WP/15/227

IMF Working Paper

Macrofinancial Analysis in the World Economy: A Panel Dynamic Stochastic General Equilibrium Approach

by Francis Vitek

INTERNATIONAL MONETARY FUND

 WP/15/227

IMF Working Paper

Monetary and Capital Markets Department

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Authorized for distribution by Ulric Erickson von Allmen

October 2015

Abstract

This paper develops a structural macroeconometric model of the world economy, disaggregated into forty national economies. This panel dynamic stochastic general equilibrium model features a range of nominal and real rigidities, extensive macrofinancial linkages, and diverse spillover transmission channels. A variety of monetary policy analysis, fiscal policy analysis, macroprudential policy analysis, spillover analysis, and forecasting applications of the estimated model are demonstrated. These include quantifying the monetary, fiscal and macroprudential transmission mechanisms, accounting for business cycle fluctuations, and generating relatively accurate forecasts of inflation and output growth.

JEL Classification Numbers: C11; C33; C51; E30; E44; E52; E62; F41; G21; G28

Keywords: Monetary policy analysis; Fiscal policy analysis; Macroprudential policy analysis; Spillover analysis; Forecasting; World economy; Bayesian econometrics

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[1] The author gratefully acknowledges advice provided by Tamim Bayoumi and Peter Dattels, as well as comments and suggestions received from seminar participants at the Bank of Canada and the IMF.

Contents Page

I. INTRODUCTION

Estimated dynamic stochastic general equilibrium models are widely used by monetary and fiscal authorities for policy analysis and forecasting purposes. This class of structural macroeconometric models has many variants, incorporating a range of nominal and real rigidities, and increasingly often macrofinancial linkages. Its unifying feature is the derivation of approximate linear equilibrium conditions from constrained optimization problems facing households and firms, which interact with governments in an uncertain environment to determine equilibrium prices and quantities under rational expectations.

Developing and estimating a dynamic stochastic general equilibrium model of the world economy, disaggregated into a large number of national economies, presents unique challenges. Adequately accounting for international business cycle comovement requires sufficient spillover transmission channels, in particular international financial linkages. Coping with the curse of dimensionality, which manifests through explosions of the numbers of variables and parameters as the number of economies increases, requires targeted parameter restrictions.

This paper develops a structural macroeconometric model of the world economy, disaggregated into forty national economies. This panel dynamic stochastic general equilibrium model features a range of nominal and real rigidities, extensive macrofinancial linkages, and diverse spillover transmission channels. Following Smets and Wouters (2003), the model features short run nominal price and wage rigidities generated by monopolistic competition, staggered reoptimization, and partial indexation in the output and labor markets. Following Christiano, Eichenbaum and Evans (2005), the resultant inertia in inflation and persistence in output is enhanced with other features such as habit persistence in consumption, adjustment costs in investment, and variable capital utilization. Following Galí (2011), the model incorporates involuntary unemployment though a reinterpretation of the labor market. Households are differentiated according to whether they are bank intermediated, capital market intermediated, or credit constrained. Bank intermediated households have access to domestic banks where they accumulate deposits, whereas capital market intermediated households have access to domestic and foreign capital markets where they trade financial assets. Following Vitek (2013), these capital market intermediated households solve a portfolio balance problem, allocating their financial wealth across domestic and foreign money, bond and stock market securities which are imperfect substitutes. To cope with the curse of dimensionality, targeted parameter restrictions are imposed on the optimality conditions determining the solution to this portfolio balance problem, avoiding the need to track the evolution of bilateral asset allocations. Firms are grouped into differentiated industries. Following Vitek (2013), the commodity industries produce internationally homogeneous goods under decreasing returns to scale, while all other industries produce internationally heterogeneous goods under constant returns to scale. Banks perform global financial intermediation subject to financial frictions and a regulatory constraint. Building on Hülsewig, Mayer and Wollmershäuser (2009), they issue risky domestic currency denominated loans to domestic and foreign firms at infrequently adjusted predetermined lending rates. Also building on Gerali, Neri, Sessa and Signoretti (2010), they obtain funding from domestic bank intermediated households via deposits and from the domestic money market via loans, and accumulate bank capital out of retained earnings given credit losses to satisfy a regulatory capital requirement. Motivated by Kiyotaki and Moore (1997), the model incorporates a financial accelerator mechanism linked to collateralized borrowing. Finally, following Monacelli (2005) the model accounts for short run incomplete exchange rate pass through with short run nominal price rigidities generated by monopolistic competition, staggered reoptimization, and partial indexation in the import markets. An approximate linear state space representation of the model is estimated by Bayesian maximum likelihood, conditional on prior information concerning the generally common values of structural parameters across economies.

A variety of monetary policy analysis, fiscal policy analysis, macroprudential policy analysis, spillover analysis, and forecasting applications of this estimated panel dynamic stochastic general equilibrium model of the world economy are demonstrated. These include quantifying the monetary, fiscal and macroprudential transmission mechanisms, accounting for business cycle fluctuations, and generating forecasts of inflation and output growth. The monetary, fiscal and macroprudential transmission mechanisms, as quantified with estimated impulse response functions, are broadly in line with the empirical literature, as are the drivers of business cycle fluctuations, as accounted for with estimated historical decompositions. Sequential unconditional forecasts of inflation and output growth dominate a random walk in terms of predictive accuracy by wide margins, on average across economies and horizons.

This paper is the sequel to Vitek (2014), which also develops a structural macroeconometric model of the world economy, disaggregated into forty national economies, to facilitate multilaterally consistent policy analysis, spillover analysis, and forecasting. These closely related panel dynamic stochastic general equilibrium models differ primarily with respect to the existence of a global banking network. This extension significantly enhances the macrofinancial linkages embedded in the present model while rendering it applicable to macroprudential policy analysis.

The organization of this paper is as follows. The next section develops a panel dynamic stochastic general equilibrium model of the world economy, while the following section describes an approximate multivariate linear rational expectations representation of it. Estimation of the model based on an approximate linear state space representation of it is the subject of section four. Policy analysis within the framework of the estimated model is conducted in section five, while spillover analysis is undertaken in section six, and forecasting in section seven. Finally, section eight offers conclusions and recommendations for further research.

II. The Theoretical Framework

Consider a finite set of structurally isomorphic national economies indexed by $i \in \{1, \ldots, N\}$ which constitutes the world economy. Each of these economies consists of households, firms, banks, and a government. The government in turn consists of a monetary authority, a fiscal authority, and a macroprudential authority. Households, firms and banks optimize intertemporally, interacting with governments in an uncertain environment to determine equilibrium prices and quantities under rational expectations in globally integrated output and financial markets. Economy i^* issues the quotation currency for transactions in the foreign exchange market.

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, and according to how they save if they are credit unconstrained, but are otherwise identical. Credit unconstrained households of type $Z = B$ and measure ϕ^B have access to domestic banks where they accumulate deposits, and are endowed with one share of each domestic firm, where $0 < \phi^B < 1$. In contrast, credit unconstrained households of type $Z = A$ and measure ϕ^A have access to domestic and foreign capital markets where they trade financial assets, where $0 < \phi^A < 1$. Finally, credit constrained households of type $Z = C$ and measure ϕ^C do not have access to banks or capital markets, and are endowed only with one share of each domestic firm, where $0 \leq \phi^C < 1$ and $\phi^B + \phi^A + \phi^C = 1$.

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 $(f,g) \in [0,1] \times [0,1]$. There is full risk sharing among household members, who supply indivisible differentiated intermediate labor services indexed by $f \in [0,1]$, incurring disutility from work determined by $g \in [0,1]$ if they are employed and zero otherwise. Trade specific intermediate labor services supplied by bank intermediated, capital market intermediated, and credit constrained households are perfect substitutes.

Consumption and Saving

The representative infinitely lived household has preferences defined over consumption $C_{h,i,s}$, labor supply $\{L_{h,f,i,s}\}_{f=0}^{1}$, real bank balances $B_{h,i,s+1}^{D,H} / P_{i,s}^{C}$, and real portfolio balances $A_{h,i,s+1}^{A,H} / P_{i,s}^{C}$ represented by intertemporal utility function

$$U_{h,i,t} = \mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} u\left(C_{h,i,s}, \{L_{h,f,i,s}\}_{f=0}^{1}, \frac{B_{h,i,s+1}^{D,H}}{P_{i,s}^{C}}, \frac{A_{h,i,s+1}^{A,H}}{P_{i,s}^{C}} \right), \tag{1}$$

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,

$$u\left(C_{h,i,s},\{L_{h,f,i,s}\}_{f=0}^{1},\frac{B_{h,i,s+1}^{D,H}}{P_{i,s}^{C}},\frac{A_{h,i,s+1}^{A,H}}{P_{i,s}^{C}}\right)=\nu_{i,s}^{C}\left[\frac{1}{1-1/\sigma}\left(C_{h,i,s}-\alpha\frac{C_{i,s-1}^{Z}}{\phi^{Z}}\right)^{1-1/\sigma}\right.$$
$$\left.-\upsilon_{i,s}^{L}\int_{0}^{1}\int_{0}^{L_{h,f,i,s}}g^{1/\eta}dgdf+\frac{\upsilon_{i,s}^{D}}{1-1/\mu}\left(\frac{B_{h,i,s+1}^{D,H}}{P_{i,s}^{C}}\right)^{1-1/\mu}+\frac{\upsilon_{i,s}^{A}}{1-1/\mu}\left(\frac{A_{h,i,s+1}^{A,H}}{P_{i,s}^{C}}\right)^{1-1/\mu}\right], \tag{2}$$

where $0\leq\alpha<1$. Endogenous preference shifters $\upsilon_{i,s}^{L}$, $\upsilon_{i,s}^{D}$ and $\upsilon_{i,s}^{A}$ depend on aggregate consumption and employment according to intratemporal subutility functions

$$\upsilon_{i,s}^{L}=\nu_{i,s}^{L}\left(\frac{C_{i,s}^{Z}}{\phi^{Z}}-\alpha\frac{C_{i,s-1}^{Z}}{\phi^{Z}}\right)^{-1/\sigma}(L_{i,s})^{-1/\iota}, \tag{3}$$

$$\upsilon_{i,s}^{D}=\nu_{i}^{D}\left(\frac{C_{i,s}^{Z}}{\phi^{Z}}-\alpha\frac{C_{i,s-1}^{Z}}{\phi^{Z}}\right)^{-1/\sigma}(C_{i,s})^{1/\mu}, \tag{4}$$

$$\upsilon_{i,s}^{A}=\nu_{i}^{A}\left(\frac{C_{i,s}^{Z}}{\phi^{Z}}-\alpha\frac{C_{i,s-1}^{Z}}{\phi^{Z}}\right)^{-1/\sigma}(C_{i,s})^{1/\mu}, \tag{5}$$

where $\iota>0$. The intratemporal utility function is strictly increasing with respect to consumption if and only if serially correlated consumption demand shock $\nu_{i,s}^{C}$ satisfies $\nu_{i,s}^{C}>0$. Given this parameter restriction, this intratemporal utility function is strictly decreasing with respect to labor supply if and only if serially correlated labor supply shock $\nu_{i,s}^{L}$ satisfies $\nu_{i,s}^{L}>0$, is strictly increasing with respect to real bank balances if and only if $\nu_{i}^{D}>0$, and is strictly increasing with respect to real portfolio balances if and only if $\nu_{i}^{A}>0$. Given these parameter restrictions, this intratemporal utility function is strictly concave if $\sigma>0$, $\eta>0$ and $\mu>0$. In steady state equilibrium, ν_{i}^{A} equates the marginal rate of substitution between real portfolio balances and consumption to one.

