \tag{42}$$

which equates the marginal revenue product of utilized capital to its marginal cost. In addition, they satisfy necessary first order condition

$$\frac{Q_{f,t}^K}{P_t^{I^K}}\mathcal{H}_1^K(f,t) + \phi_t^F(1+R_{f,t}^K)\frac{Q_t^K}{P_t^{I^K}} + \mathrm{E}_t\frac{\beta\lambda_{t+1}^F}{\lambda_t^F}\frac{P_{t+1}^{I^K}}{P_t^{I^K}}\frac{Q_{f,t+1}^K}{P_{t+1}^{I^K}}\mathcal{H}_2^K(f,t+1) = 1, \tag{43}$$

which equates the expected discounted value of an additional unit of business investment to its price. Here $Q_{f,s}^K$ denotes the shadow price of private physical capital, which is the Lagrange multiplier on the period s private physical capital accumulation function, while $R_{f,s}^K$ denotes the shadow price of corporate debt, which is proportional to the Lagrange multiplier on the period s corporate debt accumulation function. Furthermore, they satisfy necessary first order condition

$$\frac{Q_{f,t}^K}{P_t^{I^K}} = \mathrm{E}_t\frac{\beta\lambda_{t+1}^F}{\lambda_t^F}\frac{P_{t+1}^{I^K}}{P_t^{I^K}}\left[u_{f,t+1}^K\mathcal{F}_{u^K K}(f,t+1)\frac{P_{t+1}^Y}{P_{t+1}^{I^K}}\Psi_{f,t+1} - (1-\tau_{t+1}^K)\mathcal{G}_K^K(f,t+1) + (1-\delta_K)\frac{Q_{f,t+1}^K}{P_{t+1}^{I^K}}\right], \tag{44}$$

which equates the relative shadow price of private physical capital to the expected discounted value of its future value net of depreciation plus the future marginal product of private physical capital net of its real marginal utilization cost. Finally, they satisfy necessary first order condition

$$R_{f,t}^K = \mathrm{E}_t\frac{\beta\lambda_{t+1}^F}{\lambda_t^F}\left[(1-\alpha^F)R_{f,t+1}^K - (1-\delta_{t+1}^F)(\alpha^F + i_t^{F^E})\right], \tag{45}$$

which equates the shadow price of corporate debt to the expected discounted value of its amortized future value minus the marginal cost of future corporate debt service.

Output Supply

In an extension of the model of nominal output price rigidity proposed by Calvo (1983) along the lines of Smets and Wouters (2003), each period a randomly selected fraction $1-\omega^Y$ of intermediate output good firms adjust their price optimally, where $0 \leq \omega^Y < 1$. The remaining fraction ω^Y of intermediate output good firms adjust their price to account for past output price inflation according to partial indexation rule

$$P_{f,t}^Y = \left(\frac{P_{t-1}^Y}{P_{t-2}^Y}\right)^{\gamma^Y} \left(\frac{\bar{P}_{t-1}^Y}{\bar{P}_{t-2}^Y}\right)^{1-\gamma^Y} P_{f,t-1}^Y, \tag{46}$$

where $0 \leq \gamma^Y \leq 1$. Under this specification, optimal price adjustment opportunities arrive randomly, and the interval between optimal price adjustments is a random variable.

If the intermediate output good firm can adjust its price optimally in period t, then it does so to maximize pre-dividend stock market value (31) subject to production function (33), intermediate output good demand function (29), and the assumed form of nominal output price rigidity. We consider a symmetric equilibrium under which all firm specific endogenous state variables are restricted to equal their aggregate counterparts. It follows that all intermediate output good firms that adjust their price optimally in period t solve an identical value maximization problem, which implies that they all choose a common price $P_t^{Y,*}$ given by necessary first order condition:

$$\frac{P_t^{Y,*}}{P_t^Y} = \frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^Y)^{s-t} \frac{\beta^{s-t}\lambda_s^F}{\lambda_t^F} \theta_s^Y \Psi_{f,s} \left[\left(\frac{P_{t-1}^Y}{P_{s-1}^Y}\right)^{\gamma^Y} \left(\frac{\bar{P}_{t-1}^Y}{\bar{P}_{s-1}^Y}\right)^{1-\gamma^Y} \frac{P_s^Y}{P_t^Y}\right]^{\theta_s^Y} \left(\frac{P_t^{Y,*}}{P_t^Y}\right)^{-\theta_s^Y} P_s^Y Y_s}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^Y)^{s-t} \frac{\beta^{s-t}\lambda_s^F}{\lambda_t^F} (\theta_s^Y - 1)(1-\tau_s^K) \left[\left(\frac{P_{t-1}^Y}{P_{s-1}^Y}\right)^{\gamma^Y} \left(\frac{\bar{P}_{t-1}^Y}{\bar{P}_{s-1}^Y}\right)^{1-\gamma^Y} \frac{P_s^Y}{P_t^Y}\right]^{\theta_s^Y - 1} \left(\frac{P_t^{Y,*}}{P_t^Y}\right)^{-\theta_s^Y} P_s^Y Y_s}. \tag{47}$$

This necessary first order condition equates the expected discounted value of the marginal revenue gained from output supply to the expected discounted value of the marginal cost incurred from production. Aggregate output price index (30) equals an average of the price set by the fraction $1-\omega^Y$ of intermediate output good firms that adjust their price optimally in period t, and the average of the prices set by the remaining fraction ω^Y of intermediate output good firms that adjust their price according to partial indexation rule (46):

$$P_t^Y = \left\{(1-\omega^Y)(P_t^{Y,*})^{1-\theta_t^Y} + \omega^Y \left[\left(\frac{P_{t-1}^Y}{P_{t-2}^Y}\right)^{\gamma^Y} \left(\frac{\bar{P}_{t-1}^Y}{\bar{P}_{t-2}^Y}\right)^{1-\gamma^Y} P_{t-1}^Y\right]^{1-\theta_t^Y}\right\}^{\frac{1}{1-\theta_t^Y}}. \tag{48}$$

Since those intermediate output good firms able to adjust their price optimally in period t are selected randomly from among all intermediate output good firms, the average price set by the remaining intermediate output good firms equals the value of the aggregate output price index that prevailed during period $t-1$, rescaled to account for past output price inflation.

C. The Banking Sector

The banking sector supplies global financial intermediation services subject to financial frictions and regulatory constraints. In particular, global banks issue risky mortgage or corporate loans to domestic and foreign households or firms. These mortgage or corporate loans are composites of domestic currency denominated mortgage or corporate loans from domestic banks, and foreign currency denominated mortgage or corporate loans from foreign banks. These currency specific mortgage and corporate loans are issued at infrequently adjusted predetermined mortgage and corporate loan rates. Mortgage and corporate borrowing by households and firms is subject to regulatory loan to value ratio limits. Cross-border mortgage and corporate borrowing is also subject to capital controls, represented by taxes on capital inflows.

Domestic banks accumulate bank capital from retained earnings given credit losses to satisfy a regulatory capital ratio requirement. They obtain funding from domestic households via deposits and from the globally integrated interbank market via loans, giving rise to a balance sheet currency mismatch. Cross-border interbank borrowing is subject to a foreign currency liquidity regulation cost, which is influenced by foreign exchange intervention.

Credit Demand

There exist a large number of perfectly competitive risk neutral banks owned by domestic credit unconstrained households which combine the domestic final mortgage or corporate loan $D_{t+1}^{Z,h}$ with the foreign final mortgage or corporate loan $D_{t+1}^{Z,f}$ to produce global mortgage or corporate loan D_{t+1}^{Z} according to constant elasticity of substitution portfolio aggregator

$$D_{t+1}^{Z} = \left[(1-\phi_Z^B)^{\frac{1}{\psi^B}} (D_{t+1}^{Z,h})^{\frac{\psi^B-1}{\psi^B}} + (\phi_Z^B)^{\frac{1}{\psi^B}} (\mathcal{E}_t D_{t+1}^{Z,f})^{\frac{\psi^B-1}{\psi^B}} \right]^{\frac{\psi^B}{\psi^B-1}}, \tag{49}$$

where $Z \in \{H,F\}$, while $0 \le \phi_Z^B < 1$ and $\psi^B > 0$. The government levies a tax on cross-border mortgage or corporate borrowing at rate τ_t^Z. The representative global bank maximizes expected profits from intermediation of the global mortgage or corporate loan, with respect to inputs of the domestic and foreign final mortgage or corporate loans, implying demand functions:

$$D_{t+1}^{Z,h} = (1-\phi_Z^B) \left[\frac{\mathrm{E}_t(1-\delta_{t+1}^Z)(\alpha^Z + i_t^Z)}{\mathrm{E}_t(1-\delta_{t+1}^Z)(\alpha^Z + i_t^{Z^E})} \right]^{-\psi^B} D_{t+1}^Z,\; D_{t+1}^{Z,f} = \phi_Z^B \left[\frac{\mathrm{E}_t(1+\tau_t^Z)(1-\delta_{t+1}^Z)(\alpha^Z + i_t^{Z,f})\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}}{\mathrm{E}_t(1-\delta_{t+1}^Z)(\alpha^Z + i_t^{Z^E})} \right]^{-\psi^B} \frac{D_{t+1}^Z}{\mathcal{E}_t}. \tag{50}$$

Since the portfolio aggregator exhibits constant returns to scale, in equilibrium the representative global bank generates zero expected profit, implying aggregate effective gross mortgage or corporate loan rate index:

$$\mathrm{E}_t(1-\delta_{t+1}^Z)(\alpha^Z + i_t^{Z^E}) = \left\{ (1-\phi_Z^B)\left[\mathrm{E}_t(1-\delta_{t+1}^Z)(\alpha^Z + i_t^Z)\right]^{1-\psi^B} + \phi_Z^B \left[\mathrm{E}_t(1+\tau_t^Z)(1-\delta_{t+1}^Z)(\alpha^Z + i_t^{Z,f})\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \right]^{1-\psi^B} \right\}^{\frac{1}{1-\psi^B}}. \tag{51}$$

The effective mortgage or corporate loan rate equals the minimum expected cost of producing one unit of the global mortgage or corporate loan, given the expected domestic currency denominated costs of borrowing from domestic and foreign final banks.

There exist a large number of perfectly competitive banks which combine differentiated intermediate mortgage or corporate loans $\{A_{b,t+1}^{B,Z}\}_{b=0}^{1}$ supplied by intermediate banks to produce final mortgage or corporate loan $A_{t+1}^{B,Z}$ according to constant elasticity of substitution portfolio aggregator

$$A_{t+1}^{B,Z} = \left[\int_0^1 (A_{b,t+1}^{B,Z})^{\frac{\theta_{t+1}^Z - 1}{\theta_{t+1}^Z}} db \right]^{\frac{\theta_{t+1}^Z}{\theta_{t+1}^Z - 1}}, \tag{52}$$

where $Z \in \{H,F\}$. The representative domestic final bank maximizes profits from intermediation of the final mortgage or corporate loan with respect to inputs of intermediate mortgage or corporate loans, implying demand functions:

$$A_{b,t+1}^{B,Z} = \left(\frac{\alpha^Z + i_{b,t}^Z}{\alpha^Z + i_t^Z} \right)^{-\theta_{t+1}^Z} A_{t+1}^{B,Z}. \tag{53}$$

Since the portfolio aggregator exhibits constant returns to scale, in equilibrium the domestic final bank generates zero profit, implying aggregate gross mortgage or corporate loan rate index:

$$\alpha^Z + i_t^Z = \left[\int_0^1 (\alpha^Z + i_{b,t}^Z)^{1-\theta_{t+1}^Z} db \right]^{\frac{1}{1-\theta_{t+1}^Z}}. \tag{54}$$

Serially correlated mortgage or corporate loan markup shock ϑ_{t+1}^Z satisfies $\vartheta_{t+1}^Z = \theta_{t+1}^Z / (\theta_{t+1}^Z - 1)$, where the rate elasticity of demand for intermediate mortgage or corporate loans θ_{t+1}^Z satisfies $\theta_{t+1}^Z > 1$.

Funding Demand and Bank Capital Accumulation

There exists a continuum of monopolistically competitive intermediate banks indexed by $b \in [0,1]$. Intermediate banks supply differentiated intermediate mortgage and corporate loans, but are otherwise identical.

Each intermediate bank b sells shares to domestic credit unconstrained households at price $V_{b,t}^B$. Acting in the interests of its shareholders, it maximizes its pre-dividend stock market value, which in equilibrium equals the expected discounted value of current and future dividend payments:

$$\Pi_{b,t}^B + V_{b,t}^B = \mathrm{E}_t \sum_{s=t}^{\infty} \frac{\beta^{s-t} \lambda_s^U}{\lambda_t^U} \Pi_{b,s}^B. \tag{55}$$

The derivation of this result imposes a transversality condition that rules out self-fulfilling speculative asset price bubbles.

Shares entitle households to dividend payments $\Pi_{b,s}^B$, defined as profits from providing financial intermediation services less retained earnings $I_{b,s}^B$:

$$\begin{aligned} \Pi_{b,s}^B = {} & (B_{b,s+1}^{B,D} - (1+i_{s-1}^D) B_{b,s}^{B,D}) + (B_{b,s+1}^{B,B^h} - (1+i_{s-1}^B) B_{b,s}^{B,B^h}) + \mathcal{E}_s (B_{b,s+1}^{B,B^f} - (1+i_{s-1}^{B,f}) B_{b,s}^{B,B^f}) \\ & -(B_{b,s}^{B,H} - C_{b,s}^{B,H}) - (B_{b,s}^{B,F} - C_{b,s}^{B,F}) - \Phi_{b,s}^B - I_{b,s}^B. \end{aligned} \tag{56}$$

Profits are defined as the increase in deposits $B_{b,s+1}^{B,D}$ from domestic households net of interest payments at the deposit rate i_{s-1}^D, plus the increase in net loans $B_{b,s+1}^{B,B^h}$ from the domestic interbank market net of interest payments at the domestic interbank rate i_{s-1}^B, plus the domestic currency denominated increase in net loans $B_{b,s+1}^{B,B^f}$ from the foreign interbank market net of interest payments at the foreign interbank rate $i_{s-1}^{B,f}$, minus new mortgage lending $B_{b,s}^{B,H}$ net of mortgage loan income $C_{b,s}^{B,H}$, minus new corporate lending net of corporate loan income $C_{b,s}^{B,F}$, minus regulation costs $\Phi_{b,s}^B$.

The intermediate bank enters period s with previously accumulated mortgage or corporate credit outstanding $A_{b,s}^{B,Z}$, which subsequently evolves according to accumulation function

$$A_{b,s+1}^{B,Z} = (1-\alpha^Z) A_{b,s}^{B,Z} + B_{b,s}^{B,Z}, \tag{57}$$

where $Z \in \{H,F\}$, while $0 \leq \alpha^Z \leq 1$. During period s , the intermediate bank extends new mortgage or corporate credit $B_{b,s}^{B,Z}$ to satisfy demand, ultimately from domestic and foreign households or firms. Its mortgage or corporate loan income $C_{b,s}^{B,Z}$ satisfies

$$C_{b,s}^{B,Z} = (\alpha^Z + i_{b,s-1}^Z) A_{b,s}^{B,Z}, \tag{58}$$

reflecting amortization income at rate α^Z and interest income at variable mortgage or corporate loan rate i_{s-1}^Z on the outstanding stock of mortgage or corporate credit.

The intermediate bank transforms deposit and money market funding into risky differentiated intermediate mortgage and corporate loans according to balance sheet identity:

$$A_{b,s+1}^{B,H} + A_{b,s+1}^{B,F} = B_{b,s+1}^{B,D} + B_{b,s+1}^{B,B^h} + \mathcal{E}_s B_{b,s+1}^{B,B^f} + K_{b,s+1}^B. \tag{59}$$

The bank credit stock A_{s+1}^B measures aggregate bank assets, that is $A_{s+1}^B = A_{s+1}^{B,H} + A_{s+1}^{B,F}$, while the money stock M_{s+1}^S measures aggregate bank funding, that is $M_{s+1}^S = B_{s+1}^{B,D} + B_{s+1}^{B,B^h} + \mathcal{E}_s B_{s+1}^{B,B^f}$. The bank capital ratio κ_{s+1} equals the ratio of aggregate bank capital to assets, that is $\kappa_{s+1} = K_{s+1}^B / A_{s+1}^B$. The banking sector takes offsetting positions in the domestic and foreign interbank markets, that is $B_{s+1}^{B,B^h} + \mathcal{E}_s B_{s+1}^{B,B^f} = 0$.

In transforming deposit and money market funding into risky mortgage and corporate loans, the intermediate bank incurs costs of satisfying the regulatory capital and foreign currency liquidity requirements:

$$\Phi_{b,s}^B = \mathcal{G}^{B,C}(A_{b,s}^{B,H}, A_{b,s}^{B,F}, K_{b,s}^B) + \mathcal{G}^{B,L}(B_{b,s}^{B,B^f}) + F_s^B. \tag{60}$$

Motivated by Gerali, Neri, Sessa and Signoretti (2010), the capital regulation cost is decreasing in the ratio of bank capital to assets at a decreasing rate,

$$\mathcal{G}^{B,C}(A_{b,s+1}^{B,H}, A_{b,s+1}^{B,F}, K_{b,s+1}^B) = \mu^B \left[e^{(2+\eta^B)\left(1 - \frac{1}{\kappa_{s+1}^R} \frac{K_{b,s+1}^B}{A_{b,s+1}^{B,H} + A_{b,s+1}^{B,F}}\right)} - 1 \right] K_{b,s+1}^B, \tag{61}$$

given bank capital requirement κ_{s+1}^R , where $\mu^B > 0$ and $\eta^B > 0$. In steady state equilibrium, the bank capital ratio equals its required value, and the cost of capital regulation is constant. Motivated by Gabaix and Maggiori (2015), the foreign currency liquidity regulation cost is convex with respect to the ratio of net foreign interbank market funding to nominal output,

$$\mathcal{G}^{B,L}(B_{b,s+1}^{B,B^f}) = \frac{1}{\beta} \left[\frac{\gamma_s^B}{2} \left(\frac{\mathcal{E}_s B_{b,s+1}^{B,B^f}}{P_s^Y Y_s} \right)^2 - \gamma^B r \frac{\mathcal{E}_s B_{b,s+1}^{B,B^f}}{P_s^Y Y_s} \right] P_s^Y Y_s, \tag{62}$$

given foreign currency liquidity shifter γ_s^B , where $\gamma_s^B > 0$. Fixed cost F_s^B ensures that $\int_0^1 \Phi_{b,s}^B db = -\Delta K_{s+1}^B$.

The intermediate bank enters period s with previously accumulated bank capital stock $K_{b,s}^B$, which subsequently evolves according to accumulation function:

$$K_{b,s+1}^B = (1 - \delta_{b,s}^B) K_{b,s}^B + \mathcal{H}^B(I_{b,s}^B, I_{b,s-1}^B). \tag{63}$$

The bank capital destruction rate $\delta_{b,s}^B$ equals the ratio of credit losses on mortgage and corporate loans to capital, given mortgage credit loss rate $\delta_s^{H^E}$ and corporate credit loss rate $\delta_s^{F^E}$:

$$\delta_{b,s}^B K_{b,s}^B = \delta_s^{H^E} (\alpha^H + i_{b,s-1}^H) A_{b,s}^{B,H} + \delta_s^{F^E} (\alpha^F + i_{b,s-1}^F) A_{b,s}^{B,F}. \tag{64}$$

The intermediate bank smooths retained earnings intertemporally, and effective retained earnings function $\mathcal{H}^B(I_{b,s}^B, I_{b,s-1}^B)$ incorporates convex adjustment costs,

$$\mathcal{H}^B(I^B_{b,s}, I^B_{b,s-1}) = \left[1 - \frac{\chi^B}{2}\left(\frac{I^B_{b,s}}{I^B_{b,s-1}} - 1\right)^2\right] I^B_{b,s} - F^C_s, \tag{65}$$

where $\chi^B > 0$. In steady state equilibrium, these adjustment costs equal zero, and effective retained earnings equals actual retained earnings. Fixed cost F^C_s ensures that $\int_0^1 \mathcal{H}^B(I^B_{b,s}, I^B_{b,s-1})db = I^B_s$.

In period t, the intermediate bank chooses state contingent sequences for deposit funding $\{B^{B,D}_{b,s+1}\}^{\infty}_{s=t}$, net domestic interbank market funding $\{B^{B,B^h}_{b,s+1}\}^{\infty}_{s=t}$, net foreign interbank market funding $\{B^{B,B^f}_{b,s+1}\}^{\infty}_{s=t}$, retained earnings $\{I^B_{b,s}\}^{\infty}_{s=t}$ and the bank capital stock $\{K^B_{b,s+1}\}^{\infty}_{s=t}$ to maximize pre-dividend stock market value (55) subject to balance sheet identity (59), bank capital accumulation function (63), mortgage and corporate credit accumulation functions (57), and terminal nonnegativity constraint $K^B_{b,T+1} \geq 0$ for $T \to \infty$. In equilibrium, the solutions to this value maximization problem satisfy necessary first order condition

$$1 + i^B_t = 1 + i^D_t, \tag{66}$$

which equates the interbank rate to the deposit rate. They also satisfy necessary first order condition

$$\mathrm{E}_t \frac{\beta\lambda^U_{t+1}}{\lambda^U_t}\left[(1+i^B_t) - (1+i^{B,f}_t)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\right] = \mathrm{E}_t \frac{\beta\lambda^U_{t+1}}{\lambda^U_t}\frac{\mathcal{G}^{B,L}_B(b,t+1)}{\mathcal{E}_t}, \tag{67}$$

which equates the expected discounted values of the gross real foreign currency liquidity regulation cost adjusted returns on domestic and foreign interbank loans. Furthermore, they satisfy necessary first order condition

$$\frac{Q^B_{b,t}}{P^Y_t}\mathcal{H}^B_1(b,t) + \mathrm{E}_t \frac{\beta\lambda^U_{t+1}}{\lambda^U_t}\frac{Q^B_{b,t+1}}{P^Y_{t+1}}\mathcal{H}^B_2(b,t+1) = 1, \tag{68}$$

which equates the expected discounted value of an additional unit of retained earnings to its price. Here $Q^B_{b,s}$ denotes the shadow price of bank capital, which is proportional to the Lagrange multiplier on the period s bank capital accumulation function. Finally, they satisfy necessary first order condition

$$\frac{Q^B_{b,t}}{P^Y_t} = \mathrm{E}_t \frac{\beta\lambda^U_{t+1}}{\lambda^U_t}\left\{\frac{Q^B_{b,t+1}}{P^Y_{t+1}} - \left[\frac{\lambda^U_t}{\beta\lambda^U_{t+1}} - (1+i^B_t)\right] - \mathcal{G}^{B,C}_{K^B}(b,t+1)\right\}, \tag{69}$$

which equates the relative shadow price of bank capital to the expected discounted value of its future value, minus the spread of the cost of equity over interbank market funding, minus the real marginal regulation cost of bank capital.

Credit Supply

In an adaptation of the model of nominal price rigidity proposed by Calvo (1983) to the banking sector along the lines of Hülsewig, Mayer and Wollmershäuser (2009), each period a randomly selected fraction $1-\omega^B$ of intermediate banks adjust their gross mortgage and corporate loan rates optimally, where $0 \leq \omega^B < 1$. The remaining fraction ω^B of intermediate banks do not adjust their loan rates,

$$\alpha^Z + i^Z_{b,t} = \alpha^Z + i^Z_{b,t-1}, \tag{70}$$

where $Z \in \{H, F\}$. Under this financial friction, intermediate banks infrequently adjust their loan rates, mimicking the effect of maturity transformation on the spreads between the loan and deposit rates.

If the intermediate bank can adjust its gross mortgage and corporate loan rates in period t, then it does so to maximize pre-dividend stock market value (55) subject to balance sheet identity (59), intermediate loan demand function (53), and the assumed financial friction. We consider a symmetric equilibrium under which all bank specific endogenous state variables are restricted to equal their aggregate counterparts. It follows that all intermediate banks that adjust their loan rates in period t solve an identical value maximization problem, which implies that they all choose common loan rates $i_t^{Z,*}$ given by necessary first order conditions:

$$\frac{\alpha^Z + i_t^{Z,*}}{\alpha^Z + i_t^Z} = \frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^B)^{s-t} \frac{\beta^{s-t}\lambda_s^U}{\lambda_t^U} \theta_s^Z \frac{(1+i_{s-1}^B) + \mathcal{G}_{A^{B,Z}}^{B,C}(b,s)}{\alpha^Z + i_{s-1}^Z} \left(\frac{\alpha^Z + i_{s-1}^Z}{\alpha^Z + i_t^Z}\right)^{\theta_s^Z} \left(\frac{\alpha^Z + i_t^{Z,*}}{\alpha^Z + i_t^Z}\right)^{-\theta_s^Z} (\alpha^Z + i_{s-1}^Z) A_s^{B,Z}}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^B)^{s-t} \frac{\beta^{s-t}\lambda_s^U}{\lambda_t^U} \left[\theta_s^Z \left(\frac{1+i_t^{Z,*}}{\alpha^Z + i_t^{Z,*}} - \delta_s^{Z^E} \frac{Q_{b,s}^B}{P_s^Y}\right) - \left(1 - \delta_s^{Z^E} \frac{Q_{b,s}^B}{P_s^Y}\right)\right] \left(\frac{\alpha^Z + i_{s-1}^Z}{\alpha^Z + i_t^Z}\right)^{\theta_s^Z - 1} \left(\frac{\alpha^Z + i_t^{Z,*}}{\alpha^Z + i_t^Z}\right)^{-\theta_s^Z} (\alpha^Z + i_{s-1}^Z) A_s^{B,Z}}. \tag{71}$$

These necessary first order conditions equate the expected discounted value of the marginal revenue gained from mortgage or corporate loan supply to the expected discounted value of the marginal cost incurred from intermediation. Aggregate gross mortgage or corporate loan rate index (54) equals an average of the gross mortgage or corporate loan rate set by the fraction $1-\omega^B$ of intermediate banks that adjust their loan rates in period t, and the average of the gross mortgage or corporate loan rates set by the remaining fraction ω^B of intermediate banks that do not adjust their loan rates:

$$\alpha^Z + i_t^Z = \left[(1-\omega^B)(\alpha^Z + i_t^{Z,*})^{1-\theta_{t+1}^Z} + \omega^B(\alpha^Z + i_{t-1}^Z)^{1-\theta_{t+1}^Z}\right]^{\frac{1}{1-\theta_{t+1}^Z}}. \tag{72}$$

Since those intermediate banks able to adjust their loan rates in period t are selected randomly from among all intermediate banks, the average gross mortgage or corporate loan rate set by the remaining intermediate banks equals the value of the aggregate gross mortgage or corporate loan rate index that prevailed during period $t-1$.

Loan Defaults and Foreign Currency Liquidity

We define the financial gap as a weighted average of the contemporaneous deviations of real nonfinancial private sector debt and the relative prices of housing and equity from their steady state equilibrium values,

$$\ln F_t - \ln \bar{F}_t = \phi_B^F \left(\ln \frac{D_{t+1}^P}{P_t^Y} - \ln \frac{\bar{D}_{t+1}^P}{\bar{P}_t^Y}\right) + \phi_H^F \left(\ln \frac{V_t^H}{P_t^Y} - \ln \frac{\bar{V}_t^H}{\bar{P}_t^Y}\right) + \phi_F^F \left(\ln \frac{V_t^F}{P_t^Y} - \ln \frac{\bar{V}_t^F}{\bar{P}_t^Y}\right), \tag{73}$$

where $\phi_B^F > 0$, $\phi_H^F > 0$, $\phi_F^F > 0$ and $\phi_B^F + \phi_H^F + \phi_F^F = 1$. Nonfinancial private sector debt D_{t+1}^P satisfies $D_{t+1}^P = D_{t+1}^H + D_{t+1}^F$. The change in the financial gap reflects financial conditions, as well as other drivers of the financial cycle, while its level measures financial vulnerability.

The mortgage and corporate loan default rates satisfy loan default relationships exhibiting partial adjustment dynamics of the form

$$\delta_t^Z - \delta^Z = \rho^{\delta^C}(\delta_{t-1}^Z - \delta^Z) - (1-\rho^{\delta^C})\zeta^{\delta^Z}\left[(\ln Y_t - \ln Y_t^P) + \zeta^F(\ln F_t - \ln \bar{F}_t)\right] + \nu_t^{\delta^Z}, \tag{74}$$

where $Z \in \{H,F\}$, while $0 < \delta^Z < 1$, $0 \le \rho^{\delta^C} < 1$, $\zeta^{\delta^Z} > 0$ and $\zeta^F > 0$. As specified, the deviation of the mortgage or corporate loan default rate from its steady state equilibrium value is inertially decreasing in the contemporaneous output and financial gaps. Deviations from these default rate relationships are captured by mean zero and serially correlated mortgage or corporate loan default shock $\nu_t^{\delta^Z}$.

The foreign currency liquidity shifter satisfies a foreign currency liquidity relationship that helps stabilize the net foreign asset ratio of the form

$$r(\gamma_t^B - \gamma^B) = -\zeta^{\varepsilon}\left(\frac{A_{t+1}}{P_t^Y Y_t} - \frac{\bar{A}_{t+1}}{P_t^Y Y_t}\right) + \nu_t^{\varepsilon}, \tag{75}$$

where $\zeta^{\mathcal{E}} > 0$. As specified, the deviation of the foreign currency liquidity shifter from its steady state equilibrium value is decreasing in the contemporaneous deviation of the net foreign asset ratio from its steady state equilibrium value. Deviations from this foreign currency liquidity relationship are captured by mean zero and serially correlated foreign currency liquidity shock $\nu_t^{\mathcal{E}}$.

D. The Trade Sector

Let $\mathcal{Q}_t$ denote the real exchange rate, which measures the price of foreign output in terms of domestic output, that is $\mathcal{Q}_t = \mathcal{E}_t P_t^{Y,f} / P_t^Y$.

The Export Sector

The export sector transforms the final output good into a final export good under producer currency pricing, with partial indexation to contemporaneous domestic currency denominated foreign output price inflation. This partial indexation mechanism incorporates some degree of local currency pricing.

Export Demand

There exist a large number of perfectly competitive firms which combine differentiated intermediate export goods $\{X_{x,t}\}_{x=0}^{1}$ supplied by intermediate export good firms to produce final export good X_t according to constant elasticity of substitution production function:

$$X_t = \left[\int_0^1 (X_{x,t})^{\frac{\theta_t^X - 1}{\theta_t^X}} dx \right]^{\frac{\theta_t^X}{\theta_t^X - 1}}. \tag{76}$$

The representative final export good firm maximizes profits from production of the final export good with respect to inputs of intermediate export goods, implying demand functions:

$$X_{x,t} = \left(\frac{P_{x,t}^X}{P_t^X} \right)^{-\theta_t^X} X_t. \tag{77}$$

Since the production function exhibits constant returns to scale, in equilibrium the final export good firm generates zero profit, implying aggregate export price index:

$$P_t^X = \left[\int_0^1 (P_{x,t}^X)^{1-\theta_t^X} dx \right]^{\frac{1}{1-\theta_t^X}}. \tag{78}$$

Serially uncorrelated export price markup shock ϑ_t^X satisfies $\vartheta_t^X = \theta_t^X / (\theta_t^X - 1)$, where the price elasticity of demand for intermediate export goods θ_t^X satisfies $\theta_t^X > 1$.

Export Supply

There exists a continuum of monopolistically competitive intermediate export good firms indexed by $x \in [0,1]$. Intermediate export good firms supply differentiated intermediate export goods, but are otherwise identical.

Each intermediate good exporter x sells shares to domestic credit unconstrained households at price $V_{x,t}^X$. Acting in the interests of its shareholders, it maximizes its pre-dividend stock market value, which in equilibrium equals the expected discounted value of current and future dividend payments:

$$\Pi_{x,t}^X + V_{x,t}^X = \mathrm{E}_t \sum_{s=t}^{\infty} \frac{\beta^{s-t}\lambda_s^U}{\lambda_t^U} \Pi_{x,s}^X. \tag{79}$$

The derivation of this result imposes a transversality condition that rules out self-fulfilling speculative asset price bubbles.

Shares entitle households to dividend payments equal to profits $\Pi_{x,s}^X$, defined as earnings less fixed cost F_s^X:

$$\Pi_{x,s}^X = P_{x,s}^X X_{x,s} - P_s^Y X_{x,s} - F_s^X. \tag{80}$$

Earnings are defined as revenues from sales of differentiated intermediate export good $X_{x,s}$ at price $P_{x,s}^X$ minus expenditures on final output good $X_{x,s}$. The representative intermediate export good firm purchases the final output good and differentiates it. Fixed cost F_s^X ensures that $\int_0^1 \Pi_{x,s}^X dx = 0$.

In an adaptation of the model of nominal import price rigidity proposed by Monacelli (2005) to the export sector, each period a randomly selected fraction $1-\omega^X$ of intermediate export good firms adjust their price optimally, where $0 \le \omega^X < 1$. The remaining fraction ω^X of intermediate export good firms adjust their price to account for past export price inflation, as well as contemporaneous domestic currency denominated foreign output price inflation, according to partial indexation rule

$$P_{x,t}^X = \left[\left(\frac{P_{t-1}^X}{P_{t-2}^X}\right)^{1-\mu^X}\left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_{t-1}P_{t-1}^{Y,f}}\right)^{\mu^X}\right]^{\gamma^X}\left[\left(\frac{\bar{P}_{t-1}^X}{\bar{P}_{t-2}^X}\right)^{1-\mu^X}\left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_{t-1}\bar{P}_{t-1}^{Y,f}}\right)^{\mu^X}\right]^{1-\gamma^X} P_{x,t-1}^X, \tag{81}$$

where $0 \le \gamma^X \le 1$ and $0 \le \mu^X \le 1$. Under this specification, the probability that an intermediate export good firm has adjusted its price optimally is time dependent but state independent.

If the representative intermediate export good firm can adjust its price optimally in period t, then it does so to maximize pre-dividend stock market value (79) subject to intermediate export good demand function (77), and the assumed form of nominal export price rigidity. Since all intermediate export good firms that adjust their price optimally in period t solve an identical value maximization problem, in equilibrium they all choose a common price $P_t^{X,*}$ given by necessary first order condition:

$$\frac{P_t^{X,*}}{P_t^X} = \frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^X)^{s-t} \frac{\beta^{s-t}\lambda_s^U}{\lambda_t^U} \theta_s^X \frac{P_s^Y}{P_s^X} \left\{\left[\left(\frac{P_{t-1}^X}{P_{s-1}^X}\right)^{1-\mu^X}\left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_s P_s^{Y,f}}\right)^{\mu^X}\right]^{\gamma^X}\left[\left(\frac{\bar{P}_{t-1}^X}{\bar{P}_{s-1}^X}\right)^{1-\mu^X}\left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_s \bar{P}_s^{Y,f}}\right)^{\mu^X}\right]^{1-\gamma^X}\frac{P_s^X}{P_t^X}\right\}^{\theta_s^X}\left(\frac{P_t^{X,*}}{P_t^X}\right)^{-\theta_s^X} P_s^X X_s}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^X)^{s-t} \frac{\beta^{s-t}\lambda_s^U}{\lambda_t^U} (\theta_s^X - 1) \left\{\left[\left(\frac{P_{t-1}^X}{P_{s-1}^X}\right)^{1-\mu^X}\left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_s P_s^{Y,f}}\right)^{\mu^X}\right]^{\gamma^X}\left[\left(\frac{\bar{P}_{t-1}^X}{\bar{P}_{s-1}^X}\right)^{1-\mu^X}\left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_s \bar{P}_s^{Y,f}}\right)^{\mu^X}\right]^{1-\gamma^X}\frac{P_s^X}{P_t^X}\right\}^{\theta_s^X - 1}\left(\frac{P_t^{X,*}}{P_t^X}\right)^{-\theta_s^X} P_s^X X_s}. \tag{82}$$

This necessary first order condition equates the expected discounted value of the marginal revenue gained from export supply to the expected discounted value of the marginal cost incurred from production. Aggregate export price index (78) equals an average of the price set by the fraction $1-\omega^X$ of intermediate export good firms that adjust their price optimally in period t, and the average of the prices set by the remaining fraction ω^X of intermediate export good firms that adjust their price according to partial indexation rule (81):

$$P_t^X = \left\{ (1-\omega^X)(P_t^{X,*})^{1-\theta_t^X} + \omega^X \left\{ \left[\left(\frac{P_{t-1}^X}{P_{t-2}^X} \right)^{1-\mu^X} \left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_{t-1} P_{t-1}^{Y,f}} \right)^{\mu^X} \right]^{\gamma^X} \left[\left(\frac{\bar{P}_{t-1}^X}{\bar{P}_{t-2}^X} \right)^{1-\mu^X} \left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_{t-1} \bar{P}_{t-1}^{Y,f}} \right)^{\mu^X} \right]^{1-\gamma^X} P_{t-1}^X \right\}^{1-\theta_t^X} \right\}^{\frac{1}{1-\theta_t^X}}. \quad (83)$$

Since those intermediate export good firms able to adjust their price optimally in period t are selected randomly from among all intermediate export good firms, the average price set by the remaining intermediate export good firms equals the value of the aggregate export price index that prevailed during period $t-1$, rescaled to account for past export price inflation, as well as contemporaneous domestic currency denominated foreign output price inflation.

The Import Sector

The import sector transforms the foreign final export good into a final import good under local currency pricing, with partial indexation to contemporaneous domestic currency denominated foreign output price inflation. This partial indexation mechanism incorporates some degree of producer currency pricing. The final import good is then combined with the final output good to produce goods for absorption by households, firms and the government. Under this transformation, exchange rate pass-through to the prices of these absorption goods is incomplete in the short run, but complete in the long run.

Import Demand

There exist a large number of perfectly competitive firms which combine the final output good $Z_t^h \in \{C_t^h, I_t^{H,h}, I_t^{K,h}, G_t^{C,h}, G_t^{I,h}\}$ with the final import good $Z_t^f \in \{C_t^f, I_t^{H,f}, I_t^{K,f}, G_t^{C,f}, G_t^{I,f}\}$ to produce private consumption, residential investment, business investment, public consumption or public investment good $Z_t \in \{C_t, I_t^H, I_t^K, G_t^C, G_t^I\}$ according to constant elasticity of substitution production function

$$Z_t = \left[(1-\phi_Z^M)^{\frac{1}{\psi^M}} (Z_t^h)^{\frac{\psi^M-1}{\psi^M}} + (\phi_Z^M)^{\frac{1}{\psi^M}} (\vartheta^X \vartheta^M Z_t^f)^{\frac{\psi^M-1}{\psi^M}} \right]^{\frac{\psi^M}{\psi^M-1}}, \quad (84)$$

where $0 \le \phi_Z^M < 1$ and $\psi^M > 0$, while $\phi_{I^H}^M = \phi_{I^K}^M = \phi_I^M$ and $\phi_{G^C}^M = \phi_{G^I}^M = \phi_G^M$. The representative absorption good firm maximizes profits from production of the private consumption, residential investment, business investment, public consumption or public investment good, with respect to inputs of the final output and import goods, implying demand functions:

$$Z_t^h = (1-\phi_Z^M) \left(\frac{P_t^Y}{P_t^Z} \right)^{-\psi^M} Z_t, \; Z_t^f = \phi_Z^M \left(\frac{1}{\vartheta^X \vartheta^M} \frac{P_t^M}{P_t^Z} \right)^{-\psi^M} \frac{Z_t}{\vartheta^X \vartheta^M}. \quad (85)$$

Since the production function exhibits constant returns to scale, in equilibrium the representative absorption good firm generates zero profit, implying aggregate private consumption, residential investment, business investment, public consumption or public investment price index:

$$P_t^Z = \left[(1-\phi_Z^M)(P_t^Y)^{1-\psi^M} + \phi_Z^M \left(\frac{P_t^M}{\vartheta^X \vartheta^M} \right)^{1-\psi^M} \right]^{\frac{1}{1-\psi^M}}. \tag{86}$$

These aggregate absorption price indexes equal the minimum cost of producing one unit of the absorption good, given the prices of the final output and import goods.

There exist a large number of perfectly competitive firms which combine differentiated intermediate import goods $\{M_{m,t}\}_{m=0}^{1}$ supplied by intermediate import good firms to produce final import good M_t according to constant elasticity of substitution production function:

$$M_t = \left[\int_0^1 (M_{m,t})^{\frac{\theta_t^M - 1}{\theta_t^M}} dm \right]^{\frac{\theta_t^M}{\theta_t^M - 1}}. \tag{87}$$

The representative final import good firm maximizes profits from production of the final import good with respect to inputs of intermediate import goods, implying demand functions:

$$M_{m,t} = \left(\frac{P_{m,t}^M}{P_t^M} \right)^{-\theta_t^M} M_t. \tag{88}$$

Since the production function exhibits constant returns to scale, in equilibrium the final import good firm generates zero profit, implying aggregate import price index:

$$P_t^M = \left[\int_0^1 (P_{m,t}^M)^{1-\theta_t^M} dm \right]^{\frac{1}{1-\theta_t^M}}. \tag{89}$$

Serially uncorrelated import price markup shock ϑ_t^M satisfies $\vartheta_t^M = \theta_t^M / (\theta_t^M - 1)$, where the price elasticity of demand for intermediate import goods θ_t^M satisfies $\theta_t^M > 1$.

Import Supply

There exists a continuum of monopolistically competitive intermediate import good firms indexed by $m \in [0,1]$. Intermediate import good firms supply differentiated intermediate import goods, but are otherwise identical.

Each intermediate good importer m sells shares to domestic credit unconstrained households at price $V_{m,t}^M$. Acting in the interests of its shareholders, it maximizes its pre-dividend stock market value, which in equilibrium equals the expected discounted value of current and future dividend payments:

$$\Pi_{m,t}^M + V_{m,t}^M = \mathrm{E}_t \sum_{s=t}^{\infty} \frac{\beta^{s-t} \lambda_s^U}{\lambda_t^U} \Pi_{m,s}^M. \tag{90}$$

The derivation of this result imposes a transversality condition that rules out self-fulfilling speculative asset price bubbles.