The representative household has capitalist spirit motives for holding real bank and portfolio balances, independent of financing deferred consumption, motivated by Weber (1905). It also has a diversification motive over the allocation of real portfolio balances across alternative financial assets which are imperfect substitutes, motivated by Tobin (1969). The set of financial assets under consideration consists of internationally traded and local currency denominated short term bonds, long term bonds, and stocks. Short term bonds are discount bonds, while long term bonds are perpetual bonds. Preferences over the real values of internationally diversified short term bond $B_{h,i,s+1}^{S,H}/P_{i,s}^{C}$, long term bond $B_{h,i,s+1}^{L,H}/P_{i,s}^{C}$ and stock $S_{h,i,s+1}^{H}/P_{i,s}^{C}$ portfolios are represented by constant elasticity of substitution intratemporal subutility function

$$\frac{A_{h,i,s+1}^{A,H}}{P_{i,s}^{C}}=\left[(\phi_{i,M}^{A})^{\frac{1}{\psi^{A}}}\left(\frac{B_{h,i,s+1}^{S,H}}{P_{i,s}^{C}}\right)^{\frac{\psi^{A}-1}{\psi^{A}}}+(\phi_{i,B}^{A})^{\frac{1}{\psi^{A}}}\left(\upsilon_{i,s}^{B}\frac{B_{h,i,s+1}^{L,H}}{P_{i,s}^{C}}\right)^{\frac{\psi^{A}-1}{\psi^{A}}}+(\phi_{i,S}^{A})^{\frac{1}{\psi^{A}}}\left(\upsilon_{i,s}^{S}\frac{S_{h,i,s+1}^{H}}{P_{i,s}^{C}}\right)^{\frac{\psi^{A}-1}{\psi^{A}}}\right]^{\frac{\psi^{A}}{\psi^{A}-1}}, \tag{6}$$

where internationally and serially correlated duration risk premium shock $\upsilon_{i,s}^{B}$ satisfies $\upsilon_{i,s}^{B} > 0$, and internationally and serially correlated equity risk premium shock $\upsilon_{i,s}^{S}$ satisfies $\upsilon_{i,s}^{S} > 0$, while $0 \le \phi_{i,M}^{A} \le 1$, $0 \le \phi_{i,B}^{A} \le 1$, $0 \le \phi_{i,S}^{A} \le 1$, $\phi_{i,M}^{A} + \phi_{i,B}^{A} + \phi_{i,S}^{A} = 1$ and $\psi^{A} > 0$. Preferences over the real values of economy specific short term bond $\{\mathcal{E}_{i,j,s} B_{h,i,j,s+1}^{S,H} / P_{i,s}^{C}\}_{j=1}^{N}$, long term bond $\{\mathcal{E}_{i,j,s} B_{h,i,j,s+1}^{L,H} / P_{i,s}^{C}\}_{j=1}^{N}$ and stock $\{\mathcal{E}_{i,j,s} S_{h,i,j,s+1}^{H} / P_{i,s}^{C}\}_{j=1}^{N}$ portfolios are in turn represented by constant elasticity of substitution intratemporal subutility functions

$$\frac{B_{h,i,s+1}^{S,H}}{P_{i,s}^{C}} = \left[\sum_{j=1}^{N} (\phi_{i,j}^{B})^{\frac{1}{\psi^{A}}} \left(\nu_{j,s}^{\mathcal{E}} \frac{\mathcal{E}_{i,j,s} B_{h,i,j,s+1}^{S,H}}{P_{i,s}^{C}} \right)^{\frac{\psi^{A}-1}{\psi^{A}}} \right]^{\frac{\psi^{A}}{\psi^{A}-1}}, \tag{7}$$

$$\frac{B_{h,i,s+1}^{L,H}}{P_{i,s}^{C}} = \left[\sum_{j=1}^{N} (\phi_{i,j}^{B})^{\frac{1}{\psi^{A}}} \left(\nu_{j,s}^{\mathcal{E}} \frac{\mathcal{E}_{i,j,s} B_{h,i,j,s+1}^{L,H}}{P_{i,s}^{C}} \right)^{\frac{\psi^{A}-1}{\psi^{A}}} \right]^{\frac{\psi^{A}}{\psi^{A}-1}}, \tag{8}$$

$$\frac{S_{h,i,s+1}^{H}}{P_{i,s}^{C}} = \left[\sum_{j=1}^{N} (\phi_{i,j}^{S})^{\frac{1}{\psi^{A}}} \left(\nu_{j,s}^{\mathcal{E}} \frac{\mathcal{E}_{i,j,s} S_{h,i,j,s+1}^{H}}{P_{i,s}^{C}} \right)^{\frac{\psi^{A}-1}{\psi^{A}}} \right]^{\frac{\psi^{A}}{\psi^{A}-1}}, \tag{9}$$

where serially correlated currency risk premium shocks $\nu_{j,s}^{\mathcal{E}}$ satisfy $\nu_{j,s}^{\mathcal{E}} > 0$, while $0 \le \phi_{i,j}^{B} \le 1$, $\sum_{j=1}^{N} \phi_{i,j}^{B} = 1$, $0 \le \phi_{i,j}^{S} \le 1$ and $\sum_{j=1}^{N} \phi_{i,j}^{S} = 1$. Finally, preferences over the real values of economy and vintage specific long term bonds $\{\{\mathcal{E}_{i,j,s} V_{j,k,s}^{B} B_{h,i,j,k,s+1}^{L,H} / P_{i,s}^{C}\}_{k=1}^{s}\}_{j=1}^{N}$ and economy, industry and firm specific shares $\{\{\{\mathcal{E}_{i,j,s} V_{j,k,l,s}^{S} S_{h,i,j,k,l,s+1}^{H} / P_{i,s}^{C}\}_{l=0}^{1}\}_{k=1}^{M}\}_{j=1}^{N}$ are represented by constant elasticity of substitution intratemporal subutility functions

$$\frac{\mathcal{E}_{i,j,s} B_{h,i,j,s+1}^{L,H}}{P_{i,s}^{C}} = \left[\sum_{k=1}^{s} (\phi_{i,j,k,s}^{B})^{\frac{1}{\psi^{A}}} \left(\frac{\mathcal{E}_{i,j,s} V_{j,k,s}^{B} B_{h,i,j,k,s+1}^{L,H}}{P_{i,s}^{C}} \right)^{\frac{\psi^{A}-1}{\psi^{A}}} \right]^{\frac{\psi^{A}}{\psi^{A}-1}}, \tag{10}$$

$$\frac{\mathcal{E}_{i,j,s} S_{h,i,j,s+1}^{H}}{P_{i,s}^{C}} = \left[\sum_{k=1}^{M} (\phi_{i,j,k}^{S})^{\frac{1}{\psi^{A}}} \int_{0}^{1} \left(\frac{\mathcal{E}_{i,j,s} V_{j,k,l,s}^{S} S_{h,i,j,k,l,s+1}^{H}}{P_{i,s}^{C}} \right)^{\frac{\psi^{A}-1}{\psi^{A}}} dl \right]^{\frac{\psi^{A}}{\psi^{A}-1}}, \tag{11}$$

where $0 \le \phi_{i,j,k,s}^{B} \le 1$, $\sum_{k=1}^{s} \phi_{i,j,k,s}^{B} = 1$, $0 \le \phi_{i,j,k}^{S} \le 1$ and $\sum_{k=1}^{M} \phi_{i,j,k}^{S} = 1$. In the limit as $\nu_{i}^{D} \to 0$ there is no capitalist spirit motive for holding real bank balances, and in the limit as $\nu_{i}^{A} \to 0$ there is no capitalist spirit motive for holding real portfolio balances. In the limit as $\psi^{A} \to \infty$ there is no diversification motive over the allocation of real portfolio balances across alternative financial assets, which in this case are perfect substitutes.

The representative household enters period s in possession of previously accumulated bank balances $B^{D,H}_{h,i,s}$ which bear interest at deposit rate $i^{D}_{i,s-1}$, and portfolio balances $A^{A,H}_{h,i,s}$ which yield return $i^{A^{A,H}}_{h,i,s}$. These portfolio balances are distributed across the values of internationally diversified short term bond $B^{S,H}_{h,i,s}$, long term bond $B^{L,H}_{h,i,s}$ and stock $S^{H}_{h,i,s}$ portfolios which yield returns $i^{B^{S,H}}_{h,i,s}$, $i^{B^{L,H}}_{h,i,s}$ and $i^{S^{H}}_{h,i,s}$, respectively. It follows that $(1+i^{A^{A,H}}_{h,i,s})A^{A,H}_{h,i,s}=(1+i^{B^{S,H}}_{h,i,s})B^{S,H}_{h,i,s}$ $+(1+i^{B^{L,H}}_{h,i,s})B^{L,H}_{h,i,s}+(1+i^{S^{H}}_{h,i,s})S^{H}_{h,i,s}$. The values of these internationally diversified short term bond, long term bond and stock portfolios are in turn distributed across the domestic currency denominated values of economy specific short term bond $\{\mathcal{E}_{i,j,s}B^{S,H}_{h,i,j,s}\}^{N}_{j=1}$, long term bond $\{\mathcal{E}_{i,j,s}B^{L,H}_{h,i,j,s}\}^{N}_{j=1}$ and stock $\{\mathcal{E}_{i,j,s}S^{H}_{h,i,j,s}\}^{N}_{j=1}$ portfolios, where nominal bilateral exchange rate $\mathcal{E}_{i,j,s}$ measures the price of foreign currency in terms of domestic currency. It follows that $(1+i^{B^{S,H}}_{h,i,s})B^{S,H}_{h,i,s}=\sum_{j=1}^{N}\mathcal{E}_{i,j,s}(1+i^{S}_{j,s-1})B^{S,H}_{h,i,j,s}$ where $i^{S}_{j,s-1}$ denotes the economy specific yield to maturity on short term bonds, $(1+i^{B^{L,H}}_{h,i,s})B^{L,H}_{h,i,s}=\sum_{j=1}^{N}\mathcal{E}_{i,j,s}(1+i^{B^{L,H}}_{h,i,j,s})B^{L,H}_{h,i,j,s}$ where $i^{B^{L,H}}_{h,i,j,s}$ denotes the economy specific return on long term bonds, and $(1+i^{S^{H}}_{h,i,s})S^{H}_{h,i,s}=\sum_{j=1}^{N}\mathcal{E}_{i,j,s}(1+i^{S^{H}}_{h,i,j,s})S^{H}_{h,i,j,s}$ where $i^{S^{H}}_{h,i,j,s}$ denotes the economy specific return on stocks. The local currency denominated values of economy specific long term bond portfolios $\{B^{L,H}_{h,i,j,s}\}^{N}_{j=1}$ are in turn distributed across the values of economy and vintage specific long term bonds $\{\{V^{B}_{j,k,s}B^{L,H}_{h,i,j,k,s}\}^{s-1}_{k=1}\}^{N}_{j=1}$, where $V^{B}_{j,k,s}$ denotes the local currency denominated price per long term bond, with $V^{B}_{j,k,k}=1$. It follows that $(1+i^{B^{L,H}}_{h,i,j,s})B^{L,H}_{h,i,j,s}=\sum_{k=1}^{s-1}(\Pi^{B}_{j,k,s}+V^{B}_{j,k,s})B^{L,H}_{h,i,j,k,s}$, where $\Pi^{B}_{j,k,s}=i^{L}_{j,k}V^{B}_{j,k,k}$ denotes the local currency denominated coupon payment per long term bond, and $i^{L}_{j,k}$ denotes the economy and vintage specific yield to maturity on long term bonds at issuance. In parallel, the local currency denominated values of economy specific stock portfolios $\{S^{H}_{h,i,j,s}\}^{N}_{j=1}$ are distributed across the values of economy, industry and firm specific shares $\{\{\{V^{S}_{j,k,l,s}S^{H}_{h,i,j,k,l,s}\}^{1}_{l=0}\}^{M}_{k=1}\}^{N}_{j=1}$, where $V^{S}_{j,k,l,s}$ denotes the local currency denominated price per share. It follows that $(1+i^{S^{H}}_{h,i,j,s})S^{H}_{h,i,j,s}$ $=\sum_{k=1}^{M}\int_{0}^{1}(\Pi^{S}_{j,k,l,s}+V^{S}_{j,k,l,s})S^{H}_{h,i,j,k,l,s}dl$, where $\Pi^{S}_{j,k,l,s}$ denotes the local currency denominated dividend payment per share. During period s, the representative household supplies differentiated intermediate labor services $\{L_{h,f,i,s}\}^{1}_{f=0}$, earning labor income at trade specific nominal wages $\{W_{f,i,s}\}^{1}_{f=0}$. The government levies a tax on labor income at rate $\tau_{i,s}$, and remits household type specific lump sum transfer payment T^{Z}_{i}. These sources of wealth are summed in household dynamic budget constraint:

$$B^{D,H}_{h,i,s+1}+A^{A,H}_{h,i,s+1}=(1+i^{D}_{i,s-1})B^{D,H}_{h,i,s}+(1+i^{A^{A,H}}_{h,i,s})A^{A,H}_{h,i,s}+(1-\tau_{i,s})\int_{0}^{1}W_{f,i,s}L_{h,f,i,s}df+T^{Z}_{i}-P^{C}_{i,s}C_{h,i,s}. \quad (12)$$

According to this dynamic budget constraint, at the end of period s, the representative household holds bank balances $B^{D,H}_{h,i,s+1}$ and portfolio balances $A^{A,H}_{h,i,s+1}$. It allocates these portfolio balances across the values of internationally diversified short term bond $B^{S,H}_{h,i,s+1}$, long term bond $B^{L,H}_{h,i,s+1}$ and stock portfolios $S^{H}_{h,i,s+1}$, that is $A^{A,H}_{h,i,s+1}=B^{S,H}_{h,i,s+1}+B^{L,H}_{h,i,s+1}+S^{H}_{h,i,s+1}$. The values of these internationally diversified short term bond, long term bond and stock portfolios are in turn allocated across the domestic currency denominated values of economy specific short term bond $\{\mathcal{E}_{i,j,s}B^{S,H}_{h,i,j,s+1}\}^{N}_{j=1}$, long term bond $\{\mathcal{E}_{i,j,s}B^{L,H}_{h,i,j,s+1}\}^{N}_{j=1}$ and stock $\{\mathcal{E}_{i,j,s}S^{H}_{h,i,j,s+1}\}^{N}_{j=1}$ portfolios subject to $B^{S,H}_{h,i,s+1}=\sum_{j=1}^{N}\mathcal{E}_{i,j,s}B^{S,H}_{h,i,j,s+1}$, $B^{L,H}_{h,i,s+1}=\sum_{j=1}^{N}\mathcal{E}_{i,j,s}B^{L,H}_{h,i,j,s+1}$ and $S^{H}_{h,i,s+1}=\sum_{j=1}^{N}\mathcal{E}_{i,j,s}S^{H}_{h,i,j,s+1}$, respectively. The local currency denominated values of economy specific long term bond portfolios $\{B^{L,H}_{h,i,j,s+1}\}^{N}_{j=1}$ are in turn allocated across the local currency denominated values of economy and vintage specific long term bonds $\{\{V^{B}_{j,k,s}B^{L,H}_{h,i,j,k,s+1}\}^{s}_{k=1}\}^{N}_{j=1}$ subject to $B^{L,H}_{h,i,j,s+1}=\sum_{k=1}^{s}V^{B}_{j,k,s}B^{L,H}_{h,i,j,k,s+1}$.

In parallel, the local currency denominated values of economy specific stock portfolios $\{S^{H}_{h,i,j,s+1}\}_{j=1}^{N}$ are allocated across the local currency denominated values of economy, industry and firm specific shares $\{\{\{V^{S}_{j,k,l,s}S^{H}_{h,i,j,k,l,s+1}\}_{l=0}^{1}\}_{k=1}^{M}\}_{j=1}^{N}$ subject to $S^{H}_{h,i,j,s+1}=\sum_{k=1}^{M}\int_{0}^{1}V^{S}_{j,k,l,s}S^{H}_{h,i,j,k,l,s+1}dl$. Finally, the representative household purchases final private consumption good $C_{h,i,s}$ at price $P^{C}_{i,s}$.

Bank Intermediated Households

In period t, the representative bank intermediated household chooses state contingent sequences for consumption $\{C_{h,i,s}\}_{s=t}^{\infty}$, labor force participation $\{\{N_{h,f,i,s}\}_{f=0}^{1}\}_{s=t}^{\infty}$, and bank balances $\{B^{D,H}_{h,i,s+1}\}_{s=t}^{\infty}$ to maximize intertemporal utility function (1) subject to dynamic budget constraint (12), the applicable restrictions on financial asset holdings, and terminal nonnegativity constraint $B^{D,H}_{h,i,T+1}\geq 0$ for $T\rightarrow\infty$. In equilibrium, abstracting from the capitalist spirit motive for holding real bank balances, the solutions to this utility maximization problem satisfy intertemporal optimality condition

$$\mathrm{E}_{t}\frac{\beta u_{C}(h,i,t+1)}{u_{C}(h,i,t)}\frac{P^{C}_{i,t}}{P^{C}_{i,t+1}}(1+i^{D}_{i,t})=1, \tag{13}$$

which equates the expected present value of the gross real deposit rate to one. These solutions also satisfy intratemporal optimality condition

$$-\frac{u_{L_f}(h,f,i,t)}{u_{C}(h,i,t)}=(1-\tau_{i,t})\frac{W_{f,i,t}}{P^{C}_{i,t}}, \tag{14}$$

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. Provided that the intertemporal utility function is bounded and strictly concave, together with other optimality conditions, and a transversality condition derived from the necessary complementary slackness condition associated with the terminal nonnegativity constraint, these optimality conditions are sufficient for the unique utility maximizing state contingent sequence of bank intermediated household allocations.

Capital Market Intermediated Households

In period t, the representative capital market intermediated household chooses state contingent sequences for consumption $\{C_{h,i,s}\}_{s=t}^{\infty}$, labor force participation $\{\{N_{h,f,i,s}\}_{f=0}^{1}\}_{s=t}^{\infty}$, portfolio balances $\{A^{A,H}_{h,i,s+1}\}_{s=t}^{\infty}$, short term bond holdings $\{\{B^{S,H}_{h,i,j,s+1}\}_{j=1}^{N}\}_{s=t}^{\infty}$, long term bond holdings $\{\{\{B^{L,H}_{h,i,j,k,s+1}\}_{k=1}^{t}\}_{j=1}^{N}\}_{s=t}^{\infty}$, and stock holdings $\{\{\{\{S^{H}_{h,i,j,k,l,s+1}\}_{l=0}^{1}\}_{k=1}^{M}\}_{j=1}^{N}\}_{s=t}^{\infty}$ to maximize intertemporal utility function (1) subject to dynamic budget constraint (12), the applicable restrictions on financial asset holdings, and terminal nonnegativity constraints $B^{S,H}_{h,i,j,T+1}\geq 0$, $B^{L,H}_{h,i,j,k,T+1}\geq 0$ and $S^{H}_{h,i,j,k,l,T+1}\geq 0$ for $T\rightarrow\infty$. In equilibrium, abstracting from the capitalist spirit motive for holding real portfolio balances, the solutions to this utility maximization problem satisfy intertemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,i,t+1)}{u_C(h,i,t)} \frac{P_{i,t}^C}{P_{i,t+1}^C} (1 + i_{h,i,t+1}^{A^{A,H}}) = 1, \tag{15}$$

which equates the expected present value of the gross real portfolio return to one. In addition, these solutions satisfy intratemporal optimality condition

$$-\frac{u_{L_f}(h,f,i,t)}{u_C(h,i,t)} = (1-\tau_{i,t}) \frac{W_{f,i,t}}{P_{i,t}^C}, \tag{16}$$

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. Abstracting from risk premium shocks, the expected present value of the gross real portfolio return satisfies intratemporal optimality condition

$$\begin{aligned} &\phi_{i,M}^A \sum_{j=1}^N \phi_{i,j}^B \left\{ 1 + \mathrm{E}_t \frac{\beta u_C(h,i,t+1)}{u_C(h,i,t)} \frac{u_C(h,i,t)}{u_A(h,i,t)} \frac{P_{i,t}^C}{P_{i,t+1}^C} \left[(1 + i_{h,i,t+1}^{A^{A,H}}) - (1 + i_{j,t}^S) \frac{\mathcal{E}_{i,j,t+1}}{\mathcal{E}_{i,j,t}} \right] \right\}^{1-\psi^A} \\ &+ \phi_{i,B}^A \sum_{j=1}^N \phi_{i,j}^B \sum_{k=1}^t \phi_{i,j,k,t}^B \left\{ 1 + \mathrm{E}_t \frac{\beta u_C(h,i,t+1)}{u_C(h,i,t)} \frac{u_C(h,i,t)}{u_A(h,i,t)} \frac{P_{i,t}^C}{P_{i,t+1}^C} \left[(1 + i_{h,i,t+1}^{A^{A,H}}) - \frac{i_{j,k}^L + V_{j,k,t+1}^B}{V_{j,k,t}^B} \frac{\mathcal{E}_{i,j,t+1}}{\mathcal{E}_{i,j,t}} \right] \right\}^{1-\psi^A} \\ &+ \phi_{i,S}^A \sum_{j=1}^N \phi_{i,j}^S \sum_{k=1}^M \phi_{i,j,k}^S \int_0^1 \left\{ 1 + \mathrm{E}_t \frac{\beta u_C(h,i,t+1)}{u_C(h,i,t)} \frac{u_C(h,i,t)}{u_A(h,i,t)} \frac{P_{i,t}^C}{P_{i,t+1}^C} \left[(1 + i_{h,i,t+1}^{A^{A,H}}) - \frac{\Pi_{j,k,l,t+1}^S + V_{j,k,l,t+1}^S}{V_{j,k,l,t}^S} \frac{\mathcal{E}_{i,j,t+1}}{\mathcal{E}_{i,j,t}} \right] \right\}^{1-\psi^A} dl = 1, \end{aligned} \tag{17}$$

which relates it to the expected present values of the gross real returns on domestic and foreign short term bonds, long term bonds, and stocks. Furthermore, abstracting from the portfolio diversification motive these solutions satisfy intratemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,i,t+1)}{u_C(h,i,t)} \frac{P_{i,t}^C}{P_{i,t+1}^C} \left[(1 + i_{i,t}^S) - (1 + i_{j,t}^S) \frac{\mathcal{E}_{i,j,t+1}}{\mathcal{E}_{i,j,t}} \right] = -\frac{u_A(h,i,t)}{u_C(h,i,t)} (\nu_{i,t}^{\mathcal{E}} - \nu_{j,t}^{\mathcal{E}}), \tag{18}$$

which equates the expected present values of the gross real risk adjusted returns on domestic and foreign short term bonds. In addition, abstracting from the portfolio diversification motive these solutions satisfy intratemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,i,t+1)}{u_C(h,i,t)} \frac{P_{i,t}^C}{P_{i,t+1}^C} \left[(1 + i_{i,t}^S) - \frac{i_{i,k}^L + V_{i,k,t+1}^B}{V_{i,k,t}^B} \right] = -\frac{u_A(h,i,t)}{u_C(h,i,t)} \nu_{i,t}^{\mathcal{E}} (1 - \upsilon_{i,t}^B), \tag{19}$$

which equates the expected present values of the gross real risk adjusted returns on domestic short and long term bonds. Finally, abstracting from the portfolio diversification motive these solutions satisfy intratemporal optimality condition

$$\mathrm{E}_t \frac{\beta u_C(h,i,t+1)}{u_C(h,i,t)} \frac{P_{i,t}^C}{P_{i,t+1}^C} \left[(1 + i_{i,t}^S) - \frac{\Pi_{i,k,l,t+1}^S + V_{i,k,l,t+1}^S}{V_{i,k,l,t}^S} \right] = -\frac{u_A(h,i,t)}{u_C(h,i,t)} \nu_{i,t}^{\mathcal{E}} (1 - \upsilon_{i,t}^S), \tag{20}$$

which equates the expected present values of the gross real risk adjusted returns on domestic short term bonds and stocks. Provided that the intertemporal utility function is bounded and strictly concave, together with other optimality conditions, and transversality conditions derived from necessary complementary slackness conditions associated with the terminal nonnegativity constraints, these optimality conditions are sufficient for the unique utility maximizing state contingent sequence of capital market intermediated household allocations.

Credit Constrained Households

In period t, the representative credit constrained household chooses state contingent sequences for consumption $\{C_{h,i,s}\}_{s=t}^{\infty}$ and labor force participation $\{\{N_{h,f,i,s}\}_{f=0}^{1}\}_{s=t}^{\infty}$ to maximize intertemporal utility function (1) subject to dynamic budget constraint (12), and the applicable restrictions on financial asset holdings. In equilibrium, the solutions to this utility maximization problem satisfy household static budget constraint

$$P_{i,t}^{C}C_{h,i,t} = \Pi_{i,t}^{S} + (1-\tau_{i,t})\int_{0}^{1} W_{f,i,t}L_{h,f,i,t}df, \tag{21}$$

which equates consumption expenditures to the sum of profit and disposable labor income. These solutions also satisfy intratemporal optimality condition

$$-\frac{u_{L_f}(h,f,i,t)}{u_C(h,i,t)} = (1-\tau_{i,t})\frac{W_{f,i,t}}{P_{i,t}^{C}}, \tag{22}$$

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. Provided that the intertemporal utility function is bounded and strictly concave, these optimality conditions are sufficient for the unique utility maximizing state contingent sequence of credit constrained household allocations.

Labor Supply

The unemployment rate $u_{i,t}^{L}$ measures the share of the labor force $N_{i,t}$ in unemployment $U_{i,t}$, that is $u_{i,t}^{L} = \frac{U_{i,t}}{N_{i,t}}$, where unemployment equals the labor force less employment $L_{i,t}$, that is $U_{i,t} = N_{i,t} - L_{i,t}$. The labor force satisfies $N_{i,t} = \int_0^1 N_{f,i,t}df$.

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

$$L_{i,t} = \left[\int_{0}^{1} (L_{f,i,t})^{\frac{\theta_{i,t}^{L}-1}{\theta_{i,t}^{L}}} df\right]^{\frac{\theta_{i,t}^{L}}{\theta_{i,t}^{L}-1}}, \tag{23}$$

where serially uncorrelated wage markup shock $\theta_{i,t}^{L}$ satisfies $\theta_{i,t}^{L} > 1$ with $\theta_{i}^{L} = \theta^{L}$. The representative final labor service firm maximizes profits derived from production of the final labor service with respect to inputs of intermediate labor services, implying demand functions:

$$L_{f,i,t} = \left(\frac{W_{f,i,t}}{W_{i,t}} \right)^{-\theta_{i,t}^{L}} L_{i,t}. \tag{24}$$

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

$$W_{i,t} = \left[\int_{0}^{1} (W_{f,i,t})^{1-\theta_{i,t}^{L}} df \right]^{\frac{1}{1-\theta_{i,t}^{L}}}. \tag{25}$$

As the wage elasticity of demand for intermediate labor services $\theta_{i,t}^{L}$ increases, they become closer substitutes, and individual trade unions have less market power.

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 $0 \leq \omega^{L} < 1$. The remaining fraction ω^{L} of trade unions adjust their wage to account for past consumption price inflation and productivity growth according to partial indexation rule

$$W_{f,i,t} = \left(\frac{P_{i,t-1}^{C} \bar{A}_{i,t-1}}{P_{i,t-2}^{C} \bar{A}_{i,t-2}} \right)^{\gamma^{L}} \left(\frac{\bar{P}_{i,t-1}^{C} \bar{A}_{i,t-1}}{\bar{P}_{i,t-2}^{C} \bar{A}_{i,t-2}} \right)^{1-\gamma^{L}} W_{f,i,t-1}, \tag{26}$$

where $0 \leq \gamma^{L} \leq 1$. 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 the representative trade union can adjust its wage optimally in period t, then it does so to maximize intertemporal utility function (1) subject to dynamic budget constraint (12), intermediate labor service demand function (24), 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 $W_{i,t}^{*}$ given by necessary first order condition:

$$\frac{W_{i,t}^{*}}{W_{i,t}} = -\frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^{L})^{s-t} \frac{\beta^{s-t} u_C(h,i,s)}{u_C(h,i,t)} \theta_{i,s}^{L} \frac{u_{L_f}(h,f,i,s)}{u_C(h,i,s)} \left[\left(\frac{P_{i,t-1}^{C} \bar{A}_{i,t-1}}{P_{i,s-1}^{C} \bar{A}_{i,s-1}} \right)^{\gamma^{L}} \left(\frac{\bar{P}_{i,t-1}^{C} \bar{A}_{i,t-1}}{\bar{P}_{i,s-1}^{C} \bar{A}_{i,s-1}} \right)^{1-\gamma^{L}} \frac{W_{i,s}}{W_{i,t}} \right]^{\theta_{i,s}^{L}} \left(\frac{W_{i,t}^{*}}{W_{i,t}} \right)^{-\theta_{i,s}^{L}} L_{h,i,s}}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^{L})^{s-t} \frac{\beta^{s-t} u_C(h,i,s)}{u_C(h,i,t)} (\theta_{i,s}^{L}-1)(1-\tau_{i,s}) \frac{W_{i,s}}{P_{i,s}^{C}} \left[\left(\frac{P_{i,t-1}^{C} \bar{A}_{i,t-1}}{P_{i,s-1}^{C} \bar{A}_{i,s-1}} \right)^{\gamma^{L}} \left(\frac{\bar{P}_{i,t-1}^{C} \bar{A}_{i,t-1}}{\bar{P}_{i,s-1}^{C} \bar{A}_{i,s-1}} \right)^{1-\gamma^{L}} \frac{W_{i,s}}{W_{i,t}} \right]^{\theta_{i,s}^{L}-1} \left(\frac{W_{i,t}^{*}}{W_{i,t}} \right)^{-\theta_{i,s}^{L}} L_{h,i,s}}. \tag{27}$$

This necessary first order condition equates the expected present value of the marginal utility of consumption gained from labor supply to the expected present value of the marginal utility cost incurred from leisure foregone. Aggregate wage index (25) 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 (26):

$$W_{i,t} = \left\{ (1-\omega^L)(W^*_{i,t})^{1-\theta^L_{i,t}} + \omega^L \left[\left(\frac{P^C_{i,t-1}\mathcal{A}_{i,t-1}}{P^C_{i,t-2}\mathcal{A}_{i,t-2}} \right)^{\gamma^L} \left(\frac{\bar{P}^C_{i,t-1}\bar{\mathcal{A}}_{i,t-1}}{\bar{P}^C_{i,t-2}\bar{\mathcal{A}}_{i,t-2}} \right)^{1-\gamma^L} W_{i,t-1} \right]^{1-\theta^L_{i,t}} \right\}^{\frac{1}{1-\theta^L_{i,t}}}. \tag{28}$$

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 consumption price inflation and productivity growth.

B. The Production Sector

The production sector consists of a finite set of industries indexed by $k \in \{1,\ldots,M\}$, of which the first M^* produce nonrenewable commodities. In particular, the energy commodity industry labeled $k=1$ and the nonenergy commodity industry labeled $k=2$ produce internationally homogeneous goods for foreign absorption under decreasing returns to scale, representing the existence of a fixed factor, while all other industries produce internationally heterogeneous goods for domestic and foreign absorption under constant returns to scale. Labor is perfectly mobile across industries.

Output Demand

There exist a large number of perfectly competitive firms which combine industry specific final output goods $\{Y_{i,k,t}\}_{k=1}^M$ to produce final output good $Y_{i,t}$ according to fixed proportions production function

$$Y_{i,t} = \min\left\{ \frac{Y_{i,k,t}}{\phi^Y_{i,k}} \right\}_{k=1}^M, \tag{29}$$

where $0 \le \phi^Y_{i,k} \le 1$ and $\sum_{k=1}^M \phi^Y_{i,k} = 1$. The representative final output good firm maximizes profits derived from production of the final output good with respect to inputs of industry specific final output goods, implying demand functions:

$$Y_{i,k,t} = \phi^Y_{i,k} Y_{i,t}. \tag{30}$$

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

$$P^Y_{i,t} = \sum_{k=1}^M \phi^Y_{i,k} P^Y_{i,k,t}. \tag{31}$$

This aggregate output price index equals the minimum cost of producing one unit of the final output good, given the prices of industry specific final output goods.

There exist a large number of perfectly competitive firms which combine industry specific differentiated intermediate output goods $Y_{i,k,l,t}$ supplied by industry specific intermediate output good firms to produce industry specific final output good $Y_{i,k,t}$ according to constant elasticity of substitution production function

$$Y_{i,k,t} = \left[\int_0^1 (Y_{i,k,l,t})^{\frac{\theta^Y_{i,k,t}-1}{\theta^Y_{i,k,t}}} dl \right]^{\frac{\theta^Y_{i,k,t}}{\theta^Y_{i,k,t}-1}}, \tag{32}$$

where serially uncorrelated output price markup shock $\theta^Y_{i,k,t}$ satisfies $\theta^Y_{i,k,t} > 1$ with $\theta^Y_{i,k} = \theta^Y$, while $\theta^Y_{i,k,t} = \theta^Y_{k,t}$ for $1 \le k \le M^*$ and $\theta^Y_{i,k,t} = \theta^Y_{i,t}$ otherwise. The representative industry specific final output good firm maximizes profits derived from production of the industry specific final output good with respect to inputs of industry specific intermediate output goods, implying demand functions:

$$Y_{i,k,l,t} = \left(\frac{P^Y_{i,k,l,t}}{P^Y_{i,k,t}} \right)^{-\theta^Y_{i,k,t}} Y_{i,k,t}. \tag{33}$$

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

$$P^Y_{i,k,t} = \left[\int_0^1 (P^Y_{i,k,l,t})^{1-\theta^Y_{i,k,t}} dl \right]^{\frac{1}{1-\theta^Y_{i,k,t}}}. \tag{34}$$

As the price elasticity of demand for industry specific intermediate output goods $\theta^Y_{i,k,t}$ increases, they become closer substitutes, and individual industry specific intermediate output good firms have less market power.