Shares entitle households to dividend payments equal to profits $\Pi_{m,s}^M$, defined as earnings less fixed cost F_s^M:

$$\Pi_{m,s}^M = P_{m,s}^M M_{m,s} - \mathcal{E}_s P_s^{X,f} M_{m,s} - F_s^M. \tag{91}$$

Earnings are defined as revenues from sales of differentiated intermediate import good $M_{m,s}$ at price $P_{m,s}^{M}$ minus expenditures on foreign final export good $M_{m,s}$. The representative intermediate import good firm purchases the foreign final export good and differentiates it. Fixed cost F_s^M ensures that $\int_0^1 \Pi_{m,s}^M dm = 0$.

In an extension of the model of nominal import price rigidity proposed by Monacelli (2005), each period a randomly selected fraction $1-\omega^M$ of intermediate import good firms adjust their price optimally, where $0 \leq \omega^M < 1$. The remaining fraction ω^M of intermediate import good firms adjust their price to account for past import price inflation, as well as contemporaneous domestic currency denominated foreign output price inflation, according to partial indexation rule

$$P_{m,t}^{M} = \left[\left(\frac{P_{t-1}^{M}}{P_{t-2}^{M}}\right)^{1-\mu^M}\left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_{t-1}P_{t-1}^{Y,f}}\right)^{\mu^M}\right]^{\gamma^M}\left[\left(\frac{\bar{P}_{t-1}^{M}}{\bar{P}_{t-2}^{M}}\right)^{1-\mu^M}\left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_{t-1}\bar{P}_{t-1}^{Y,f}}\right)^{\mu^M}\right]^{1-\gamma^M} P_{m,t-1}^{M}, \tag{92}$$

where $0 \leq \gamma^M \leq 1$ and $0 \leq \mu^M \leq 1$. Under this specification, the probability that an intermediate import good firm has adjusted its price optimally is time dependent but state independent.

If the representative intermediate import good firm can adjust its price optimally in period t, then it does so to maximize pre-dividend stock market value (90) subject to intermediate import good demand function (88), and the assumed form of nominal import price rigidity. Since all intermediate import good firms that adjust their price optimally in period t solve an identical value maximization problem, in equilibrium they all choose a common price $P_t^{M,*}$ given by necessary first order condition:

$$\frac{P_t^{M,*}}{P_t^M} = \frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^M)^{s-t} \frac{\beta^{s-t}\lambda_s^U}{\lambda_t^U} \theta_s^M \frac{\mathcal{E}_s P_s^{X,f}}{P_s^M}\left\{\left[\left(\frac{P_{t-1}^{M}}{P_{s-1}^{M}}\right)^{1-\mu^M}\left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_s P_s^{Y,f}}\right)^{\mu^M}\right]^{\gamma^M}\left[\left(\frac{\bar{P}_{t-1}^{M}}{\bar{P}_{s-1}^{M}}\right)^{1-\mu^M}\left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_s \bar{P}_s^{Y,f}}\right)^{\mu^M}\right]^{1-\gamma^M}\frac{P_s^M}{P_t^M}\right\}^{\theta_s^M}\left(\frac{P_t^{M,*}}{P_t^M}\right)^{-\theta_s^M} P_s^M M_s}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^M)^{s-t} \frac{\beta^{s-t}\lambda_s^U}{\lambda_t^U} (\theta_s^M - 1)\left\{\left[\left(\frac{P_{t-1}^{M}}{P_{s-1}^{M}}\right)^{1-\mu^M}\left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_s P_s^{Y,f}}\right)^{\mu^M}\right]^{\gamma^M}\left[\left(\frac{\bar{P}_{t-1}^{M}}{\bar{P}_{s-1}^{M}}\right)^{1-\mu^M}\left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_s \bar{P}_s^{Y,f}}\right)^{\mu^M}\right]^{1-\gamma^M}\frac{P_s^M}{P_t^M}\right\}^{\theta_s^M - 1}\left(\frac{P_t^{M,*}}{P_t^M}\right)^{-\theta_s^M} P_s^M M_s}. \tag{93}$$

This necessary first order condition equates the expected discounted value of the marginal revenue gained from import supply to the expected discounted value of the marginal cost incurred from production. Aggregate import price index (89) equals an average of the price set by the fraction $1-\omega^M$ of intermediate import good firms that adjust their price optimally in period t, and the average of the prices set by the remaining fraction ω^M of intermediate import good firms that adjust their price according to partial indexation rule (92):

$$P_t^M = \left\{(1-\omega^M)(P_t^{M,*})^{1-\theta_t^M} + \omega^M\left\{\left[\left(\frac{P_{t-1}^{M}}{P_{t-2}^{M}}\right)^{1-\mu^M}\left(\frac{\mathcal{E}_t P_t^{Y,f}}{\mathcal{E}_{t-1}P_{t-1}^{Y,f}}\right)^{\mu^M}\right]^{\gamma^M}\left[\left(\frac{\bar{P}_{t-1}^{M}}{\bar{P}_{t-2}^{M}}\right)^{1-\mu^M}\left(\frac{\bar{\mathcal{E}}_t \bar{P}_t^{Y,f}}{\bar{\mathcal{E}}_{t-1}\bar{P}_{t-1}^{Y,f}}\right)^{\mu^M}\right]^{1-\gamma^M} P_{t-1}^{M}\right\}^{1-\theta_t^M}\right\}^{\frac{1}{1-\theta_t^M}}. \tag{94}$$

Since those intermediate import good firms able to adjust their price optimally in period t are selected randomly from among all intermediate import good firms, the average price set by the remaining intermediate import good firms equals the value of the aggregate import price index that prevailed during period $t-1$, rescaled to account for past import price inflation, as well as contemporaneous domestic currency denominated foreign output price inflation.

E. The Monetary, Fiscal, and Macroprudential Authorities

The government consists of a monetary authority, a fiscal authority, and a macroprudential authority. The monetary authority conducts monetary policy and executes foreign exchange intervention. The fiscal authority conducts fiscal policy and administers capital controls. The macroprudential authority conducts macroprudential policy.

The Monetary Authority

The monetary authority takes offsetting positions in the domestic and foreign interbank markets, transferring profits Π_t^C to the fiscal authority,

$$\Pi_t^C = (B_{t+1}^{C,B^h} - (1+i_{t-1}^B)B_t^{C,B^h}) + \mathcal{E}_t(B_{t+1}^{C,B^f} - (1+i_{t-1}^{B,f})B_t^{C,B^f}), \tag{95}$$

where $B_{t+1}^{C,B^h} + \mathcal{E}_t B_{t+1}^{C,B^f} = 0$. Profits are defined as the increase in net loans B_{t+1}^{C,B^h} from the domestic interbank market net of interest payments at the domestic interbank rate i_{t-1}^B, plus the domestic currency denominated increase in net loans B_{t+1}^{C,B^f} from the foreign interbank market net of interest payments at the foreign interbank rate $i_{t-1}^{B,f}$. The stock of foreign exchange reserves R_{t+1} satisfies $R_{t+1} = -B_{t+1}^{C,B^f}$, while the foreign exchange reserve ratio r_{t+1} satisfies $r_{t+1} = \mathcal{E}_t R_{t+1} / P_t^Y Y_t$, and foreign exchange intervention FXI_t satisfies $FXI_t = \Delta r_{t+1}$. Changes in foreign exchange reserves are fully sterilized since $\Delta\mathcal{E}_t R_{t+1} = \Delta B_{t+1}^{C,B^h}$.

Monetary Policy

The monetary authority implements monetary policy through control of the interbank rate according to a monetary policy rule exhibiting partial adjustment dynamics of the form

$$i_t^B - \bar{i}_t^B = \rho^{i^B}(i_{t-1}^B - \bar{i}_{t-1}^B) + (1-\rho^{i^B})\left[\xi^{\pi^C}\mathrm{E}_t(\pi_{t+1}^C - \bar{\pi}_{t+1}^C) + \xi^{Y^G}(\ln Y_t - \ln Y_t^P)\right] + \nu_t^{i^B}, \tag{96}$$

where $0 \leq \rho^{i^B} < 1$, $\xi^{\pi^C} > 1$ and $\xi^{Y^G} \geq 0$. As specified, the deviation of the interbank rate from its steady state equilibrium value is inertially increasing in the expected future deviation of consumption price inflation from its target value, as well as the contemporaneous output gap. We define the output gap as the deviation of output from its potential value, which we define as that output level consistent with full utilization of private physical capital and effective labor, given the private physical capital stock and effective labor force. Deviations from this monetary policy rule are captured by mean zero and serially uncorrelated monetary policy shock $\nu_t^{i^B}$.

Foreign Exchange Intervention

The foreign exchange reserve ratio satisfies a foreign exchange intervention rule that helps stabilize the real exchange rate of the form

$$r_{t+1} - r = -\xi^r(\ln\mathcal{Q}_t - \ln\bar{\mathcal{Q}}_t) + \nu_t^r, \tag{97}$$

where $r > 0$, $0 \leq \rho^r < 1$ and $\xi^r \geq 0$. As specified, the deviation of the foreign exchange reserve ratio from its steady state equilibrium value is decreasing in the contemporaneous deviation of the real exchange rate from its steady state equilibrium value. Deviations from this foreign exchange intervention rule are captured by mean zero and serially correlated foreign exchange intervention shock ν_t^r.

The Fiscal Authority

The fiscal authority issues domestic currency denominated government bonds to domestic households, securing new government borrowing $B_t^{G,G}$. It also levies taxes on corporate earnings at rate τ_t^K, on household labor income at rate τ_t^L, on household consumption expenditures at rate τ_t^C, on cross-border mortgage borrowing at rate τ_t^H, and on cross-border corporate borrowing at rate τ_t^F, generating tax revenues T_t. In addition, the fiscal authority receives profit transfer Π_t^C from the monetary authority. These sources of funds are summed in government dynamic budget constraint:

$$C_t^{G,G} + P_t^{G^C} G_t^C + P_t^{G^I} G_t^I + \int_0^1 T_{h,t}^Z dh = B_t^{G,G} + \int_0^1 \tau_t^K (P_{f,t}^Y Y_{f,t} - W_t L_{f,t} - \Phi_{f,t}^F) df + \int_0^1 \tau_t^L \int_0^1 W_{i,t} L_{h,i,t} di dh$$
$$+ \int_0^1 \tau_t^C P_t^C C_{h,t} dh + \tau_{t-1}^H (1-\delta_t^H)(\alpha^H + i_{t-1}^{H,f}) \mathcal{E}_t D_t^{H,f} + \tau_{t-1}^F (1-\delta_t^F)(\alpha^F + i_{t-1}^{F,f}) \mathcal{E}_t D_t^{F,f} + \Pi_t^C. \tag{98}$$

According to this dynamic budget constraint, the fiscal authority services its debt at cost $C_t^{G,G}$. It also purchases public consumption good G_t^C at price $P_t^{G^C}$, and public investment good G_t^I at price $P_t^{G^I}$, accumulating the public capital stock K_{t+1}^G according to $K_{t+1}^G = (1-\delta_G) K_t^G + G_t^I$ where $0 \le \delta_G \le 1$. Finally, the fiscal authority remits household type specific lump sum transfer payments $\{T_{h,t}^Z\}_{h=0}^1$, which it allocates across nondiscretionary transfers $\{T_{h,t}^{Z,N}\}_{h=0}^1$ and discretionary transfers $\{T_{h,t}^{Z,D}\}_{h=0}^1$, that is $T_{h,t}^Z = T_{h,t}^{Z,N} + T_{h,t}^{Z,D}$. Nondiscretionary transfers sum to zero across households, that is $\int_0^1 T_{h,t}^{Z,N} dh = 0$, while discretionary transfers are targeted at credit constrained households, that is $T_{h,t}^{U,D} = 0$. In steady state equilibrium, nondiscretionary transfers equate consumption across credit unconstrained and credit constrained households.

The fiscal authority enters period t with previously accumulated public debt D_t^G, which subsequently evolves according to accumulation function

$$D_{t+1}^G = (1-\alpha^G) D_t^G + B_t^{G,G}, \tag{99}$$

where $\alpha^G = 1-\omega^G$, which implies that $0 \le \alpha^G < 1$. Its debt service cost satisfies $C_t^{G,G} = (\alpha^G + i_{t-1}^{G^E}) D_t^G$, reflecting an amortization payment at rate α^G and an interest payment at effective rate $i_{t-1}^{G^E}$ on the outstanding stock of public debt. This effective government rate evolves according to

$$i_t^{G^E} = \left(1 - \frac{B_{t-1}^{G,G}}{D_t^G}\right) i_{t-1}^{G^E} + \frac{B_{t-1}^{G,G}}{D_t^G} i_{t-1}^G, \tag{100}$$

as a weighted average of the interest rates applicable to outstanding and new public debt, the latter given by the past government bond yield.

Fiscal Policy

Public consumption and investment satisfy countercyclical fiscal expenditure rules exhibiting partial adjustment dynamics of the form

$$\ln \frac{G_t^Z}{\bar{G}_t^Z} = \rho^G \ln \frac{G_{t-1}^Z}{\bar{G}_{t-1}^Z} - (1-\rho^G) \xi^{G^Z} (\ln Y_t - \ln Y_t^P) + \nu_t^{G^Z}, \tag{101}$$

where $Z \in \{C, I\}$, while $0 \le \rho^G < 1$ and $\xi^{G^Z} \ge 0$. As specified, the deviation of public consumption or investment from its steady state equilibrium value is inertially decreasing in the contemporaneous output gap. Deviations from these fiscal expenditure rules are captured by mean zero and serially correlated public consumption or investment shock $\nu_t^{G^Z}$.

The tax rates applicable to corporate earnings, household labor income and household consumption expenditures satisfy acyclical fiscal revenue rules of the form

$$\tau_t^Z - \tau^Z = \rho^\tau (\tau_{t-1}^Z - \tau^Z) + \nu_t^{\tau^Z}, \tag{102}$$

where $Z \in \{K, L, C\}$, while $0 < \tau^Z < 1$ and $0 \leq \rho^\tau < 1$. Deviations from these fiscal revenue rules are captured by mean zero and serially correlated corporate, labor income or consumption tax rate shock $\nu_t^{\tau^Z}$.

Nondiscretionary transfers to credit constrained households satisfy a transfer payment rule that gradually stabilizes the net foreign asset ratio of the form

$$\frac{T_t^{C,N}}{P_t^Y Y_t} - \frac{\bar{T}_t^{C,N}}{\bar{P}_t^Y \bar{Y}_t} = \xi^{T^N} \left(\frac{A_{t+1}}{P_t^Y Y_t} - \frac{\bar{A}_{t+1}}{P_t^Y Y_t} \right), \tag{103}$$

where $\xi^{T^N} > 0$. As specified, the deviation of the nondiscretionary transfer payment ratio from its steady state equilibrium value is increasing in the contemporaneous deviation of the net foreign asset ratio from its steady state equilibrium value. Discretionary transfers to credit constrained households satisfy a transfer payment rule that gradually stabilizes the public debt ratio of the form

$$\frac{T_t^{C,D}}{P_t^Y Y_t} - \frac{\bar{T}_t^{C,D}}{\bar{P}_t^Y \bar{Y}_t} = -\xi^{T^D} \left(\frac{D_{t+1}^G}{P_t^Y Y_t} - \frac{\bar{D}_{t+1}^G}{P_t^Y Y_t} \right) + \nu_t^T, \tag{104}$$

where $\xi^{T^D} > 0$. As specified, the deviation of the discretionary transfer payment ratio from its steady state equilibrium value is decreasing in the contemporaneous deviation of the public debt ratio from its target value. Deviations from this transfer payment rule are captured by mean zero and serially correlated transfer payment shock ν_t^T.

Capital Flow Management

The tax rates applicable to cross-border mortgage and corporate borrowing satisfy capital flow management rules exhibiting partial adjustment dynamics of the form

$$\tau_t^Z = \rho^{\tau^C} \tau_{t-1}^Z + (1 - \rho^{\tau^C}) \xi^{\tau^Z} \left(\ln \frac{\mathcal{E}_t D_{t+1}^{Z,f}}{P_t^Y} - \ln \frac{\bar{\mathcal{E}}_t \bar{D}_{t+1}^{Z,f}}{\bar{P}_t^Y} \right) + \nu_t^{\tau^Z}, \tag{105}$$

where $Z \in \{H, F\}$, while $\tau^Z = 0$, $0 \leq \rho^{\tau^C} < 1$ and $\xi^{\tau^Z} \geq 0$. As specified, the mortgage or corporate capital control tax rate is inertially increasing in the contemporaneous deviation of the real domestic currency denominated value of external mortgage or corporate debt from its steady state equilibrium value. Deviations from these capital flow management rules are captured by mean zero and serially correlated mortgage or corporate capital control shock $\nu_t^{\tau^Z}$.[1]

[1] These capital controls may be classified as both capital flow management and macroprudential policy measures, as they limit both capital inflows and systemic risk arising from them.

The Macroprudential Authority

The regulatory bank capital ratio requirement satisfies a countercyclical capital buffer rule exhibiting partial adjustment dynamics of the form

$$\kappa_{t+1}^R - \kappa^R = \rho^{\kappa^R}(\kappa_t^R - \kappa^R) + (1-\rho^{\kappa^R})\xi^{\kappa^R}\left(\ln\frac{A_{t+1}^B}{P_t^Y} - \ln\frac{\bar{A}_{t+1}^B}{\bar{P}_t^Y}\right) + \nu_t^{\kappa^R}, \tag{106}$$

where $0<\kappa^R<1$, $0\le\rho^{\kappa^R}<1$ and $\xi^{\kappa^R}\ge 0$. As specified, the deviation of the bank capital requirement from its steady state equilibrium value is inertially increasing in the contemporaneous deviation of real bank credit from its steady state equilibrium value. Deviations from this countercyclical capital buffer rule are captured by mean zero and serially correlated bank capital requirement shock $\nu_t^{\kappa^R}$.

The regulatory mortgage and corporate loan to value ratio limits satisfy loan to value limit rules exhibiting partial adjustment dynamics of the form

$$\phi_t^Z - \phi^Z = \rho^{\phi}(\phi_{t-1}^Z - \phi^Z) - (1-\rho^{\phi})\xi^{\phi^Z}\left(\ln\frac{D_{t+1}^Z}{P_t^Y} - \ln\frac{\bar{D}_{t+1}^Z}{\bar{P}_t^Y}\right) + \nu_t^{\phi^Z}, \tag{107}$$

where $Z\in\{H,F\}$, while $0<\phi^Z<1$, $0\le\rho^{\phi}<1$ and $\xi^{\phi^Z}\ge 0$. As specified, the deviation of the mortgage or corporate loan to value limit from its steady state equilibrium value is inertially decreasing in the contemporaneous deviation of real mortgage or corporate debt from its steady state equilibrium value. Deviations from these loan to value limit rules are captured by mean zero and serially correlated mortgage or corporate loan to value limit shock $\nu_t^{\phi^Z}$.

F. Market Clearing Conditions

A rational expectations equilibrium in this DSGE model of the world economy consists of state contingent sequences of allocations for domestic and foreign households, firms and banks that solve their constrained optimization problems given prices and policies, together with state contingent sequences of allocations for the domestic and foreign governments that satisfy their policy rules and constraints given prices, with supporting prices such that all markets clear.

Clearing of the final output good market requires that the value of exports X_t equal the value of final output good supply minus demand from households, firms and the government,

$$P_t^X X_t = P_t^Y(Y_t - C_t^h - I_t^{H,h} - I_t^{K,h} - G_t^{C,h} - G_t^{I,h}), \tag{108}$$

where $X_t = M_t^f$. Clearing of the final import good market requires that the volume of imports M_t equal the volume of demand from households, firms and the government,

$$M_t = C_t^f + I_t^{H,f} + I_t^{K,f} + G_t^{C,f} + G_t^{I,f}, \tag{109}$$

where $M_t = X_t^f$. In equilibrium, combination of these final output and import good market clearing conditions yields output expenditure decomposition,

$$P_t^Y Y_t = P_t^C C_t + P_t^I I_t + P_t^G G_t + P_t^X X_t - P_t^M M_t, \tag{110}$$

where the price of investment satisfies $P_t^I = P_t^{I^H} = P_t^{I^K}$ while investment satisfies $I_t = I_t^H + I_t^K$, and the price of public demand satisfies $P_t^G = P_t^{G^C} = P_t^{G^I}$ while public demand satisfies $G_t = G_t^C + G_t^I$.

Clearing of the final mortgage or corporate loan market requires that bank credit supply equal bank credit demand, ultimately from domestic and foreign households or firms,

$$A_{t+1}^{B,Z} = D_{t+1}^{Z,h} + D_{t+1}^{Z,f,f}, \tag{111}$$

where $Z \in \{H,F\}$. In equilibrium, clearing of the final mortgage or corporate loan payment system implies that the mortgage or corporate credit loss rate satisfies:

$$\delta_t^{Z^E} A_t^{B,Z} = \delta_t^Z D_t^{Z,h} + \delta_t^{Z,f} D_t^{Z,f,f}. \tag{112}$$

The derivation of this result equates the debt service receipts of domestic banks to the debt service payments of domestic and foreign households or firms. To close the model, we assume that the economy has zero net exposure to the foreign interbank market, that is $B_{t+1}^{B,B^f} + B_{t+1}^{C,B^f} = 0$.

Let A_{t+1} denote the net foreign asset position, which equals the sum of the assets less liabilities of households, firms, banks and the government:

$$A_{t+1} = \int_0^1 A_{b,t+1}^{B,H} db + \int_0^1 A_{b,t+1}^{B,F} db - D_{t+1}^H - D_{t+1}^F. \tag{113}$$

Imposing equilibrium conditions on government dynamic budget constraint (98) reveals that the fiscal deficit $FD_t = D_{t+1}^G - D_t^G$ equals the sum of interest expenditures, the primary fiscal deficit $PD_t = P_t^G G_t + T_t^{C,D} - T_t$, and the cost of holding foreign exchange reserves,

$$\begin{aligned} D_{t+1}^G - D_t^G &= i_{t-1}^{G^E} D_t^G + P_t^G G_t + T_t^{C,D} - \tau_t^K (P_t^Y Y_t - W_t L_t) - \tau_t^L W_t L_t \\ &\quad - \tau_t^C P_t^C C_t - \sum_Z \tau_{t-1}^Z (1-\delta_t^Z)(\alpha^Z + i_{t-1}^{Z,f})\mathcal{E}_t D_t^{Z,f} + \left[(1+i_{t-1}^B) - (1+i_{t-1}^{B,f})\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\right]\mathcal{E}_{t-1} R_t, \end{aligned} \tag{114}$$

where $Z \in \{H,F\}$. Imposing equilibrium conditions on household dynamic budget constraint (5), and combining it with government dynamic budget constraint (114), firm dividend payment definition (32), bank dividend payment definition (56), output expenditure decomposition (110), and mortgage or corporate credit loss rate decomposition (112) reveals that the current account balance $CA_t = A_{t+1} - A_t$ equals the sum of net international investment income and the trade balance $TB_t = P_t^X X_t - P_t^M M_t$,

$$\begin{aligned} A_{t+1} - A_t = \sum_Z \Bigg[&(1-\delta_t^{Z,f})(\alpha^Z + i_{t-1}^Z)(A_t^{B,Z} - D_t^{Z,h}) \\ &- (1-\delta_t^Z)(\alpha^Z + i_{t-1}^{Z,f})\mathcal{E}_t D_t^{Z,f} - \alpha^Z \left(\int_0^1 A_{b,t}^{B,Z} db - D_t^Z\right)\Bigg] + P_t^X X_t - P_t^M M_t, \end{aligned} \tag{115}$$

where $Z \in \{H,F\}$. The derivation of this result imposes deposit market clearing condition $B_{t+1}^{H,D} = B_{t+1}^{B,D}$, government bond market clearing conditions $D_{t+1}^G = \sum_{v=1}^t V_{v,t}^G S_{v,t+1}^G$ and $(1+i_{t-1}^{G^E})D_t^G = \sum_{v=1}^{t-1}(\Pi_{v,t}^G + V_{v,t}^G)S_{v,t}^G$, stock market clearing conditions $S_{f,t+1}^F = 1$ for all $f \in [0,1]$ and $S_{b,t+1}^B = 1$ for all $b \in [0,1]$, and domestic interbank market clearing condition $B_{t+1}^{B,B^h} + B_{t+1}^{C,B^h} = 0$.

III. The Empirical Framework

Estimation, inference and forecasting are based on an augmented linear state space representation of an approximate multivariate linear rational expectations representation of this DSGE model of the world economy, expressed as a function of its potentially heteroskedastic structural shocks. This multivariate linear rational expectations representation is derived by analytically linearizing the equilibrium conditions of the DSGE model around a stationary deterministic steady state equilibrium that abstracts from long run balanced growth, and consolidating them by substituting out intermediate variables.[2] Its linear state space representation is augmented with empirically flexible trend component specifications for observed endogenous variables that account for long run balanced growth while absorbing intermittent structural breaks. It is also augmented with state dependent conditional heteroskedasticity specifications for structural shocks that generate endogenous risk, by parsimoniously capturing intertemporal dependence of the conditional variances of endogenous variables on their conditional means, yielding a nonlinear empirical framework.

A. Endogenous Variables

In what follows, $\hat{x}_t$ denotes the cyclical component of variable x_t, while $\overline{x}_t$ denotes its trend component, where $x_t = \hat{x}_t + \overline{x}_t$. The relative sizes of the domestic and foreign economies are measured by their steady state equilibrium world output shares w^Y and $w^{Y,f}$, where $w^Y + w^{Y,f} = 1$.

Cyclical Components

Credit unconstrained consumption $\ln \hat{C}_t^U$ depends on its past and expected future values, and is driven by the real interbank rate adjusted by the housing, duration and equity risk premia, according to Euler equation:

$$\begin{aligned} \ln \hat{C}_t^U &= \frac{\alpha^C}{1+\alpha^C} \ln \hat{C}_{t-1}^U + \frac{1}{1+\alpha^C} \mathrm{E}_t \ln \hat{C}_{t+1}^U \\ &\quad -\sigma \frac{1-\alpha^C}{1+\alpha^C} \mathrm{E}_t \left[(\hat{i}_t^B + \phi_H^C \hat{v}_t^H + \phi_B^C \hat{\tilde{v}}_t^B + \phi_S^C \hat{\tilde{v}}_t^S - \hat{\pi}_{t+1}^C) - \frac{1}{1+\tau^C} \Delta \hat{\tau}_{t+1}^C + \Delta \ln \hat{v}_{t+1}^C \right]. \end{aligned} \tag{116}$$

Credit unconstrained consumption is also driven by the change in the consumption tax rate. Credit constrained consumption $\ln \hat{C}_t^C$ satisfies static budget constraint

$$(1+\tau^C)\frac{C}{Y}\left(\ln \frac{\hat{P}_t^C \hat{C}_t^C}{\hat{P}_t^Y \hat{Y}_t} + \frac{1}{1+\tau^C} \hat{\tau}_t^C \right) = (1-\tau^L)\frac{WL}{P^Y Y}\left(\ln \frac{\hat{W}_t \hat{L}_t}{\hat{P}_t^Y \hat{Y}_t} - \frac{1}{1-\tau^L} \hat{\tau}_t^L \right) + \frac{1}{\phi^C} \frac{\hat{T}_t^C}{P_t^Y Y_t}, \tag{117}$$

which equates credit constrained consumption expenditures to household disposable labor income plus transfers.

The unemployment rate depends on its past value, and is driven by employment and the real effective wage, determining the labor force $\ln \hat{N}_t$ according to supply function:

$$\hat{u}_t^L = \alpha^L \hat{u}_{t-1}^L - (1-\alpha^L)\left\{ \mu \ln \frac{\hat{L}_t}{\hat{v}_t^N} - \eta \left[\ln \frac{\hat{W}_t}{\hat{P}_t^C \hat{A}_t^T} - \frac{1}{1-\tau^L} \hat{\tau}_t^L - \frac{1}{1+\tau^C} \hat{\tau}_t^C \right] \right\}. \tag{118}$$

The unemployment rate also depends on the labor income and consumption tax rates. The unemployment rate $\hat{u}_t^L$ satisfies $\hat{u}_t^L = \ln \hat{N}_t - \ln \hat{L}_t$.

The deviation of wage inflation $\hat{\pi}_t^W$ from its partially indexed value depends on its expected future value, and is driven by the contemporaneous and past unemployment rate, according to Phillips curve:

[2] In steady state equilibrium $\nu^C = \nu^{I^H} = \nu^{I^K} = 1$, $\nu^B = \nu^H = \nu^S = \nu^{\delta^H} = \nu^{\delta^F} = \nu^{\mathcal{E}} = \nu^{i^B} = \nu^r = \nu^{G^C} = \nu^{G^I} = \nu^{\tau^K} = \nu^{\tau^L} = \nu^{\tau^C} = \nu^T = \nu^{\kappa^R} = \nu^{\phi^H} = \nu^{\phi^F} = \nu^{\tau^H} = \nu^{\tau^F} = 0$, $\tilde{\nu}^Z = \nu^Z$ for $Z \in \{A,B,S\}$, and $A^{B,Z} / P^Y Y = D^Z / P^Y Y$ for $Z \in \{H,F\}$.

$$\hat{\pi}_t^W - \gamma^L((1-\mu^L)\hat{\pi}_{t-1}^W + \mu^L(\hat{\pi}_{t-1}^C + \hat{g}_{t-1}^{A^T})) = \beta \mathrm{E}_t\left[\hat{\pi}_{t+1}^W - \gamma^L((1-\mu^L)\hat{\pi}_t^W + \mu^L(\hat{\pi}_t^C + \hat{g}_t^{A^T}))\right]$$
$$-\frac{(1-\omega^L)(1-\omega^L\beta)}{\omega^L}\left[\frac{1}{\eta}\frac{1}{1-\alpha^L}(\hat{u}_t^L - \alpha^L\hat{u}_{t-1}^L) - \ln\hat{\vartheta}_t^L\right]. \tag{119}$$

The partially indexed value of wage inflation depends on its past value, as well as past consumption price inflation and trend productivity growth. The wage $\ln\hat{W}_t$ satisfies $\hat{\pi}_t^W = \ln\hat{W}_t - \ln\hat{W}_{t-1}$.

The price of housing $\ln\hat{V}_t^H$ depends on its expected future value, and is driven by the user cost of housing, according to asset pricing relationship:

$$\ln\hat{V}_t^H = \beta \mathrm{E}_t \ln\hat{V}_{t+1}^H + (1-\beta)\mathrm{E}_t \ln\hat{\Pi}_{t+1}^H - (\hat{i}_t^B + \hat{\tilde{v}}_t^B + \hat{v}_t^H). \tag{120}$$

The price of housing is also driven by the interbank rate adjusted by the duration and housing risk premia. The user cost of housing $\ln\hat{\Pi}_t^H$ satisfies

$$\frac{\Pi^H}{P^Y Y}\ln\hat{\Pi}_t^H = \ln(\hat{P}_t^H\hat{H}_t) + \frac{A^{B,H}}{P^Y Y}\left[\alpha^H \ln\hat{B}_t^{H,H} - (1-\delta^H)(\alpha^H + i^H)\ln\hat{C}_t^{H,H}\right] - \frac{I^H}{Y}\ln(\hat{P}_t^I\hat{I}_t^H), \tag{121}$$

where $\frac{\Pi^H}{P^Y Y} = 1 - \left[1 - \frac{\phi^H}{1+\phi^H(1+R^H)}\left(1-(1-\delta^H)\frac{\alpha^H+i^H}{\alpha^H}\right)\right]\frac{I^H}{Y}$. New mortgage borrowing $\ln\hat{B}_t^{H,H}$ satisfies $\ln\hat{B}_t^{H,H} = \frac{\hat{\phi}_t^H}{\phi^H} + \ln(\hat{Q}_t^H\hat{I}_t^H)$, while mortgage debt service cost $\ln\hat{C}_t^{H,H}$ satisfies:

$$\ln\hat{C}_t^{H,H} = \frac{1+i^H}{\alpha^H + i^H}\hat{i}_{t-1}^{H^E} - \hat{\delta}_t^H + \ln\hat{D}_t^H. \tag{122}$$

Mortgage debt $\ln\hat{D}_{t+1}^H$ is accumulated from new mortgage borrowing according to $\ln\hat{D}_{t+1}^H = (1-\alpha^H)\ln\hat{D}_t^H + \alpha^H\ln\hat{B}_t^{H,H}$.

The deviation of residential investment expenditures from nominal output depends on its past and expected future values, and is driven by the relative shadow price of housing, shadow price of mortgage debt and regulatory mortgage loan to value ratio limit, determining residential investment $\ln\hat{I}_t^H$ according to demand function:

$$\ln\frac{\hat{P}_t^I\hat{I}_t^H}{\hat{P}_t^Y\hat{Y}_t} = \frac{1}{1+\beta}\ln\frac{\hat{P}_{t-1}^I\hat{I}_{t-1}^H}{\hat{P}_{t-1}^Y\hat{Y}_{t-1}} + \frac{\beta}{1+\beta}\mathrm{E}_t\ln\frac{\hat{P}_{t+1}^I\hat{I}_{t+1}^H}{\hat{P}_{t+1}^Y\hat{Y}_{t+1}}$$
$$+\frac{1}{\chi^H(1+\beta)}\left[\ln\left(\hat{v}_t^{I^H}\frac{\hat{Q}_t^H}{\hat{P}_t^I}\right) + \phi^H(1+R^H)\left(\ln\frac{\hat{Q}_t^H}{\hat{P}_t^I} - \frac{\hat{\phi}_t^H}{\phi^H}\right) + \phi^H\hat{R}_t^H\right]. \tag{123}$$

The relative shadow price of housing depends on its expected future value, and is driven by the real interbank rate adjusted by the duration and housing risk premia, determining the shadow price of housing $\ln\hat{Q}_t^H$ according to Euler equation:

$$\ln\frac{\hat{Q}_t^H}{\hat{P}_t^I} = \mathrm{E}_t\left[\beta(1-\delta_H)\ln\frac{\hat{Q}_{t+1}^H}{\hat{P}_{t+1}^I} - (\hat{i}_t^B + \hat{\tilde{v}}_t^B + \hat{v}_t^H - \hat{\pi}_{t+1}^I) + (1-\beta(1-\delta_H))\ln\frac{\hat{P}_{t+1}^H}{\hat{P}_{t+1}^I}\right]. \tag{124}$$

The relative shadow price of housing is also driven by the relative implicit rental price of housing. The implicit rental price of housing $\ln\hat{P}_t^H$ satisfies:

$$\ln\frac{\hat{P}_t^H}{\hat{P}_t^C} - \frac{1}{1+\tau^C}\hat{\tau}_t^C = -\frac{1}{\varsigma}\ln\frac{\hat{H}_t}{\hat{C}_t}. \tag{125}$$

The shadow price of mortgage debt $\hat{R}_t^H$ depends on its expected future value, and is driven by the interbank rate adjusted by the duration and housing risk premia, according to Euler equation

$$\frac{\hat{R}_t^H}{R^H} = \mathrm{E}_t\left[\beta(1-\alpha^H)\frac{\hat{R}_{t+1}^H}{R^H} - (\hat{i}_t^B + \hat{\tilde{v}}_t^B + \hat{v}_t^H) + (1-\beta(1-\alpha^H))\frac{1+i^H}{\alpha^H + i^H}\hat{i}_t^{H^E}\right], \tag{126}$$

where $R^H = -\frac{\beta(1-\delta^H)(\alpha^H+i^H)}{1-\beta(1-\alpha^H)}$. The shadow price of mortgage debt is also driven by the effective mortgage loan rate. The housing stock $\ln\hat{H}_{t+1}$ is accumulated from residential investment according to $\ln\hat{H}_{t+1} = (1-\delta_H)\ln\hat{H}_t + \delta_H \ln(\hat{v}_t^{I^H}\hat{I}_t^H)$.[3]

The government bond yield $\hat{i}_t^G$ depends on its expected future value, and is driven by the interbank rate adjusted by the duration risk premium, according to asset pricing relationship:

$$\hat{i}_t^G = \omega^G \beta \mathrm{E}_t \hat{i}_{t+1}^G + \frac{1-\omega^G\beta}{1-\omega^G(1-\omega^G)\beta}(\hat{i}_t^B + \hat{v}_t^B). \tag{127}$$

The term premium $\hat{\mu}_t^B$ depends on its expected future value, and is driven by the duration risk premium, according to:

$$\hat{\mu}_t^B = \omega^G \beta \mathrm{E}_t \hat{\mu}_{t+1}^B + \frac{1-\omega^G\beta}{1-\omega^G(1-\omega^G)\beta}\hat{v}_t^B. \tag{128}$$

The duration risk premium $\hat{v}_t^B$ may be internationally correlated given $\hat{v}_t^B = \lambda^B \hat{v}_t^{B,f} + (1-\lambda^B)\hat{v}_t^B$ where $0 \le \lambda^B \le 1$, capturing international bond market contagion.

Output depends on utilized private physical capital and effective employment, determining employment $\ln\hat{L}_t$ according to production function:

$$\ln\hat{Y}_t = \left(1-\vartheta^Y \frac{WL}{P^Y Y}\right)\ln(\hat{u}_t^K \hat{K}_t) + \vartheta^Y \frac{WL}{P^Y Y}\ln(\hat{A}_t \hat{L}_t). \tag{129}$$

Potential output $\ln\hat{Y}_t^P$ depends on the private physical capital stock and effective labor force according to:

$$\ln\hat{Y}_t^P = \left(1-\vartheta^Y \frac{WL}{P^Y Y}\right)\ln\hat{K}_t + \vartheta^Y \frac{WL}{P^Y Y}\ln(\hat{A}_t \hat{N}_t). \tag{130}$$

The output gap $\ln\hat{Y}_t^G$ satisfies $\ln\hat{Y}_t^G = \ln\hat{Y}_t - \ln\hat{Y}_t^P$. Productivity $\ln\hat{A}_t$ depends on the productivity shifter and public capital intensity according to:

$$\ln\hat{A}_t = \phi^A \ln\hat{v}_t^A + (1-\phi^A)\ln\frac{\hat{K}_t^G}{\hat{N}_t}. \tag{131}$$

The productivity shifter $\ln\hat{v}_t^A$ may be internationally correlated given $\ln\hat{v}_t^A = \lambda^A \ln\hat{v}_t^{A,f} + (1-\lambda^A)\ln\hat{v}_t^A$, where $0 \le \lambda^A \le 1$. Trend productivity $\ln\hat{A}_t^T$ satisfies $\ln\hat{A}_t^T = \rho^{A^T}\ln\hat{A}_{t-1}^T + (1-\rho^{A^T})\ln\hat{A}_t$, while trend productivity growth $\hat{g}_t^{A^T}$ satisfies $\hat{g}_t^{A^T} = \ln\hat{A}_t^T - \ln\hat{A}_{t-1}^T$.

The price of equity $\ln\hat{V}_t^F$ depends on its expected future value, and is driven by corporate profit, according to asset pricing relationship:

$$\ln\hat{V}_t^F = \beta \mathrm{E}_t \ln\hat{V}_{t+1}^F + (1-\beta)\mathrm{E}_t \ln\hat{\Pi}_{t+1}^F - (\hat{i}_t^B + \hat{v}_t^B + \hat{v}_t^S). \tag{132}$$

The price of equity is also driven by the interbank rate adjusted by the duration and equity risk premia. The equity risk premium $\hat{v}_t^S$ may be internationally correlated given $\hat{v}_t^S = \lambda^S \hat{v}_t^{S,f} + (1-\lambda^S)\hat{v}_t^S$ where $0 \le \lambda^S \le 1$, capturing international stock market contagion. Corporate profit $\ln\hat{\Pi}_t^F$ satisfies

$$\begin{aligned}\frac{\Pi^F}{P^Y Y}\ln\hat{\Pi}_t^F &= (1-\tau^K)\left[\ln(\hat{P}_t^Y \hat{Y}_t) - \frac{WL}{P^Y Y}\ln(\hat{W}_t \hat{L}_t)\right] - \left(1-\frac{WL}{P^Y Y}\right)\hat{\tau}_t^K \\ &\quad + \frac{A^{B,F}}{P^Y Y}\left[\alpha^F \ln\hat{B}_t^{F,F} - (1-\delta^F)(\alpha^F + i^F)\ln\hat{C}_t^{F,F}\right] - \frac{I^K}{Y}\ln(\hat{P}_t^I \hat{I}_t^K),\end{aligned} \tag{133}$$

[3] The inclusion of asset risk premia, exclusion of the mortgage loan default rate, and sign on the mortgage loan to value ratio limit in these equations are not microfounded.

where $\frac{\Pi^F}{P^Y Y} = (1-\tau^K)\left(1-\frac{WL}{P^Y Y}\right) - \left[1-\frac{\phi^F}{1+\phi^F(1+R^K)}\left(1-(1-\delta^F)\frac{\alpha^F+i^F}{\alpha^F}\right)\right]\frac{I^K}{Y}$. New corporate borrowing $\ln\hat{B}_t^{F,F}$ satisfies $\ln\hat{B}_t^{F,F} = \frac{\hat{\phi}_t^F}{\phi^F} + \ln(\hat{Q}_t^K \hat{I}_t^K)$, while corporate debt service cost $\ln\hat{C}_t^{F,F}$ satisfies:

$$\ln\hat{C}_t^{F,F} = \frac{1+i^F}{\alpha^F+i^F}\hat{i}_{t-1}^{F^E} - \hat{\delta}_t^F + \ln\hat{D}_t^F. \tag{134}$$

Corporate debt $\ln\hat{D}_{t+1}^F$ is accumulated from new corporate borrowing according to $\ln\hat{D}_{t+1}^F = (1-\alpha^F)\ln\hat{D}_t^F + \alpha^F\ln\hat{B}_t^{F,F}$.

The deviation of business investment expenditures from nominal output depends on its past and expected future values, and is driven by the relative shadow price of private physical capital, shadow price of corporate debt and regulatory corporate loan to value ratio limit, determining business investment $\ln\hat{I}_t^K$ according to demand function:

$$\begin{aligned}\ln\frac{\hat{P}_t^I\hat{I}_t^K}{\hat{P}_t^Y\hat{Y}_t} &= \frac{1}{1+\beta}\ln\frac{\hat{P}_{t-1}^I\hat{I}_{t-1}^K}{\hat{P}_{t-1}^Y\hat{Y}_{t-1}} + \frac{\beta}{1+\beta}\mathrm{E}_t\ln\frac{\hat{P}_{t+1}^I\hat{I}_{t+1}^K}{\hat{P}_{t+1}^Y\hat{Y}_{t+1}} \\ &\quad + \frac{1}{\chi^K(1+\beta)}\left[\ln\left(\hat{v}_t^{I^K}\frac{\hat{Q}_t^K}{\hat{P}_t^I}\right) + \phi^F(1+R^K)\left(\ln\frac{\hat{Q}_t^K}{\hat{P}_t^I} - \frac{\hat{\phi}_t^F}{\phi^F}\right) + \phi^F\hat{R}_t^K\right].\end{aligned} \tag{135}$$

The relative shadow price of private physical capital depends on its expected future value, and is driven by the real interbank rate adjusted by the duration and equity risk premia, determining the shadow price of private physical capital $\ln\hat{Q}_t^K$ according to Euler equation:

$$\ln\frac{\hat{Q}_t^K}{\hat{P}_t^I} = \mathrm{E}_t\left[\beta(1-\delta_K)\ln\frac{\hat{Q}_{t+1}^K}{\hat{P}_{t+1}^I} - (\hat{i}_t^B + \hat{\bar{v}}_t^B + \hat{\bar{v}}_t^S - \hat{\pi}_{t+1}^I) + (1-\beta(1-\delta_K))\left(\eta^K\ln\hat{u}_{t+1}^K - \frac{1}{1-\tau^K}\hat{\tau}_{t+1}^K\right)\right]. \tag{136}$$

The relative shadow price of private physical capital is also driven by the capital utilization and corporate tax rates. The capital utilization rate $\ln\hat{u}_t^K$ satisfies:

$$\ln\hat{u}_t^K = \frac{1}{1+\eta^K}\ln\frac{\hat{W}_t\hat{L}_t}{\hat{P}_t^I\hat{K}_t}. \tag{137}$$

The shadow price of corporate debt $\hat{R}_t^K$ depends on its expected future value, and is driven by the interbank rate adjusted by the duration and equity risk premia, according to Euler equation

$$\frac{\hat{R}_t^K}{R^K} = \mathrm{E}_t\left[\beta(1-\alpha^F)\frac{\hat{R}_{t+1}^K}{R^K} - (\hat{i}_t^B + \hat{\bar{v}}_t^B + \hat{\bar{v}}_t^S) + (1-\beta(1-\alpha^F))\frac{1+i^F}{\alpha^F+i^F}\hat{i}_t^{F^E}\right], \tag{138}$$

where $R^K = -\frac{\beta(1-\delta^F)(\alpha^F+i^F)}{1-\beta(1-\alpha^F)}$. The shadow price of corporate debt is also driven by the effective corporate loan rate. The private physical capital stock $\ln\hat{K}_{t+1}$ is accumulated from business investment according to $\ln\hat{K}_{t+1} = (1-\delta_K)\ln\hat{K}_t + \delta_K\ln(\hat{v}_t^{I^K}\hat{I}_t^K)$.[4]

The deviation of output price inflation $\hat{\pi}_t^Y$ from its partially indexed value depends on its expected future value, and is driven by the labor income share, according to Phillips curve:

$$\hat{\pi}_t^Y - \gamma^Y\hat{\pi}_{t-1}^Y = \beta\mathrm{E}_t(\hat{\pi}_{t+1}^Y - \gamma^Y\hat{\pi}_t^Y) + \frac{(1-\omega^Y)(1-\omega^Y\beta)}{\omega^Y}\left(\ln\frac{\hat{W}_t\hat{L}_t}{\hat{P}_t^Y\hat{Y}_t} + \ln\hat{\vartheta}_t^Y\right). \tag{139}$$

The partially indexed value of output price inflation depends on its past value. The price of output $\ln\hat{P}_t^Y$ satisfies $\hat{\pi}_t^Y = \ln\hat{P}_t^Y - \ln\hat{P}_{t-1}^Y$.

[4] The exclusion of the corporate loan default rate and sign on the corporate loan to value ratio limit in these equations are not microfounded.

Domestic mortgage or corporate debt $\ln\hat{D}_{t+1}^{Z,h}$ depends on total mortgage or corporate debt, as well as the deviation of the mortgage or corporate loan rate from its effective value, according to demand function

$$\ln\hat{D}_{t+1}^{Z,h} = \ln\hat{D}_{t+1}^{Z} - \psi^{B}\frac{1+i^{Z}}{\alpha^{Z}+i^{Z}}(\hat{i}_{t}^{Z} - \hat{i}_{t}^{Z^{E}}), \tag{140}$$

where $Z \in \{H,F\}$. The domestic currency denominated value of external mortgage or corporate debt depends on total mortgage or corporate debt, determining external mortgage or corporate debt $\ln\hat{D}_{t+1}^{Z,f}$ according to demand function:

$$\ln(\hat{\mathcal{E}}_{t}\hat{D}_{t+1}^{Z,f}) = \ln\hat{D}_{t+1}^{Z} - \psi^{B}\left[\hat{\tau}_{t}^{Z} + \frac{1+i^{Z}}{\alpha^{Z}+i^{Z}}\hat{i}_{t}^{Z,f} + \mathrm{E}_{t}\Delta\ln\hat{\mathcal{E}}_{t+1} - \frac{1+i^{Z}}{\alpha^{Z}+i^{Z}}\hat{i}_{t}^{Z^{E}}\right]. \tag{141}$$

The domestic currency denominated value of external mortgage or corporate debt also depends on the deviation of the foreign mortgage or corporate loan rate from its effective value, adjusted by the mortgage or corporate capital control tax and nominal currency depreciation rates. The effective mortgage or corporate loan rate $\hat{i}_{t}^{Z^{E}}$ depends on the mortgage or corporate loan rate according to

$$\frac{1+i^{Z}}{\alpha^{Z}+i^{Z}}\hat{i}_{t}^{Z^{E}} = (1-\phi_{Z}^{B})\frac{1+i^{Z}}{\alpha^{Z}+i^{Z}}\hat{i}_{t}^{Z} + \phi_{Z}^{B}\left[\hat{\tau}_{t}^{Z} + \frac{1+i^{Z}}{\alpha^{Z}+i^{Z}}\hat{i}_{t}^{Z,f} + \mathrm{E}_{t}\Delta\ln\hat{\mathcal{E}}_{t+1}\right], \tag{142}$$

where $\phi_{Z}^{B} = \frac{\mathcal{E}D^{Z,f}}{D^{Z}}$ with $\phi_{Z}^{B}w^{Y}\frac{A^{B,Z}}{P^{Y}Y} = \phi_{Z}^{B,f}w^{Y,f}\frac{A^{B,Z,f}}{P^{Y,f}Y^{f}}$. The effective mortgage or corporate loan rate also depends on the foreign mortgage or corporate loan rate, adjusted by the mortgage or corporate capital control tax and nominal currency depreciation rates.

The money stock $\ln\hat{M}_{t+1}^{S}$ satisfies $\ln\hat{A}_{t+1}^{B} = (1-\kappa^{R})\ln\hat{M}_{t+1}^{S} + \kappa^{R}\ln\hat{K}_{t+1}^{B}$, while bank credit $\ln\hat{A}_{t+1}^{B}$ depends on contemporaneous mortgage and corporate credit according to

$$\frac{A^{B}}{P^{Y}Y}\ln\hat{A}_{t+1}^{B} = \frac{A^{B,H}}{P^{Y}Y}\ln\hat{A}_{t+1}^{B,H} + \frac{A^{B,F}}{P^{Y}Y}\ln\hat{A}_{t+1}^{B,F}, \tag{143}$$

where $\frac{A^{B}}{P^{Y}Y} = \frac{A^{B,H}}{P^{Y}Y} + \frac{A^{B,F}}{P^{Y}Y}$ with $\frac{A^{B,H}}{P^{Y}Y} = \frac{1}{\alpha^{H}}\frac{\phi^{H}}{1+\phi^{H}(1+R^{H})}\frac{I^{H}}{Y}$ and $\frac{A^{B,F}}{P^{Y}Y} = \frac{1}{\alpha^{F}}\frac{\phi^{F}}{1+\phi^{F}(1+R^{K})}\frac{I^{K}}{Y}$. New mortgage or corporate lending $\ln\hat{B}_{t}^{B,Z}$ satisfies $\ln\hat{A}_{t+1}^{B,Z} = (1-\alpha^{Z})\ln\hat{A}_{t}^{B,Z} + \alpha^{Z}\ln\hat{B}_{t}^{B,Z}$, while mortgage or corporate loan income $\ln\hat{C}_{t}^{B,Z}$ satisfies

$$\ln\hat{C}_{t}^{B,Z} = \frac{1+i^{Z}}{\alpha^{Z}+i^{Z}}\hat{i}_{t-1}^{Z} + \ln\hat{A}_{t}^{B,Z}, \tag{144}$$

where $Z \in \{H,F\}$. Mortgage or corporate credit $\ln\hat{A}_{t+1}^{B,Z}$ depends on domestic and foreign external mortgage or corporate debt according to $\ln\hat{A}_{t+1}^{B,Z} = (1-\phi_{Z}^{B})\ln\hat{D}_{t+1}^{Z,h} + \phi_{Z}^{B}\ln\hat{D}_{t+1}^{Z,f,f}$.

Bank retained earnings $\ln\hat{I}_{t}^{B}$ depends on its past and expected future values, and is driven by the relative shadow price of bank capital, according to:

$$\ln\hat{I}_{t}^{B} = \frac{1}{1+\beta}\ln\hat{I}_{t-1}^{B} + \frac{\beta}{1+\beta}\mathrm{E}_{t}\ln\hat{I}_{t+1}^{B} + \frac{1}{\chi^{B}(1+\beta)}\ln\frac{\hat{Q}_{t}^{B}}{\hat{P}_{t}^{Y}}. \tag{145}$$

The relative shadow price of bank capital depends on its expected future value, and is driven by the interbank rate, determining the shadow price of bank capital $\ln\hat{Q}_{t}^{B}$ according to Euler equation:

$$\ln\frac{\hat{Q}_{t}^{B}}{\hat{P}_{t}^{Y}} = \beta\mathrm{E}_{t}\ln\frac{\hat{Q}_{t+1}^{B}}{\hat{P}_{t+1}^{Y}} - \hat{i}_{t}^{B} - (1-\beta)\frac{\eta^{B}}{\kappa^{R}}(\hat{\kappa}_{t+1} - \hat{\kappa}_{t+1}^{R}). \tag{146}$$

The relative shadow price of bank capital is also driven by the deviation of the bank capital ratio from its required value. The bank capital ratio $\hat{\kappa}_{t+1}$ satisfies $\hat{\kappa}_{t+1} = \kappa^{R}(\ln\hat{K}_{t+1}^{B} - \ln\hat{A}_{t+1}^{B})$. The bank capital stock $\ln\hat{K}_{t+1}^{B}$ is accumulated from retained earnings given credit losses according to $\ln\hat{K}_{t+1}^{B} = (1-\delta^{B})(\ln\hat{K}_{t}^{B} - \hat{\delta}_{t}^{B}) + \delta^{B}\ln\hat{I}_{t}^{B}$.

The financial gap $\ln\hat{F}_t$ depends on real nonfinancial private sector debt, as well as the relative prices of housing and equity, according to

$$\ln\hat{F}_t = \phi_B^F \ln\frac{\hat{D}_{t+1}^P}{\hat{P}_t^Y} + \phi_H^F \ln\frac{\hat{V}_t^H}{\hat{P}_t^Y} + \phi_F^F \ln\frac{\hat{V}_t^F}{\hat{P}_t^Y}, \tag{147}$$

where nonfinancial private sector debt $\ln\hat{D}_{t+1}^P$ satisfies $\frac{A^B}{P^Y Y}\ln\hat{D}_{t+1}^P = \frac{A^{B,H}}{P^Y Y}\ln\hat{D}_{t+1}^H + \frac{A^{B,F}}{P^Y Y}\ln\hat{D}_{t+1}^F$. The mortgage or corporate loan default rate $\hat{\delta}_t^Z$ responds inertially to the output and financial gaps according to:

$$\hat{\delta}_t^Z = \rho^{\delta^C}\hat{\delta}_{t-1}^Z - (1-\rho^{\delta^C})\zeta^{\delta^Z}(\ln\hat{Y}_t^G + \zeta^F \ln\hat{F}_t) + \hat{v}_t^{\delta^Z}. \tag{148}$$

The effective mortgage or corporate loan default rate $\hat{\delta}_t^{Z^E}$ satisfies $\hat{\delta}_t^{Z^E} = (1-\phi_Z^B)\hat{\delta}_t^Z + \phi_Z^B\hat{\delta}_t^{Z,f}$. The bank capital destruction rate $\hat{\delta}_t^B$ depends on the effective mortgage and corporate loan default rates according to

$$\delta^B\kappa^R\frac{A^B}{P^Y Y}\left[\frac{1-\delta^B}{\delta^B}\hat{\delta}_t^B + \ln\hat{K}_t^B\right] = \sum_Z \delta^Z(\alpha^Z + i^Z)\frac{A^{B,Z}}{P^Y Y}\left[\frac{1+i^Z}{\alpha^Z + i^Z}\hat{i}_{t-1}^Z + \frac{1-\delta^Z}{\delta^Z}\hat{\delta}_t^{Z^E} + \ln\hat{A}_t^{B,Z}\right], \tag{149}$$

where $\delta^B\kappa^R\frac{A^B}{P^Y Y} = \delta^H(\alpha^H + i^H)\frac{A^{B,H}}{P^Y Y} + \delta^F(\alpha^F + i^F)\frac{A^{B,F}}{P^Y Y}$. The bank capital destruction rate also depends on the bank capital buffer and credit risk exposures.

The change in the mortgage or corporate loan rate $\hat{i}_t^Z$ depends on its expected future value, and is driven by the interbank rate and mortgage or corporate loan rate, according to Phillips curves

$$\begin{aligned}\Delta\hat{i}_t^Z = \beta E_t\Delta\hat{i}_{t+1}^Z + \frac{(1-\omega^C)(1-\omega^C\beta)}{\omega^C}\Bigg\{&\frac{\vartheta^Z}{\beta(1-\delta^Z)(1+i^Z)}\left[\hat{i}_{t-1}^B - \eta^B(1-\beta)\left(\hat{\kappa}_t - \frac{1+\eta^B}{\eta^B}\hat{\kappa}_t^R\right)\right]\\ &+\frac{\alpha^Z + i^Z}{1+i^Z}\left[\hat{\delta}_t^{Z^E} + \frac{\delta^Z}{1-\delta^Z}\ln\frac{\hat{Q}_t^B}{\hat{P}_t^Y} + \ln\hat{\vartheta}_t^Z\right] - \hat{i}_t^Z\Bigg\},\end{aligned} \tag{150}$$

where $\vartheta^Z = \frac{\beta(1-\delta^Z)(\alpha^Z + i^Z)}{1+\kappa^R(1-\beta)-\beta(1-\alpha^Z)}$. The change in the mortgage or corporate loan rate is also driven by the bank capital ratio and its required value, as well as the effective mortgage or corporate loan default rate and relative shadow price of bank capital.

The interbank rate $\hat{i}_t^B$ responds inertially to consumption price inflation and the output gap according to monetary policy rule:

$$\hat{i}_t^B = \rho^{i^B}\hat{i}_{t-1}^B + (1-\rho^{i^B})(\xi^{\pi^C}E_t\hat{\pi}_{t+1}^C + \xi^{Y^G}\ln\hat{Y}_t^G) + \hat{v}_t^{i^B}. \tag{151}$$

The foreign exchange reserve ratio $\hat{r}_{t+1}$ responds to the real exchange rate according to foreign exchange intervention rule:

$$\hat{r}_{t+1} = -\xi^r \ln\hat{\mathcal{Q}}_t + \hat{v}_t^r. \tag{152}$$

Foreign exchange intervention $\widehat{FXI}_t$ satisfies $\widehat{FXI}_t = \Delta\hat{r}_{t+1}$, while the foreign exchange reserve stock $\ln\hat{R}_{t+1}$ satisfies $\hat{r}_{t+1} = r(\ln\hat{\mathcal{E}}_t + \ln\hat{R}_{t+1} - \ln\hat{P}_t^Y - \ln\hat{Y}_t)$.

Public consumption or investment $\ln\hat{G}_t^Z$ responds inertially to the output gap according to fiscal expenditure rule

$$\ln\hat{G}_t^Z = \rho^G\ln\hat{G}_{t-1}^Z - (1-\rho^G)\xi^{G^Z}\ln\hat{Y}_t^G + \hat{v}_t^{G^Z}, \tag{153}$$

where $Z \in \{C, I\}$. The public capital stock $\ln\hat{K}_{t+1}^G$ is accumulated from public investment according to $\ln\hat{K}_{t+1}^G = (1-\delta_G)\ln\hat{K}_t^G + \delta_G\ln\hat{G}_t^I$. The corporate, labor income or consumption tax rate $\hat{\tau}_t^Z$ satisfies fiscal revenue rule

$$\hat{\tau}_t^Z = \rho^\tau\hat{\tau}_{t-1}^Z + \hat{v}_t^{\tau^Z}, \tag{154}$$

where $Z \in \{K, L, C\}$. The mortgage or corporate capital control tax rate $\hat{\tau}_t^Z$ responds inertially to the real domestic currency denominated value of external mortgage or corporate debt according to capital flow management rule

$$\hat{\tau}_t^Z = \rho^{\tau^C} \hat{\tau}_{t-1}^Z + (1-\rho^{\tau^C}) \xi^{\tau^Z} \ln \frac{\hat{\mathcal{E}}_t \hat{D}_{t+1}^{Z,f}}{\hat{P}_t^Y} + \nu_t^{\tau^Z}, \tag{155}$$

where $Z \in \{H, F\}$. The nondiscretionary transfer payment ratio $\frac{\hat{T}_t^{C,N}}{P_t^Y Y_t}$ satisfies $\frac{\hat{T}_t^{C,N}}{P_t^Y Y_t} = \xi^{T^N} \frac{\hat{A}_{t+1}}{P_t^Y Y_t}$, while the discretionary transfer payment ratio $\frac{\hat{T}_t^{C,D}}{P_t^Y Y_t}$ satisfies $\frac{\hat{T}_t^{C,D}}{P_t^Y Y_t} = -\xi^{T^D} \frac{\hat{D}_{t+1}^G}{P_t^Y Y_t} + \hat{\nu}_t^{T}$.

The regulatory bank capital ratio requirement $\hat{\kappa}_{t+1}^R$ responds inertially to real bank credit according to countercyclical capital buffer rule:

$$\hat{\kappa}_{t+1}^R = \rho^{\kappa^R} \hat{\kappa}_t^R + (1-\rho^{\kappa^R}) \xi^{\kappa^R} \ln \frac{\hat{A}_{t+1}^B}{\hat{P}_t^Y} + \hat{\nu}_t^{\kappa^R}. \tag{156}$$

The regulatory mortgage or corporate loan to value ratio limit $\hat{\phi}_t^Z$ responds inertially to real mortgage or corporate debt according to loan to value limit rule

$$\hat{\phi}_t^Z = \rho^{\phi} \hat{\phi}_{t-1}^Z - (1-\rho^{\phi}) \xi^{\phi^Z} \ln \frac{\hat{D}_{t+1}^Z}{\hat{P}_t^Y} + \hat{\nu}_t^{\phi^Z}, \tag{157}$$

where $Z \in \{H, F\}$.

The nominal exchange rate $\ln \hat{\mathcal{E}}_t$ depends on its expected future value, and is driven by the international interbank rate differential, according to uncovered interest parity condition:

$$\ln \hat{\mathcal{E}}_t = \mathrm{E}_t \ln \hat{\mathcal{E}}_{t+1} - (\hat{i}_t^B - \hat{i}_t^{B,f}) + \gamma^B \hat{r}_{t+1} - \zeta^{\mathcal{E}} \frac{\hat{A}_{t+1}}{P_t^Y Y_t} + \hat{\nu}_t^{\mathcal{E}}. \tag{158}$$

The nominal exchange rate is also driven by the foreign exchange reserve and net foreign asset ratios. The real exchange rate $\ln \hat{\mathcal{Q}}_t$ satisfies $\ln \hat{\mathcal{Q}}_t = \ln \hat{\mathcal{E}}_t + \ln \hat{P}_t^{Y,f} - \ln \hat{P}_t^Y$.

The deviation of export price inflation $\hat{\pi}_t^X$ from its partially indexed value depends on its expected future value, and is driven by the price of output relative to exports, according to Phillips curve:

$$\begin{aligned} \hat{\pi}_t^X - \gamma^X((1-\mu^X)\hat{\pi}_{t-1}^X + \mu^X \Delta \ln(\hat{\mathcal{E}}_t \hat{P}_t^{Y,f})) &= \beta \mathrm{E}_t \left[\hat{\pi}_{t+1}^X - \gamma^X((1-\mu^X)\hat{\pi}_t^X + \mu^X \Delta \ln(\hat{\mathcal{E}}_{t+1} \hat{P}_{t+1}^{Y,f})) \right] \\ &+ \frac{(1-\omega^X)(1-\omega^X \beta)}{\omega^X} \left(\ln \frac{\hat{P}_t^Y}{\hat{P}_t^X} + \ln \hat{\vartheta}_t^X \right). \end{aligned} \tag{159}$$

The partially indexed value of export price inflation depends on its past value, as well as contemporaneous domestic currency denominated foreign output price inflation. The price of exports $\ln \hat{P}_t^X$ satisfies $\hat{\pi}_t^X = \ln \hat{P}_t^X - \ln \hat{P}_{t-1}^X$.

The deviation of import price inflation $\hat{\pi}_t^M$ from its partially indexed value depends on its expected future value, and is driven by the domestic currency denominated foreign price of exports relative to imports, according to Phillips curve:

$$\begin{aligned} \hat{\pi}_t^M - \gamma^M((1-\mu^M)\hat{\pi}_{t-1}^M + \mu^M \Delta \ln(\hat{\mathcal{E}}_t \hat{P}_t^{Y,f})) &= \beta \mathrm{E}_t \left[\hat{\pi}_{t+1}^M - \gamma^M((1-\mu^M)\hat{\pi}_t^M + \mu^M \Delta \ln(\hat{\mathcal{E}}_{t+1} \hat{P}_{t+1}^{Y,f})) \right] \\ &+ \frac{(1-\omega^M)(1-\omega^M \beta)}{\omega^M} \left(\ln \frac{\hat{\mathcal{E}}_t \hat{P}_t^{X,f}}{\hat{P}_t^M} + \ln \hat{\vartheta}_t^M \right). \end{aligned} \tag{160}$$

The partially indexed value of import price inflation depends on its past value, as well as contemporaneous domestic currency denominated foreign output price inflation. The price of imports $\ln \hat{P}_t^M$ satisfies $\hat{\pi}_t^M = \ln \hat{P}_t^M - \ln \hat{P}_{t-1}^M$.

The price of absorption $\ln\hat{P}_t^Z$ depends on the price of output, as well as the relative price of imports, according to

$$\ln\frac{\hat{P}_t^Z}{\hat{v}_t^P}=\ln\hat{P}_t^Y+\phi_Z^M\ln\frac{\hat{P}_t^M}{\hat{P}_t^Y}, \tag{161}$$

where $Z\in\{C,I,G\}$. Absorption price inflation $\hat{\pi}_t^Z$ satisfies $\hat{\pi}_t^Z=\ln\hat{P}_t^Z-\ln\hat{P}_{t-1}^Z$. Imports $\ln\hat{M}_t$ depend on private consumption, private investment and public demand according to demand function

$$\vartheta^X\vartheta^M\frac{M}{Y}\ln\frac{\hat{M}_t}{\hat{v}_t^M}=\phi_C^M\frac{C}{Y}\left(\ln\hat{C}_t-\psi^M\ln\frac{\hat{P}_t^M}{\hat{P}_t^C}\right)+\phi_I^M\frac{I}{Y}\left(\ln\hat{I}_t-\psi^M\ln\frac{\hat{P}_t^M}{\hat{P}_t^I}\right)+\phi_G^M\frac{G}{Y}\left(\ln\hat{G}_t-\psi^M\ln\frac{\hat{P}_t^M}{\hat{P}_t^G}\right), \tag{162}$$

where $\vartheta^X\vartheta^M\frac{M}{Y}=\phi_C^M\frac{C}{Y}+\phi_I^M\frac{I}{Y}+\phi_G^M\frac{G}{Y}$ with $w^Y\vartheta^M\frac{M}{Y}=w^{Y,f}\frac{M^f}{Y^f}$. Imports also depend on the corresponding relative prices of imports. Exports $\ln\hat{X}_t$ satisfy $\ln\hat{X}_t=\ln(\hat{v}_t^X\hat{M}_t^f)$.[5]

Nominal output depends on consumption expenditures, investment expenditures, government expenditures, export revenues and import expenditures, determining output $\ln\hat{Y}_t$ according to market clearing condition

$$\ln(\hat{P}_t^Y\hat{Y}_t)=\frac{C}{Y}\ln(\hat{P}_t^C\hat{C}_t)+\frac{I}{Y}\ln(\hat{P}_t^I\hat{I}_t)+\frac{G}{Y}\ln(\hat{P}_t^G\hat{G}_t)+\vartheta^X\vartheta^M\frac{M}{Y}\ln\frac{\hat{P}_t^X\hat{X}_t}{\hat{P}_t^M\hat{M}_t}, \tag{163}$$

where $\frac{C}{Y}+\frac{I}{Y}+\frac{G}{Y}=1$. Private consumption $\ln\hat{C}_t$ satisfies $\ln\hat{C}_t=(1-\phi^C)\ln\hat{C}_t^U+\phi^C\ln\hat{C}_t^C$, while private investment $\ln\hat{I}_t$ satisfies $\frac{I}{Y}\ln\hat{I}_t=\frac{I^H}{Y}\ln\hat{I}_t^H+\frac{I^K}{Y}\ln\hat{I}_t^K$ with $\frac{I}{Y}=\frac{I^H}{Y}+\frac{I^K}{Y}$, and public demand $\ln\hat{G}_t$ satisfies $\frac{G}{Y}\ln\hat{G}_t=\frac{G^C}{Y}\ln\hat{G}_t^C+\frac{G^I}{Y}\ln\hat{G}_t^I$ with $\frac{G}{Y}=\frac{G^C}{Y}+\frac{G^I}{Y}$.

The fiscal deficit ratio $\frac{\widehat{FD}_t}{P_t^YY_t}$ depends on public debt service cost, the primary fiscal deficit ratio and the central bank profit transfer according to dynamic budget constraint:

$$\begin{aligned}\frac{\widehat{FD}_t}{P_t^YY_t}&=\frac{1-\omega^G(1-\omega^G)\beta}{\omega^G\beta}\frac{D^G}{P^YY}\hat{i}_{t-1}^{G^E}\\&+\left(\frac{1-\omega^G(1-\omega^G)\beta}{\omega^G\beta}-1\right)\left(\frac{\hat{D}_t^G}{P_{t-1}^YY_{t-1}}-\frac{D^G}{P^YY}\ln\frac{\hat{P}_t^Y\hat{Y}_t}{\hat{P}_{t-1}^Y\hat{Y}_{t-1}}\right)+\frac{\widehat{PD}_t}{P_t^YY_t}+\frac{r}{\beta}\left(\hat{i}_{t-1}^B-\hat{i}_{t-1}^{B,f}-\ln\frac{\hat{\mathcal{E}}_t}{\hat{\mathcal{E}}_{t-1}}\right).\end{aligned} \tag{164}$$

The effective government rate $\hat{i}_t^{G^E}$ satisfies $\hat{i}_t^{G^E}=\omega^G\hat{i}_{t-1}^{G^E}+(1-\omega^G)\hat{i}_{t-1}^G$. The primary fiscal deficit ratio $\frac{\widehat{PD}_t}{P_t^YY_t}$ depends on the government expenditure, discretionary transfer payment and tax revenue ratios according to:

$$\frac{\widehat{PD}_t}{P_t^YY_t}=\frac{G}{Y}\ln\frac{\hat{P}_t^G\hat{G}_t}{\hat{P}_t^Y\hat{Y}_t}+\frac{\hat{T}_t^{C,D}}{P_t^YY_t}-\frac{\hat{T}_t}{P_t^YY_t}. \tag{165}$$

The transfer payment ratio $\frac{\hat{T}_t^C}{P_t^YY_t}$ satisfies $\frac{\hat{T}_t^C}{P_t^YY_t}=\frac{\hat{T}_t^{C,N}}{P_t^YY_t}+\frac{\hat{T}_t^{C,D}}{P_t^YY_t}$. The tax revenue ratio $\frac{\hat{T}_t}{P_t^YY_t}$ depends on the corporate, labor income and consumption tax rates, as well as the mortgage and corporate capital control tax rates, according to:

$$\begin{aligned}\frac{\hat{T}_t}{P_t^YY_t}&=\hat{\tau}_t^K-\frac{WL}{P^YY}\left(\hat{\tau}_t^K+\tau^K\ln\frac{\hat{W}_t\hat{L}_t}{\hat{P}_t^Y\hat{Y}_t}\right)\\&+\frac{WL}{P^YY}\left(\hat{\tau}_t^L+\tau^L\ln\frac{\hat{W}_t\hat{L}_t}{\hat{P}_t^Y\hat{Y}_t}\right)+\frac{C}{Y}\left(\hat{\tau}_t^C+\tau^C\ln\frac{\hat{P}_t^C\hat{C}_t}{\hat{P}_t^Y\hat{Y}_t}\right)+\sum_Z\phi_Z^B(1-\delta^Z)(\alpha^Z+i^Z)\frac{A^{B,Z}}{P^YY}\hat{\tau}_{t-1}^Z.\end{aligned} \tag{166}$$

The tax revenue ratio also depends on the corporate, labor income and consumption tax bases. The public debt ratio $\frac{\hat{D}_{t+1}^G}{P_t^YY_t}$ satisfies $\frac{\widehat{FD}_t}{P_t^YY_t}=\frac{\hat{D}_{t+1}^G}{P_t^YY_t}-\left(\frac{\hat{D}_t^G}{P_{t-1}^YY_{t-1}}-\frac{D^G}{P^YY}\ln\frac{\hat{P}_t^Y\hat{Y}_t}{\hat{P}_{t-1}^Y\hat{Y}_{t-1}}\right)$.

[5] The inclusion of shocks in these equations is not microfounded.

The current account balance ratio $\frac{\widehat{CA}_t}{P_t^Y Y_t}$ depends on net international investment income and the trade balance ratio according to dynamic budget constraint

$$\frac{\widehat{CA}_t}{P_t^Y Y_t} = \sum_Z \frac{A^{B,Z}}{P^Y Y}\left\{(1-\delta^Z)(\alpha^Z + i^Z)\left\{\phi_Z^B\left[\left(\frac{1+i^Z}{\alpha^Z + i^Z}\hat{i}_{t-1}^Z - \hat{\delta}_t^{Z,f} + \ln \hat{D}_t^{Z,h}\right) - \left(\frac{1+i^Z}{\alpha^Z + i^Z}\hat{i}_{t-1}^{Z,f} - \hat{\delta}_t^Z + \ln(\hat{\mathcal{E}}_t \hat{D}_t^{Z,f})\right)\right] + \ln \frac{\hat{A}_t^{B,Z}}{\hat{D}_t^{Z,h}}\right\} - \alpha^Z \ln \frac{\hat{A}_t^{B,Z}}{\hat{D}_t^Z}\right\} + \frac{\widehat{TB}_t}{P_t^Y Y_t}, \tag{167}$$

where $Z \in \{H,F\}$. The trade balance ratio $\frac{\widehat{TB}_t}{P_t^Y Y_t}$ satisfies $\frac{\widehat{TB}_t}{P_t^Y Y_t} = \vartheta^X \vartheta^M \frac{M}{Y} \ln \frac{\hat{P}_t^X \hat{X}_t}{\hat{P}_t^M \hat{M}_t}$, while the net foreign asset ratio $\frac{\hat{A}_{t+1}}{P_t^Y Y_t}$ satisfies $\frac{\widehat{CA}_t}{P_t^Y Y_t} = \frac{\hat{A}_{t+1}}{P_t^Y Y_t} - \frac{\hat{A}_t}{P_{t-1}^Y Y_{t-1}}$.

Trend Components

The changes in the trend components of the price of output $\ln \bar{P}_t^Y$, output $\ln \bar{Y}_t$, price of consumption $\ln \bar{P}_t^C$, consumption $\ln \bar{C}_t$, investment $\ln \bar{I}_t$, exports $\ln \bar{X}_t$, imports $\ln \bar{M}_t$, price of housing $\ln \bar{V}_t^H$, price of equity $\ln \bar{V}_t^F$, bank credit $\ln \bar{A}_t^B$, nominal exchange rate $\ln \bar{\mathcal{E}}_t$, wage $\ln \bar{W}_t$ and employment $\ln \bar{L}_t$ follow stationary first order autoregressive processes

$$\Delta \bar{x}_t = (1-\rho)\mu_x + \rho \Delta \bar{x}_{t-1} + \bar{\varepsilon}_t^x,\ \bar{\varepsilon}_t^x \mid \mathcal{I}_{t-1} \sim \mathcal{N}(0, \bar{h}^x), \tag{168}$$

where $\bar{x}_t \in \{\ln \bar{P}_t^Y, \ln \bar{Y}_t, \ln \bar{P}_t^C, \ln \bar{C}_t, \ln \bar{I}_t, \ln \bar{X}_t, \ln \bar{M}_t, \ln \bar{V}_t^H, \ln \bar{V}_t^F, \ln \bar{A}_t^B, \ln \bar{\mathcal{E}}_t, \ln \bar{W}_t, \ln \bar{L}_t\}$, with corresponding unconditional means $\mu_x \in \{\pi, g+n, \pi, g+n, g+n, g+n, g+n, \pi+g, \pi+g+n, \pi+g+n, \pi-\pi^f, \pi+g, n\}$ and innovations $\bar{\varepsilon}_t^x \in \{\bar{\varepsilon}_t^{P^Y}, \bar{\varepsilon}_t^Y, \bar{\varepsilon}_t^{P^C}, \bar{\varepsilon}_t^C, \bar{\varepsilon}_t^I, \bar{\varepsilon}_t^X, \bar{\varepsilon}_t^M, \bar{\varepsilon}_t^{V^H}, \bar{\varepsilon}_t^{V^F}, \bar{\varepsilon}_t^{A^B}, \bar{\varepsilon}_t^{\mathcal{E}}, \bar{\varepsilon}_t^W, \bar{\varepsilon}_t^L\}$ having unconditional variances $\bar{h}^x \in \{\bar{\sigma}_{P^Y}^2, \bar{\sigma}_Y^2, \bar{\sigma}_{P^C}^2, \bar{\sigma}_C^2, \bar{\sigma}_I^2, \bar{\sigma}_X^2, \bar{\sigma}_M^2, \bar{\sigma}_{V^H}^2, \bar{\sigma}_{V^F}^2, \bar{\sigma}_{A^B}^2, \bar{\sigma}_{\mathcal{E}}^2, \bar{\sigma}_W^2, \bar{\sigma}_L^2\}$. These trend components converge asymptotically at a common speed determined by ρ to a long run balanced growth path featuring constant inflation at rate π, productivity growth at rate g, and population growth at rate n. In parallel, the changes in the trend components of the interbank rate $\bar{i}_t^B$, government bond yield $\bar{i}_t^G$ and unemployment rate $\bar{u}_t^L$ follow stationary first order autoregressive processes with zero unconditional means

$$\Delta \bar{x}_t = \rho \Delta \bar{x}_{t-1} + \bar{\varepsilon}_t^x,\ \bar{\varepsilon}_t^x \mid \mathcal{I}_{t-1} \sim \mathcal{N}(0, \bar{h}^x), \tag{169}$$

where $\bar{x}_t \in \{\bar{i}_t^B, \bar{i}_t^G, \bar{u}_t^L\}$, with corresponding innovations $\bar{\varepsilon}_t^x \in \{\bar{\varepsilon}_t^{i^B}, \bar{\varepsilon}_t^{i^G}, \bar{\varepsilon}_t^{u^L}\}$ having unconditional variances $\bar{h}^x \in \{\bar{\sigma}_{i^B}^2, \bar{\sigma}_{i^G}^2, \bar{\sigma}_{u^L}^2\}$. These trend components converge asymptotically at the same speed to a long run balanced growth path featuring constant interest and unemployment rates. As an identifying restriction, all innovations are assumed to be contemporaneously uncorrelated.

B. Exogenous Variables

All structural shocks follow stationary first order autoregressive or serially uncorrelated processes, driven by conditionally normally distributed heteroskedastic or homoskedastic innovations.

Conditional Means

The productivity $\ln \hat{v}_t^A$, labor supply $\ln \hat{v}_t^N$, private consumption demand $\ln \hat{v}_t^C$, residential investment demand $\ln \hat{v}_t^{I^H}$, business investment demand $\ln \hat{v}_t^{I^K}$, export demand $\ln \hat{v}_t^X$, import demand $\ln \hat{v}_t^M$, duration risk premium $\hat{v}_t^B$, housing risk premium $\hat{v}_t^H$, equity risk premium $\hat{v}_t^S$ and foreign currency liquidity $\hat{v}_t^{\mathcal{E}}$ shocks follow stationary first order autoregressive processes driven by conditionally normally distributed heteroskedastic innovations

$$\hat{v}_t^Z = \rho_Z \hat{v}_{t-1}^Z + \hat{\varepsilon}_t^Z,\ \hat{\varepsilon}_t^Z \mid \mathcal{I}_{t-1} \sim \mathcal{N}(0, \hat{h}_t^Z), \tag{170}$$

where $\hat{v}_t^Z \in \{\ln \hat{v}_t^A, \ln \hat{v}_t^N, \ln \hat{v}_t^C, \ln \hat{v}_t^{I^H}, \ln \hat{v}_t^{I^K}, \ln \hat{v}_t^X, \ln \hat{v}_t^M, \hat{v}_t^B, \hat{v}_t^H, \hat{v}_t^S, \hat{v}_t^{\mathcal{E}}\}$, with corresponding autoregressive coefficients $\rho_Z \in \{\rho_A, \rho_N, \rho_C, \rho_I, \rho_I, \rho_X, \rho_M, \rho_B, \rho_H, \rho_S, \rho_{\mathcal{E}}\}$ and innovations $\hat{\varepsilon}_t^Z \in \{\hat{\varepsilon}_t^A, \hat{\varepsilon}_t^N, \hat{\varepsilon}_t^C, \hat{\varepsilon}_t^{I^H}, \hat{\varepsilon}_t^{I^K}, \hat{\varepsilon}_t^X, \hat{\varepsilon}_t^M, \hat{\varepsilon}_t^B, \hat{\varepsilon}_t^H, \hat{\varepsilon}_t^S, \hat{\varepsilon}_t^{\mathcal{E}}\}$ having conditional variances $\hat{h}_t^Z \in \{\hat{h}_t^A, \hat{h}_t^N, \hat{h}_t^C, \hat{h}_t^I, \hat{h}_t^I, \hat{h}_t^X, \hat{h}_t^M, \hat{h}_t^B, \hat{h}_t^H, \hat{h}_t^S, \hat{h}_t^{\mathcal{E}}\}$. Furthermore, the output price markup $\ln \hat{\vartheta}_t^Y$, wage markup $\ln \hat{\vartheta}_t^L$, export price markup $\ln \hat{\vartheta}_t^X$, import price markup $\ln \hat{\vartheta}_t^M$ and monetary policy $\hat{v}_t^{i^B}$ shocks follow serially uncorrelated processes driven by conditionally normally distributed homoskedastic innovations

$$\hat{v}_t^Z = \hat{\varepsilon}_t^Z,\ \hat{\varepsilon}_t^Z \mid \mathcal{I}_{t-1} \sim \mathcal{N}(0, \hat{h}^Z), \tag{171}$$

where $\hat{v}_t^Z \in \{\ln \hat{\vartheta}_t^Y, \ln \hat{\vartheta}_t^L, \ln \hat{\vartheta}_t^X, \ln \hat{\vartheta}_t^M, \hat{v}_t^{i^B}\}$, with corresponding innovations $\hat{\varepsilon}_t^Z \in \{\hat{\varepsilon}_t^{\vartheta^Y}, \hat{\varepsilon}_t^{\vartheta^L}, \hat{\varepsilon}_t^{\vartheta^X}, \hat{\varepsilon}_t^{\vartheta^M}, \hat{\varepsilon}_t^{i^B}\}$ having unconditional variances $\hat{h}_t^Z \in \{\hat{\sigma}_{\vartheta^Y}^2, \hat{\sigma}_{\vartheta^L}^2, \hat{\sigma}_{\vartheta^X}^2, \hat{\sigma}_{\vartheta^M}^2, \hat{\sigma}_{i^B}^2\}$. Finally, the mortgage loan markup $\ln \hat{\vartheta}_t^H$, corporate loan markup $\ln \hat{\vartheta}_t^F$, mortgage loan default $\hat{v}_t^{\delta^H}$, corporate loan default $\hat{v}_t^{\delta^F}$, absorption price $\ln \hat{v}_t^P$, foreign exchange intervention $\hat{v}_t^r$, public consumption demand $\hat{v}_t^{G^C}$, public investment demand $\hat{v}_t^{G^I}$, corporate tax rate $\hat{v}_t^{\tau^K}$, labor income tax rate $\hat{v}_t^{\tau^L}$, consumption tax rate $\hat{v}_t^{\tau^C}$, transfer payment $\hat{v}_t^T$, bank capital requirement $\hat{v}_t^{\kappa^R}$, mortgage loan to value limit $\hat{v}_t^{\phi^H}$, corporate loan to value limit $\hat{v}_t^{\phi^F}$, mortgage capital control $\hat{v}_t^{\tau^H}$ and corporate capital control $\hat{v}_t^{\tau^F}$ shocks follow stationary first order autoregressive processes driven by conditionally normally distributed homoskedastic innovations

$$\hat{v}_t^Z = \rho_Z \hat{v}_{t-1}^Z + \hat{\varepsilon}_t^Z,\ \hat{\varepsilon}_t^Z \mid \mathcal{I}_{t-1} \sim \mathcal{N}(0, \hat{h}^Z), \tag{172}$$

where $\hat{v}_t^Z \in \{\ln \hat{\vartheta}_t^H, \ln \hat{\vartheta}_t^F, \hat{v}_t^{\delta^H}, \hat{v}_t^{\delta^F}, \ln \hat{v}_t^P, \hat{v}_t^r, \hat{v}_t^{G^C}, \hat{v}_t^{G^I}, \hat{v}_t^{\tau^K}, \hat{v}_t^{\tau^L}, \hat{v}_t^{\tau^C}, \hat{v}_t^T, \hat{v}_t^{\kappa^R}, \hat{v}_t^{\phi^H}, \hat{v}_t^{\phi^F}, \hat{v}_t^{\tau^H}, \hat{v}_t^{\tau^F}\}$, with corresponding autoregressive coefficients $\rho_Z \in \{\rho_{\vartheta^C}, \rho_{\vartheta^C}, \rho_{\delta^C}, \rho_{\delta^C}, \rho_P, \rho_r, \rho_G, \rho_G, \rho_\tau, \rho_\tau, \rho_\tau, \rho_T, \rho_\kappa, \rho_\phi, \rho_\phi, \rho_{\tau^C}, \rho_{\tau^C}\}$ and innovations $\hat{\varepsilon}_t^Z \in \{\hat{\varepsilon}_t^{\vartheta^H}, \hat{\varepsilon}_t^{\vartheta^F}, \hat{\varepsilon}_t^{\delta^H}, \hat{\varepsilon}_t^{\delta^F}, \hat{\varepsilon}_t^P, \hat{\varepsilon}_t^r, \hat{\varepsilon}_t^{G^C}, \hat{\varepsilon}_t^{G^I}, \hat{\varepsilon}_t^{\tau^K}, \hat{\varepsilon}_t^{\tau^L}, \hat{\varepsilon}_t^{\tau^C}, \hat{\varepsilon}_t^T, \hat{\varepsilon}_t^{\kappa^R}, \hat{\varepsilon}_t^{\phi^H}, \hat{\varepsilon}_t^{\phi^F}, \hat{\varepsilon}_t^{\tau^H}, \hat{\varepsilon}_t^{\tau^F}\}$ having unconditional variances $\hat{h}^Z \in \{\hat{\sigma}_{\vartheta^C}^2, \hat{\sigma}_{\vartheta^C}^2, \hat{\sigma}_{\delta^C}^2, \hat{\sigma}_{\delta^C}^2, \hat{\sigma}_P^2, \hat{\sigma}_r^2, \hat{\sigma}_G^2, \hat{\sigma}_G^2, \hat{\sigma}_\tau^2, \hat{\sigma}_\tau^2, \hat{\sigma}_\tau^2, \hat{\sigma}_T^2, \hat{\sigma}_\kappa^2, \hat{\sigma}_\phi^2, \hat{\sigma}_\phi^2, \hat{\sigma}_{\tau^C}^2, \hat{\sigma}_{\tau^C}^2\}$. As an identifying restriction, all innovations are assumed to be contemporaneously uncorrelated.