Labor Demand and Investment

There exist continuums of monopolistically competitive industry specific intermediate output good firms indexed by $l \in [0,1]$. Intermediate output good firms supply industry specific differentiated intermediate output goods, but are otherwise identical. We rule out entry into and exit out of the monopolistically competitive industry specific intermediate output good sectors.

The representative industry specific intermediate output good firm sells shares to domestic and foreign capital market intermediated households at price $V^S_{i,k,l,t}$. Acting in the interests of its shareholders, it maximizes its pre-dividend stock market value, which abstracting from the capitalist spirit motive for holding real portfolio balances equals the expected present value of current and future dividend payments

$$\mathit{\Pi}_{i,k,l,t}^{S}+V_{i,k,l,t}^{S}=\mathrm{E}_t\sum_{s=t}^{\infty}\frac{\beta^{s-t}\lambda_{i,s}^{A}}{\lambda_{i,t}^{A}}\mathit{\Pi}_{i,k,l,s}^{S}, \tag{35}$$

where $\lambda_{i,s}^{A}$ denotes the Lagrange multiplier associated with the period s capital market intermediated household dynamic budget constraint. The derivation of this result imposes a transversality condition which rules out self-fulfilling speculative asset price bubbles.

Shares entitle households to dividend payments equal to net profits $\mathit{\Pi}_{i,k,l,s}^{S}$, defined as the sum of after tax earnings and net borrowing less investment expenditures,

$$\mathit{\Pi}_{i,k,l,s}^{S}=(1-\tau_{i,s})(P_{i,k,l,s}^{Y}Y_{i,k,l,s}-W_{i,s}L_{i,k,l,s}-\mathit{\Phi}_{i,k,l,s})+(B_{i,k,l,s+1}^{C,F}-(1-\delta_{i,s}^{C})(1+i_{i,s}^{C,E})B_{i,k,l,s}^{C,F})-P_{i,s}^{I}I_{i,k,l,s}, \tag{36}$$

where $Y_{i,k,l,s}=\mathcal{F}(u_{i,k,l,s}^{K}K_{i,k,l,s},\mathcal{A}_{i,s}L_{i,k,l,s})$. Earnings are defined as revenues derived from sales of industry specific differentiated intermediate output good $Y_{i,k,l,s}$ at price $P_{i,k,l,s}^{Y}$ less expenditures on final labor service $L_{i,k,l,s}$, and other variable costs $\mathit{\Phi}_{i,k,l,s}$. The government levies a tax on earnings at rate $\tau_{i,s}$.

Motivated by the collateralized borrowing variant of the financial accelerator mechanism due to Kiyotaki and Moore (1997), the financial policy of the representative industry specific intermediate output good firm is to maintain debt equal to a fixed fraction of the value of the capital stock,

$$\frac{B_{i,k,l,s+1}^{C,F}}{P_{i,s}^{I}K_{i,k,l,s+1}}=\phi, \tag{37}$$

where $0<\phi<1$. Net borrowing is defined as the increase in loans $B_{i,k,l,s+1}^{C,F}$ from domestic and foreign banks net of writedowns at loan default rate $\delta_{i,s}^{C}$ where $0<\delta_{i,s}^{C}<1$, and interest payments at corporate loan rate $i_{i,s}^{C,E}$. This loan default rate applies uniformly to all loans received from domestic and foreign banks.

The representative industry specific intermediate output good firm utilizes capital $K_{i,k,l,s}$ at rate $u_{i,k,l,s}^{K}$ and rents final labor service $L_{i,k,l,s}$ to produce industry specific differentiated intermediate output good $Y_{i,k,l,s}$ according to production function

$$\mathcal{F}(u_{i,k,l,s}^{K}K_{i,k,l,s},\mathcal{A}_{i,s}L_{i,k,l,s})=(u_{i,k,l,s}^{K}K_{i,k,l,s})^{\phi_k^K}(\mathcal{A}_{i,s}L_{i,k,l,s})^{\phi_k^L}, \tag{38}$$

where serially correlated productivity shock $\mathcal{A}_{i,s}$ satisfies $\mathcal{A}_{i,s}>0$, while $\phi_k^K=(1-\phi_k^F)\phi^K$ and $\phi_k^L=(1-\phi_k^F)\phi^L$ with $\phi^K+\phi^L=1$ and $\phi_k^F>0$ for $1\le k\le M^*$ and $\phi_k^F=0$ otherwise.

In utilizing capital to produce output, the representative industry specific intermediate output good firm incurs a cost $\mathcal{G}(u_{i,k,l,s}^{K},K_{i,k,l,s})$ denominated in terms of capital,

$$\mathit{\Phi}_{i,k,l,s}=P_{i,s}^{I}\mathcal{G}(u_{i,k,l,s}^{K},K_{i,k,l,s})+F_{i,k,s}^{Y}, \tag{39}$$

where industry specific fixed cost $F_{i,k,s}^{Y}$ ensures that $\mathit{\Phi}_{i,k,s}=0$. Following Christiano, Eichenbaum and Evans (2005), this capital utilization cost is increasing in the capital utilization rate at an increasing rate,

$$\mathcal{G}(u_{i,k,l,s}^K, K_{i,k,l,s}) = \mu^K \left[e^{\eta^K (u_{i,k,l,s}^K - 1)} - 1 \right] K_{i,k,l,s}, \tag{40}$$

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.

The representative industry specific intermediate output good firm enters period s in possession of previously accumulated capital stock $K_{i,k,l,s}$, which subsequently evolves according to accumulation function

$$K_{i,k,l,s+1} = (1-\delta)K_{i,k,l,s} + \mathcal{H}(I_{i,k,l,s}, I_{i,k,l,s-1}), \tag{41}$$

where $0 \leq \delta \leq 1$. Following Christiano, Eichenbaum and Evans (2005), effective investment function $\mathcal{H}(I_{i,k,l,s}, I_{i,k,l,s-1})$ incorporates convex adjustment costs,

$$\mathcal{H}(I_{i,k,l,s}, I_{i,k,l,s-1}) = \nu_{i,s}^I \left[1 - \frac{\chi}{2} \left(\frac{I_{i,k,l,s}}{I_{i,k,l,s-1}} - 1 \right)^2 \right] I_{i,k,l,s}, \tag{42}$$

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

In period t, the representative industry specific intermediate output good firm chooses state contingent sequences for employment $\{L_{i,k,l,s}\}_{s=t}^{\infty}$, the capital utilization rate $\{u_{i,k,l,s}^K\}_{s=t}^{\infty}$, investment $\{I_{i,k,l,s}\}_{s=t}^{\infty}$, and the capital stock $\{K_{i,k,l,s+1}\}_{s=t}^{\infty}$ to maximize pre-dividend stock market value (35) subject to production function (38), capital accumulation function (41), and terminal nonnegativity constraint $K_{i,k,l,T+1} \geq 0$ for $T \rightarrow \infty$. In equilibrium, demand for the final labor service satisfies necessary first order condition

$$\mathcal{F}_{\mathcal{A}L}(u_{i,k,l,t}^K K_{i,k,l,t}, \mathcal{A}_{i,t} L_{i,k,l,t}) \Psi_{i,k,l,t} = (1-\tau_{i,t}) \frac{W_{i,t}}{P_{i,k,t}^Y \mathcal{A}_{i,t}}, \tag{43}$$

where $P_{i,k,s}^Y \Psi_{i,k,l,s}$ denotes the Lagrange multiplier associated with the period s production technology constraint. This necessary first order condition equates real marginal cost $\Psi_{i,k,l,t}$ to the ratio of the after tax industry specific real wage to the marginal product of labor. In equilibrium, the capital utilization rate satisfies necessary first order condition

$$\mathcal{F}_{u^K K}(u_{i,k,l,t}^K K_{i,k,l,t}, \mathcal{A}_{i,t} L_{i,k,l,t}) \frac{P_{i,k,t}^Y \Psi_{i,k,l,t}}{P_{i,t}^I} = (1-\tau_{i,t}) \frac{\mathcal{G}_{u^K}(u_{i,k,l,t}^K, K_{i,k,l,t})}{K_{i,k,l,t}}, \tag{44}$$

which equates the marginal revenue product of utilized capital to its marginal cost. In equilibrium, demand for the final investment good satisfies necessary first order condition

$$Q_{i,k,l,t} \mathcal{H}_1(I_{i,k,l,t}, I_{i,k,l,t-1}) + \mathrm{E}_t \frac{\beta \lambda_{i,t+1}^A}{\lambda_{i,t}^A} Q_{i,k,l,t+1} \mathcal{H}_2(I_{i,k,l,t+1}, I_{i,k,l,t}) = P_{i,t}^I, \tag{45}$$

which equates the expected present value of an additional unit of investment to its price, where $Q_{i,k,l,s}$ denotes the Lagrange multiplier associated with the period s capital accumulation function. In equilibrium, this shadow price of capital satisfies necessary first order condition

$$Q_{i,k,l,t} = \mathrm{E}_t \frac{\beta\lambda^A_{i,t+1}}{\lambda^A_{i,t}} \left\{ P^I_{i,t+1} \left\{ u^K_{i,k,l,t+1} \mathcal{F}_{u^K K}(u^K_{i,k,l,t+1} K_{i,k,l,t+1}, \mathcal{A}_{i,t+1} L_{i,k,l,t+1}) \frac{P^Y_{i,k,t+1} \Psi_{i,k,l,t+1}}{P^I_{i,t+1}} \right.\right.$$
$$\left.\left. -(1-\tau_{i,t+1}) \mathcal{G}_K(u^K_{i,k,l,t+1}, K_{i,k,l,t+1}) - \phi \frac{P^I_{i,t}}{P^I_{i,t+1}} \left[(1-\delta^C_{i,t+1})(1+i^{C,E}_{i,t+1}) - \frac{\lambda^A_{i,t}}{\beta\lambda^A_{i,t+1}} \right] \right\} + (1-\delta) Q_{i,k,l,t+1} \right\}, \tag{46}$$

which equates it to the expected present value of the sum of the future marginal revenue product of capital net of its marginal utilization cost, and the future shadow price of capital net of depreciation, less the product of the loan to value ratio with the spread between the effective cost of bank and capital market funding. Provided that the pre-dividend stock market value is bounded and strictly concave, together with other necessary first order conditions, and a transversality condition derived from the necessary complementary slackness condition associated with the terminal nonnegativity constraint, these necessary first order conditions are sufficient for the unique value maximizing state contingent sequence of industry specific intermediate output good firm allocations.