Conditional Variances

The conditional variances of the productivity $\hat{h}_t^A$, labor supply $\hat{h}_t^N$, consumption demand $\hat{h}_t^C$, investment demand $\hat{h}_t^I$, export demand $\hat{h}_t^X$ and import demand $\hat{h}_t^M$ shocks are loglinear functions of the past changes in and levels of the domestic and foreign output gaps

$$\ln \hat{h}_t^Z = \ln \hat{\sigma}_Z^2 - \lambda^M (\psi_{\Delta Y} \Delta \ln \hat{Y}_{t-1}^{G,f} - \psi_Y \ln \hat{Y}_{t-1}^{G,f}) - (1-\lambda^M)(\psi_{\Delta Y} \Delta \ln \hat{Y}_{t-1}^G - \psi_Y \ln \hat{Y}_{t-1}^G), \tag{173}$$

where $Z \in \{A, N, C, I, X, M\}$, while $0 \le \lambda^M \le 1$. If $\psi_{\Delta Y} > 0$ then the conditional variances of these macroeconomic shocks are higher during a domestic or foreign business cycle contraction than during an expansion, while if $\psi_Y > 0$ then they are higher when domestic or foreign capacity pressures are elevated than when they are subdued. In parallel, the conditional variances of the duration risk premium $\hat{h}_t^B$, housing risk premium $\hat{h}_t^H$, equity risk premium $\hat{h}_t^S$ and foreign currency liquidity $\hat{h}_t^{\mathcal{E}}$ shocks are loglinear functions of the past changes in and levels of the domestic and foreign financial gaps

$$\ln \hat{h}_t^Z = \ln \hat{\sigma}_Z^2 - \lambda^F (\psi_{\Delta F} \Delta \ln \hat{F}_{t-1}^f - \psi_F \ln \hat{F}_{t-1}^f) - (1-\lambda^F)(\psi_{\Delta F} \Delta \ln \hat{F}_{t-1} - \psi_F \ln \hat{F}_{t-1}), \tag{174}$$

where $Z \in \{B, H, S, \mathcal{E}\}$, while $0 \le \lambda^F \le 1$. If $\psi_{\Delta F} > 0$ then the conditional variances of these financial shocks are higher during a domestic or foreign financial cycle downturn than during an upturn, while if $\psi_F > 0$ then they are higher when domestic or foreign financial vulnerabilities are elevated than when they are subdued. These loglinear functional forms ensure positive conditional variances $\hat{h}_t^Z$, which converge asymptotically to unconditional variances of $\hat{\sigma}_Z^2$, given that the lagged output and financial gaps are stationary predetermined endogenous variables with zero unconditional means.

IV. Estimation, Inference, and Forecasting

We interpret our linearized DSGE model with state dependent conditional heteroskedasticity as a representation of the joint probability distribution of the data, and estimate a restricted version of it using the Bayesian maximum likelihood procedure documented in Adrian and Vitek (2020). This restricted version of the model consolidates or eliminates those structural shocks that are weakly identified by our macrofinancial time series data sets. Given the parameter estimates, we then conduct scenario analysis using the unrestricted version of the model.

A. Estimation

The set of parameters associated with our heteroskedastic linearized DSGE model is partitioned into two subsets. Those parameters that enter into the conditional mean function of its augmented linear state space representation are calibrated, whereas those that enter into its conditional variance function are estimated. Most calibrated and all estimated parameters are subject to cross-economy equality restrictions.

Calibrated Parameters

The calibrated values of steady state equilibrium parameters are reported in Table 4 of Appendix A. All reported steady state equilibrium great ratios are set to their sample average values for the economy under consideration, while all unreported ones are derived from these given steady state equilibrium relationships. In steady state equilibrium, the import share of private investment ϕ_I^M is set to 1.25 times that of private consumption ϕ_C^M and public demand ϕ_G^M. The steady state equilibrium annualized depreciation rate of the housing stock δ_H is set to 5.0 percent, while that of the private physical capital stock δ_K is set to 10.0 percent, and that of the public capital stock δ_G is set to 7.5 percent. In steady state equilibrium, the annualized mortgage i^H and corporate i^F loan rates are set to 4.0 and 6.0 percent, while the annualized mortgage α^H and corporate α^F loan amortization rates are set to 2.5 and 5.0 percent, and the annualized mortgage δ^H and corporate δ^F loan default rates are set to 1.0 and 2.0 percent, respectively. Finally, the output ϑ^Y, export ϑ^X and import ϑ^M price markup parameters are all set to imply steady state equilibrium price markups of 25 percent.

The calibrated values of behavioral parameters lie within the range of estimates reported in the existing empirical literature where available, and are differentiated across the advanced versus emerging market economies under consideration where appropriate, as reported in Table 5 of Appendix A. For example, the habit persistence in consumption α^C and labor supply α^L parameters are both set to 0.8, while the subjective discount factor β is set to imply a steady state equilibrium annualized interbank rate of 2.0 percent. The intertemporal elasticity of substitution in consumption σ is set to 1.0, while the intratemporal elasticity of substitution in labor supply η is set to 0.5. In addition, the share of credit constrained households ϕ^C is set to 20 percent in the advanced economies under consideration, versus 25 percent in the emerging market economies. Furthermore, the adjustment cost parameters for residential χ^H and business χ^K investment are both set to 3.0. The partial indexation parameters for output price γ^Y, wage γ^L, export price γ^X and import price γ^M determination are all set to 0.8. In addition, the nominal rigidity parameters for output price ω^Y and wage ω^L determination are both set to imply average reoptimization intervals of 8 quarters in the advanced economies under consideration, versus 6 quarters in the emerging market economies. Furthermore, the nominal rigidity parameters for export ω^X and import ω^M price determination are both set to imply average reoptimization intervals of 6 quarters, while the financial friction parameter for nominal mortgage and corporate loan rate determination ω^B is set to imply an average adjustment interval of 4 quarters. The intratemporal elasticities of substitution in import ψ^M and external bank credit ψ^B demand are both set to 0.5. Finally, the international bond and stock market contagion coefficients λ^B and λ^S are set to 40 and 50 percent in the advanced economies under consideration, versus 60 and 75 percent in the emerging market economies, respectively.

The calibrated values of policy rule parameters also lie within the range of estimates reported in the existing empirical literature where available, as reported in Table 6 of Appendix A. In the monetary policy rule, the response coefficient on consumption price inflation ξ^{π^C} is set to 2.0, while that on the output gap ξ^{Y^G} is set to 0.5 at the annual frequency. In the foreign exchange intervention rule, the steady state equilibrium foreign exchange reserve ratio r is set to its sample average value for the economy under consideration, while the response coefficient on the real exchange rate ξ^r is set to 0.1 at the annual frequency. In the fiscal expenditure rules, the response coefficients for public consumption ξ^{G^C} and investment ξ^{G^I} with respect to the output gap are both set to 1.0. In the fiscal revenue rules, the steady state equilibrium corporate τ^K, labor income τ^L and consumption τ^C tax rates are set to their sample average values for the economy under consideration. In the countercyclical capital buffer rule, the steady state equilibrium bank capital ratio κ^R is set to 5.0 percent, while the response coefficient on real bank credit ξ^{κ^R} is set to 0.1. In the loan to value limit rules, the steady state equilibrium mortgage ϕ^H and corporate ϕ^F loan to value ratio limits are both set to 80 percent, while the response coefficients on real mortgage ξ^{ϕ^H} and corporate ξ^{ϕ^F} debt are both set to 0.5. Finally, in the capital flow management rules, the response coefficients on the real domestic currency denominated value of external mortgage ξ^{τ^H} and corporate ξ^{τ^F} debt are both set to 0.1 at the annual frequency.

The calibrated values of trend component parameters are reported in Table 7 of Appendix A. The common speed of convergence parameter ρ is set to imply a half life of deviations from the long run balanced growth path of 10 years. Along this balanced growth path, the constant inflation π, productivity growth g and population growth n rates are set to their sample average values for the economy under consideration.

Estimated Parameters

Estimation of the restricted version of our heteroskedastic linearized DSGE model is based on the levels of a total of 31 endogenous variables observed for four pairs of economies over the sample period 2001Q1 to 2019Q4. Each pair of economies combines a small open advanced or emerging market economy with the United States, which is taken to represent the rest of the world. This choice is motivated by our focus on the global financial cycle, but the rest of the world could alternatively be represented by another systemic economy such as the Euro Area, depending on the application. The small open advanced economies under consideration are Korea and Switzerland, while the small open emerging market economies are South Africa and Thailand. These economies have experienced volatile capital flows, span a wide range of structural characteristics, and satisfy our data availability requirements.

The observed macroeconomic and financial market variables under consideration are the gross domestic product price deflator, real gross domestic product, the headline consumer price index, real private consumption, real private investment, real exports, real imports, the nominal policy interest rate, a benchmark long term nominal government bond yield, a house price index, an equity price index, credit to the nonfinancial private sector, the nominal bilateral exchange rate, a nominal wage index, the unemployment rate, and employment. The macroeconomic variables are all seasonally adjusted. The nominal wage index is derived from observed labor income and employment. For Switzerland and the United States, the estimated shadow nominal policy interest rate substitutes for the observed nominal policy interest rate, to account for the effects of unconventional monetary policy at the effective lower bound. All data was obtained from the GDS database compiled by the IMF where available, and from databases produced by the BIS or HAVER otherwise.

The restricted version of our model consolidates or eliminates those structural shocks that are weakly identified by our macrofinancial time series data sets. In particular, we consolidate the residential and business investment demand shocks into an investment demand shock, the public consumption and investment demand shocks into a public demand shock, and the mortgage and corporate loan to value limit shocks into a loan to value limit shock. In addition, we eliminate the mortgage and corporate loan markup shocks, the mortgage and corporate loan default shocks, the export and import price markup shocks, the foreign exchange intervention shock, the corporate, labor income and consumption tax rate shocks, the transfer payment shock, the bank capital requirement shock, and the mortgage and corporate capital control shocks.

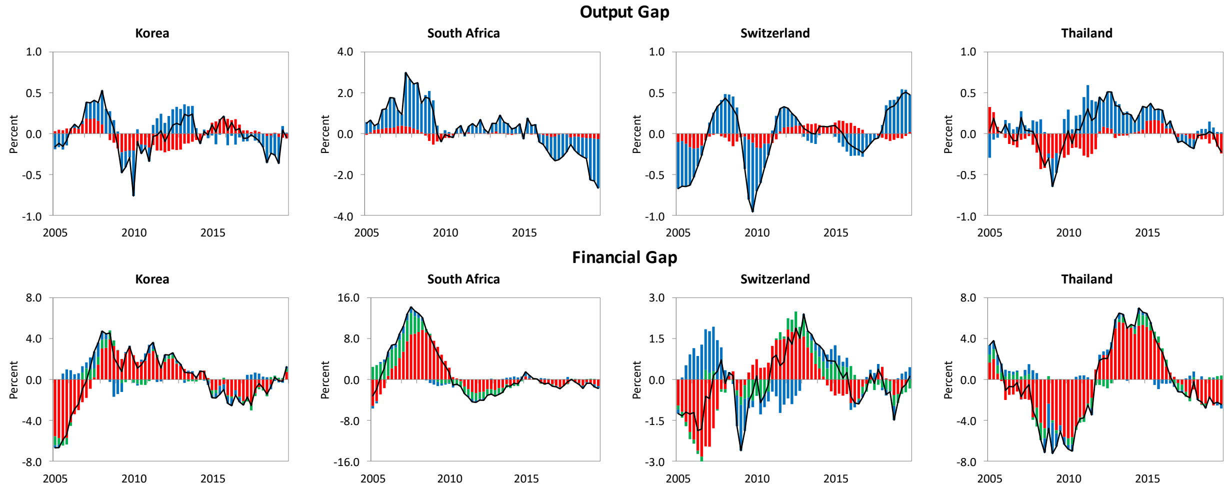
Parameter estimation results based on effective sample period 2001Q3 to 2019Q4 are reported in Table 9 of Appendix A. The data is very informative regarding many of the estimated parameters that enter into the conditional variance function, as evidenced by substantial updates from prior to posterior. The prior means of the slope parameters associated with our state dependent conditional heteroskedasticity mechanism are aligned with the estimated posterior modes reported for different economies in Adrian and Vitek (2020). The posterior modes of these slope parameters exhibit substantial economy specific deviations around these common prior means.

B. Inference

Our estimated DSGE model generates output and financial gap estimates, which summarize the business and financial cycles. As shown in Figure 1, our output gap estimates indicate abrupt synchronized business cycle contractions during the global financial crisis (GFC) in all of the economies under consideration, followed by recoveries of varying intensity. These business cycle dynamics reflect reinforcing fluctuations in capital and labor utilization.[6] In parallel, our financial gap estimates indicate synchronized financial cycle downturns during the GFC, followed by upturns that lag behind the business cycle recoveries. These financial cycle dynamics reflect reinforcing credit cycle dynamics and asset price adjustments.

[6] The output gap satisfies $\ln \hat{Y}_t^G = \left(1 - \vartheta^Y \frac{WL}{P^Y Y}\right) \ln \hat{u}_t^K - \vartheta^Y \frac{WL}{P^Y Y} \hat{u}_t^L$.

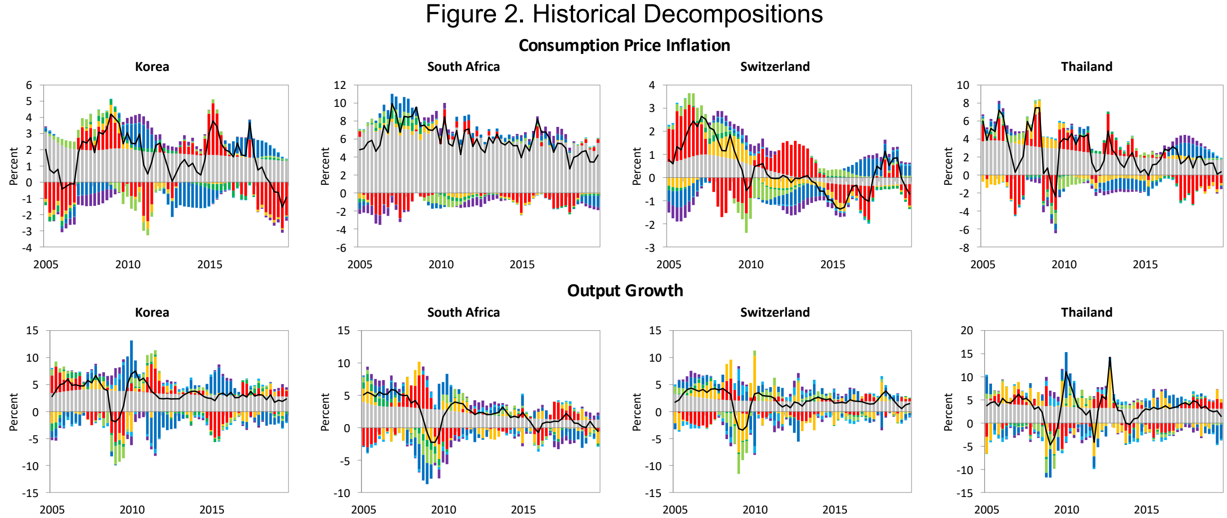
Figure 1. Business and Financial Cycles



Note: Decomposes smoothed estimates of the output gap ■ into contributions from the capital utilization ■ and unemployment ■ rate gaps. Also decomposes smoothed estimates of the financial gap ■ into contributions from the debt ■, house price ■ and equity price ■ gaps.

Our historical decompositions of consumption price inflation and output growth yield economically plausible explanations of their evolution over time, as shown in Figure 2. Those of consumption price inflation attribute deviations from trend rates primarily to macroeconomic shocks, in particular to price and wage markup shocks. In parallel, our historical decompositions of output growth attribute business cycle dynamics around trend growth rates primarily to macroeconomic and financial shocks, in particular to demand and risk premia shocks. Consistent with conventional views, these historical decompositions identify adverse demand and risk premia shocks in the United States as the primary drivers of the business cycle contractions that occurred during the GFC. Finally, they identify policy shocks as countercyclical mitigants of these business cycle contractions, particularly in the advanced economies under consideration.

Figure 2. Historical Decompositions

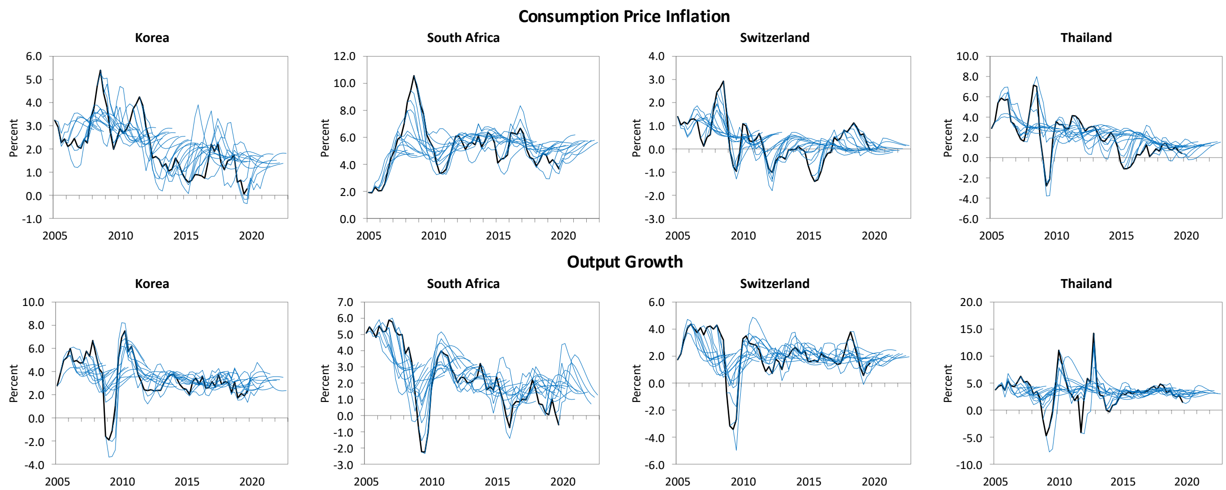


Note: Decomposes observed consumption price inflation or output growth ■ as measured by the seasonal logarithmic difference of the consumption price level or output into the sum of a trend component ■ and contributions from domestic macroeconomic ■, foreign macroeconomic ■, domestic financial ■, foreign financial ■, domestic policy ■, foreign policy ■, and world terms of trade ■ shocks.

C. Forecasting

Our sequential dynamic forecasts of consumption price inflation and output growth track their observed realizations reasonably accurately, as shown in Figure 3. We measure the dynamic forecasting performance of our estimated DSGE model relative to that of a random walk in sample at the 1 to 12 quarter horizons on the basis of the logarithm of the *U* statistic due to Theil (1966), which equals the ratio of root mean squared prediction errors. We find that the model dominates a random walk in terms of predictive accuracy for consumption price inflation and output growth, for all of the economies under consideration. Indeed, over the holdout sample period 2005Q2 to 2019Q4, the root mean squared prediction error is 19 to 40 percent lower for consumption price inflation, and 40 to 46 percent lower for output growth, on average across horizons.

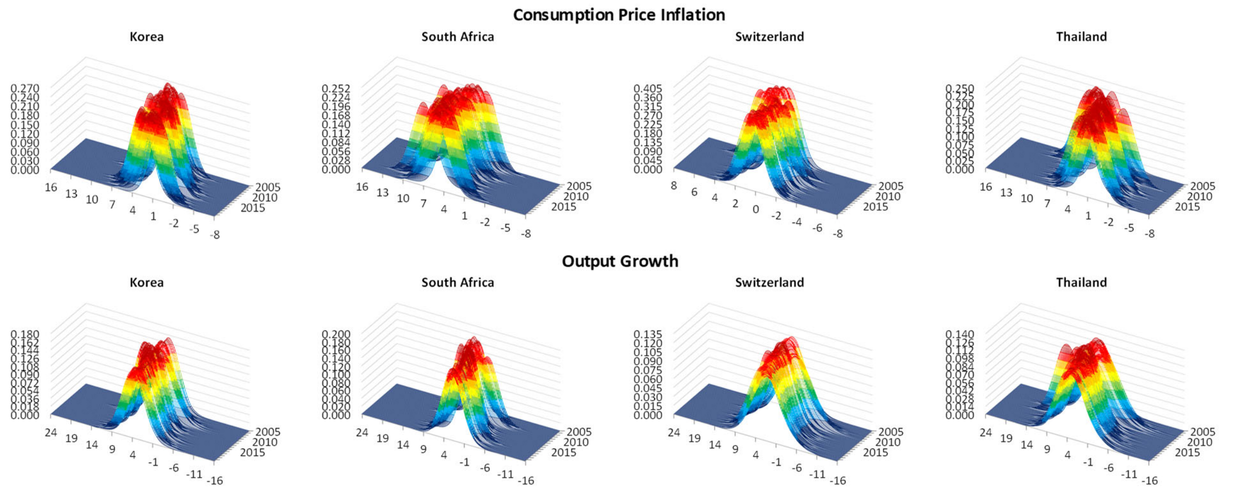
Figure 3. Sequential Dynamic Forecasts



Note: Depicts observed consumption price inflation or output growth ■ as measured by the seasonal difference of the logarithm of the consumption price level or output versus sequential dynamic forecasts ■.

Policymakers are often concerned with the risks surrounding their central forecasts. In our model, these risks vary systematically with respect to the phase and position of the domestic and global business and financial cycles. As shown in Figure 4, the entire conditional distribution of output growth, and not just its central tendency, evolves over time. Indeed, both the location and scale of the conditional distribution of output growth shift in response to changes in domestic and global macroeconomic and financial conditions and vulnerabilities. Moreover, these shifts are negatively correlated, generating conditional distributions that are skewed to the downside, particularly at times of domestic or global macrofinancial stress. In contrast, the conditional distribution of consumption price inflation is roughly symmetric.

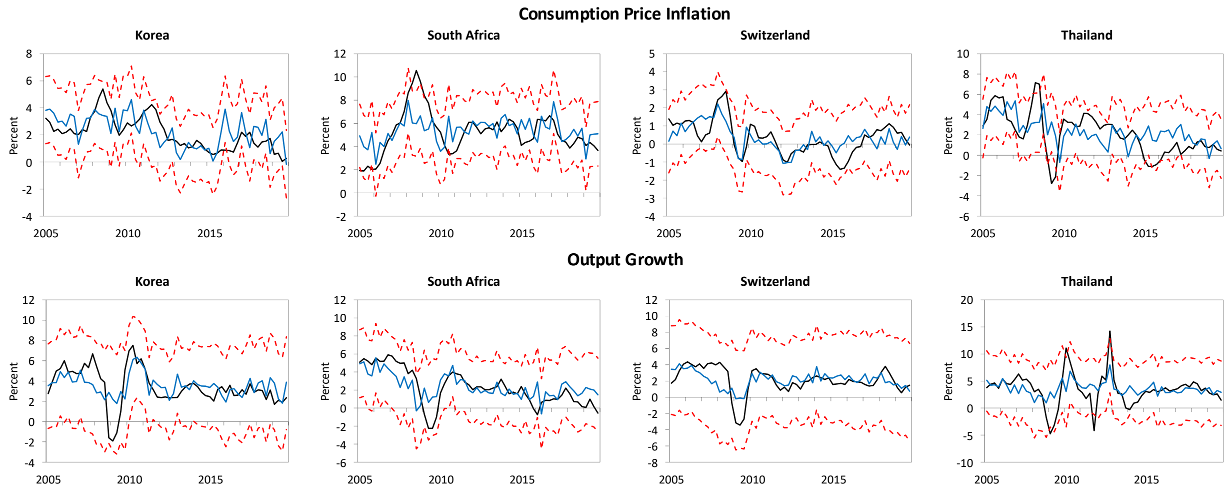
Figure 4. Conditional Distributions



Note: Depicts the one year ahead predicted probability density function of consumption price inflation or output growth, estimated using a normal kernel based on a Monte Carlo simulation with 100,000 replications.

Consistent with the key stylized facts of growth at risk documented in Adrian and Vitek (2020), in our model the conditional lower quantile of output growth is more volatile than its conditional mean, which in turn is more volatile than its conditional upper quantile, as shown in Figure 5. This reflects the strong dependence of output growth dynamics on demand and risk premia shocks, which are conditionally heteroskedastic. Given the specification of our state dependent conditional heteroskedasticity mechanism, adverse demand and risk premia shocks not only reduce the conditional mean of output growth, but also raise its conditional variance, and vice versa. This generates a negative correlation between the conditional mean and variance of output growth, which ranges from -0.14 to -0.49 across the economies under consideration. In contrast, for consumption price inflation the conditional lower and upper quantiles are roughly equally volatile in our model. This reflects the strong dependence of consumption price inflation dynamics on price and wage markup shocks, which are conditionally homoskedastic.

Figure 5. Conditional Quantiles



Note: Depicts observed consumption price inflation or output growth ■ as measured by the seasonal difference of the logarithm of the consumption price level or output versus the one year ahead predicted mean ■ and 0.05 and 0.95 quantiles ■. The quantiles are estimated based on a Monte Carlo simulation with 100,000 replications.

V. Policy Analysis

Having verified that our estimated DSGE model yields economically plausible historical decompositions and reasonably accurate sequential dynamic forecasts of consumption price inflation and output growth, we proceed to conduct policy analysis using it. In particular, we quantify its monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, and capital flow management transmission mechanisms with impulse responses. We then jointly optimize the response coefficients of the simple instrument rules governing the conduct of these policies. Finally, we examine the jointly optimized responses of these policies under domestic and global financial cycle upturn and downturn scenarios, with and without policy space constraints.

In what follows, note that under the parameterization of our model, Korea and Switzerland have well anchored inflation expectations, whereas South Africa and Thailand have less well anchored inflation expectations, as reflected in the values of the nominal rigidity parameters for output price ω^Y and wage ω^L determination. Furthermore, Switzerland and Thailand have relatively high trade openness, whereas Korea and South Africa have relatively low trade openness, as reflected in the value of the steady state equilibrium import ratio M/Y. Finally, Switzerland and South Africa have the largest unhedged foreign currency denominated mortgage and corporate external debt exposures, while Korea and Thailand have the smallest, as reflected in the values of the steady state equilibrium external debt ratios $\mathcal{E}D^{H,f}/P^YY$ and $\mathcal{E}D^{F,f}/P^YY$, respectively.[7]

[7] Calibration of the mortgage and corporate external debt exposures is based on the Locational Banking Statistics and Debt Securities Statistics databases compiled by the BIS. The mortgage external debt exposures capture cross-border bank credit to households, while the corporate external debt exposures capture cross-border bank credit to and international debt securities issued by nonfinancial firms. We assume that these observed nonfinancial private sector external debt exposures are entirely foreign currency denominated, and that they are 75 percent currency hedged for Switzerland versus 25 percent for the other small open economies under consideration, motivated by Du and Schreger (2021).

A. Policy Transmission Mechanisms

Our estimated DSGE model features extensive interactions among its monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, and capital flow management transmission mechanisms. We quantify these policy transmission mechanisms and interactions with impulse responses.

Monetary Policy

A monetary easing through an interbank rate cut lowers bank lending rates and raises asset prices, as shown in Figure 6 of Appendix B. The resultant loosening of financial conditions stimulates private domestic demand, in particular residential and business investment. The currency depreciates in nominal and real terms, slightly increasing exports and moderately offsetting the rise in imports. Output expands more than potential, and the output gap rises while the unemployment rate falls, associated with higher price and wage inflation. The currency depreciation also increases import price inflation, amplifying and accelerating the rise in consumption price inflation. Quantitatively, lowering the interbank rate by one percentage point boosts consumption price inflation by 0.2 to 0.3 percentage points peak after 2 to 4 quarters, and output by 0.3 to 0.4 percent peak after 3 to 4 quarters, across the economies under consideration. Bank credit rises with mortgage and corporate debt. The fiscal deficit ratio of the consolidated public sector initially falls, reflecting a valuation gain on foreign exchange reserves held by the central bank, contributing to the reduction in the public debt ratio. The current account balance ratio also falls, reflecting higher import expenditures, reducing the net foreign asset ratio.

Foreign Exchange Intervention

A foreign exchange intervention through reserve sales appreciates the currency, slightly decreasing exports and moderately raising imports, as shown in Figure 7 of Appendix B. Quantitatively, lowering the foreign exchange reserve ratio by one percentage point appreciates the currency by 1.5 percent on impact in nominal and real terms, consistent with the empirical estimates of Adler, Lisack and Mano (2019).[8] Output contracts more than potential, and the output gap falls while the unemployment rate rises, associated with lower price and wage inflation. The currency appreciation also reduces import price inflation, amplifying and accelerating the fall in consumption price inflation. The central bank cuts the interbank rate to mitigate the falls in consumption price inflation and the output gap, stimulating private domestic demand, in particular residential and business investment. Bank credit eventually rises with mortgage and corporate debt, while external debt falls due to a valuation effect. The fiscal deficit ratio of the consolidated public sector initially increases, reflecting a valuation loss on foreign exchange reserves held by the central bank, contributing to the rise in the public debt ratio. The current account balance ratio eventually falls, reflecting lower export receipts and higher import expenditures, reducing the net foreign asset ratio.

[8] The panel regression on which these empirical estimates are based covers a wide sample of advanced and emerging market economies, including all of the small open economies under consideration in this paper.

Fiscal Policy

A public consumption or investment based fiscal stimulus boosts public demand, while raising the fiscal deficit and public debt ratios, as shown in Figure 8 or Figure 9 of Appendix B. Output expands more than potential, and the output gap rises while the unemployment rate falls, associated with higher price and wage inflation. Quantitatively, the peak output multiplier for a public consumption based fiscal stimulus ranges from 0.7 to 1.0, while that for a public investment based fiscal stimulus ranges from 0.7 to 1.1, across the economies under consideration. But the expansionary effects of the public investment based fiscal stimulus are far more persistent, reflecting the productivity gains from building up the public capital stock. To stabilize consumption price inflation and output, the central bank hikes the interbank rate, and the currency appreciates in real terms. Private domestic demand initially rises as output expands, then falls as financial conditions tighten. Substitution from domestic to external mortgage and corporate debt occurs. The current account balance ratio falls, reflecting higher import expenditures, reducing the net foreign asset ratio.

A corporate, labor income or consumption tax based fiscal stimulus boosts private domestic demand, while raising the fiscal deficit and public debt ratios, as shown in Figure 10 to Figure 12 of Appendix B. A corporate tax rate cut expands output more than potential by incentivizing labor demand more than labor supply, and the output gap rises while the unemployment rate falls, associated with higher price and wage inflation. In contrast, a labor income or consumption tax rate cut expands output less than potential by incentivizing labor supply more than labor demand, and the output gap falls while the unemployment rate rises, associated with lower price and wage inflation. Quantitatively, the peak output multiplier for a corporate tax rate cut ranges from 0.1 to 0.2, while that for a labor income tax rate cut ranges from 0.4 to 0.6, and that for a consumption tax rate cut ranges from 0.5 to 0.8, across the economies under consideration. Given their opposite effects on consumption price inflation and the output gap, the central bank hikes the interbank rate in response to a corporate tax rate cut, but cuts it in response to a labor income or consumption tax rate cut. The increase in private domestic demand induced by a corporate tax rate cut is concentrated in business investment, whereas that induced by a labor income or consumption tax rate cut is broad-based. In all cases, bank credit rises with mortgage or corporate debt. The current account balance ratio falls, reflecting higher import expenditures, reducing the net foreign asset ratio.

A targeted transfer payment based fiscal stimulus boosts private consumption, while raising the fiscal deficit and public debt ratios, as shown in Figure 13 of Appendix B. Output expands more than potential, and the output gap rises while the unemployment rate falls, associated with higher price and wage inflation. Quantitatively, the peak output multiplier for a targeted transfer payment based fiscal stimulus ranges from 0.7 to 1.2 across the economies under consideration, reflecting differences in their share of credit constrained households and trade openness. To stabilize consumption price inflation and output, the central bank hikes the interbank rate, and the currency appreciates in real terms. Residential and business investment initially rise as output expands, then fall as financial conditions tighten. Bank credit rises then falls with mortgage and corporate debt, while substitution from domestic to external debt occurs. The current account balance ratio falls, reflecting higher import expenditures, reducing the net foreign asset ratio.

Macroprudential Policy

A macroprudential tightening through a countercyclical capital buffer increase widens bank lending spreads, enabling banks to accumulate capital through retained earnings, as shown in Figure 14 of Appendix B. The increases in real mortgage and corporate loan rates reduce residential and business investment. Output contracts more than potential, and the output gap falls while the unemployment rate rises, associated with lower price and wage inflation. The central bank cuts the interbank rate to mitigate the falls in consumption price inflation and the output gap. Bank credit falls with mortgage and corporate debt, while substitution from domestic to external debt occurs. The fiscal deficit ratio increases, reflecting lower nominal output, raising the public debt ratio. The current account balance ratio also increases, reflecting lower import expenditures, raising the net foreign asset ratio.

In response to a macroprudential tightening through a mortgage or corporate loan to value limit reduction, residential or business investment falls, as shown in Figure 15 or Figure 16 of Appendix B. The associated reduction in mortgage or corporate debt lowers bank credit. Output contracts more than potential, and the output gap falls while the unemployment rate rises, associated with lower price and wage inflation. The central bank cuts the interbank rate to mitigate the falls in consumption price inflation and the output gap. The fiscal deficit ratio increases, reflecting lower nominal output, raising the public debt ratio. The current account balance ratio also increases, reflecting lower import expenditures, raising the net foreign asset ratio.

Capital Flow Management

Capital flow management through a mortgage or corporate capital control tightening raises the cost of cross-border mortgage or corporate borrowing, as shown in Figure 17 or Figure 18 of Appendix B. Bank credit rises as households or firms substitute from external to domestic mortgage or corporate debt, whereas residential or business investment falls. Output contracts more than potential, and the output gap falls while the unemployment rate rises, associated with lower price and wage inflation. The central bank cuts the interbank rate to mitigate the falls in consumption price inflation and the output gap. The currency depreciates only slightly in real terms, because raising the tax rate applicable to cross-border mortgage or corporate borrowing alters the composition of capital inflows without reducing the total much, consistent with the empirical findings of Magud, Reinhart and Rogoff (2018). The fiscal deficit ratio falls, reflecting higher capital control revenues, reducing the public debt ratio. The current account balance ratio increases, reflecting lower import expenditures, raising the net foreign asset ratio.

B. Optimized Policy Rules

Suppose that the government has preferences defined over inflation and output stabilization objectives, as well as instrument smoothing objectives, represented by intertemporal loss function

$$\mathcal{L}_t = (1-\beta)\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \ell(\hat{\pi}_s^C, \ln \hat{Y}_s^G, \hat{\boldsymbol{z}}_s), \tag{175}$$

where $\hat{\boldsymbol{z}}_s = (\hat{i}_s^B, \hat{r}_{s+1}, \ln \hat{G}_s^C, \ln \hat{G}_s^I, \hat{\kappa}_{s+1}^R, \hat{\phi}_s^H, \hat{\phi}_s^F, \hat{\tau}_s^H, \hat{\tau}_s^F)$. The N policy instruments under consideration are the interbank rate, the foreign exchange reserve ratio, public consumption and investment, the bank capital ratio requirement, the mortgage and corporate loan to value ratio limits, and the mortgage and corporate capital control tax rates. For fiscal policy, we abstract from the tax rates and transfer payments, because in practice these policy instruments are linked to automatic fiscal stabilizers, and are rarely used to provide fiscal stimulus.

The intratemporal loss function quadratically penalizes the deviations of consumption price inflation from target and output from potential, as well as the deviations of the policy instruments from their steady state equilibrium values,

$$\ell(\hat{\pi}_s^C, \ln \hat{Y}_s^G, \hat{\boldsymbol{z}}_s) = (\hat{\pi}_s^C)^2 + \lambda_0 (\ln \hat{Y}_s^G)^2 + \sum_{i=1}^{N} \lambda_i (\hat{z}_{i,s})^2, \tag{176}$$

where $\lambda_i \geq 0$ for all $i = 0,...,N$. As specified, this intratemporal loss function does not represent an independent financial stability objective, which is instead internalized in the inflation and output stabilization objectives. Note that its conditional mean depends on the conditional means and variances of its arguments:

$$\mathrm{E}_t \ell(\hat{\pi}_s^C, \ln \hat{Y}_s^G, \hat{\boldsymbol{z}}_s) = \left[(\mathrm{E}_t \hat{\pi}_s^C)^2 + \mathrm{Var}_t(\hat{\pi}_s^C)\right] + \lambda_0 \left[(\mathrm{E}_t \ln \hat{Y}_s^G)^2 + \mathrm{Var}_t(\ln \hat{Y}_s^G)\right] + \sum_{i=1}^{N} \lambda_i \left[(\mathrm{E}_t \hat{z}_{i,s})^2 + \mathrm{Var}_t(\hat{z}_{i,s})\right]. \quad (177)$$

By making the conditional variances of all endogenous variables state dependent, our endogenous risk mechanism has the potential to alter the optimal conduct of policy under quadratic loss, by capturing intertemporal risk-return policy tradeoffs. For example, stimulating the economy with monetary easing builds up financial vulnerabilities in our framework, which makes drawing large shocks more likely under our state dependent conditional heteroskedasticity mechanism, which further puts growth at risk if such shocks tighten financial conditions. As shown in Adrian and Vitek (2020), accounting for this macrofinancial feedback loop calls for accompanying monetary easing with more aggressive macroprudential tightening, to enhance the resilience of the banking sector to financial vulnerabilities while leaning against their buildup.

Suppose that the government minimizes its intertemporal loss function under long run commitment to its policy rules with respect to their response coefficients, subject to the structure of the world economy as represented by the rest of our estimated DSGE model. Note that this constrained minimization problem takes as given our postulated functional dependence of policy instruments on intermediate targets. We consider a flexible inflation targeting regime with a dual mandate, and set the weight on output fluctuations λ_0 to 0.50. To account for instrument smoothing, we set the weights on the policy instruments under consideration λ_i to 1.00 for all $i = 1,...,N$. We evaluate the intertemporal loss function by forecasting the means and variances of its annualized arguments out 25 years, conditional on the estimated state of the world economy. Under long run commitment, we then average this intertemporal loss function across all historical states, to eliminate its dependence on initial conditions. Finally, we numerically minimize this average intertemporal loss function, jointly with respect to the response coefficients of the relevant policy rules, subject to inequality constraints on them.