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 $1-\omega^Y_k$ of industry specific intermediate output good firms adjust their price optimally, where $0 \le \omega^Y_k < 1$ with $\omega^Y_k = \omega^Y$ for $k > M^*$. The remaining fraction ω^Y_k of intermediate output good firms adjust their price to account for past industry specific output price inflation according to partial indexation rule

$$P^Y_{i,k,l,t} = \left(\frac{P^Y_{i,k,t-1}}{P^Y_{i,k,t-2}} \right)^{\gamma^Y_k} \left(\frac{\overline{P}^Y_{i,k,t-1}}{\overline{P}^Y_{i,k,t-2}} \right)^{1-\gamma^Y_k} P^Y_{i,k,l,t-1}, \tag{47}$$

where $0 \le \gamma^Y_k \le 1$ with $\gamma^Y_k = 0$ for $1 \le k \le M^*$ and $\gamma^Y_k = \gamma^Y$ otherwise. Under this specification, optimal price adjustment opportunities arrive randomly, and the interval between optimal price adjustments is a random variable.

If the representative industry specific intermediate output good firm can adjust its price optimally in period t, then it does so to maximize pre-dividend stock market value (35) subject to production function (38), industry specific intermediate output good demand function (33), and the assumed form of nominal output price rigidity. We consider a symmetric equilibrium under which all industry and firm specific endogenous state variables are restricted to equal their industry specific 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 $P_{i,k,t}^{Y,*}$ given by necessary first order condition:

$$\frac{P_{i,k,t}^{Y,*}}{P_{i,k,t}^{Y}} = \frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega_k^Y)^{s-t} \frac{\beta^{s-t}\lambda_{i,s}^A}{\lambda_{i,t}^A} \theta_{i,k,s}^Y \Psi_{i,k,l,s} \left[\left(\frac{P_{i,k,t-1}^Y}{P_{i,k,s-1}^Y}\right)^{\gamma_k^Y} \left(\frac{\overline{P}_{i,k,t-1}^Y}{\overline{P}_{i,k,s-1}^Y}\right)^{1-\gamma_k^Y} \frac{P_{i,k,s}^Y}{P_{i,k,t}^Y} \right]^{\theta_{i,k,s}^Y} \left(\frac{P_{i,k,t}^{Y,*}}{P_{i,k,t}^Y}\right)^{-\theta_{i,k,s}^Y} P_{i,k,s}^Y Y_{i,k,s}}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega_k^Y)^{s-t} \frac{\beta^{s-t}\lambda_{i,s}^A}{\lambda_{i,t}^A} (\theta_{i,k,s}^Y - 1)(1-\tau_{i,s}) \left[\left(\frac{P_{i,k,t-1}^Y}{P_{i,k,s-1}^Y}\right)^{\gamma_k^Y} \left(\frac{\overline{P}_{i,k,t-1}^Y}{\overline{P}_{i,k,s-1}^Y}\right)^{1-\gamma_k^Y} \frac{P_{i,k,s}^Y}{P_{i,k,t}^Y} \right]^{\theta_{i,k,s}^Y - 1} \left(\frac{P_{i,k,t}^{Y,*}}{P_{i,k,t}^Y}\right)^{-\theta_{i,k,s}^Y} P_{i,k,s}^Y Y_{i,k,s}}. \quad (48)$$

This necessary first order condition equates the expected present value of the after tax marginal revenue gained from output supply to the expected present value of the marginal cost incurred from production. Aggregate output price index (34) equals an average of the price set by the fraction $1-\omega_k^Y$ 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_k^Y of intermediate output good firms that adjust their price according to partial indexation rule (47):

$$P_{i,k,t}^Y = \left\{ (1-\omega_k^Y)(P_{i,k,t}^{Y,*})^{1-\theta_{i,k,t}^Y} + \omega_k^Y \left[\left(\frac{P_{i,k,t-1}^Y}{P_{i,k,t-2}^Y}\right)^{\gamma_k^Y} \left(\frac{\overline{P}_{i,k,t-1}^Y}{\overline{P}_{i,k,t-2}^Y}\right)^{1-\gamma_k^Y} P_{i,k,t-1}^Y \right]^{1-\theta_{i,k,t}^Y} \right\}^{\frac{1}{1-\theta_{i,k,t}^Y}}. \quad (49)$$

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 industry specific aggregate output price index that prevailed during period $t-1$, rescaled to account for past industry specific output price inflation.

C. The Banking Sector

The banking sector performs global financial intermediation subject to financial frictions and a regulatory constraint. In particular, banks issue risky domestic currency denominated loans to domestic and foreign firms at infrequently adjusted predetermined lending rates, obtain funding from domestic bank intermediated households via deposits and from the domestic money market via loans, and accumulate bank capital out of retained earnings given credit losses to satisfy a regulatory capital requirement.

Credit Demand

There exist a large number of perfectly competitive banks which combine local currency denominated final loans $\{B_{i,j,t}^{C,F}\}_{j=1}^{N}$ to produce domestic currency denominated final loan $B_{i,t}^{C,F}$ according to fixed proportions portfolio aggregator

$$B_{i,t}^{C,F} = \min\left\{\frac{\mathcal{E}_{i,j,t-1}B_{i,j,t}^{C,F}}{\phi_{i,j}^{F}}\right\}_{j=1}^{N}, \tag{50}$$

where $0 \leq \phi_{i,j}^{F} \leq 1$ and $\sum_{j=1}^{N}\phi_{i,j}^{F} = 1$. The representative international final bank maximizes profits derived from intermediation of the domestic currency denominated final loan with respect to inputs of local currency denominated final loans, implying demand functions:

$$B_{i,j,t}^{C,F} = \phi_{i,j}^{F}\frac{B_{i,t}^{C,F}}{\mathcal{E}_{i,j,t-1}}. \tag{51}$$

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

$$1+i_{i,t}^{C,E} = \sum_{j=1}^{N}\phi_{i,j}^{F}(1+i_{j,t-1}^{C})\frac{\mathcal{E}_{i,j,t}}{\mathcal{E}_{i,j,t-1}}. \tag{52}$$

This aggregate gross corporate loan rate index equals the minimum cost of producing one unit of the domestic currency denominated final loan, given the rates on local currency denominated final loans.

There exist a large number of perfectly competitive banks which combine differentiated intermediate loans $B_{i,m,t+1}^{C,B}$ supplied by intermediate banks to produce final loan $B_{i,t+1}^{C,B}$ according to constant elasticity of substitution portfolio aggregator

$$B_{i,t+1}^{C,B} = \left[\int_0^1 (B_{i,m,t+1}^{C,B})^{\frac{\theta_{i,t+1}^{C}-1}{\theta_{i,t+1}^{C}}}\,dm\right]^{\frac{\theta_{i,t+1}^{C}}{\theta_{i,t+1}^{C}-1}}, \tag{53}$$

where serially uncorrelated lending rate markup shock $\theta_{i,t+1}^{C}$ satisfies $\theta_{i,t+1}^{C} > 1$ with $\theta_{i}^{C} = \theta^{C}$. The representative domestic final bank maximizes profits derived from intermediation of the final loan with respect to inputs of intermediate loans, implying demand functions:

$$B_{i,m,t+1}^{C,B} = \left(\frac{1+i_{i,m,t}^{C}}{1+i_{i,t}^{C}}\right)^{-\theta_{i,t+1}^{C}} B_{i,t+1}^{C,B}. \tag{54}$$

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

$$1+i_{i,t}^{C} = \left[\int_0^1 (1+i_{i,m,t}^{C})^{1-\theta_{i,t+1}^{C}}\,dm\right]^{\frac{1}{1-\theta_{i,t+1}^{C}}}. \tag{55}$$

As the rate elasticity of demand for intermediate loans $\theta_{i,t+1}^{C}$ increases, they become closer substitutes, and individual intermediate banks have less market power.

Funding Demand and Provisioning

There exists a continuum of monopolistically competitive intermediate banks indexed by $m \in [0,1]$. Intermediate banks supply differentiated intermediate loans, but are otherwise identical. We rule out entry into and exit out of the monopolistically competitive intermediate banking sector.

The representative intermediate bank sells shares to domestic bank intermediated households at price $V_{i,m,t}^{C}$. Acting in the interests of its shareholders, it maximizes its pre-dividend stock market value, which abstracting from the capitalist spirit motive for holding real portfolio balances equals the expected present value of current and future dividend payments

$$\Pi_{i,m,t}^{C} + V_{i,m,t}^{C} = \mathrm{E}_t \sum_{s=t}^{\infty} \frac{\beta^{s-t} \lambda_{i,s}^{B}}{\lambda_{i,t}^{B}} \Pi_{i,m,s}^{C}, \tag{56}$$

where $\lambda_{i,s}^{B}$ denotes the Lagrange multiplier associated with the period s bank intermediated household dynamic budget constraint. The derivation of this result imposes a transversality condition which rules out self-fulfilling speculative asset price bubbles.

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

$$\Pi_{i,m,s}^{C} = (B_{i,m,s+1}^{D,B} - (1+i_{i,s-1}^{D}) B_{i,m,s}^{D,B}) + (B_{i,m,s+1}^{S,B} - (1+i_{i,s-1}^{S}) B_{i,m,s}^{S,B}) - (B_{i,m,s+1}^{C,B} - (1-\delta_{i,s}^{C,E})(1+i_{i,m,s-1}^{C}) B_{i,m,s}^{C,B}) - \Phi_{i,m,s}^{B} - I_{i,m,s}^{B}. \tag{57}$$

Profits are defined as the sum of the increase in deposits $B_{i,m,s+1}^{D,B}$ from households net of interest payments at the deposit rate and the increase in loans $B_{i,m,s+1}^{S,B}$ from the money market net of interest payments at the yield to maturity on short term bonds, less the increase in differentiated intermediate loans $B_{i,m,s+1}^{C,B}$ to firms net of writedowns at credit loss rate $\delta_{i,s}^{C,E}$ and interest receipts at lending rate $i_{i,m,s-1}^{C}$, less a cost of satisfying the regulatory capital requirement $\Phi_{i,m,s}^{B}$.

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

$$B_{i,m,s+1}^{C,B} = B_{i,m,s+1}^{D,B} + B_{i,m,s+1}^{S,B} + K_{i,m,s+1}^{B}. \tag{58}$$

The money stock $M_{i,s+1}^{S}$ measures aggregate bank funding, that is $M_{i,s+1}^{S} = B_{i,s+1}^{D,B} + B_{i,s+1}^{S,B}$, while the bank capital ratio $\kappa_{i,s+1}$ equals the ratio of aggregate bank capital to assets, that is $\kappa_{i,s+1} = \frac{K_{i,s+1}^{B}}{B_{i,s+1}^{C,B}}$.

In transforming deposit and money market funding into risky loans, the representative intermediate bank incurs a cost of satisfying the regulatory capital requirement,

$$\Phi_{i,m,s}^{B} = \mathcal{G}^{B}(B_{i,m,s}^{C,B}, K_{i,m,s}^{B}) + F_{i,s}^{B}, \tag{59}$$

where fixed cost $F_{i,s}^{B}$ ensures that $\Pi_{i,s}^{C} = 0$. Motivated by Gerali, Neri, Sessa and Signoretti (2010), this regulation cost is decreasing in the ratio of bank capital to assets at a decreasing rate,

$$\mathcal{G}^B(B_{i,m,s}^{C,B}, K_{i,m,s}^B) = \mu^C \left[e^{(2+\eta^C)\left(1-\frac{1}{\kappa_{i,s}^R}\frac{K_{i,m,s}^B}{B_{i,m,s}^{C,B}}\right)} - 1 \right] K_{i,m,s}^B, \tag{60}$$

where regulatory capital requirement $\kappa_{i,s}^R$ satisfies $0 < \kappa_{i,s}^R < 1$, while $\mu^C > 0$ and $\eta^C > 0$. In steady state equilibrium, the bank capital ratio equals its required value, and the cost of regulation is constant.

The financial policy of the representative intermediate bank is to smooth retained earnings intertemporally, given credit losses. It enters period s in possession of previously accumulated bank capital stock $K_{i,m,s}^B$, which subsequently evolves according to accumulation function

$$K_{i,m,s+1}^B = (1-\delta_{i,s}^B)K_{i,m,s}^B + \mathcal{H}^B(I_{i,m,s}^B, I_{i,m,s-1}^B), \tag{61}$$

where bank capital destruction rate $\delta_{i,s}^B$ satisfies $\delta_{i,s}^B = \chi^B \delta_{i,s}^{C,E}$ with $\chi^B > 0$. Effective retained earnings function $\mathcal{H}^B(I_{i,m,s}^B, I_{i,m,s-1}^B)$ incorporates convex adjustment costs,

$$\mathcal{H}^B(I_{i,m,s}^B, I_{i,m,s-1}^B) = \left[1 - \frac{\chi^C}{2}\left(\frac{I_{i,m,s}^B}{I_{i,m,s-1}^B} - 1 \right)^2 \right] I_{i,m,s}^B, \tag{62}$$

where $\chi^C > 0$. In steady state equilibrium, these adjustment costs equal zero, and effective retained earnings equals actual retained earnings.

In period t, the representative intermediate bank chooses state contingent sequences for deposit funding $\{B_{i,m,s+1}^{D,B}\}_{s=t}^{\infty}$, money market funding $\{B_{i,m,s+1}^{S,B}\}_{s=t}^{\infty}$, retained earnings $\{I_{i,m,s}^B\}_{s=t}^{\infty}$, and the bank capital stock $\{K_{i,m,s+1}^B\}_{s=t}^{\infty}$ to maximize pre-dividend stock market value (56) subject to balance sheet identity (58), bank capital accumulation function (61), and terminal nonnegativity constraints $B_{i,m,T+1}^{D,B} \geq 0$, $B_{i,m,T+1}^{S,B} \geq 0$ and $K_{i,m,T+1}^B \geq 0$ for $T \to \infty$. In equilibrium, the solutions to this value maximization problem satisfy necessary first order condition

$$1 + i_{i,t}^D = 1 + i_{i,t}^S, \tag{63}$$

which equates the deposit rate to the yield to maturity on short term bonds. In equilibrium, retained earnings satisfies necessary first order condition

$$Q_{i,m,t}^B \mathcal{H}_1^B(I_{i,m,t}^B, I_{i,m,t-1}^B) + \mathrm{E}_t \frac{\beta\lambda_{i,t+1}^B}{\lambda_{i,t}^B} Q_{i,m,t+1}^B \mathcal{H}_2^B(I_{i,m,t+1}^B, I_{i,m,t}^B) = 1, \tag{64}$$

which equates the expected present value of an additional unit of retained earnings to its marginal cost, where $Q_{i,k,l,s}$ denotes the Lagrange multiplier associated with the period s bank capital accumulation function. In equilibrium, this shadow price of bank capital satisfies necessary first order condition

$$Q_{i,m,t}^B = \mathrm{E}_t \frac{\beta\lambda_{i,t+1}^B}{\lambda_{i,t}^B} \left\{ (1-\delta_{i,t+1}^B) Q_{i,m,t+1}^B - \left\{ \mathcal{G}_K^B(B_{i,m,t+1}^{C,B}, K_{i,m,t+1}^B) + \left[\frac{\lambda_{i,t}^B}{\beta\lambda_{i,t+1}^B} - (1+i_{i,t}^S) \right] \right\} \right\}, \tag{65}$$

which equates it to the expected present value of the future shadow price of bank capital net of destruction, less the sum of the marginal utilization cost of bank capital and the spread between the cost of deposit and money market funding. Provided that the pre-dividend stock market value is bounded and strictly concave, together with other necessary first order conditions, and transversality conditions derived from the necessary complementary slackness conditions associated with the terminal nonnegativity constraints, these necessary first order conditions are sufficient for the unique value maximizing state contingent sequence of intermediate bank allocations.

Credit Supply

In an adaptation of the model of nominal output 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 $1-\omega^C$ of intermediate banks adjust their gross lending rate optimally, where $0 \leq \omega^C < 1$. The remaining fraction ω^C of intermediate banks do not adjust their lending rate:

$$1+i^C_{i,m,t} = 1+i^C_{i,m,t-1}. \tag{66}$$

Under this financial friction, intermediate banks infrequently adjust their lending rate, mimicking the effect of maturity transformation on the spread between the lending and deposit rates.

If the representative intermediate bank can adjust its gross lending rate in period t, then it does so to maximize pre-dividend stock market value (56) subject to balance sheet identity (58), intermediate loan demand function (54), 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 lending rate in period t solve an identical value maximization problem, which implies that they all choose a common lending rate $i^{C,*}_{i,t}$ given by necessary first order condition:

$$\frac{1+i^{C,*}_{i,t}}{1+i^C_{i,t}} = \frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^C)^{s-t} \frac{\beta^{s-t}\lambda^B_{i,s}}{\lambda^B_{i,t}} \theta^C_{i,s} \frac{(1+i^S_{i,s-1}) + \mathcal{G}^B_B(B^{C,B}_{i,m,s}, K^B_{i,m,s})}{1+i^C_{i,s-1}} \left(\frac{1+i^C_{i,s-1}}{1+i^C_{i,t}}\right)^{\theta^C_{i,s}} \left(\frac{1+i^{C,*}_{i,t}}{1+i^C_{i,t}}\right)^{-\theta^C_{i,s}} (1+i^C_{i,s-1}) B^{C,B}_{i,s}}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^C)^{s-t} \frac{\beta^{s-t}\lambda^B_{i,s}}{\lambda^B_{i,t}} (\theta^C_{i,s}-1)(1-\delta^{C,E}_{i,s}) \left(\frac{1+i^C_{i,s-1}}{1+i^C_{i,t}}\right)^{\theta^C_{i,s}-1} \left(\frac{1+i^{C,*}_{i,t}}{1+i^C_{i,t}}\right)^{-\theta^C_{i,s}} (1+i^C_{i,s-1}) B^{C,B}_{i,s}}. \tag{67}$$

This necessary first order condition equates the expected present value of the marginal revenue gained from loan supply to the expected present value of the marginal cost incurred from intermediation. Aggregate gross lending rate index (55) equals an average of the gross lending rate set by the fraction $1-\omega^C$ of intermediate banks that adjust their lending rate in period t, and the average of the gross lending rates set by the remaining fraction ω^C of intermediate banks that do not adjust their lending rate:

$$1+i^C_{i,t} = \left[(1-\omega^C)(1+i^{C,*}_{i,t})^{1-\theta^C_{i,t+1}} + \omega^C(1+i^C_{i,t-1})^{1-\theta^C_{i,t+1}}\right]^{\frac{1}{1-\theta^C_{i,t+1}}}. \tag{68}$$

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

D. The Trade Sector

The nominal effective exchange rate $\mathcal{E}_{i,t}$ measures the trade weighted average price of foreign currency in terms of domestic currency, while the real effective exchange rate $\mathcal{Q}_{i,t}$ measures the trade weighted average price of foreign output in terms of domestic output,

$$\mathcal{E}_{i,t} = \prod_{j=1}^{N} (\mathcal{E}_{i,j,t})^{w_{i,j}^T}, \ \mathcal{Q}_{i,t} = \prod_{j=1}^{N} (\mathcal{Q}_{i,j,t})^{w_{i,j}^T}, \tag{69}$$

where the real bilateral exchange rate $\mathcal{Q}_{i,j,t}$ satisfies $\mathcal{Q}_{i,j,t} = \frac{\mathcal{E}_{i,j,t} P_{j,t}^Y}{P_{i,t}^Y}$, and bilateral trade weight $w_{i,j}^T$ satisfies $w_{i,i}^T = 0$, $0 \le w_{i,j}^T \le 1$ and $\sum_{j=1}^{N} w_{i,j}^T = 1$. Furthermore, the terms of trade $\mathcal{T}_{i,t}$ equals the ratio of the internal terms of trade to the external terms of trade,

$$\mathcal{T}_{i,t} = \frac{\mathcal{T}_{i,t}^X}{\mathcal{T}_{i,t}^M}, \ \mathcal{T}_{i,t}^X = \frac{P_{i,t}^X}{P_{i,t}}, \ \mathcal{T}_{i,t}^M = \frac{P_{i,t}^M}{P_{i,t}}, \tag{70}$$

where the internal terms of trade $\mathcal{T}_{i,t}^X$ measures the relative price of exports, and the external terms of trade $\mathcal{T}_{i,t}^M$ measures the relative price of imports, while $P_{i,t}$ denotes the price of the final noncommodity output good. Finally, under the law of one price $\mathcal{E}_{i*,i,t} P_{i,k,t}^Y = P_{k,t}^Y$ for $1 \le k \le M^*$, which implies that

$$P_{k,t}^Y = \sum_{i=1}^{N} w_i^Y \mathcal{E}_{i*,i,t} P_{i,k,t}^Y, \tag{71}$$

where $P_{k,t}^Y$ denotes the quotation currency denominated price of energy or nonenergy commodities, and world output weight w_i^Y satisfies $0 < w_i^Y < 1$ and $\sum_{i=1}^{N} w_i^Y = 1$.

The Export Sector

There exist a large number of perfectly competitive firms which combine industry specific final output goods $\{X_{i,k,t}\}_{k=1}^{M}$ to produce final export good $X_{i,t}$ according to fixed proportions production function

$$X_{i,t} = \min \left\{ \frac{X_{i,k,t}}{\phi_{i,k}^X} \right\}_{k=1}^{M}, \tag{72}$$

where $X_{i,k,t} = Y_{i,k,t}$ for $1 \le k \le M^*$, while $0 \le \phi_{i,k}^X \le 1$ and $\sum_{k=1}^{M} \phi_{i,k}^X = 1$. The representative final export good firm maximizes profits derived from production of the final export good with respect to inputs of industry specific final output goods, implying demand functions:

$$X_{i,k,t} = \phi_{i,k}^{X} X_{i,t}. \tag{73}$$

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

$$P_{i,t}^{X} = \sum_{k=1}^{M} \phi_{i,k}^{X} P_{i,k,t}^{Y}. \tag{74}$$

This aggregate export price index equals the minimum cost of producing one unit of the final export good, given the prices of industry specific final output goods.