The optimized policy rule response coefficients are all positive, as shown in Table 1. This absence of corner solutions implies that all of the policies under consideration should be systematically used to help stabilize inflation and output in our framework, on average across states of the world economy. Across the economies under consideration, monetary policy should respond aggressively to expected future consumption price inflation and moderately to the output gap. Indeed, our optimized monetary policy rules are similar to that advocated by Taylor (1993). In the pursuit of inflation and output stabilization objectives, foreign exchange intervention should respond mildly to the change in the real exchange rate, by adjusting the foreign exchange reserve ratio in response to its level. This finding is consistent with Lama and Medina (2020), who also rationalize leaning against real exchange rate changes through foreign exchange intervention under a flexible inflation targeting regime. Fiscal policy should respond moderately to the output gap, by adjusting public consumption and investment over the business cycle. Macroprudential policy should respond mildly to real bank credit, by adjusting the countercyclical capital buffer over the credit cycle. It should also respond mildly to real mortgage and corporate debt, by adjusting the mortgage and corporate loan to value ratio limits. Finally, capital flow management should respond mildly to real external mortgage and corporate debt, by adjusting the mortgage and corporate capital control tax rates.

Table 1. Optimized Policy Rule Response Coefficients

	Korea	South Africa	Switzerland	Thailand
Monetary policy				
ξ^{π^C}	1.6663	1.5050	1.4337	1.7387
ξ^{Y^G}	0.8447 / S	0.1787 / S	0.6652 / S	0.3137 / S
Foreign exchange intervention				
ξ^{r}	0.0258S	0.0036S	0.0481S	0.0032S
Fiscal policy				
ξ^{G^C}	1.6330	0.9694	1.6255	1.3297
ξ^{G^I}	1.5909	0.9079	1.6179	1.2938
Macroprudential policy				
ξ^{κ^R}	0.0166	0.0094	0.0161	0.0100
ξ^{ϕ^H}	0.0854	0.0438	0.0481	0.0439
ξ^{ϕ^F}	0.0723	0.0560	0.0889	0.0503
Capital flow management				
ξ^{τ^H}	$0.0182 f(\alpha^H, i^H)$	$0.0124 f(\alpha^H, i^H)$	$0.0171 f(\alpha^H, i^H)$	$0.0109 f(\alpha^H, i^H)$
ξ^{τ^F}	$0.0205 f(\alpha^F, i^F)$	$0.0189 f(\alpha^F, i^F)$	$0.0178 f(\alpha^F, i^F)$	$0.0111 f(\alpha^F, i^F)$

Note: The parameterization is a function of the seasonal frequency S, evaluated at $S = 4$. Also, $f(\alpha^Z, i^Z) = \frac{1+i^Z}{\alpha^Z + i^Z}\frac{1}{S}$ for $Z \in \{H, F\}$.

While the absence of corner solutions implies in principle that all of the policies under consideration should systematically respond to all shocks in our continuous framework, in practice the prescribed adjustments to policy instrument settings will often fall short of conventional discrete response thresholds. For example, monetary policy responses through interbank rate adjustments are conventionally measured in 25 basis point increments. If comparable thresholds are applied to the other policy instruments under consideration, then the magnitudes of our optimized policy rule response coefficients imply that foreign exchange intervention, macroprudential policy and capital flow management responses will rarely be warranted in practice. Indeed, they will only be warranted in response to large changes in the relevant intermediate targets, which tend to arise from sequences of large mutually reinforcing shocks.

The substantial variation in the optimized policy rule response coefficients across economies reflects differences in their calibrated structural characteristics and estimated shock exposures. A general principle that emerges from examining these patterns is that economies with larger international trade and financial exposures should more actively use foreign exchange intervention and capital flow management. Intuitively, foreign exchange intervention tends to be more effective at stabilizing inflation and output in economies with higher trade openness due to stronger exchange rate pass-through and expenditure switching. In parallel, capital flow management tends to be more effective at stabilizing economies with larger unhedged external foreign currency denominated debt exposures due to more sensitive financial conditions and vulnerabilities, which influence growth at risk. Indeed, this calibrated structural characteristic is strongly associated with the optimized intensity of capital flow management in our framework.

This general principle is conditional on foreign exchange intervention and capital flow management being effective. Its application in practice is also conditional on their response thresholds being crossed. In our model, foreign exchange intervention affects the real exchange rate under our assumption that $\gamma^B > 0$, which ensures that the foreign currency liquidity regulation cost drives a wedge into the uncovered interest parity condition, indicative of a shallow foreign exchange market. Capital flow management affects capital inflows if nonfinancial private sector external debt exposures exist, which in our model are foreign currency denominated and unhedged. If foreign exchange intervention or capital flow management do not affect these intermediate targets, then the intertemporal loss function does not tradeoff inflation and output stabilization benefits from using them against instrument smoothing costs, driving the corresponding optimized policy rule response coefficients to zero.

C. Optimized Policy Responses

We now examine how the policy mix should be adjusted in response to domestic and global financial cycle upturns and downturns, with and without policy space constraints. This scenario analysis is conditional on our jointly optimized monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, and capital flow management rules. To focus on differences in the optimized policy responses across the small open economies under consideration, we consider stylized scenarios based on harmonized assumptions. In reality, greater differentiation across the advanced versus emerging market economies may be expected, reflecting phenomena that we abstract from such as safe haven capital inflows to government bond markets in the former group at times of stress.

Financial Cycle Upturn Scenarios

Our domestic and global financial cycle upturn scenarios assume a gradual loosening of financial conditions and rise in confidence, in either the small open economy or rest of the world, as detailed in Table 2. In particular, the compression of duration, housing and equity risk premia reduces the government bond yield and raises the prices of housing and equity. In addition, higher foreign currency liquidity appreciates the currency of the small open economy. Furthermore, the compression of mortgage and corporate loan markups narrows the mortgage and corporate loan spreads. Finally, higher confidence among households and firms further raises private domestic demand.

Table 2. Financial Cycle Upturn Scenario Assumptions

Layer 1: Asset prices	
Term premium, duration risk premium shocks	-50 basis points
Relative price of housing, housing risk premium shocks	+5 percent
Relative price of equity, equity risk premium shocks	+10 percent
Real exchange rate, foreign currency liquidity shocks	+/-5 percent
Layer 2: Bank credit	
Mortgage loan spread, mortgage loan markup shocks	-50 basis points
Corporate loan spread, corporate loan markup shocks	-100 basis points
Layer 3: Confidence	
Private consumption, private consumption demand shocks	+0.5 percent
Residential investment, residential investment demand shocks	+2.0 percent
Business investment, business investment demand shocks	+2.0 percent

Note: All scenario assumptions are expressed as deviations from baseline at the annual frequency, with effects phased in over two years. They apply to the small open economy under the domestic financial cycle upturn scenario, and to the rest of the world under the global financial cycle upturn scenario. Under both scenarios, the small open economy experiences currency appreciation.

Under our domestic and global financial cycle upturn scenarios, looser financial conditions and higher confidence stimulate private domestic demand, in particular residential and business investment, as shown in Figure 19 or Figure 20 of Appendix C. Under our domestic financial cycle upturn scenario, this gradual loosening of financial conditions reflects both higher asset prices and narrower bank lending spreads. In contrast, under our global financial cycle upturn scenario, it mainly reflects a lower government bond yield and higher price of equity. These asset price adjustments are transmitted from the rest of the world to the small open economy under consideration via international bond and stock market contagion effects, which are stronger for the emerging market economies. Under both scenarios, output initially expands more than potential, and the output gap rises while the unemployment rate falls, associated with higher output price and wage inflation. But consumption price inflation falls due to appreciation of the currency, which reduces import price inflation. It also induces expenditure switching from exports to imports, mitigating the output expansion. As a result, exports fall moderately under our domestic financial cycle upturn scenario, but rise substantially under our global financial cycle upturn scenario, driven by higher private domestic demand in the rest of the world. Finally, financial vulnerabilities build up under both scenarios, reflected in higher bank credit, as well as higher mortgage and corporate debt, in particular external corporate debt.

Under these domestic and global financial cycle upturn scenarios, if the economy under consideration has well anchored inflation expectations and relatively low trade openness, then the central bank can look through the temporary fall in consumption price inflation, and hikes the interbank rate to stabilize output. In contrast, if the economy has less well anchored inflation expectations and relatively high trade openness, then the central bank initially cuts the interbank rate to raise consumption price inflation to target, amplifying the output expansion. Nevertheless, foreign exchange intervention limits the need for a procyclical interbank rate cut, with the central bank leaning against the currency appreciation through reserve purchases, mitigating the fall in consumption price inflation. In addition, countercyclical fiscal consolidation by the government helps stabilize output, through lower public consumption and investment expenditures. Furthermore, macroprudential tightening leans against the buildup of financial vulnerabilities, through a higher countercyclical capital buffer, as well as lower mortgage and corporate loan to value limits. Finally, capital flow management leans against the buildup of external corporate debt, through a corporate capital control tightening.

Quantitatively, monetary policy plays the primary role in stabilizing consumption price inflation and output under these domestic and global financial cycle upturn scenarios, as shown in Figure 23 to Figure 30 of Appendix D. Foreign exchange intervention plays a supporting role in raising consumption price inflation to target, through reserve purchases to depreciate the currency. The destabilizing effect of foreign exchange intervention on output is offset by fiscal policy, through expenditure based fiscal consolidation which reinforces expenditure switching from imports to exports. In addition, automatic fiscal stabilizers are allowed to operate fully, further mitigating the output expansion. While macroprudential policy and capital flow management have much smaller effects on the conditional means of consumption price inflation and the output gap, they help maintain macroeconomic stability by safeguarding financial stability, by leaning against the buildup of financial vulnerabilities that put growth at risk. In economies with relatively large financial exposures, this significantly mitigates the buildup of bank credit, as well as mortgage and corporate debt, in particular external corporate debt.

Financial Cycle Downturn Scenarios

Our domestic and global financial cycle downturn scenarios are qualitatively symmetric to our domestic and global financial cycle upturn scenarios, but are quantitatively more severe. They assume an abrupt tightening of financial conditions and fall in confidence, in either the small open economy or rest of the world, as detailed in Table 3. In particular, the decompression of duration, housing and equity risk premia raises the government bond yield and reduces the prices of housing and equity. In addition, lower foreign currency liquidity depreciates the currency of the small open economy. Furthermore, the decompression of mortgage and corporate loan markups widens the mortgage and corporate loan spreads. Finally, lower confidence among households and firms further reduces private domestic demand.

Table 3. Financial Cycle Downturn Scenario Assumptions

Layer 1: Asset prices	
Term premium, duration risk premium shocks	+100 basis points
Relative price of housing, housing risk premium shocks	-10 percent
Relative price of equity, equity risk premium shocks	-20 percent
Real exchange rate, foreign currency liquidity shocks	+/-10 percent
Layer 2: Bank credit	
Mortgage loan spread, mortgage loan markup shocks	+100 basis points
Corporate loan spread, corporate loan markup shocks	+200 basis points
Layer 3: Confidence	
Private consumption, private consumption demand shocks	-1.0 percent
Residential investment, residential investment demand shocks	-4.0 percent
Business investment, business investment demand shocks	-4.0 percent

Note: All scenario assumptions are expressed as deviations from baseline at the annual frequency, with effects phased in over one year. They apply to the small open economy under the domestic financial cycle downturn scenario, and to the rest of the world under the global financial cycle downturn scenario. Under both scenarios, the small open economy experiences currency depreciation.

Under our domestic and global financial cycle downturn scenarios, tighter financial conditions and lower confidence depress private domestic demand, in particular residential and business investment, as shown in Figure 21 or Figure 22 of Appendix C. Under our domestic financial cycle downturn scenario, this abrupt tightening of financial conditions reflects both lower asset prices and wider bank lending spreads. In contrast, under our global financial cycle downturn scenario, it mainly reflects a higher government bond yield and lower price of equity, transmitted via international bond and stock market contagion effects. Under both scenarios, output initially contracts more than potential, and the output gap falls while the unemployment rate rises, associated with lower output price and wage inflation. But consumption price inflation rises due to depreciation of the currency, while expenditure switching from imports to exports mitigates the output contraction. As a result, exports rise moderately under our domestic financial cycle downturn scenario, but fall substantially under our global financial cycle downturn scenario, driven by lower private domestic demand in the rest of the world. Finally, financial vulnerabilities unwind under both scenarios, reflected in lower bank credit, as well as lower mortgage and corporate debt, in particular external corporate debt.

Under these domestic and global financial cycle downturn scenarios, if the economy under consideration has well anchored inflation expectations and relatively low trade openness, then the central bank can look through the temporary rise in consumption price inflation, and cuts the interbank rate to stabilize output. In contrast, if the economy has less well anchored inflation expectations and relatively high trade openness, then the central bank initially hikes the interbank rate to reduce consumption price inflation to target, amplifying the output contraction. This prediction is consistent with the empirical finding of Vegh and Vuletin (2013), that many emerging market economies tend to respond to capital outflow surges with procyclical monetary policy tightening. Nevertheless, foreign exchange intervention limits the need for a procyclical interbank rate hike, with the central bank leaning against the currency depreciation through reserve sales, mitigating the rise in consumption price inflation. This use of foreign exchange intervention during a financial cycle downturn parallels Adrian, Erceg, Kolasa, Lindé and Zabczyk (2021), who emphasize the resultant monetary autonomy gain. In addition, countercyclical fiscal stimulus by the government helps stabilize output, through higher public consumption and investment expenditures. Furthermore, macroprudential easing helps support bank credit supply through a lower countercyclical capital buffer, as well as bank credit demand through higher mortgage and corporate loan to value limits. Finally, capital flow management limits the retrenchment of cross-border corporate borrowing, through a corporate capital control easing.

Quantitatively, monetary policy plays the primary role in stabilizing consumption price inflation and output under these domestic and global financial cycle downturn scenarios, as shown in Figure 31 to Figure 38 of

Appendix D. Foreign exchange intervention plays a supporting role in reducing consumption price inflation to target, through reserve sales to appreciate the currency. The destabilizing effect of foreign exchange intervention on output is offset by fiscal policy, through expenditure based fiscal stimulus. In addition, automatic fiscal stabilizers are allowed to operate fully, further mitigating the output contraction. While macroprudential policy and capital flow management have much smaller effects on the conditional means of consumption price inflation and the output gap, they help maintain macroeconomic stability by safeguarding financial stability, by supporting domestic bank credit supply, as well as domestic and cross-border bank credit demand.

VI. CONCLUSION

Recurrent capital inflow and outflow surges—often associated with domestic or global financial cycle upturns and downturns—confront policymakers in small open advanced and emerging market economies with complex policy tradeoffs. To maintain macroeconomic and financial stability amid volatile capital flows, these policymakers have developed toolkits spanning some combination of monetary policy, foreign exchange intervention, fiscal policy, macroprudential policy, or capital flow management. Optimally adjusting such a high dimensional policy mix in response to shocks while internalizing tradeoffs requires an IPF.

This paper develops and estimates a medium-scale heteroskedastic linearized DSGE model of the world economy, disaggregated into a pair of asymmetric economies, to help support the IPF. Our model integrates the full range of policies used to cope with recurrent capital inflow and outflow surges. Applying it to four small open advanced and emerging market economies, our optimal policy analysis broadly supports their observed tendency to respond to domestic or global financial cycle upturns and downturns with eclectic policy mix adjustments. We find that economies with larger international trade and financial exposures should more actively use foreign exchange intervention and capital flow management, under some conditions. We illustrate this general principle by simulating domestic and global financial cycle upturn and downturn scenarios using our model, conditional on our optimized policy rules. When unconstrained, monetary policy plays the primary role in stabilizing consumption price inflation and output. Foreign exchange intervention enhances monetary autonomy through a supporting role in stabilizing consumption price inflation, while its destabilizing effect on output under these scenarios is offset by fiscal policy. Finally, macroprudential policy and capital flow management lean against financial developments that put growth at risk.

Our policy analysis framework is subject to important caveats. Notably, the specification of our endogenous risk mechanism is not derived from microeconomic foundations, so its slope coefficients may not be invariant to policy rule changes, exposing our policy analysis to the critique due to Lucas (1976). In addition, the frequent use of foreign exchange intervention and capital flow management can change structural characteristics of the financial markets on which these policies operate, altering their transmission mechanisms. While adopted from the inflation targeting literature, the loss function that we use is inconsistent with our model, as choosing the response coefficients of our policy rules to minimize it does not maximize the welfare of the representative household. Furthermore, these policy rules restrict the functional dependence of policy instruments on intermediate targets to postulated simple linear relationships, so their policy prescriptions may depart from the unconstrained optimum. Finally, jointly optimizing these policy rules disregards institutional realities that may preclude such a high degree of policy coordination in practice. Despite these caveats, we view our model as a useful approximation to reality—and our policy analysis framework as a powerful tool—to help guide policymakers in adjusting their policy mix to cope with capital flow surges in an integrated way.

Appendix A. Parameter Values

Table 4. Calibrated Steady State Equilibrium Parameters

	Korea	South Africa	Switzerland	Thailand	United States
C/Y	0.5122	0.6050	0.5463	0.5292	0.6761
I/Y	0.2523	0.1588	0.2096	0.1820	0.1699
I^H/Y	0.0362	0.0362	0.0314	0.0362	0.0410
I^K/Y	0.2161	0.1226	0.1782	0.1458	0.1289
G/Y	0.2356	0.2362	0.2441	0.2888	0.1540
G^C/Y	0.1717	0.1997	0.2154	0.2126	0.1134
G^I/Y	0.0639	0.0365	0.0287	0.0762	0.0406
M/Y	0.1831	0.1678	0.2988	0.2909	…
WL/P^YY	0.6667	0.6667	0.6667	0.6667	0.6667
w^Y	0.0689	0.0186	0.0340	0.0194	…
$\mathcal{E}D^{H,f}/P^YY$	$0.0001S$	$0.0024S$	$0.0061S$	$0.0011S$	…
$\mathcal{E}D^{F,f}/P^YY$	$0.0401S$	$0.0585S$	$0.0365S$	$0.0266S$	…
D^G/P^YY	$0.3126S$	$0.4072S$	$0.4721S$	$0.4220S$	$0.8572S$
δ_H	$0.0500/S$	$0.0500/S$	$0.0500/S$	$0.0500/S$	$0.0500/S$
δ_K	$0.1000/S$	$0.1000/S$	$0.1000/S$	$0.1000/S$	$0.1000/S$
δ_G	$0.0750/S$	$0.0750/S$	$0.0750/S$	$0.0750/S$	$0.0750/S$
i^H	$0.0400/S$	$0.0400/S$	$0.0400/S$	$0.0400/S$	$0.0400/S$
i^F	$0.0600/S$	$0.0600/S$	$0.0600/S$	$0.0600/S$	$0.0600/S$
α^H	0.0250	0.0250	0.0250	0.0250	0.0250
α^F	0.0500	0.0500	0.0500	0.0500	0.0500
δ^H	$0.0100f(\alpha^H,i^H)$	$0.0100f(\alpha^H,i^H)$	$0.0100f(\alpha^H,i^H)$	$0.0100f(\alpha^H,i^H)$	$0.0100f(\alpha^H,i^H)$
δ^F	$0.0200f(\alpha^F,i^F)$	$0.0200f(\alpha^F,i^F)$	$0.0200f(\alpha^F,i^F)$	$0.0200f(\alpha^F,i^F)$	$0.0200f(\alpha^F,i^F)$
ϑ^Y	1.2500	1.2500	1.2500	1.2500	1.2500
ϑ^X	1.2500	1.2500	1.2500	1.2500	1.2500
ϑ^M	1.2500	1.2500	1.2500	1.2500	1.2500

Note: The calibration is a function of the seasonal frequency S, evaluated at $S=4$. Also, $f(\alpha^Z,i^Z)=\frac{1+i^Z}{\alpha^Z+i^Z}\frac{1}{S}$ for $Z\in\{H,F\}$.

Table 5. Calibrated Behavioral Parameters

	Korea	South Africa	Switzerland	Thailand	United States
α^C	0.8000	0.8000	0.8000	0.8000	0.8000
α^L	0.8000	0.8000	0.8000	0.8000	0.8000
β	$1/(1+0.0200/S)$	$1/(1+0.0200/S)$	$1/(1+0.0200/S)$	$1/(1+0.0200/S)$	$1/(1+0.0200/S)$
χ^H	3.0000	3.0000	3.0000	3.0000	3.0000
χ^K	3.0000	3.0000	3.0000	3.0000	3.0000
χ^B	0.5000	0.5000	0.5000	0.5000	0.5000
η	0.5000	0.5000	0.5000	0.5000	0.5000
η^K	1.0000	1.0000	1.0000	1.0000	1.0000
η^B	25.0000	25.0000	25.0000	25.0000	25.0000
γ^Y	0.8000	0.8000	0.8000	0.8000	0.8000
γ^L	0.8000	0.8000	0.8000	0.8000	0.8000
γ^X	0.8000	0.8000	0.8000	0.8000	0.8000
γ^M	0.8000	0.8000	0.8000	0.8000	0.8000
γ^B	$0.9000/S$	$0.9000/S$	$0.9000/S$	$0.9000/S$	…
λ^A	0.5000	0.5000	0.5000	0.5000	0.0000
λ^B	0.4000	0.6000	0.4000	0.6000	0.0000
λ^S	0.5000	0.7500	0.5000	0.7500	0.0000
μ	0.5000	0.5000	0.5000	0.5000	0.5000
μ^L	0.0500	0.0500	0.0500	0.0500	0.0500
μ^X	0.0500	0.0500	0.0500	0.0500	0.0500
μ^M	0.0500	0.0500	0.0500	0.0500	0.0500
ω^Y	$(8.0000-1)/8.0000$	$(6.0000-1)/6.0000$	$(8.0000-1)/8.0000$	$(6.0000-1)/6.0000$	$(8.0000-1)/8.0000$
ω^L	$(8.0000-1)/8.0000$	$(6.0000-1)/6.0000$	$(8.0000-1)/8.0000$	$(6.0000-1)/6.0000$	$(8.0000-1)/8.0000$
ω^X	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$
ω^M	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$	$(6.0000-1)/6.0000$
ω^B	$(4.0000-1)/4.0000$	$(4.0000-1)/4.0000$	$(4.0000-1)/4.0000$	$(4.0000-1)/4.0000$	$(4.0000-1)/4.0000$
ω^G	0.9500	0.9500	0.9500	0.9500	0.9500
ϕ^A	0.9500	0.9500	0.9500	0.9500	0.9500
ϕ^C	0.2000	0.2500	0.2000	0.2500	0.2000
ϕ^C_H	0.3000	0.3000	0.3000	0.3000	0.3000
ϕ^C_B	0.3000	0.3000	0.3000	0.3000	0.3000
ϕ^C_S	0.0500	0.0500	0.0500	0.0500	0.0500
ϕ^F_B	0.7500	0.7500	0.7500	0.7500	0.7500
ϕ^F_H	0.2000	0.2000	0.2000	0.2000	0.2000
ϕ^F_F	0.0500	0.0500	0.0500	0.0500	0.0500
ψ^M	0.5000	0.5000	0.5000	0.5000	0.5000
ψ^B	0.5000	0.5000	0.5000	0.5000	0.5000
ρ^{A^T}	0.9500	0.9500	0.9500	0.9500	0.9500
ρ^{δ^C}	0.8000	0.8000	0.8000	0.8000	0.8000
σ	1.0000	1.0000	1.0000	1.0000	1.0000
ς	1.0000	1.0000	1.0000	1.0000	1.0000
ζ^{δ^H}	$0.0667f(\alpha^H,i^H)$	$0.0667f(\alpha^H,i^H)$	$0.0667f(\alpha^H,i^H)$	$0.0667f(\alpha^H,i^H)$	$0.0667f(\alpha^H,i^H)$
ζ^{δ^F}	$0.1333f(\alpha^F,i^F)$	$0.1333f(\alpha^F,i^F)$	$0.1333f(\alpha^F,i^F)$	$0.1333f(\alpha^F,i^F)$	$0.1333f(\alpha^F,i^F)$
ζ^F	0.2500	0.2500	0.2500	0.2500	0.2500
ζ^{ε}	$0.0500/S^2$	$0.0500/S^2$	$0.0500/S^2$	$0.0500/S^2$	…

Note: The calibration is a function of the seasonal frequency S, evaluated at $S=4$. Also, $f(\alpha^Z,i^Z)=\frac{1+i^Z}{\alpha^Z+i^Z}\frac{1}{S}$ for $Z\in\{H,F\}$.

Table 6. Calibrated Policy Rule Parameters

	Korea	South Africa	Switzerland	Thailand	United States
ρ^{i^B}	0.8000	0.8000	0.8000	0.8000	0.8000
ξ^{π^C}	2.0000	2.0000	2.0000	2.0000	2.0000
ξ^{Y^G}	0.5000 / S	0.5000 / S	0.5000 / S	0.5000 / S	0.5000 / S
r	0.2317S	0.1026S	0.4730S	0.3633S	0.0029S
ξ^{r}	0.1000S	0.1000S	0.1000S	0.1000S	0.0000S
ρ^{G}	0.8000	0.8000	0.8000	0.8000	0.8000
ξ^{G^C}	1.0000	1.0000	1.0000	1.0000	1.0000
ξ^{G^I}	1.0000	1.0000	1.0000	1.0000	1.0000
τ^{K}	0.0868	0.1700	0.1119	0.1336	0.0572
τ^{L}	0.0506	0.1260	0.0874	0.0278	0.1450
τ^{C}	0.1058	0.1411	0.1139	0.1662	0.0619
ρ^{τ}	0.8000	0.8000	0.8000	0.8000	0.8000
ξ^{T^N}	0.1000 / S	0.1000 / S	0.1000 / S	0.1000 / S	0.1000 / S
ξ^{T^D}	0.1000 / S	0.1000 / S	0.1000 / S	0.1000 / S	0.1000 / S
κ^{R}	0.0500	0.0500	0.0500	0.0500	0.0500
ρ^{κ^R}	0.8000	0.8000	0.8000	0.8000	0.8000
ξ^{κ^R}	0.1000	0.1000	0.1000	0.1000	0.1000
ϕ^{H}	0.8000	0.8000	0.8000	0.8000	0.8000
ϕ^{F}	0.8000	0.8000	0.8000	0.8000	0.8000
ρ^{ϕ}	0.8000	0.8000	0.8000	0.8000	0.8000
ξ^{ϕ^H}	0.5000	0.5000	0.5000	0.5000	0.5000
ξ^{ϕ^F}	0.5000	0.5000	0.5000	0.5000	0.5000
ρ^{τ^C}	0.8000	0.8000	0.8000	0.8000	0.8000
ξ^{τ^H}	$0.1000f(\alpha^H,i^H)$	$0.1000f(\alpha^H,i^H)$	$0.1000f(\alpha^H,i^H)$	$0.1000f(\alpha^H,i^H)$	$0.1000f(\alpha^H,i^H)$
ξ^{τ^F}	$0.1000f(\alpha^F,i^F)$	$0.1000f(\alpha^F,i^F)$	$0.1000f(\alpha^F,i^F)$	$0.1000f(\alpha^F,i^F)$	$0.0000f(\alpha^F,i^F)$

Note: The calibration is a function of the seasonal frequency S, evaluated at $S=4$. Also, $f(\alpha^Z,i^Z)=\frac{1+i^Z}{\alpha^Z+i^Z}\frac{1}{S}$ for $Z\in\{H,F\}$.

Table 7. Calibrated Trend Component Parameters

	Korea	South Africa	Switzerland	Thailand	United States
ρ	$\exp(-\ln 2/(10S))$	$\exp(-\ln 2/(10S))$	$\exp(-\ln 2/(10S))$	$\exp(-\ln 2/(10S))$	$\exp(-\ln 2/(10S))$
π	1.8769 / S	6.2544 / S	0.3977 / S	2.6296 / S	1.8909 / S
g	2.4014 / S	0.9396 / S	0.6663 / S	2.9058 / S	1.1898 / S
n	1.2544 / S	1.6237 / S	1.3279 / S	0.8301 / S	0.7503 / S

Note: The calibration is a function of the seasonal frequency S, evaluated at $S=4$.

Table 8. Calibrated Exogenous Variable Parameters

	Korea	South Africa	Switzerland	Thailand	United States
ρ_A	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_N	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_C	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_I	0.6000	0.6000	0.6000	0.6000	0.6000
ρ_X	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_M	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_B	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_H	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_S	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_{q^C}	0.6000	0.6000	0.6000	0.6000	0.6000
ρ_δ	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_ε	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_P	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_r	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_G	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_τ	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_T	0.8000	0.8000	0.8000	0.8000	0.8000
ρ_κ	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_ϕ	0.4000	0.4000	0.4000	0.4000	0.4000
ρ_{τ^C}	0.4000	0.4000	0.4000	0.4000	0.4000

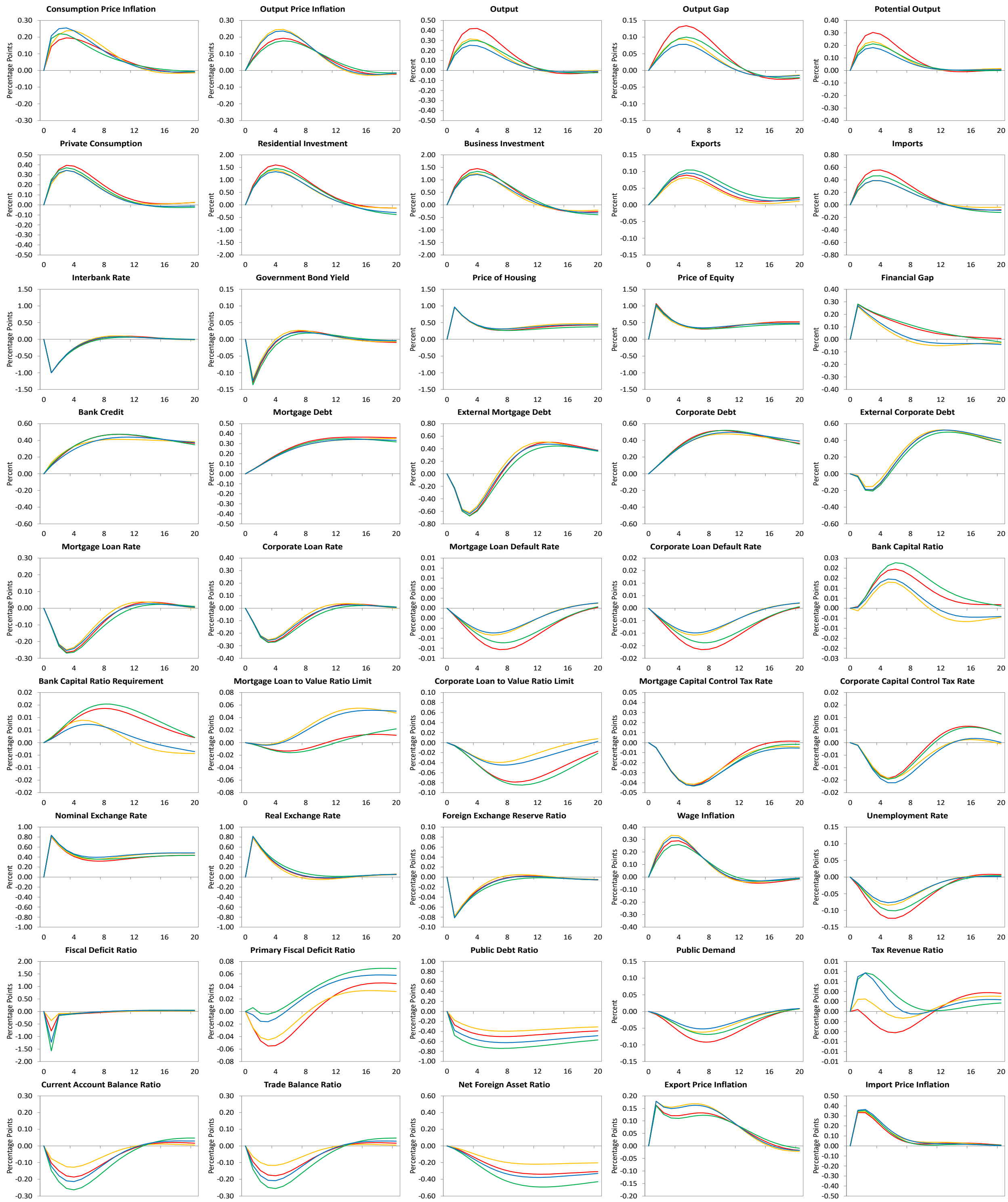
Table 9. Estimated Conditional Variance Function Parameters

	Prior		Posterior							
			Korea		South Africa		Switzerland		Thailand	
	Mean	SD	Mode	SE	Mode	SE	Mode	SE	Mode	SE
$\hat{\sigma}_A$	1.0000	0.1000	1.1144	0.0550	1.4748	0.0654	1.0573	0.0524	1.8838	0.0739
$\hat{\sigma}_N$	1.0000	0.1000	1.6746	0.0704	2.8410	0.0858	1.5044	0.0664	1.6016	0.0687
$\hat{\sigma}_C$	1.0000	0.1000	2.1211	0.0776	1.8379	0.0724	1.6246	0.0692	2.9187	0.0859
$\hat{\sigma}_I$	1.0000	0.1000	1.9646	0.0762	1.9723	0.0763	1.8053	0.0733	2.6449	0.0843
$\hat{\sigma}_X$	1.0000	0.1000	1.9010	0.0744	1.9831	0.0759	2.4499	0.0822	2.2082	0.0791
$\hat{\sigma}_M$	1.0000	0.1000	1.6164	0.0689	1.6421	0.0695	1.9000	0.0746	1.7255	0.0713
$\hat{\sigma}_B$	0.2500	0.0250	0.4508	0.0182	0.5639	0.0197	0.3774	0.0166	0.5121	0.0192
$\hat{\sigma}_H$	0.5000	0.0500	0.5479	0.0266	0.6126	0.0287	0.5265	0.0257	0.5867	0.0280
$\hat{\sigma}_S$	1.0000	0.1000	2.3880	0.0797	2.2356	0.0779	1.7589	0.0704	2.5416	0.0812
$\hat{\sigma}_{\mathcal{E}}$	1.0000	0.1000	1.8231	0.0799	2.3456	0.0823	1.5644	0.0778	1.4175	0.0748
$\hat{\sigma}_{q^Y}$	10.0000	1.0000	25.2219	0.8290	15.9204	0.7565	15.3141	0.6715	21.5679	0.7857
$\hat{\sigma}_{q^L}$	10.0000	1.0000	18.0707	0.8038	29.6099	0.8676	24.1758	0.8177	24.8969	0.8262
$\hat{\sigma}_P$	0.5000	0.0500	0.5383	0.0268	0.4643	0.0250	0.4410	0.0231	0.5379	0.0267
$\hat{\sigma}_{i^B}$	0.2500	0.0250	0.2101	0.0110	0.1728	0.0097	0.1450	0.0081	0.1884	0.0101
$\hat{\sigma}_G$	1.0000	0.1000	2.2103	0.0797	2.1405	0.0810	3.1335	0.0879	2.8321	0.0859
$\hat{\sigma}_\phi$	1.0000	0.1000	1.7241	0.0822	1.6114	0.0818	1.6523	0.0825	1.6679	0.0840
λ^M	0.5000	0.0500	0.6042	0.0478	0.8695	0.0459	0.5506	0.0491	0.4291	0.0485
λ^F	0.5000	0.0500	0.5540	0.0463	0.5522	0.0493	0.4644	0.0484	0.5239	0.0470
$\psi_{\Delta Y}$	1.0000	0.1000	1.3821	0.0892	0.8927	0.0860	0.8553	0.0887	1.1128	0.0900
ψ_Y	0.1000	0.0100	0.0836	0.0097	0.0932	0.0097	0.0796	0.0098	0.0536	0.0098
$\psi_{\Delta F}$	0.2500	0.0250	0.2580	0.0238	0.2541	0.0235	0.2656	0.0239	0.2305	0.0236
ψ_F	0.1000	0.0100	0.1022	0.0089	0.0454	0.0081	0.0793	0.0090	0.0822	0.0088
$\bar{\sigma}_{P^Y}$	...	∞	0.0348	0.0057	0.7850	0.0492	0.0260	0.0045	0.0366	0.0058
$\bar{\sigma}_Y$	...	∞	0.0484	0.0073	0.0434	0.0078	0.0223	0.0046	0.0412	0.0073
$\bar{\sigma}_{P^C}$	...	∞	0.0360	0.0055	0.0494	0.0067	0.0223	0.0038	0.0380	0.0063
$\bar{\sigma}_C$	...	∞	0.0351	0.0064	0.0516	0.0082	0.0225	0.0039	0.0441	0.0080
$\bar{\sigma}_I$	...	∞	0.0541	0.0134	0.1070	0.0208	0.0492	0.0121	0.0833	0.0204
$\bar{\sigma}_X$	...	∞	0.1024	0.0184	0.0514	0.0119	0.0497	0.0113	0.0742	0.0152
$\bar{\sigma}_M$	...	∞	0.0817	0.0154	0.0886	0.0187	0.0507	0.0115	0.1014	0.0209
$\bar{\sigma}_{i^B}$	...	∞	0.0024	0.0006	0.0031	0.0008	0.0027	0.0007	0.0023	0.0006
$\bar{\sigma}_{i^G}$	...	∞	0.0014	0.0003	0.0016	0.0004	0.0012	0.0003	0.0010	0.0003
$\bar{\sigma}_{V^H}$	...	∞	0.1138	0.0222	0.1772	0.0385	0.1045	0.0196	0.1002	0.0199
$\bar{\sigma}_{V^F}$	...	∞	0.1953	0.0412	0.1721	0.0395	0.1582	0.0322	0.2030	0.0396
$\bar{\sigma}_{\Delta^B}$	...	∞	0.6489	0.0387	2.2395	0.1312	0.9272	0.0547	1.4781	0.0868
$\bar{\sigma}_{\mathcal{E}}$	...	∞	0.0994	0.0326	0.2570	0.0617	0.1032	0.0264	0.0695	0.0217
$\bar{\sigma}_W$	...	∞	0.5478	0.0373	0.0942	0.0141	0.0284	0.0048	0.0587	0.0092
$\bar{\sigma}_{u^L}$	...	∞	0.0054	0.0012	0.0103	0.0028	0.0068	0.0016	0.0066	0.0016
$\bar{\sigma}_L$	...	∞	0.0173	0.0038	0.0208	0.0052	0.0177	0.0040	0.0300	0.0062

Note: All priors are normally distributed, while all posteriors are asymptotically normally distributed.

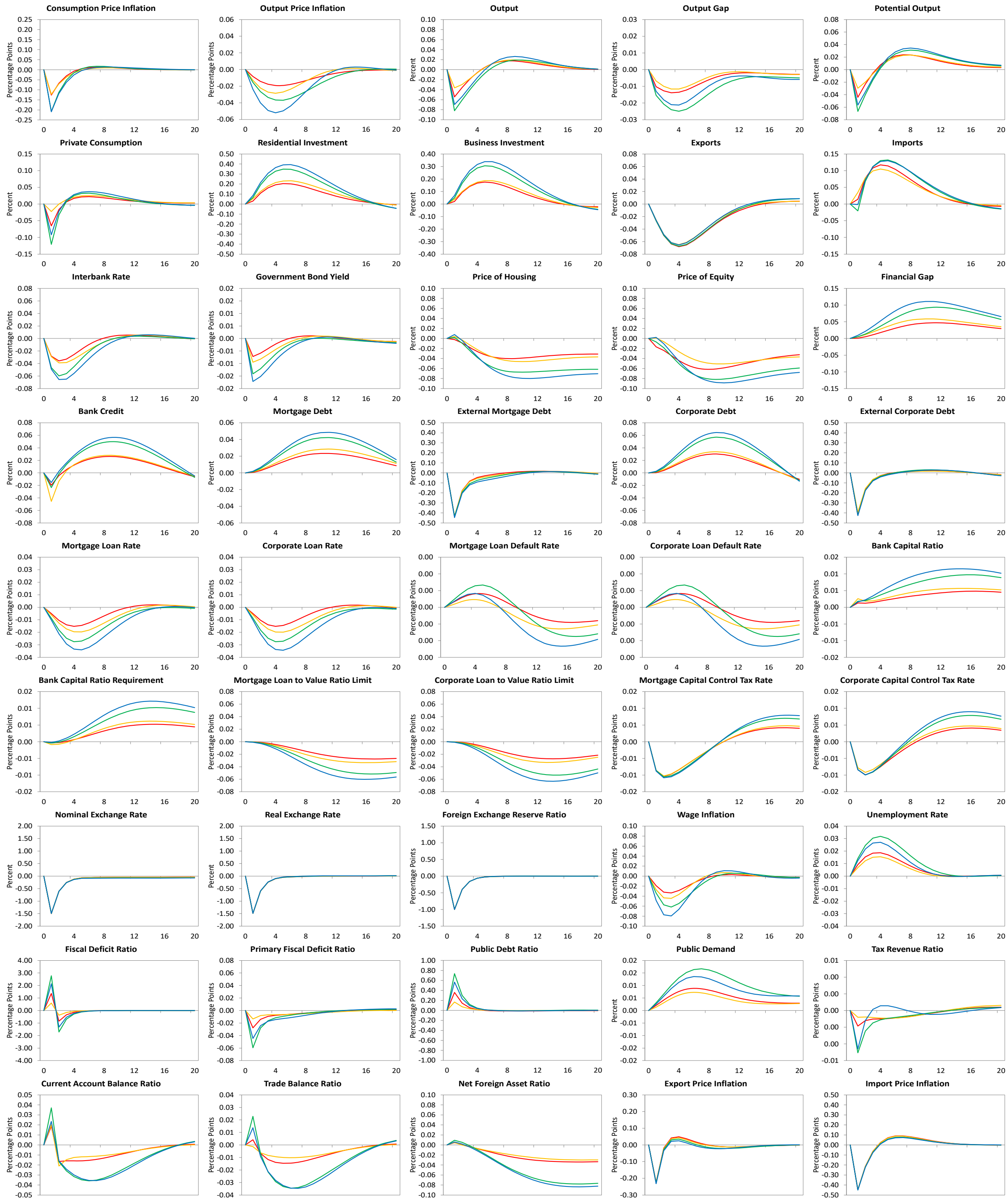
Appendix B. Transmission Mechanisms

Figure 6. Monetary Easing: Interbank Rate Cut



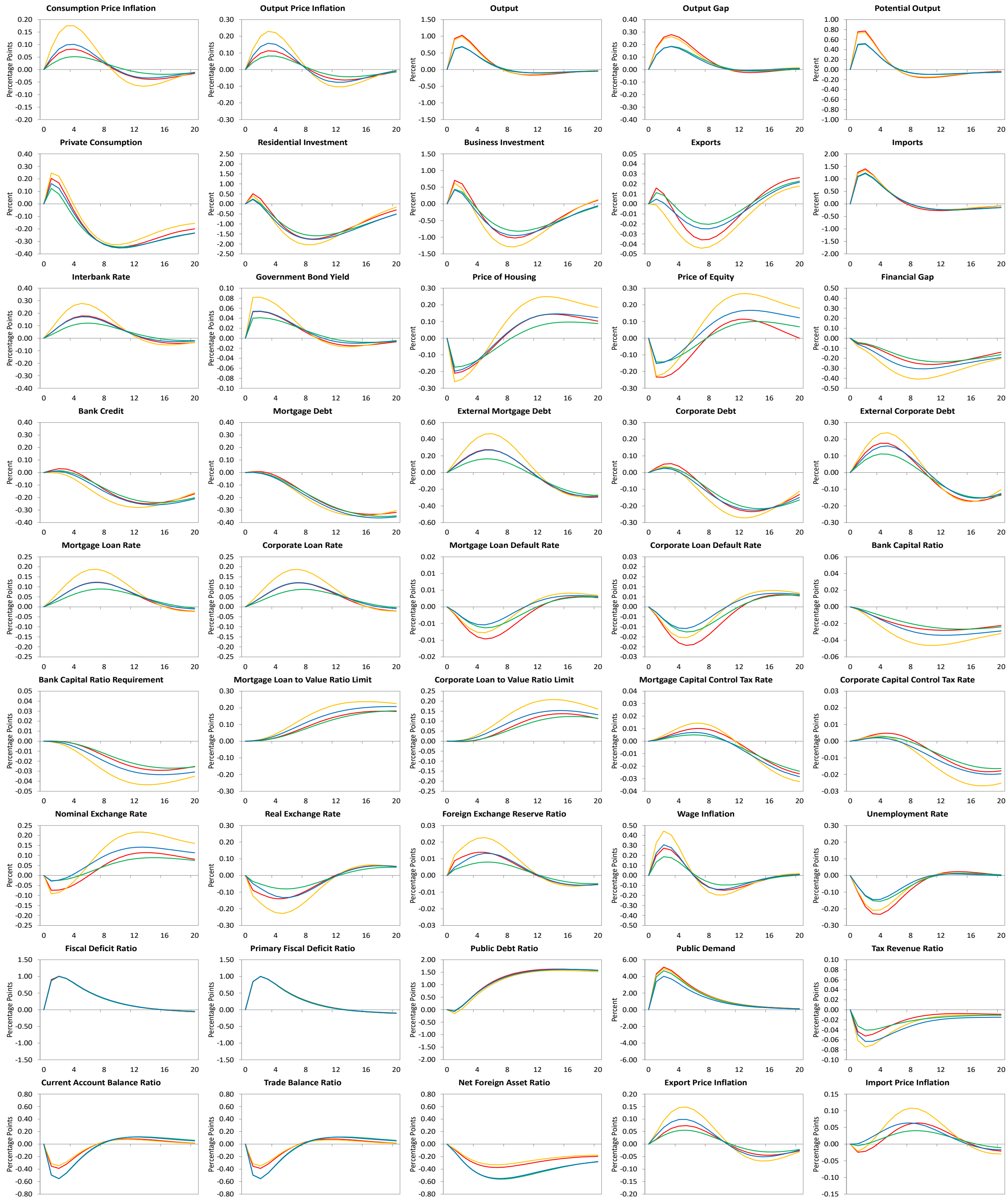
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a monetary policy shock that reduces the interbank rate by one percentage point. All variables are annualized, where applicable.

Figure 7. Foreign Exchange Intervention: Reserve Sales



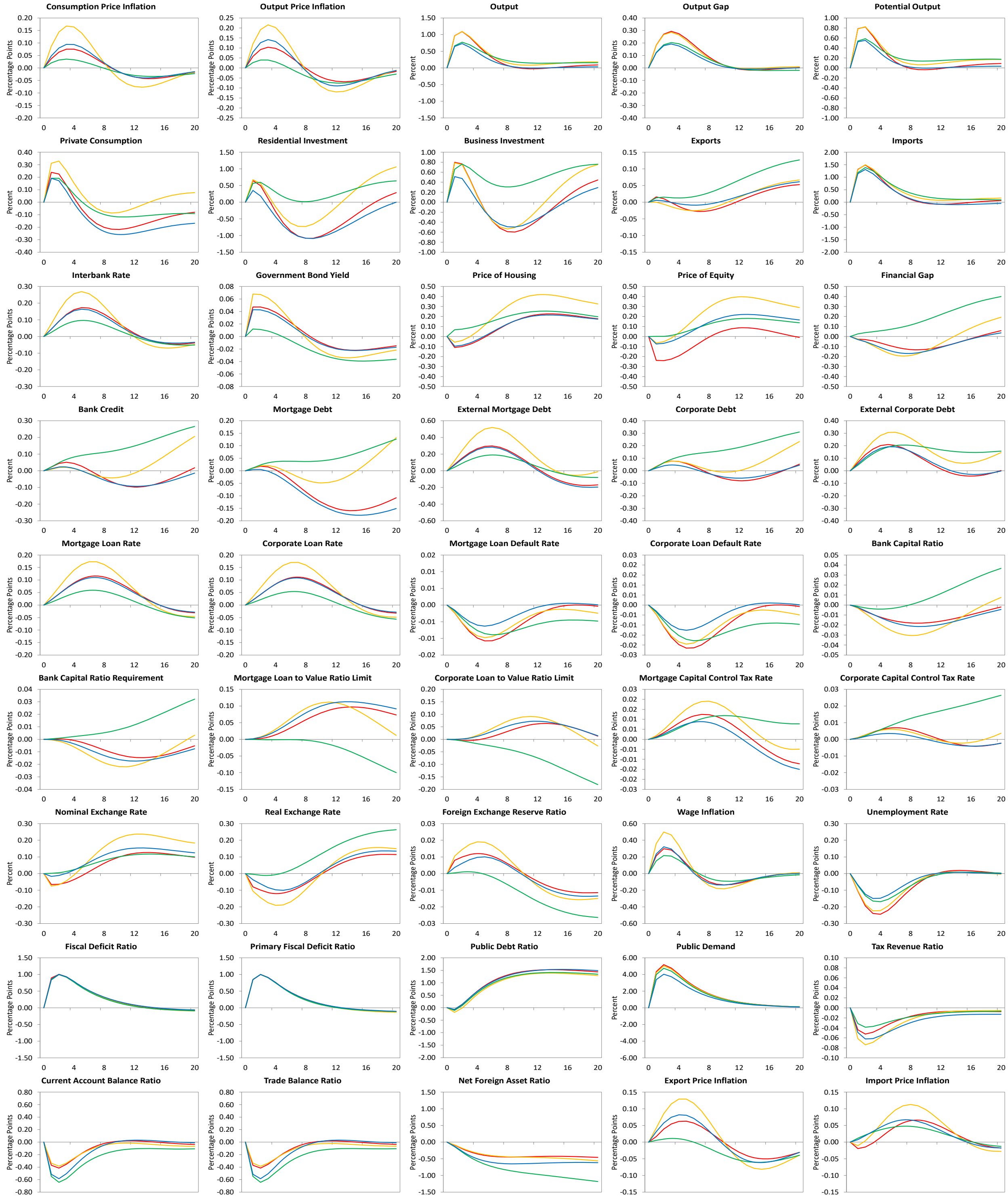
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a foreign exchange intervention shock that reduces the foreign exchange reserve ratio by one percentage point. All variables are annualized, where applicable.

Figure 8. Fiscal Stimulus: Public Consumption Increase



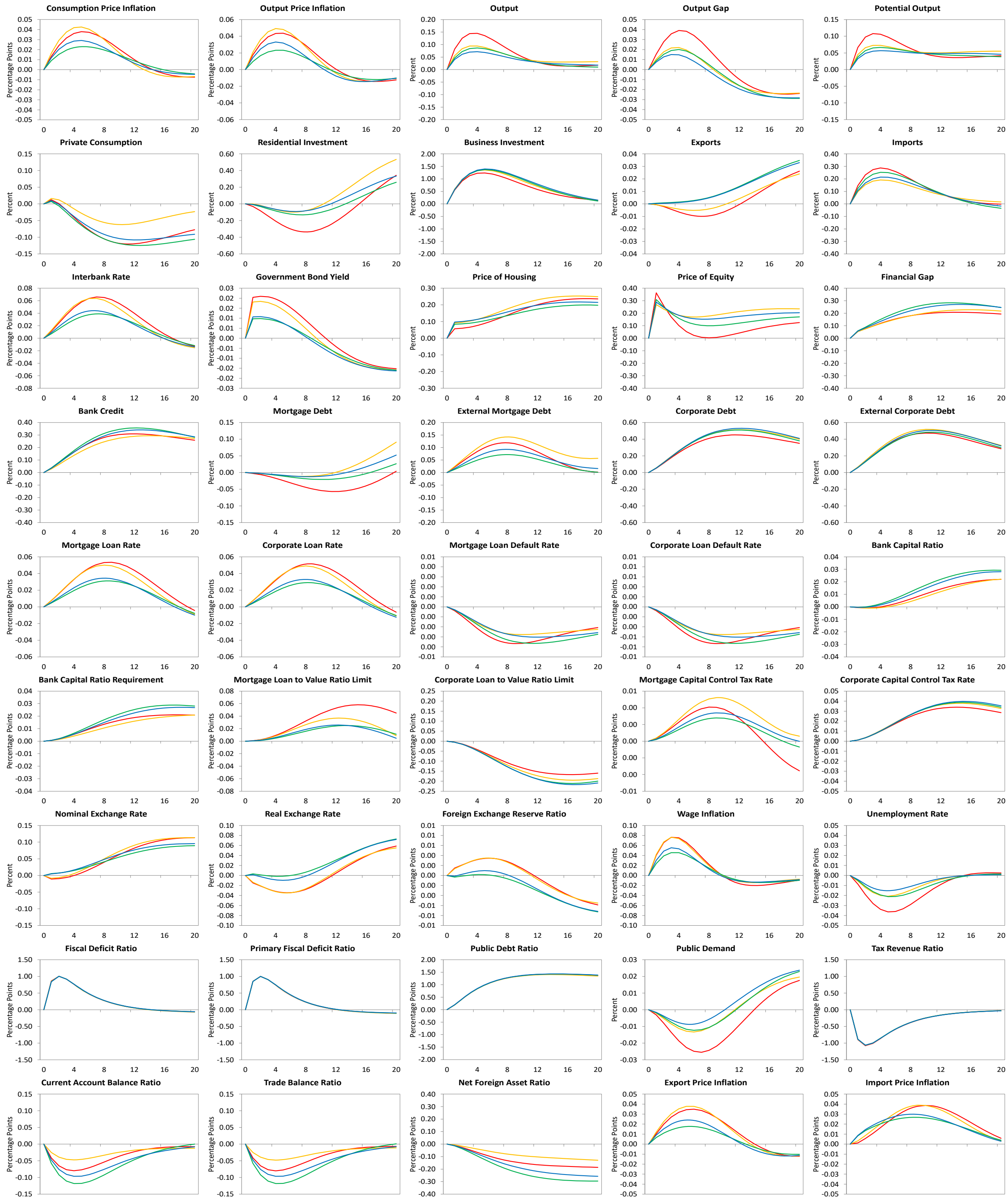
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a public consumption demand shock that raises the primary fiscal deficit ratio by one percentage point. All variables are annualized, where applicable.

Figure 9. Fiscal Stimulus: Public Investment Increase



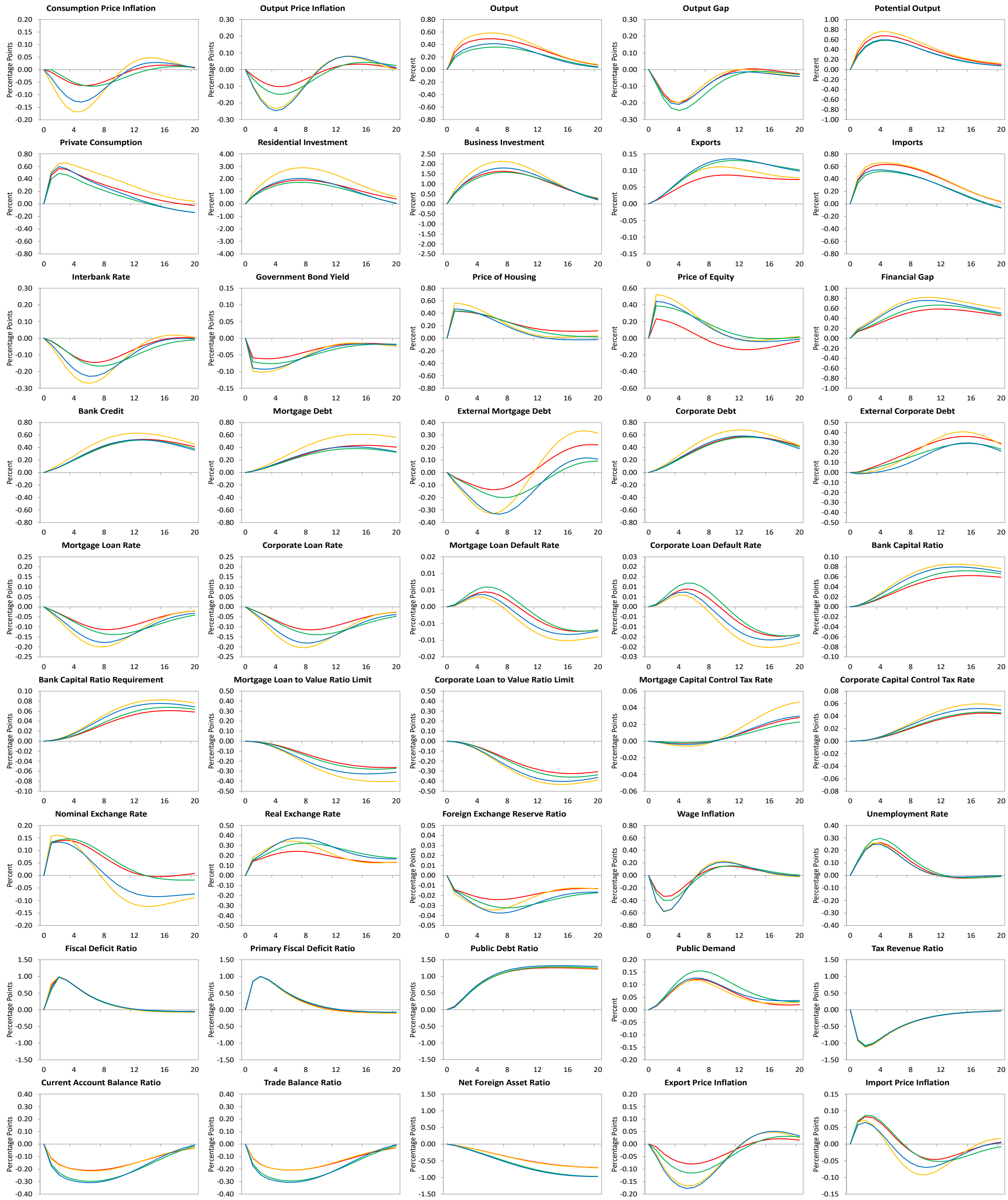
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a public investment demand shock that raises the primary fiscal deficit ratio by one percentage point. All variables are annualized, where applicable.

Figure 10. Fiscal Stimulus: Corporate Tax Rate Cut



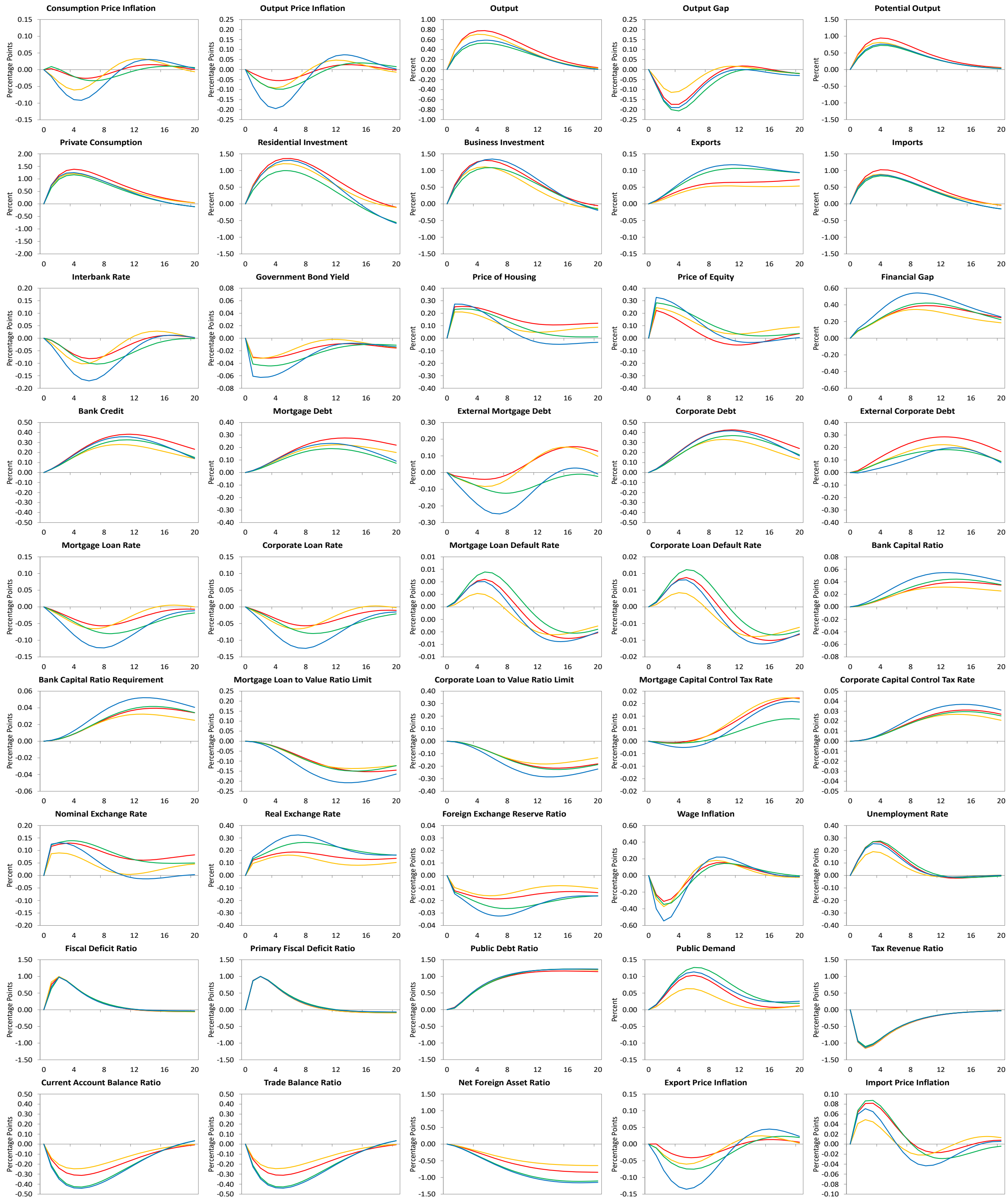
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a corporate tax rate shock that raises the primary fiscal deficit ratio by one percentage point. All variables are annualized, where applicable.

Figure 11. Fiscal Stimulus: Labor Income Tax Rate Cut



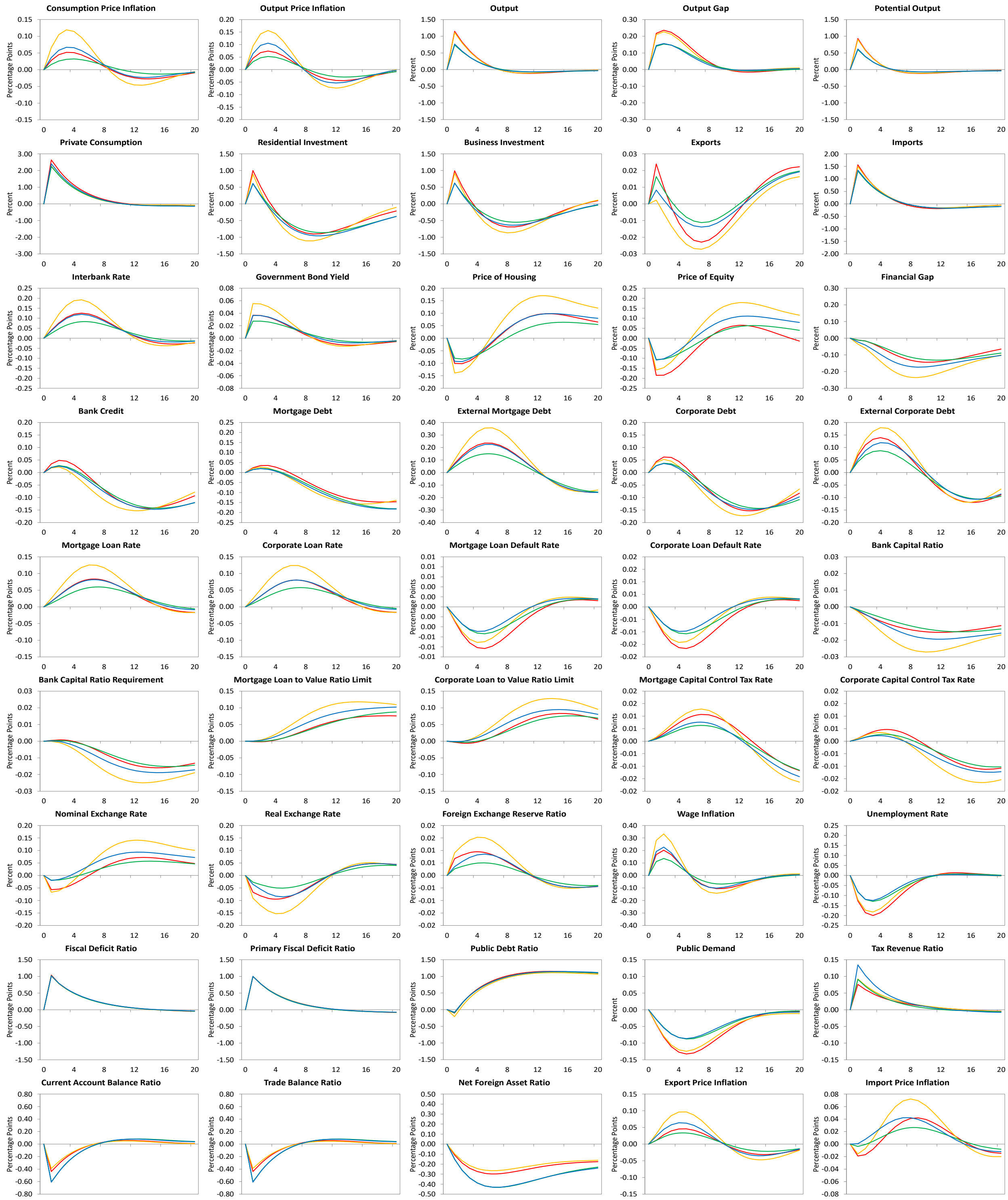
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a labor income tax rate shock that raises the primary fiscal deficit ratio by one percentage point. All variables are annualized, where applicable.

Figure 12. Fiscal Stimulus: Consumption Tax Rate Cut



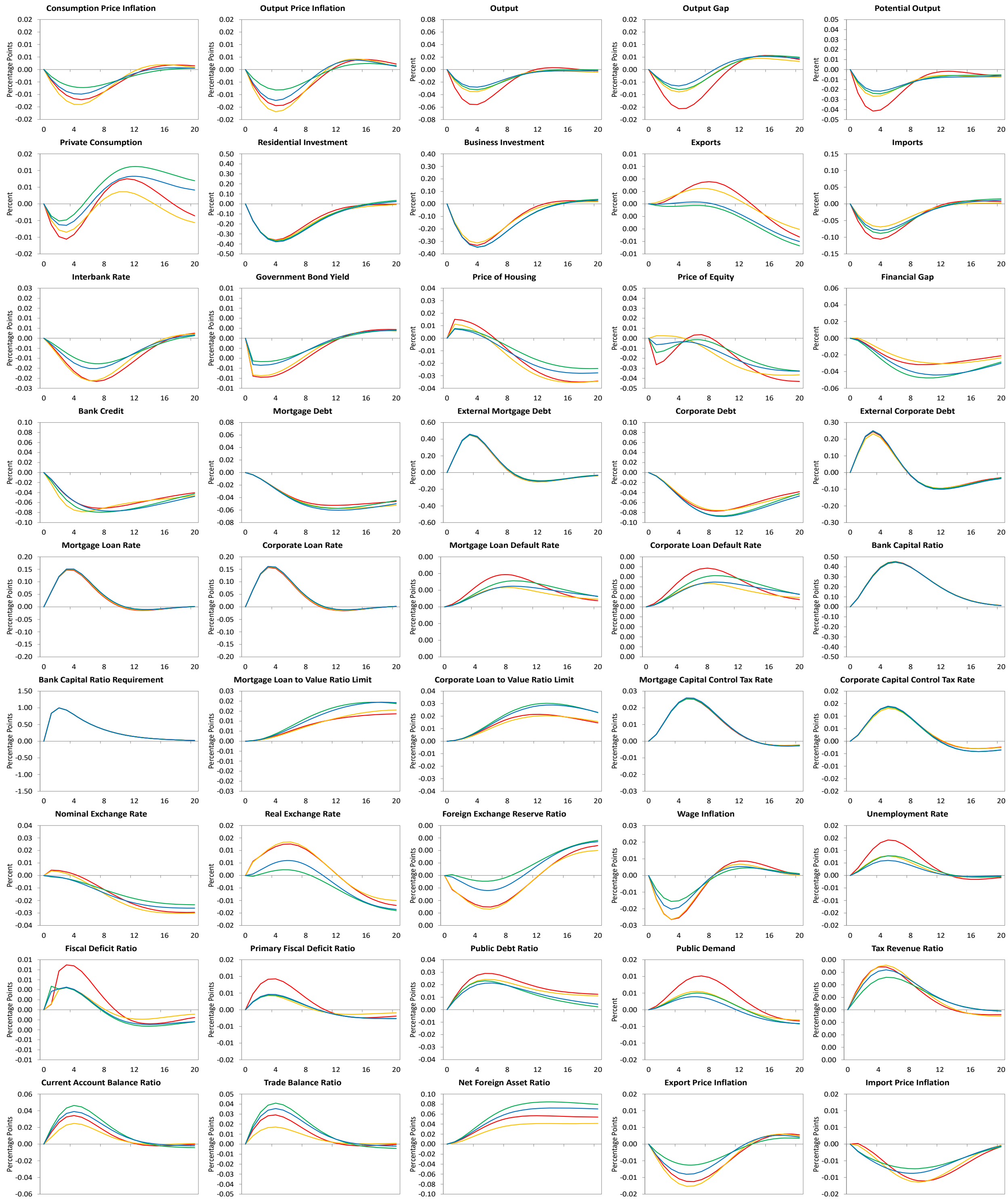
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a consumption tax rate shock that raises the primary fiscal deficit ratio by one percentage point. All variables are annualized, where applicable.

Figure 13. Fiscal Stimulus: Targeted Transfer Payments



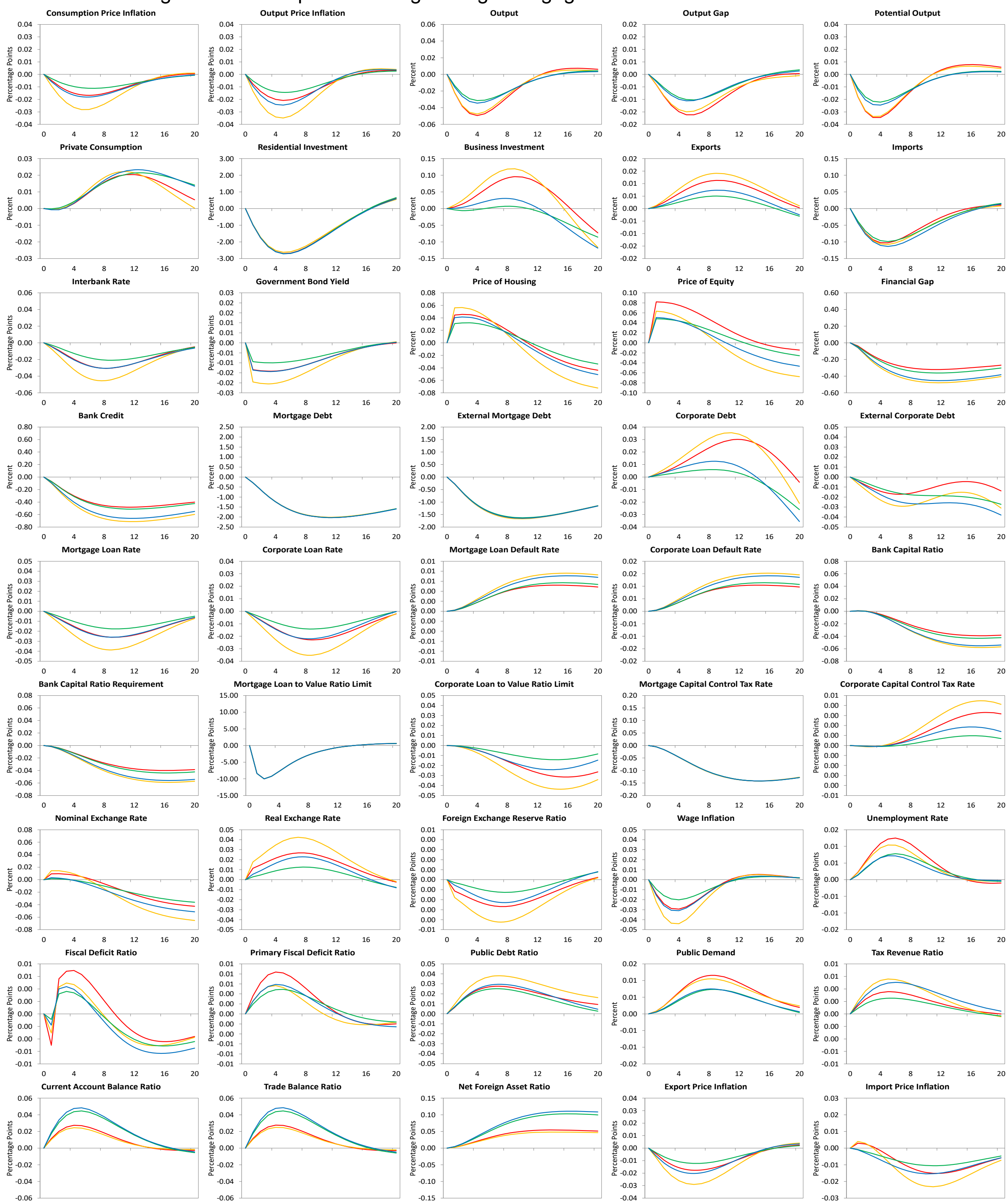
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a transfer payment shock that raises the primary fiscal deficit ratio by one percentage point. All variables are annualized, where applicable.

Figure 14. Macroprudential Tightening: Countercyclical Capital Buffer Increase



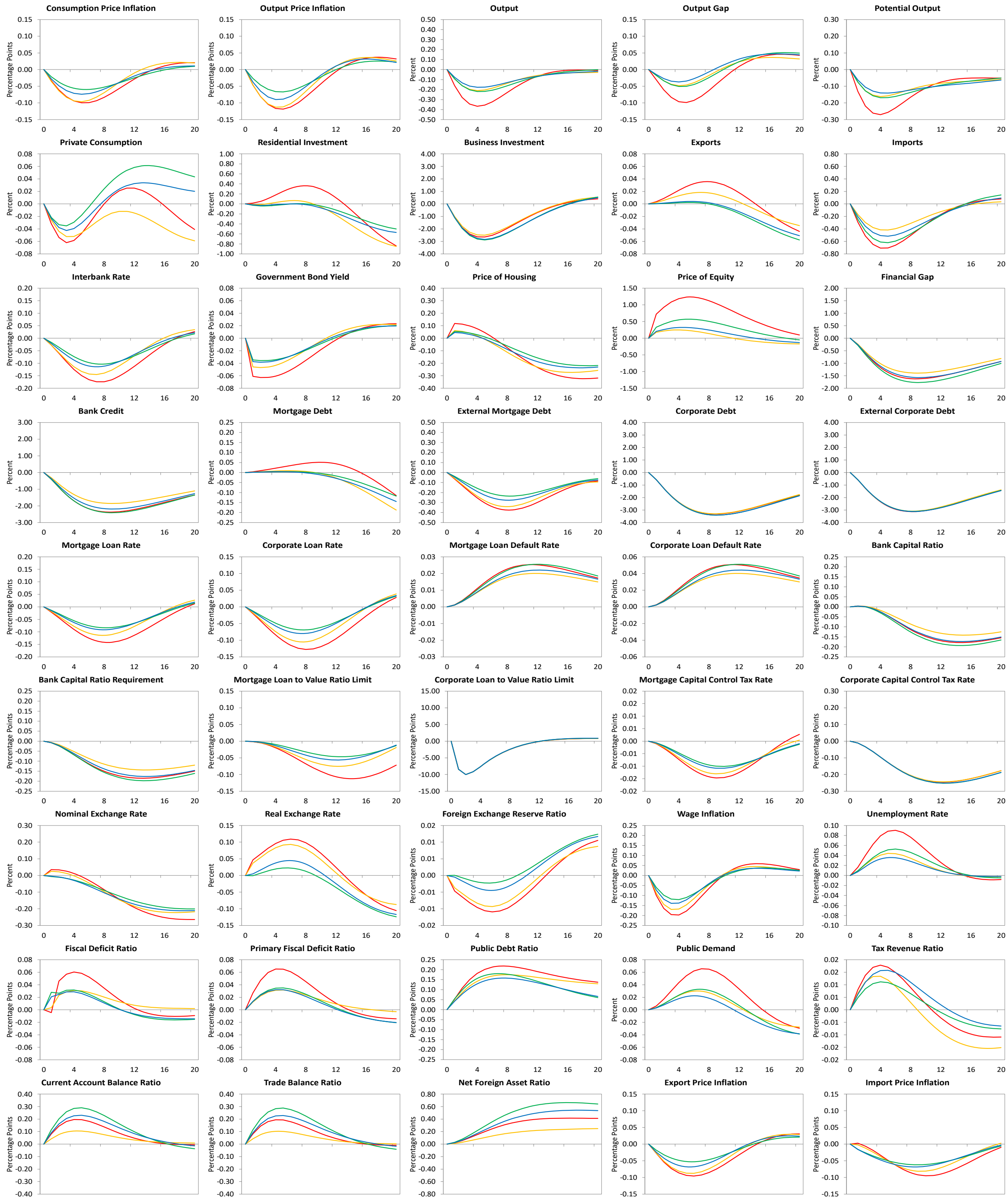
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a bank capital requirement shock that raises the bank capital ratio requirement by one percentage point. All variables are annualized, where applicable.

Figure 15. Macroprudential Tightening: Mortgage Loan to Value Limit Reduction



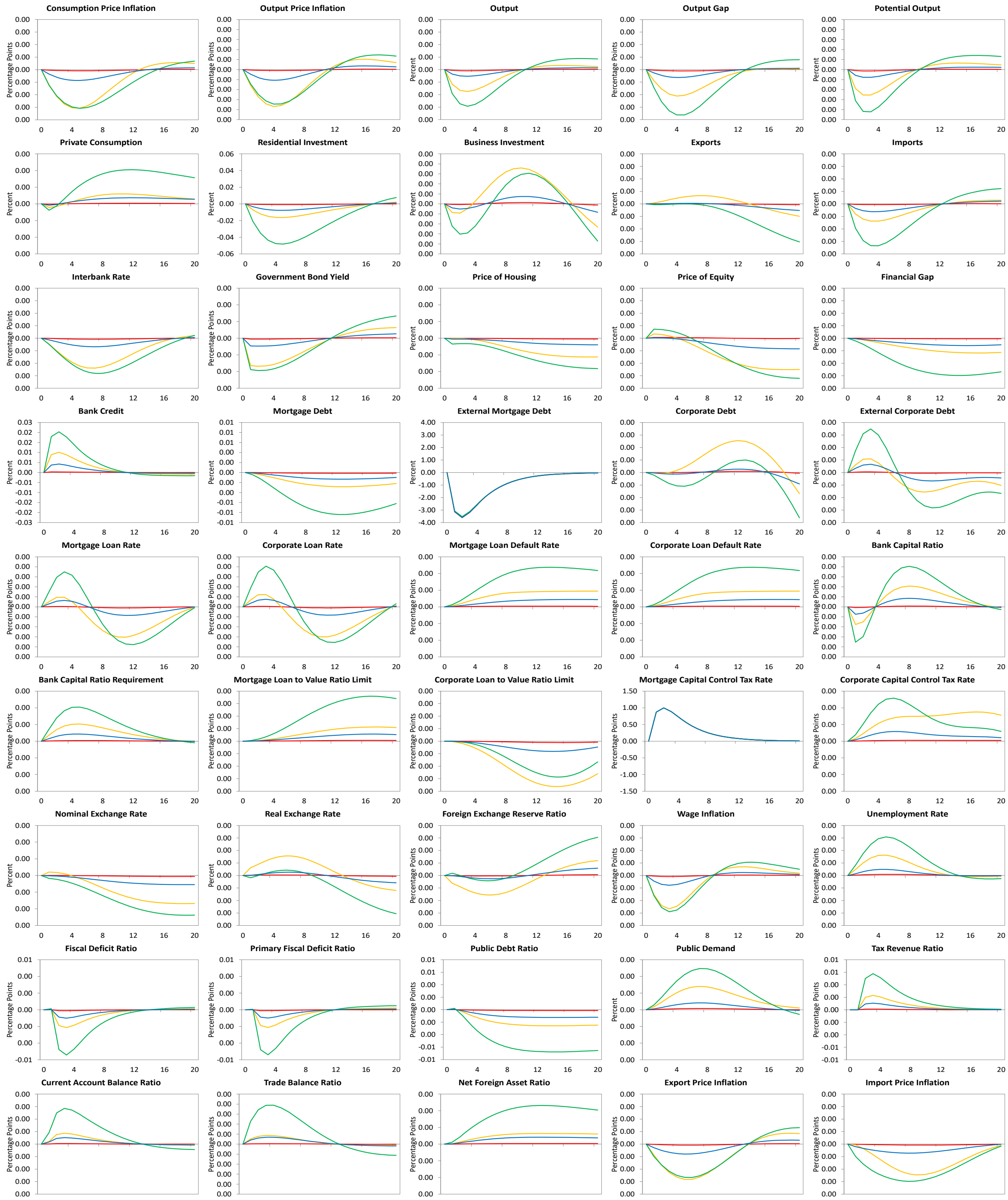
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a mortgage loan to value limit shock that reduces the mortgage loan to value ratio limit by ten percentage points. All variables are annualized, where applicable.

Figure 16. Macroprudential Tightening: Corporate Loan to Value Limit Reduction



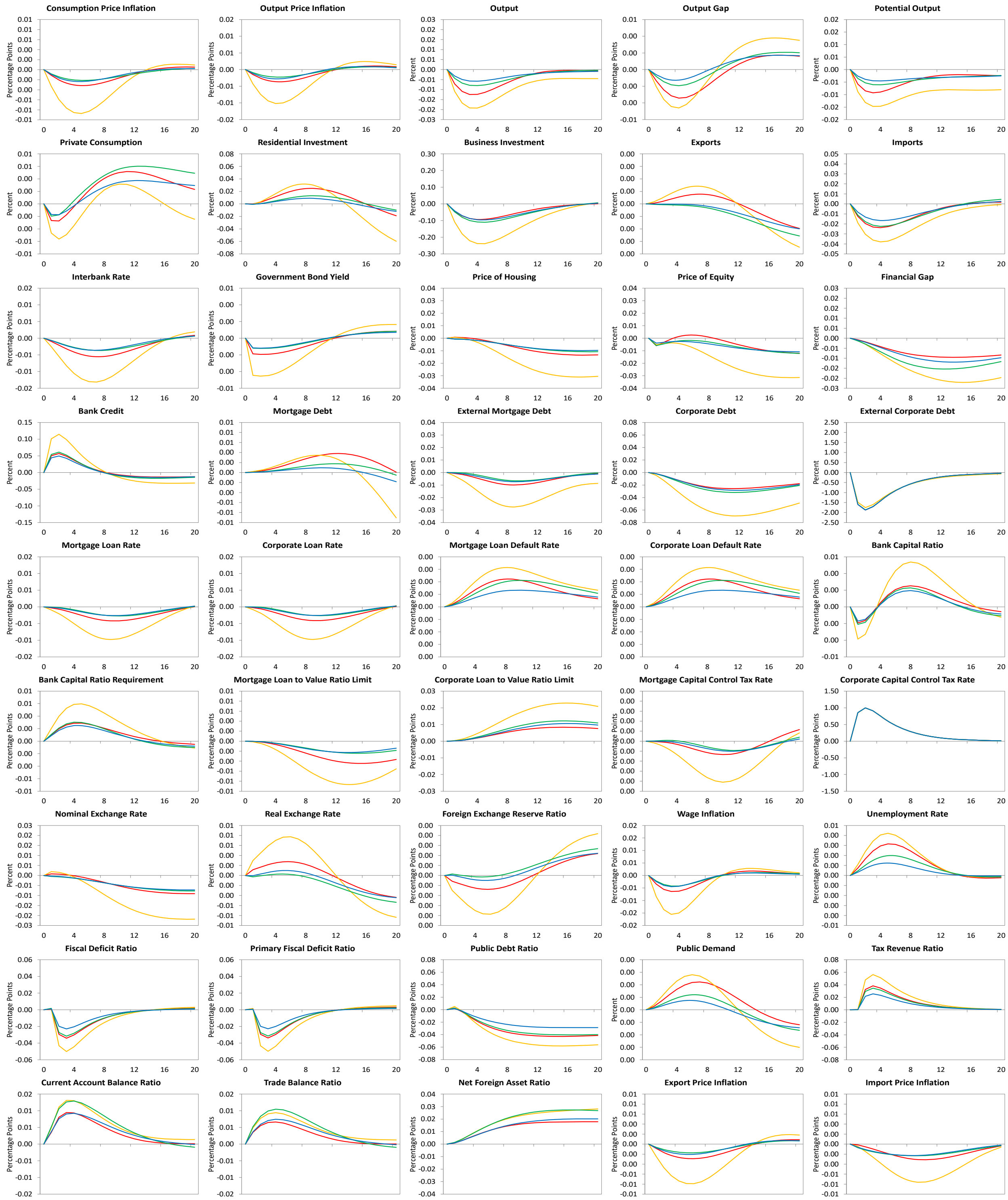
Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a corporate loan to value limit shock that reduces the corporate loan to value ratio limit by ten percentage points. All variables are annualized, where applicable.

Figure 17. Capital Flow Management: Mortgage Capital Control Tightening



Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a mortgage capital control shock that raises the mortgage capital control tax rate by one percentage point. All variables are annualized, where applicable.

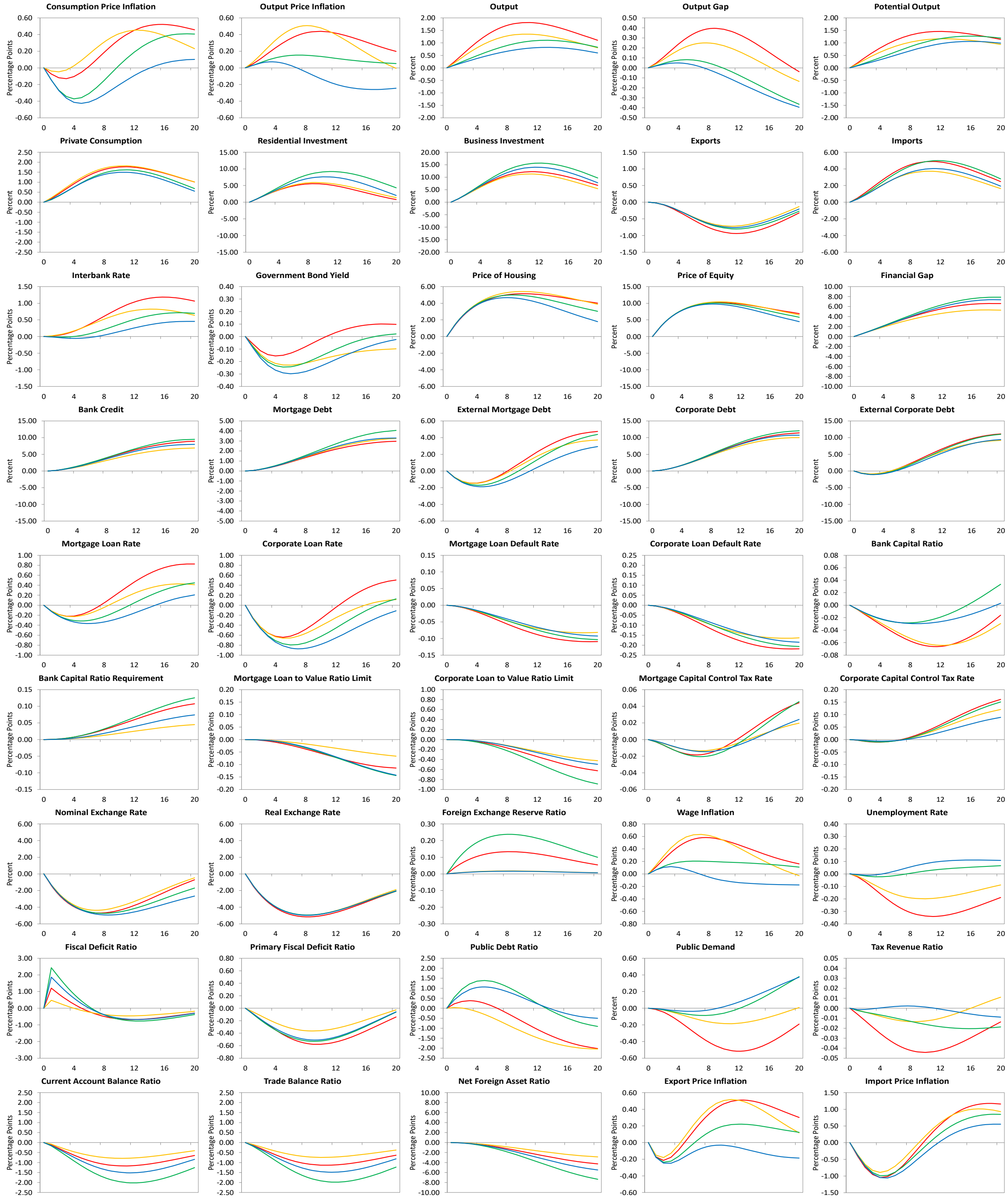
Figure 18. Capital Flow Management: Corporate Capital Control Tightening



Note: Depicts impulse responses for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ to a corporate capital control shock that raises the corporate capital control tax rate by one percentage point. All variables are annualized, where applicable.

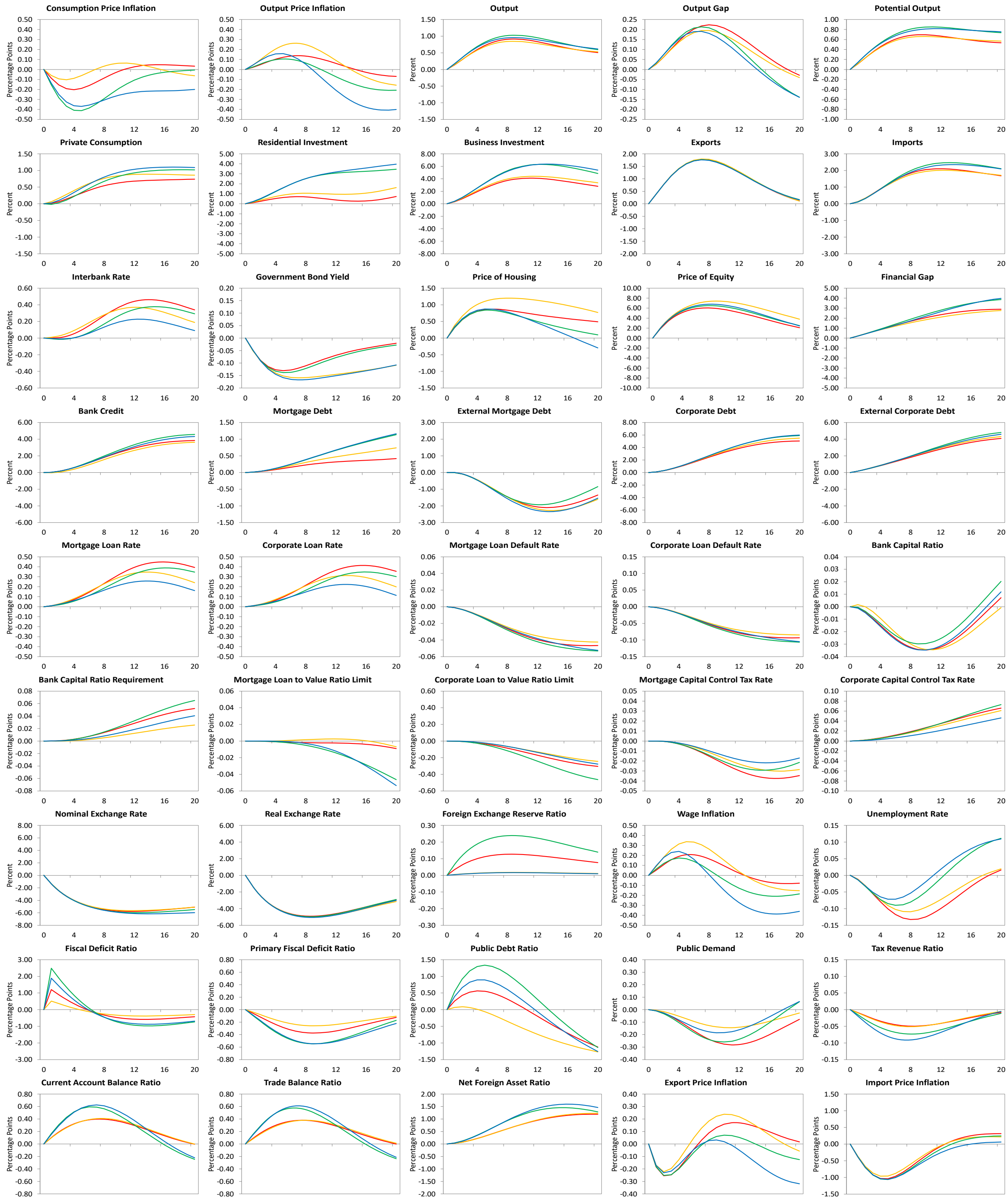
Appendix C. Unconstrained Scenarios

Figure 19. Domestic Financial Cycle Upturn Scenario



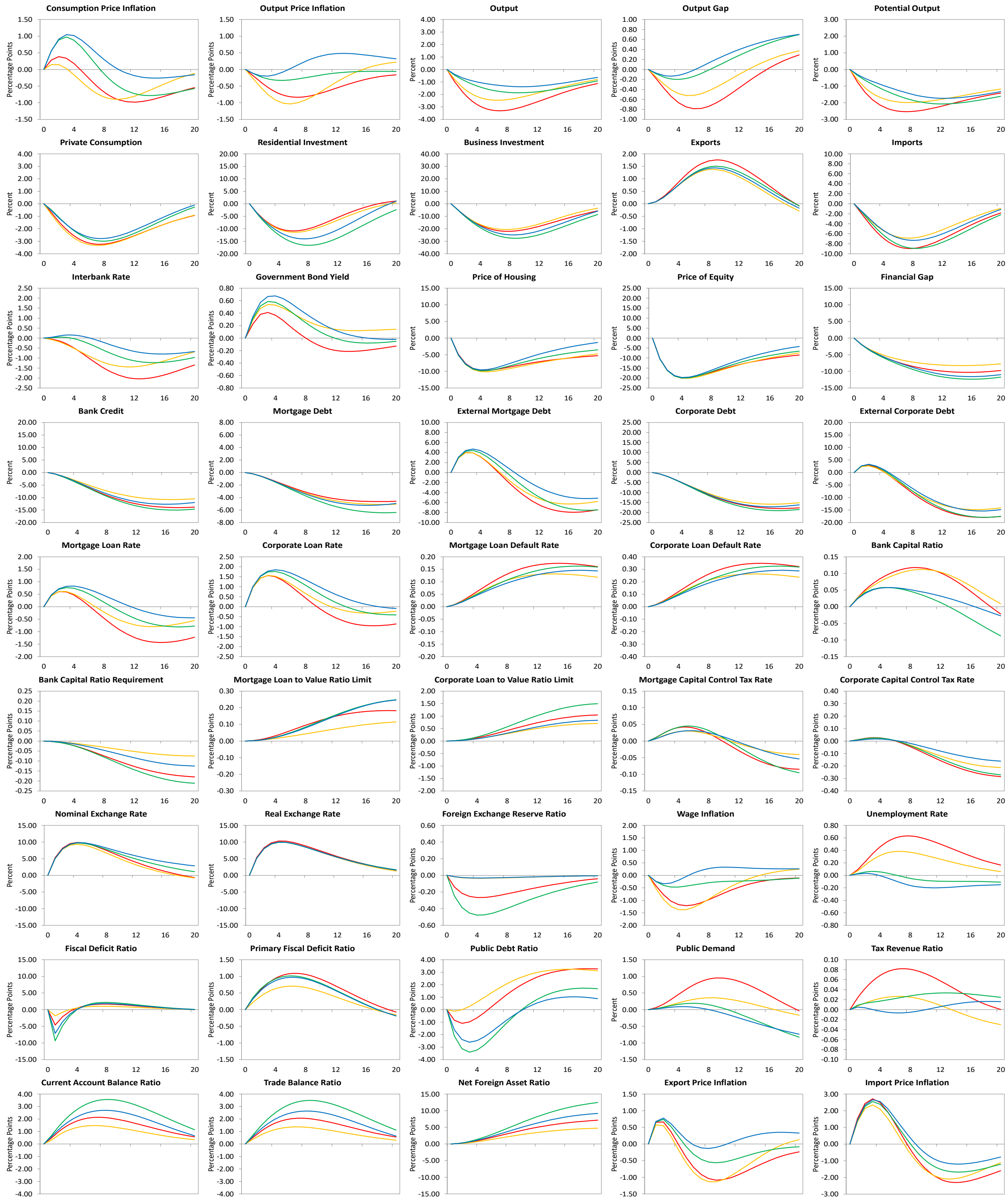
Note: Depicts simulation results for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ under our domestic financial cycle upturn scenario. All variables are annualized, where applicable.

Figure 20. Global Financial Cycle Upturn Scenario



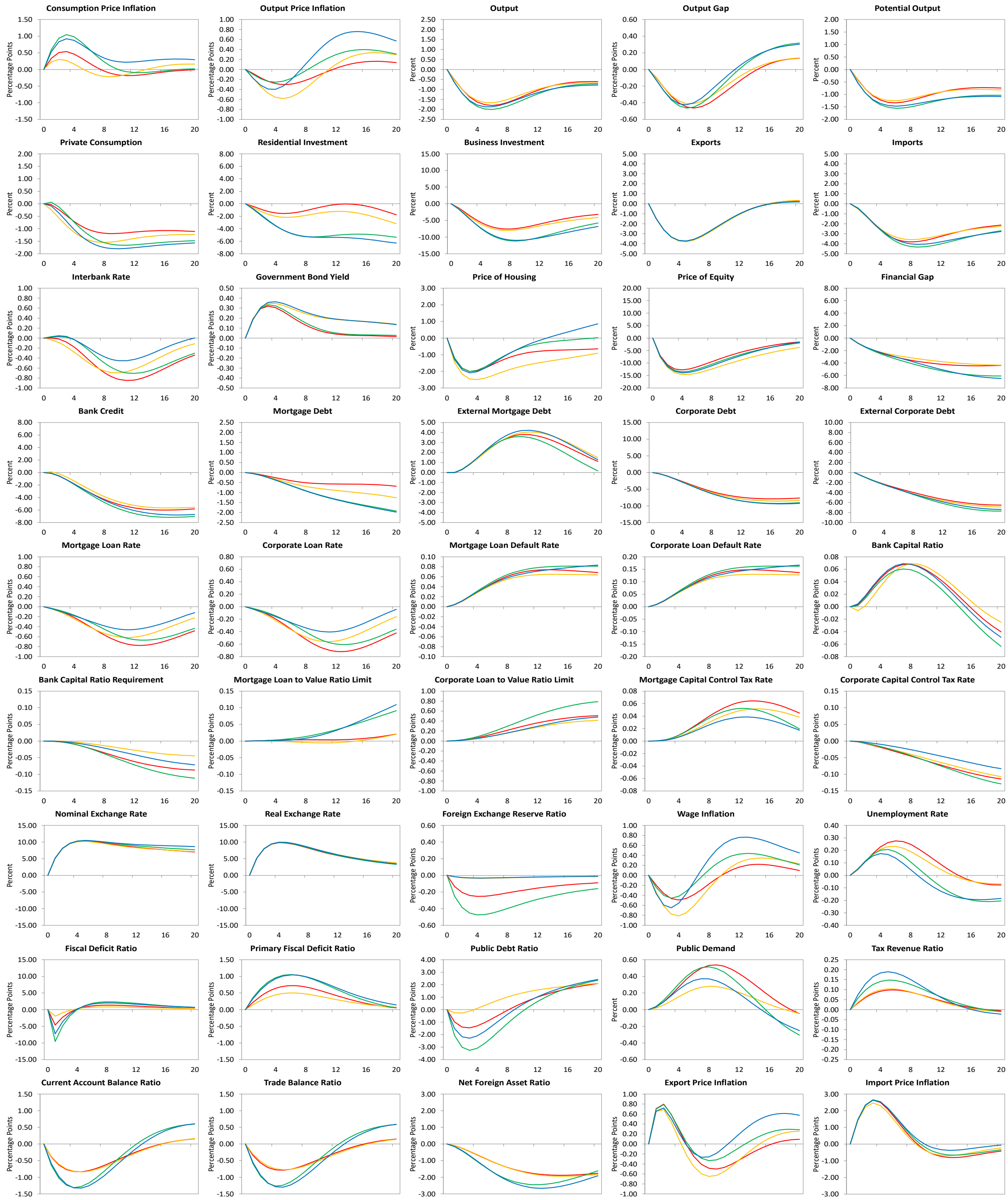
Note: Depicts simulation results for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ under our global financial cycle upturn scenario. All variables are annualized, where applicable.

Figure 21. Domestic Financial Cycle Downturn Scenario



Note: Depicts simulation results for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ under our domestic financial cycle downturn scenario. All variables are annualized, where applicable.

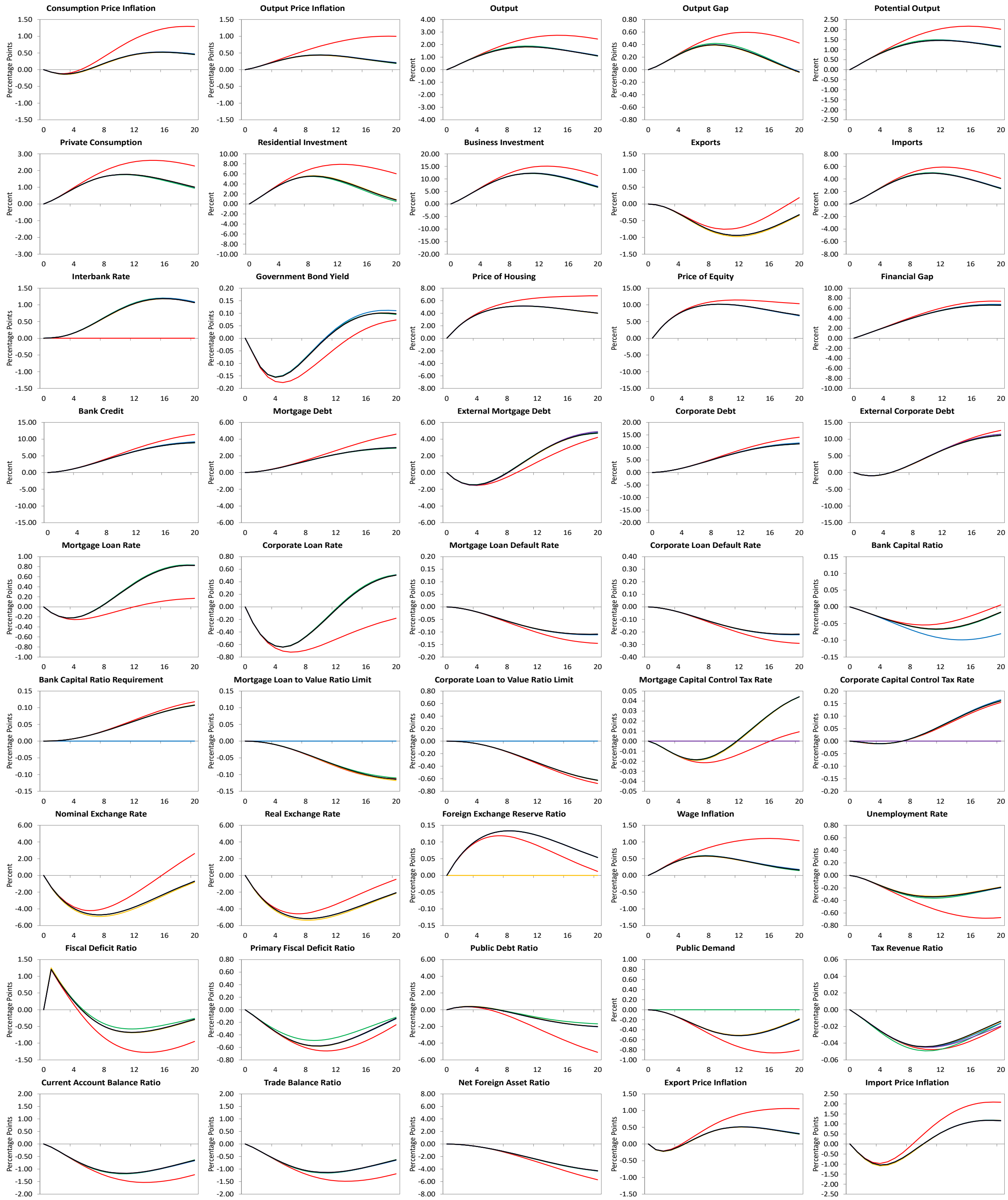
Figure 22. Global Financial Cycle Downturn Scenario



Note: Depicts simulation results for Korea ■, South Africa ■, Switzerland ■ and Thailand ■ under our global financial cycle downturn scenario. All variables are annualized, where applicable.

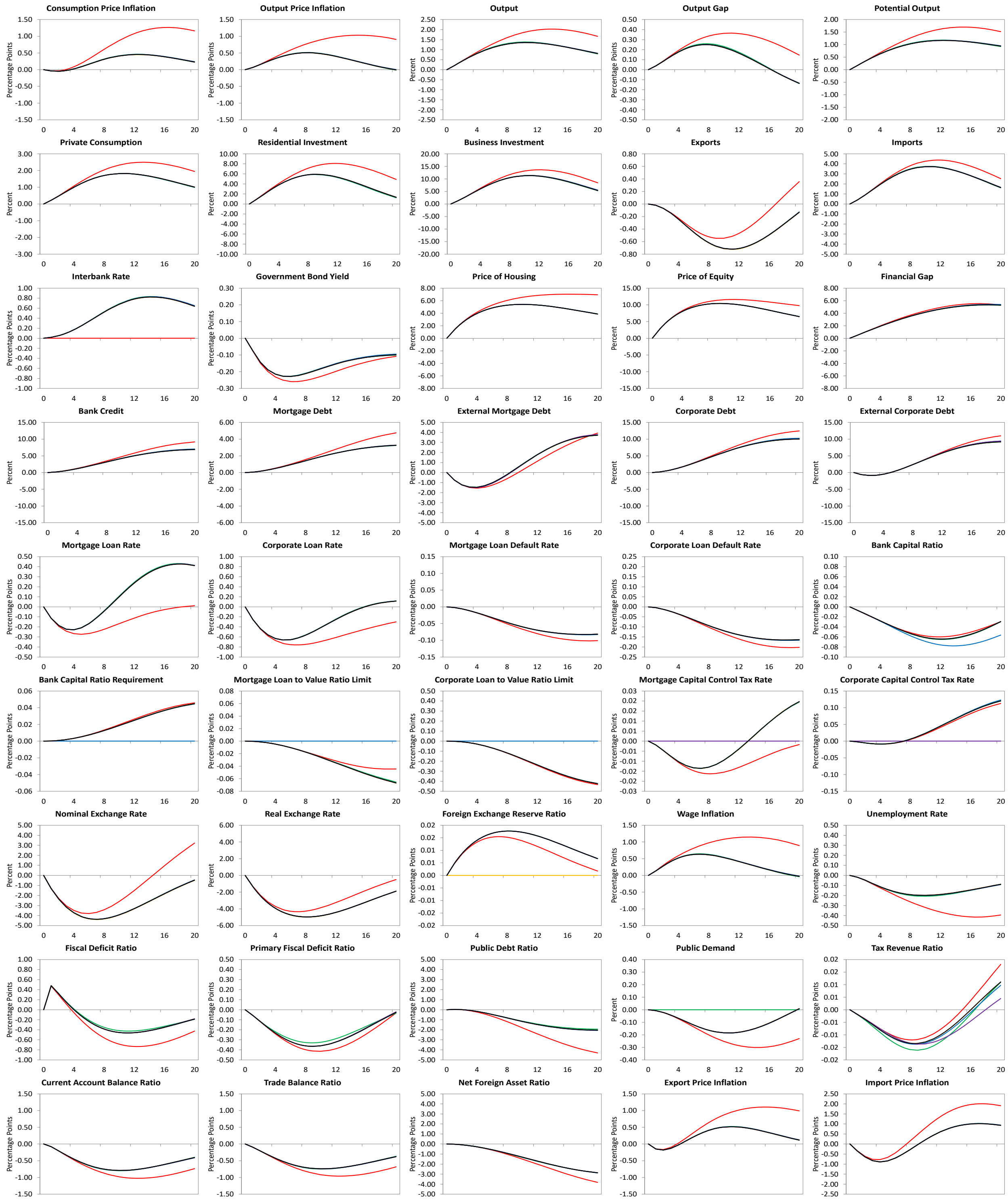
Appendix D. Constrained Scenarios

Figure 23. Domestic Financial Cycle Upturn Scenario for Korea



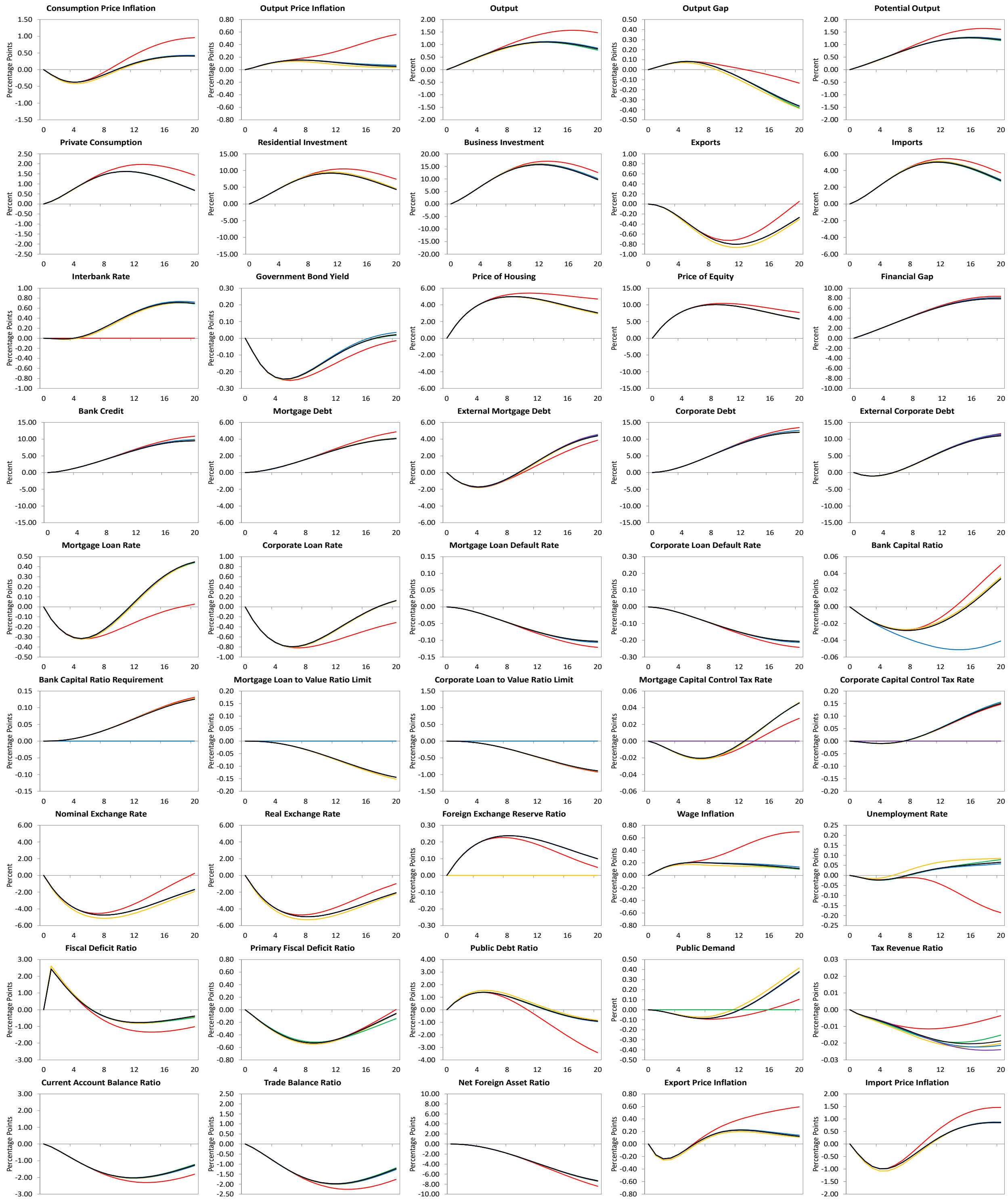
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 24. Domestic Financial Cycle Upturn Scenario for South Africa



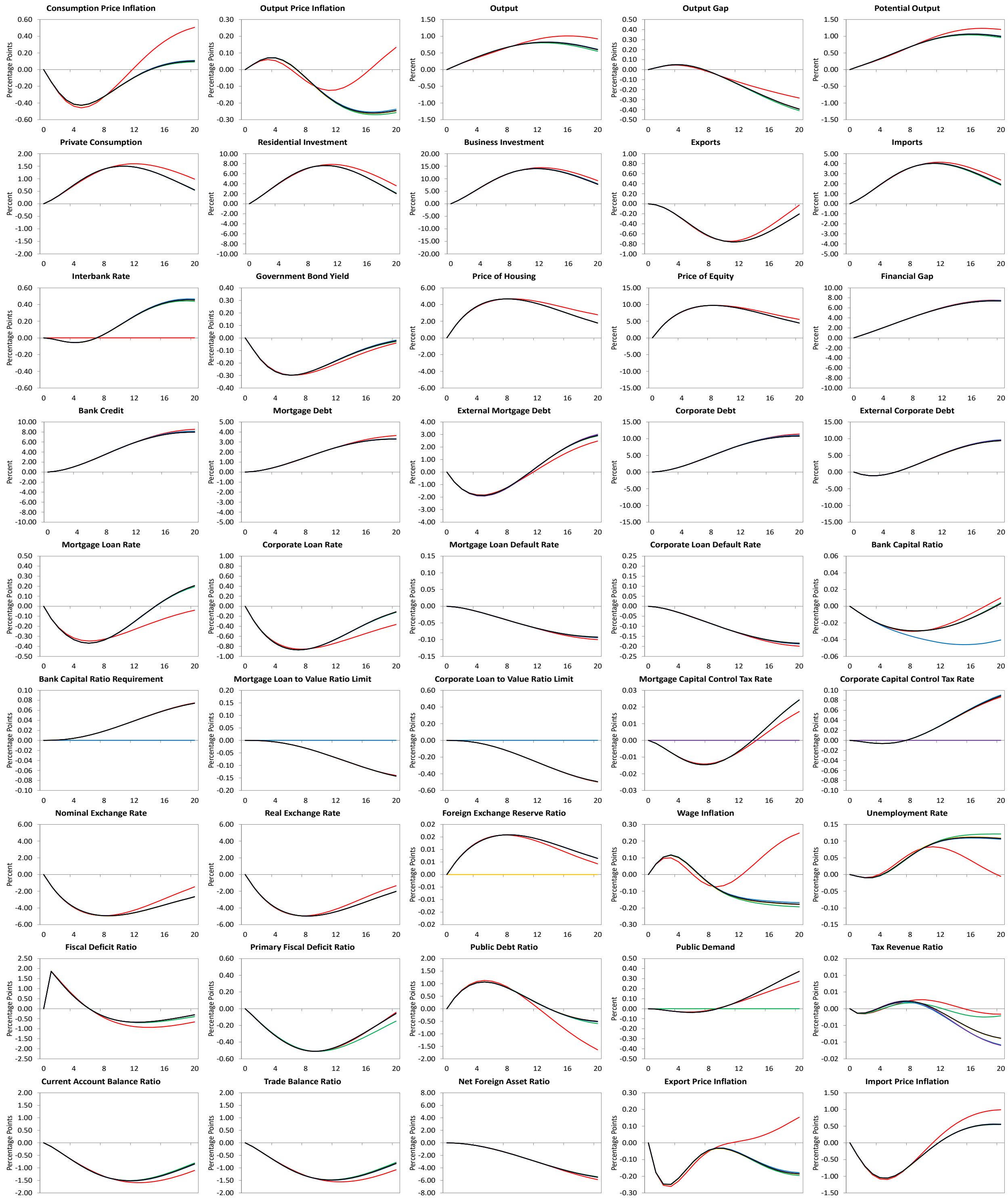
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 25. Domestic Financial Cycle Upturn Scenario for Switzerland



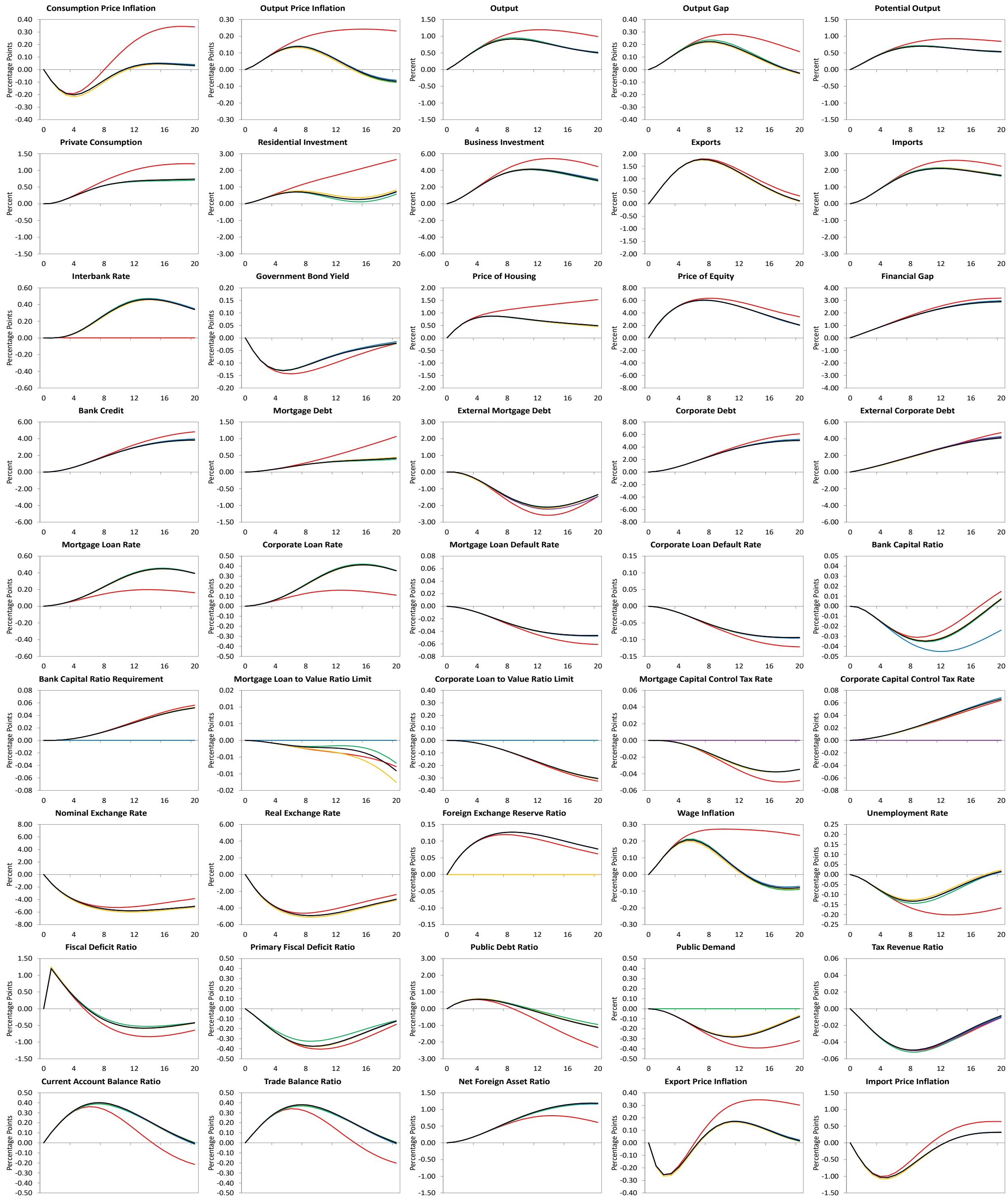
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 26. Domestic Financial Cycle Upturn Scenario for Thailand



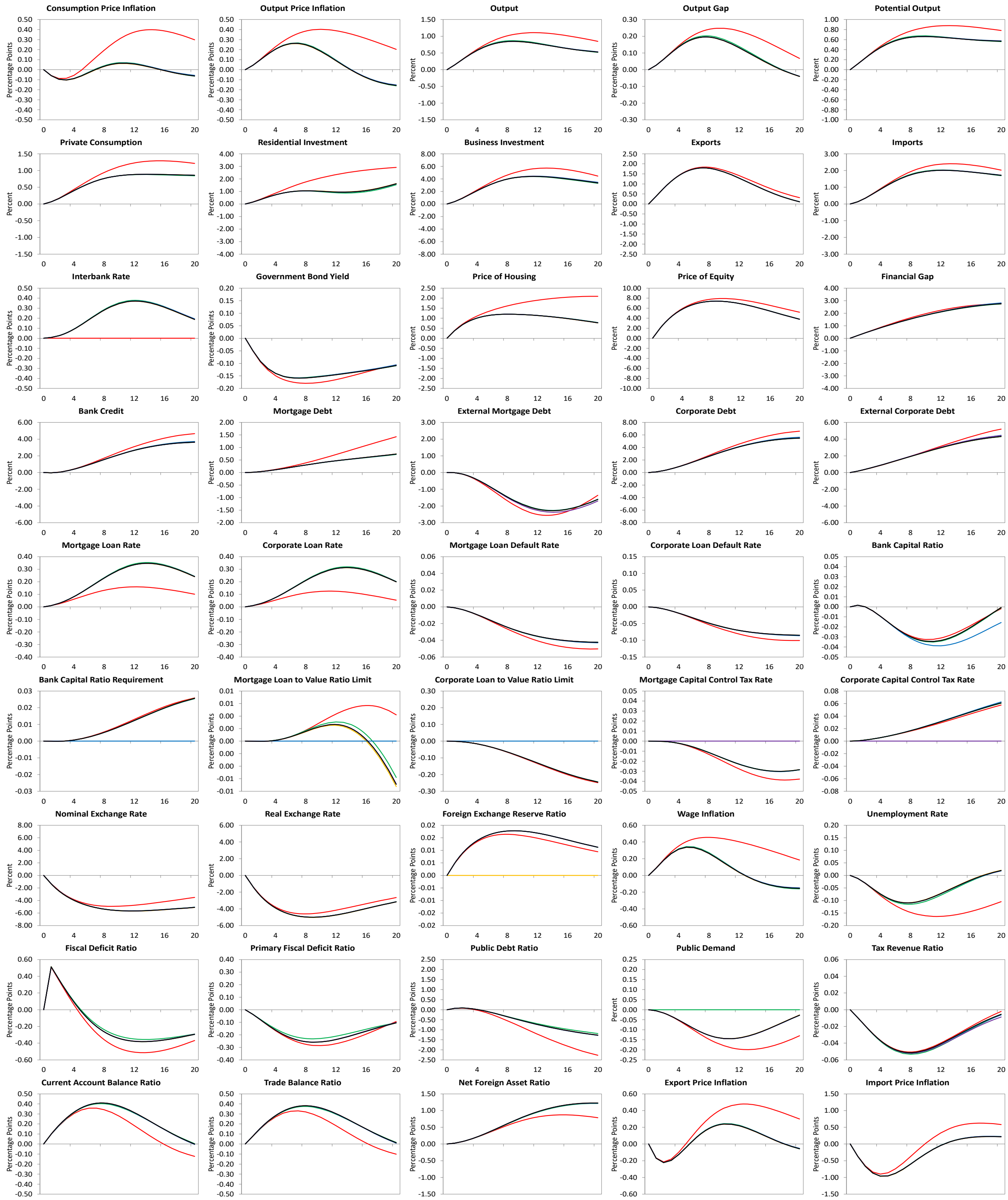
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 27. Global Financial Cycle Upturn Scenario for Korea



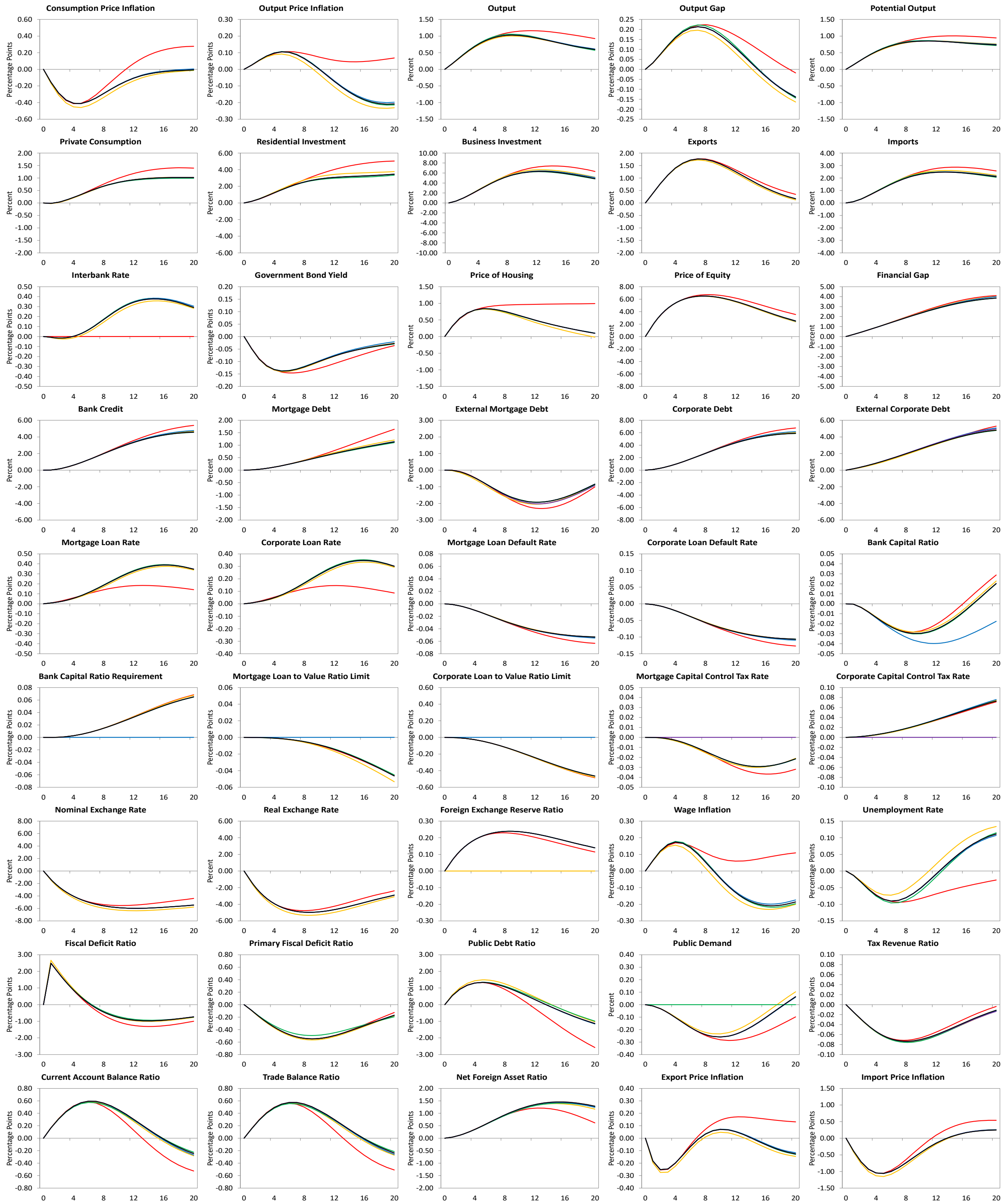
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 28. Global Financial Cycle Upturn Scenario for South Africa



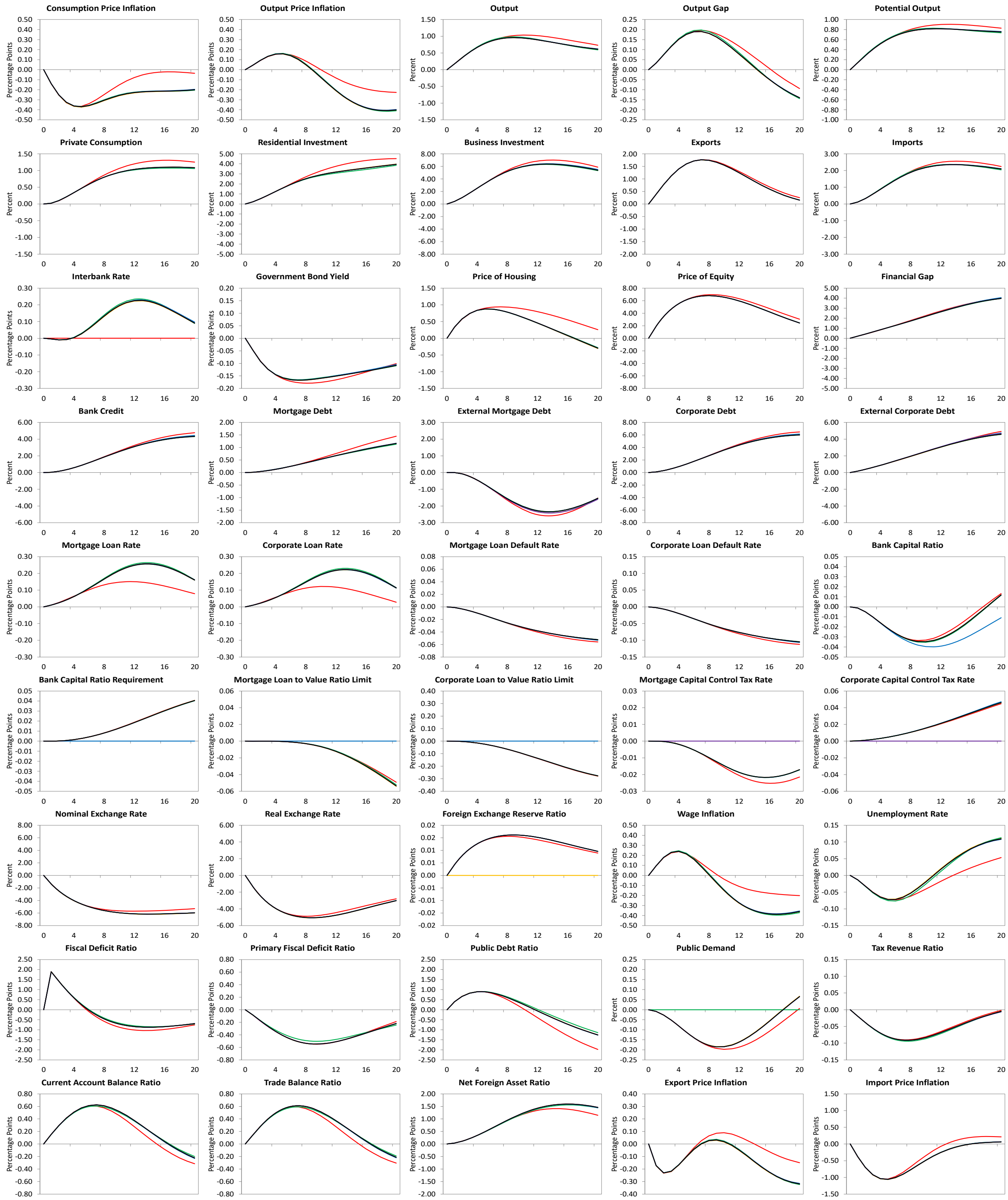
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 29. Global Financial Cycle Upturn Scenario for Switzerland



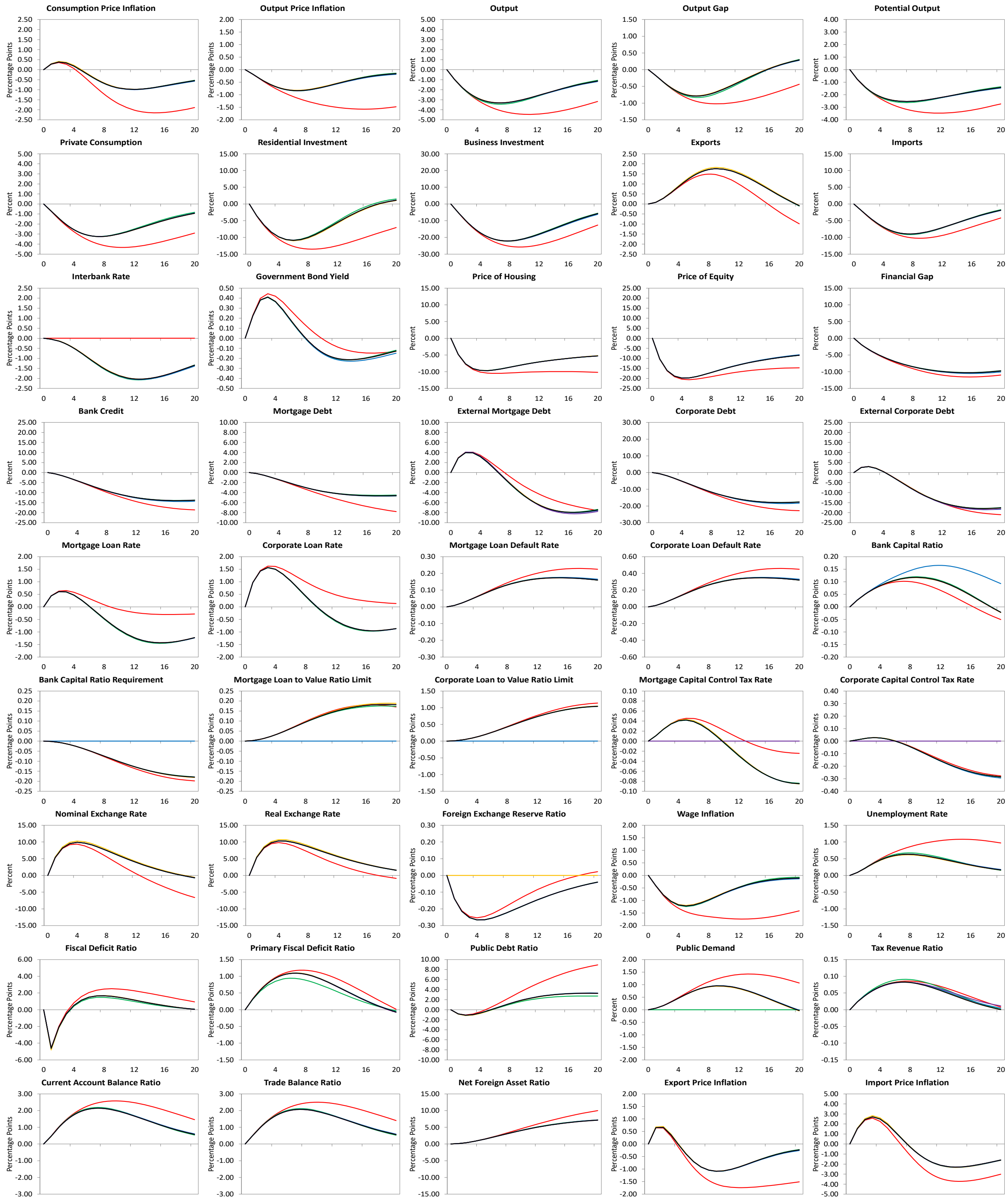
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 30. Global Financial Cycle Upturn Scenario for Thailand



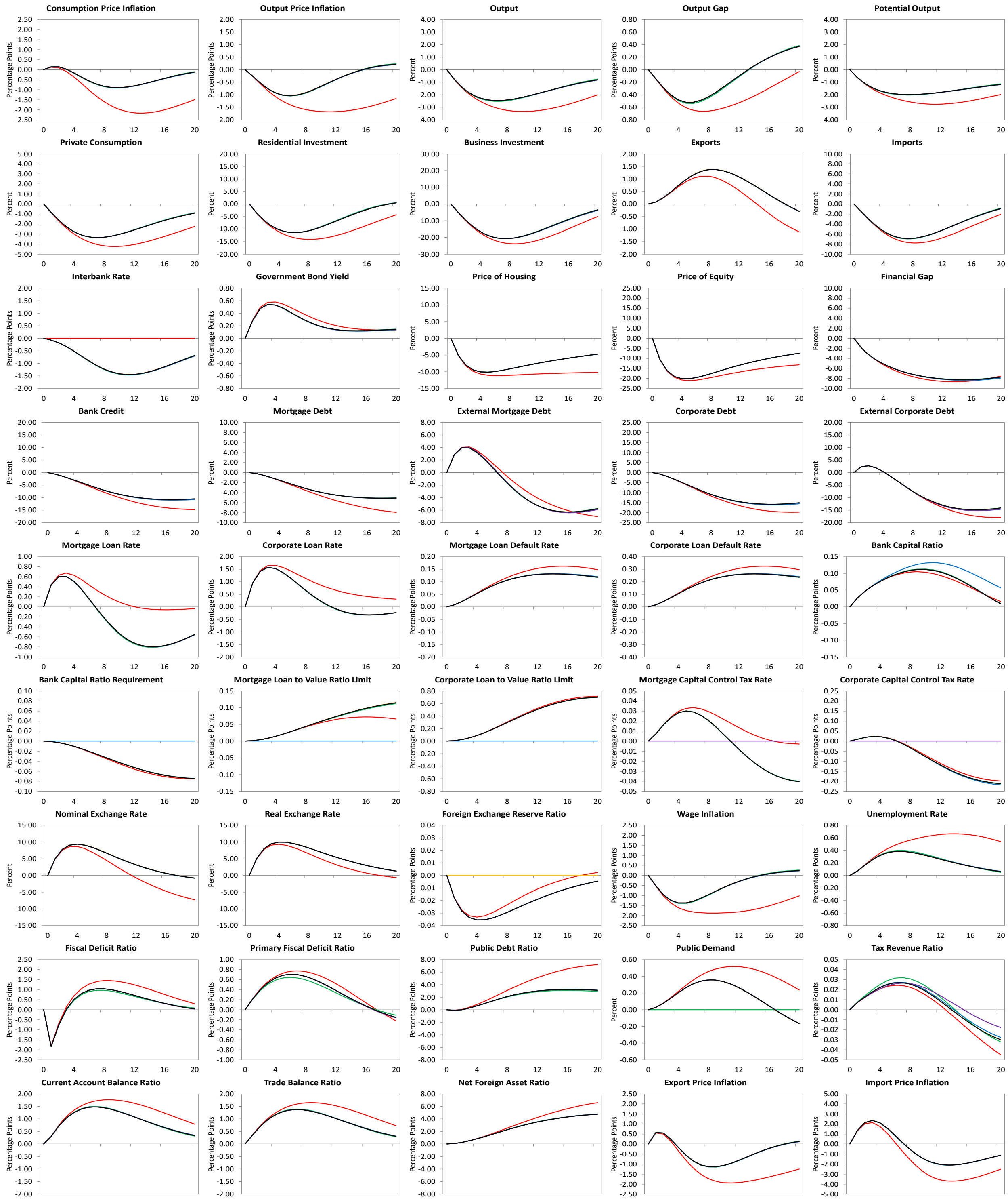
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 31. Domestic Financial Cycle Downturn Scenario for Korea



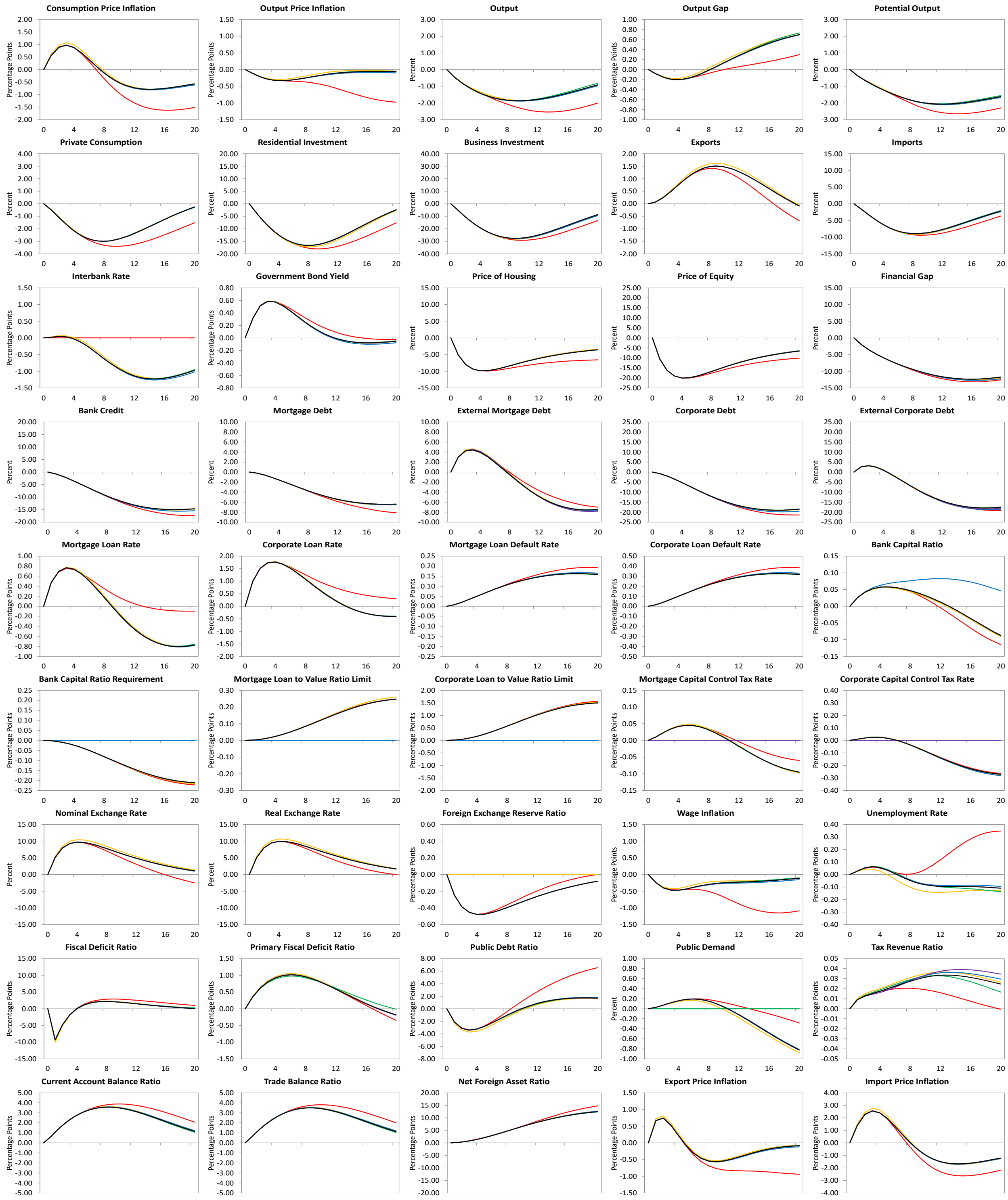
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 32. Domestic Financial Cycle Downturn Scenario for South Africa



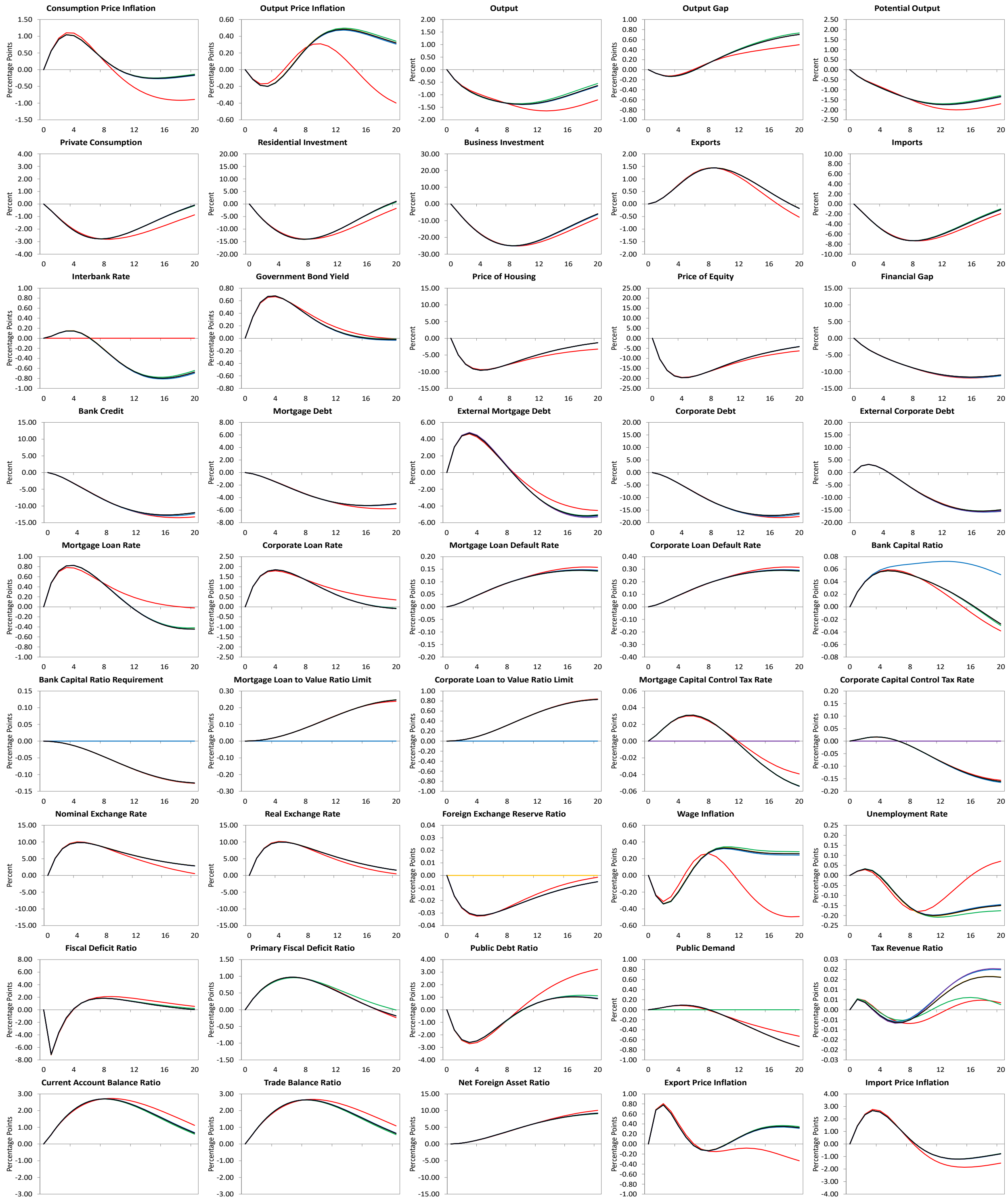
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 33. Domestic Financial Cycle Downturn Scenario for Switzerland



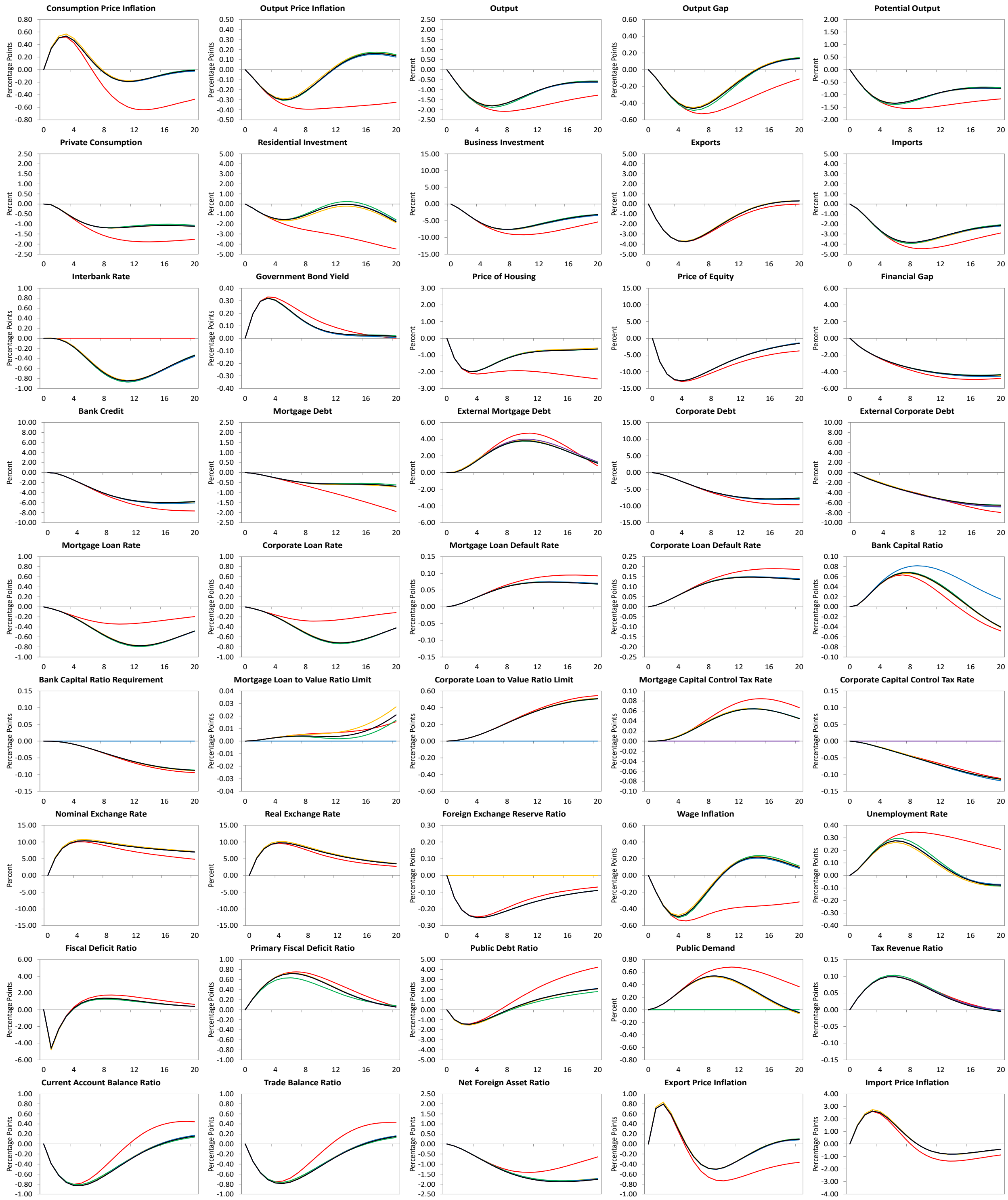
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 34. Domestic Financial Cycle Downturn Scenario for Thailand



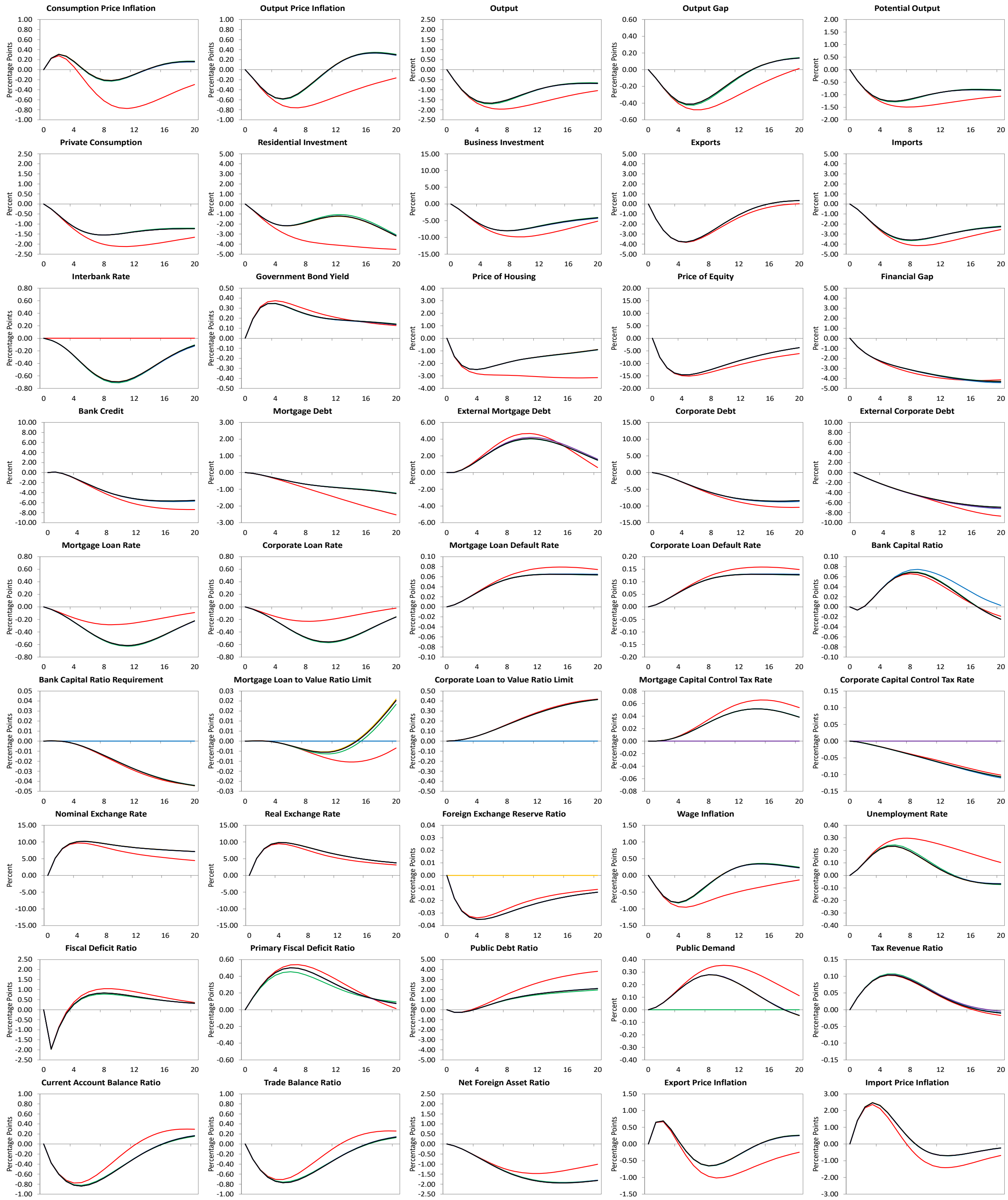
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 35. Global Financial Cycle Downturn Scenario for Korea



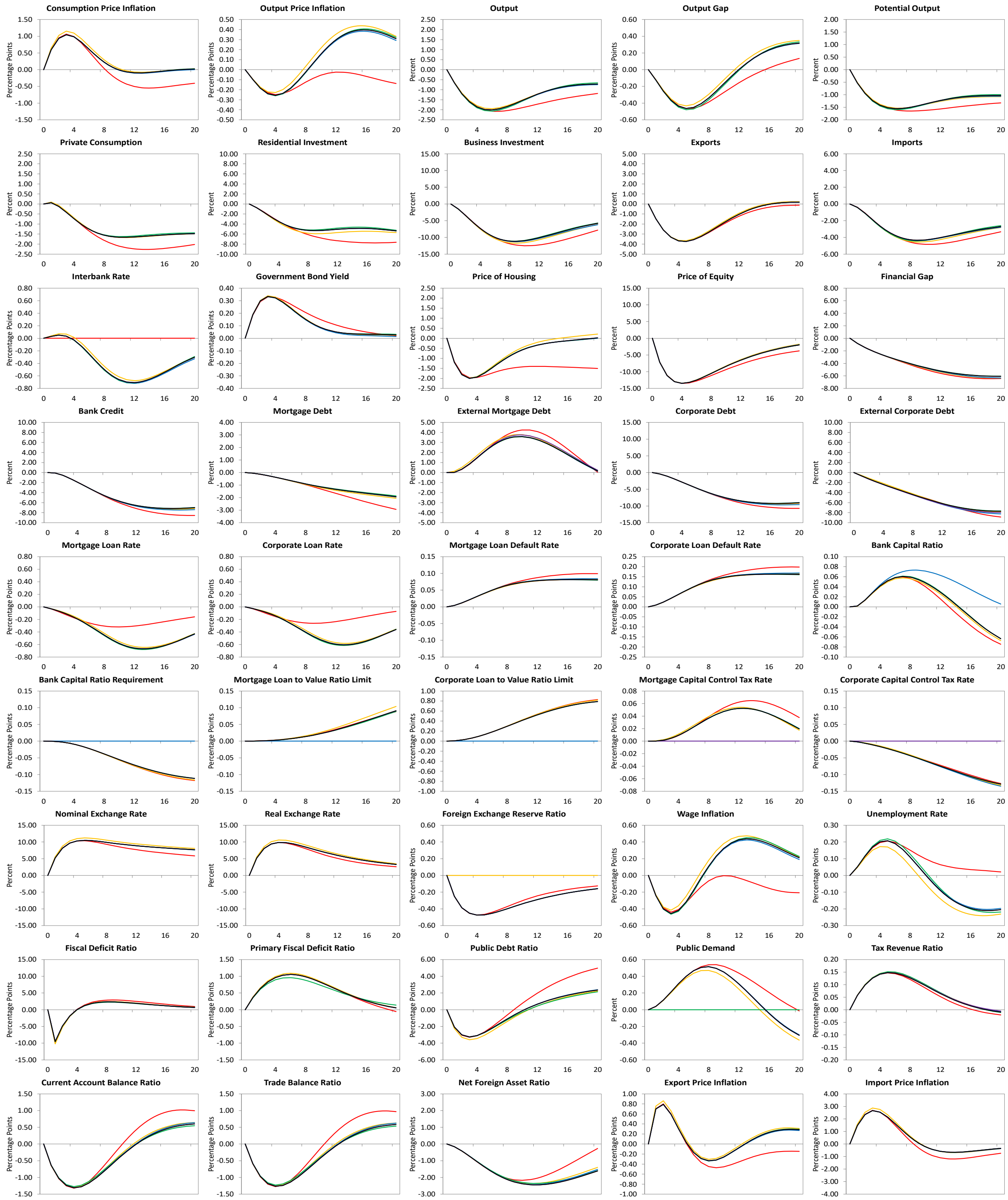
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 36. Global Financial Cycle Downturn Scenario for South Africa



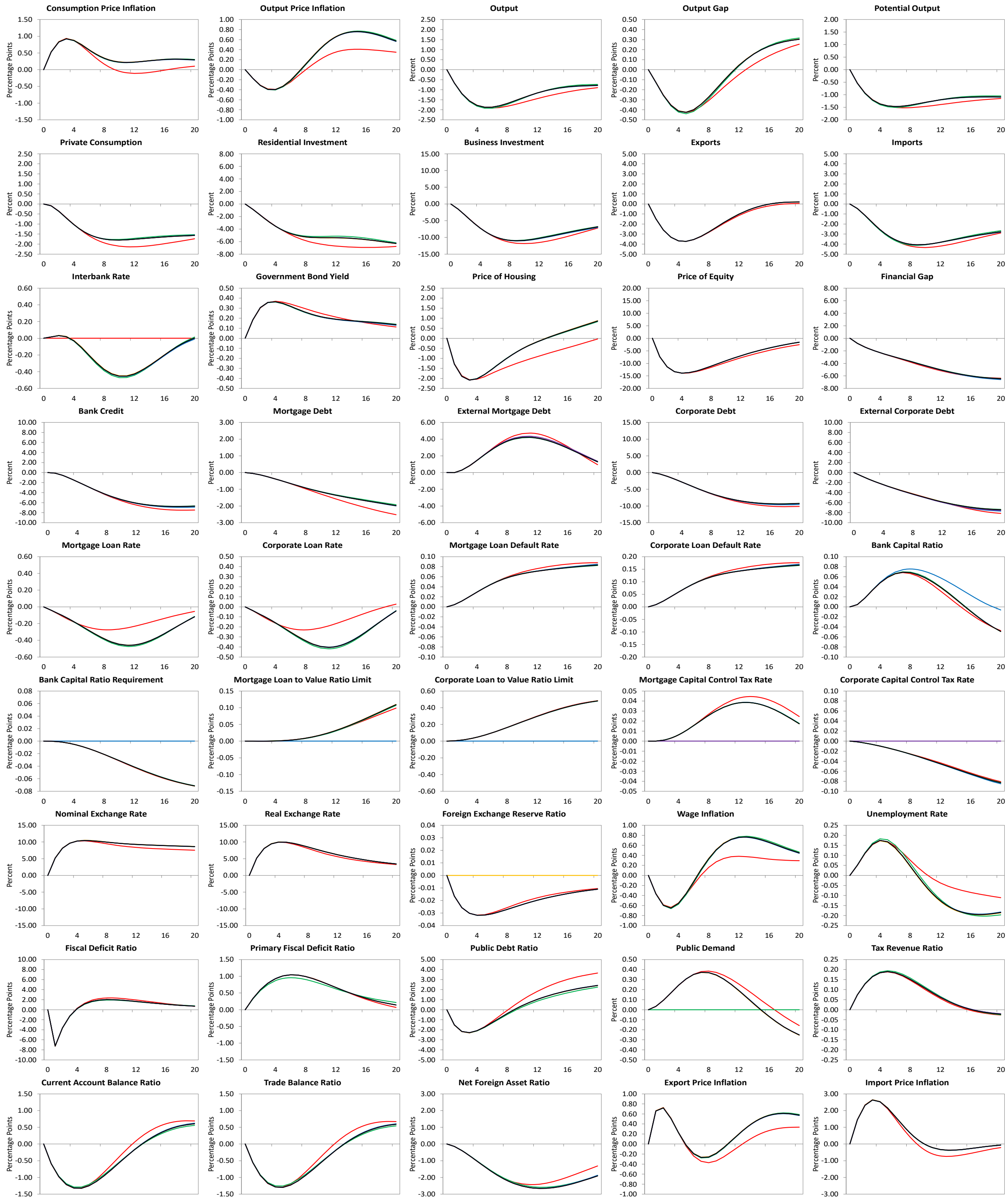
Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 37. Global Financial Cycle Downturn Scenario for Switzerland



Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

Figure 38. Global Financial Cycle Downturn Scenario for Thailand



Note: Depicts simulation results with unconstrained policies ■ versus constrained monetary policy ■, foreign exchange intervention ■, fiscal policy ■, macroprudential policy ■, and capital flow management ■. All variables are annualized, where applicable.

References

Adler, G., N. Lisack and R. Mano (2019), "Unveiling the Effects of Foreign Exchange Intervention: A Panel Approach", *Emerging Markets Review*, Vol. 40, pp. 1-29.

Adrian, T., N. Boyarchenko and D. Giannone (2019), "Vulnerable Growth", *American Economic Review*, Vol. 109, pp. 1263-1289.

Adrian, T., C. Erceg, M. Kolasa, J. Lindé and P. Zabczyk (2021), "A Quantitative Microfounded Model for the Integrated Policy Framework", *IMF Working Paper*, No. 292.

Adrian, T. and F. Vitek (2020), "Managing Macrofinancial Risk", *IMF Working Paper*, No. 151.

Basu, S., E. Boz, G. Gopinath, F. Roch and F. Unsal (2020), "A Conceptual Model for the Integrated Policy Framework", *IMF Working Paper*, No. 121.

Calvo, G. (1983), "Staggered Prices in a Utility-Maximizing Framework", *Journal of Monetary Economics*, Vol. 12, pp. 383-398.

Christiano, L., M. Eichenbaum and C. Evans (2005), "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy", *Journal of Political Economy*, Vol. 113, pp. 1-45.

Du, W. and J. Schreger (2021), "Sovereign Risk, Currency Risk, and Corporate Balance Sheets", *Unpublished Manuscript*.

Erceg, C., D. Henderson and A. Levin (2000), "Optimal Monetary Policy with Staggered Wage and Price Contracts", *Journal of Monetary Economics*, Vol. 46, pp. 281-313.

Gabaix, X. and M. Maggiori (2015), "International Liquidity and Exchange Rate Dynamics", *Quarterly Journal of Economics*, Vol. 130, pp. 1369-1420.

Galí, J. (2011), "The Return of the Wage Phillips Curve", *Journal of the European Economic Association*, Vol. 9, pp. 436-461.

Gerali, A., S. Neri, L. Sessa and F. Signoretti (2010), "Credit and Banking in a DSGE Model of the Euro Area", *Journal of Money, Credit and Banking*, Vol. 42, pp. 107-141.

Hülsewig, O., E. Mayer and T. Wollmershäuser (2009), "Bank Behavior, Incomplete Interest Rate Pass-Through, and the Cost Channel of Monetary Policy Transmission", *Economic Modelling*, Vol. 26, pp. 1310-1327.

International Monetary Fund (2020), "Toward an Integrated Policy Framework", *IMF Policy Paper*, No. 46.

Kiyotaki, N. and J. Moore (1997), "Credit Cycles", *Journal of Political Economy*, Vol. 105, pp. 211-248.

Lama, R. and J. Medina (2020), "Shocks Matter: Managing Capital Flows with Multiple Instruments in Emerging Economies", *IMF Working Paper*, No. 97.

Lucas, R. (1976), "Econometric Policy Evaluation: A Critique", *Carnegie-Rochester Conference Series on Public Policy*, Vol. 1, pp. 19-46.

Magud, N., C. Reinhart and K. Rogoff (2018), "Capital Controls: Myth and Reality", *Annals of Economics and Finance*, Vol. 19, pp. 1-47.

Monacelli, T. (2005), "Monetary Policy in a Low Pass-Through Environment", *Journal of Money, Credit and Banking*, Vol. 37, pp. 1047-1066.

Smets, F. and R. Wouters (2003), "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area", *Journal of the European Economic Association*, Vol. 1, pp. 1123-1175.

Taylor, J. (1993), "Discretion versus Policy Rules in Practice", *Carnegie-Rochester Conference Series on Public Policy*, Vol. 39, pp. 195-214.

Theil, H. (1966), *Applied Economic Forecasting*, North Holland Press.

Vegh, C. and G. Vuletin (2013), "Overcoming the Fear of Free Falling: Monetary Policy Graduation in Emerging Markets", *The Role of Central Banks in Financial Stability: How Has It Changed?*, World Scientific Publishing Company.

Vitek, F. (2008), *Monetary Policy Analysis in a Small Open Economy: Development and Evaluation of Quantitative Tools*, VDM Verlag.

Woodford, M. (2001), "Fiscal Requirements for Price Stability", *Journal of Money, Credit and Banking*, Vol. 33, pp. 669-728.

PUBLICATIONS

A Medium-Scale DSGE Model for the Integrated Policy Framework

Working Paper No. WP/2022/XX