The Import Sector

There exist a large number of perfectly competitive firms which combine the final noncommodity output good $Z_{i,t}^{h} \in \{C_{i,t}^{h}, I_{i,t}^{h}, G_{i,t}^{h}\}$ with the final import good $Z_{i,t}^{f} \in \{C_{i,t}^{f}, I_{i,t}^{f}, G_{i,t}^{f}\}$ to produce final private consumption, private investment or public consumption good $Z_{i,t} \in \{C_{i,t}, I_{i,t}, G_{i,t}\}$ according to constant elasticity of substitution production function

$$Z_{i,t} = \left[(\phi_{i,Y}^{D})^{\frac{1}{\psi^{M}}} (Z_{i,t}^{h})^{\frac{\psi^{M}-1}{\psi^{M}}} + (\phi_{i,M}^{D})^{\frac{1}{\psi^{M}}} (\nu_{i,t}^{M} Z_{i,t}^{f})^{\frac{\psi^{M}-1}{\psi^{M}}} \right]^{\frac{\psi^{M}}{\psi^{M}-1}}, \tag{75}$$

where serially correlated import demand shock $\nu_{i,t}^{M}$ satisfies $\nu_{i,t}^{M} > 0$, while $0 \leq \phi_{i,Y}^{D} \leq 1$, $0 \leq \phi_{i,M}^{D} \leq 1$, $\phi_{i,Y}^{D} + \phi_{i,M}^{D} = 1$ and $\psi^{M} > 0$. The representative final absorption good firm maximizes profits derived from production of the final private consumption, private investment or public consumption good, with respect to inputs of the final noncommodity output and import goods, implying demand functions:

$$Z_{i,t}^{h} = \phi_{i,Y}^{D} \left(\frac{P_{i,t}}{P_{i,t}^{Z}} \right)^{-\psi^{M}} Z_{i,t}, \; Z_{i,t}^{f} = \phi_{i,M}^{D} \left(\frac{1}{\nu_{i}^{M}} \frac{P_{i,t}^{M}}{P_{i,t}^{Z}} \right)^{-\psi^{M}} \frac{Z_{i,t}}{\nu_{i,t}^{M}}. \tag{76}$$

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

$$P_{i,t}^{Z} = \left[\phi_{i,Y}^{D} (P_{i,t})^{1-\psi^{M}} + \phi_{i,M}^{D} \left(\frac{P_{i,t}^{M}}{\nu_{i}^{M}} \right)^{1-\psi^{M}} \right]^{\frac{1}{1-\psi^{M}}}. \tag{77}$$

Combination of this aggregate private consumption, private investment or public consumption price index with final noncommodity output and import good demand functions (76) yields:

$$Z_{i,t}^{h} = \phi_{i,Y}^{D} \left[\phi_{i,Y}^{D} + \phi_{i,M}^{D} \left(\frac{\mathcal{T}_{i,t}^{M}}{\nu_{i}^{M}} \right)^{1-\psi^{M}} \right]^{\frac{\psi^{M}}{1-\psi^{M}}} Z_{i,t}, \; Z_{i,t}^{f} = \phi_{i,M}^{D} \left[\phi_{i,M}^{D} + \phi_{i,Y}^{D} \left(\frac{\mathcal{T}_{i,t}^{M}}{\nu_{i}^{M}} \right)^{\psi^{M}-1} \right]^{\frac{\psi^{M}}{1-\psi^{M}}} \frac{Z_{i,t}}{\nu_{i,t}^{M}}. \tag{78}$$

These demand functions for the final noncommodity output and import goods are directly proportional to final private consumption, private investment or public consumption good demand, with a proportionality coefficient that varies with the external terms of trade. The derivation of these results selectively abstracts from import demand shocks.

Import Demand

There exist a large number of perfectly competitive firms which combine economy specific final import goods $\{M_{i,j,t}\}_{j=1}^{N}$ to produce final import good $M_{i,t}$ according to fixed proportions production function

$$M_{i,t} = \min\left\{ \nu_{j,t}^{X} \frac{M_{i,j,t}}{\phi_{i,j}^{M}} \right\}_{j=1}^{N}, \tag{79}$$

where serially correlated export demand shock $\nu_{i,t}^{X}$ satisfies $\nu_{i,t}^{X} > 0$, while $\phi_{i,i}^{M} = 0$, $0 \leq \phi_{i,j}^{M} \leq 1$ and $\sum_{j=1}^{N} \phi_{i,j}^{M} = 1$. The representative final import good firm maximizes profits derived from production of the final import good with respect to inputs of economy specific final import goods, implying demand functions:

$$M_{i,j,t} = \phi_{i,j}^{M} \frac{M_{i,t}}{\nu_{j,t}^{X}}. \tag{80}$$

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

$$P_{i,t}^{M} = \sum_{j=1}^{N} \phi_{i,j}^{M} \frac{P_{i,j,t}^{M}}{\nu_{j}^{X}}. \tag{81}$$

This aggregate import price index equals the minimum cost of producing one unit of the final import good, given the prices of economy specific final import goods. The derivation of these results selectively abstracts from export demand shocks.

There exist a large number of perfectly competitive firms which combine economy specific differentiated intermediate import goods $M_{i,j,n,t}$ supplied by economy specific intermediate import good firms to produce economy specific final import good $M_{i,j,t}$ according to constant elasticity of substitution production function

$$M_{i,j,t} = \left[\int_{0}^{1} (M_{i,j,n,t})^{\frac{\theta_{i,t}^{M}-1}{\theta_{i,t}^{M}}} dn \right]^{\frac{\theta_{i,t}^{M}}{\theta_{i,t}^{M}-1}}, \tag{82}$$

where serially uncorrelated import price markup shock $\theta_{i,t}^{M}$ satisfies $\theta_{i,t}^{M} > 1$ with $\theta_{i}^{M} = \theta^{M}$. The representative economy specific final import good firm maximizes profits derived from production of the economy specific final import good with respect to inputs of economy specific intermediate import goods, implying demand functions:

$$M_{i,j,n,t} = \left(\frac{P^M_{i,j,n,t}}{P^M_{i,j,t}} \right)^{-\theta^M_{i,t}} M_{i,j,t}. \tag{83}$$

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

$$P^M_{i,j,t} = \left[\int_0^1 (P^M_{i,j,n,t})^{1-\theta^M_{i,t}} dn \right]^{\frac{1}{1-\theta^M_{i,t}}}. \tag{84}$$

As the price elasticity of demand for economy specific intermediate import goods $\theta^M_{i,t}$ increases, they become closer substitutes, and individual economy specific intermediate import good firms have less market power.

Import Supply

There exist continuums of monopolistically competitive economy specific intermediate import good firms indexed by $n \in [0,1]$. Intermediate import good firms supply economy specific differentiated intermediate import goods, but are otherwise identical. We rule out entry into and exit out of the monopolistically competitive economy specific intermediate import good sectors.

The representative economy specific intermediate import good firm sells shares to domestic capital market intermediated households at price $V^M_{i,j,n,t}$. Acting in the interests of its shareholders, it maximizes its pre-dividend stock market value, which abstracting from the capitalist spirit motive for holding real portfolio balances equals the expected present value of current and future dividend payments:

$$\Pi^M_{i,j,n,t} + V^M_{i,j,n,t} = \mathrm{E}_t \sum_{s=t}^{\infty} \frac{\beta^{s-t} \lambda^A_{i,s}}{\lambda^A_{i,t}} \Pi^M_{i,j,n,s}. \tag{85}$$

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

Shares entitle households to dividend payments equal to profits $\Pi^M_{i,j,n,s}$, defined as earnings less economy specific fixed cost $F^M_{i,j,s}$:

$$\Pi^M_{i,j,n,s} = P^M_{i,j,n,s} M_{i,j,n,s} - \mathcal{E}_{i,j,s} P^X_{j,s} M_{i,j,n,s} - F^M_{i,j,s}. \tag{86}$$

Earnings are defined as revenues derived from sales of economy specific differentiated intermediate import good $M_{i,j,n,s}$ at price $P^M_{i,j,n,s}$ less expenditures on foreign final export good $M_{i,j,n,s}$. The representative economy specific intermediate import good firm purchases the foreign final export good and differentiates it. Fixed cost $F^M_{i,j,s}$ ensures that $\Pi^M_{i,j,s} = 0$.

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 economy specific 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 economy specific import price inflation, as well as contemporaneous changes in the domestic currency denominated prices of energy and nonenergy commodities, according to partial indexation rule

$$P_{i,j,n,t}^{M} = \left[\left(\frac{P_{i,j,t-1}^{M}}{P_{i,j,t-2}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\mathcal{E}_{i,i^*,t}P_{k,t}^{Y}}{\mathcal{E}_{i,i^*,t-1}P_{k,t-1}^{Y}}\right)^{\mu_{i,k}^M}\right]^{\gamma^M} \left[\left(\frac{\bar{P}_{i,j,t-1}^{M}}{\bar{P}_{i,j,t-2}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\bar{\mathcal{E}}_{i,i^*,t}\bar{P}_{k,t}^{Y}}{\bar{\mathcal{E}}_{i,i^*,t-1}\bar{P}_{k,t-1}^{Y}}\right)^{\mu_{i,k}^M}\right]^{1-\gamma^M} P_{i,j,n,t-1}^{M}, \quad (87)$$

where $0 \leq \gamma^{M} \leq 1$, while $\mu_i^M = \sum_{k=1}^{M^*}\mu_{i,k}^M$ with $\mu_{i,k}^M = \mu^M \frac{\bar{M}_{i,k,t}}{\bar{M}_{i,t}}$ and $\mu^M \geq 0$. 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 economy specific intermediate import good firm can adjust its price optimally in period t, then it does so to maximize pre-dividend stock market value (85) subject to economy specific intermediate import good demand function (83), 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 $P_{i,j,t}^{M,*}$ given by necessary first order condition:

$$\frac{P_{i,j,t}^{M,*}}{P_{i,j,t}^{M}} = \frac{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^M)^{s-t} \frac{\beta^{s-t}\lambda_{i,s}^A}{\lambda_{i,t}^A} \theta_{i,s}^M \frac{\mathcal{E}_{i,j,s}P_{j,s}^X}{P_{i,j,s}^M} \left\{\left[\left(\frac{P_{i,j,t-1}^{M}}{P_{i,j,s-1}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\mathcal{E}_{i,i^*,t}P_{k,t}^{Y}}{\mathcal{E}_{i,i^*,s}P_{k,s}^{Y}}\right)^{\mu_{i,k}^M}\right]^{\gamma^M} \left[\left(\frac{\bar{P}_{i,j,t-1}^{M}}{\bar{P}_{i,j,s-1}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\bar{\mathcal{E}}_{i,i^*,t}\bar{P}_{k,t}^{Y}}{\bar{\mathcal{E}}_{i,i^*,s}\bar{P}_{k,s}^{Y}}\right)^{\mu_{i,k}^M}\right]^{1-\gamma^M} \frac{P_{i,j,s}^M}{P_{i,j,t}^M}\right\}^{\theta_{i,s}^M} \left(\frac{P_{i,j,t}^{M,*}}{P_{i,j,t}^{M}}\right)^{-\theta_{i,s}^M} P_{i,j,s}^M M_{i,j,s}}{\mathrm{E}_t \sum_{s=t}^{\infty} (\omega^M)^{s-t} \frac{\beta^{s-t}\lambda_{i,s}^A}{\lambda_{i,t}^A} (\theta_{i,s}^M - 1) \left\{\left[\left(\frac{P_{i,j,t-1}^{M}}{P_{i,j,s-1}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\mathcal{E}_{i,i^*,t}P_{k,t}^{Y}}{\mathcal{E}_{i,i^*,s}P_{k,s}^{Y}}\right)^{\mu_{i,k}^M}\right]^{\gamma^M} \left[\left(\frac{\bar{P}_{i,j,t-1}^{M}}{\bar{P}_{i,j,s-1}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\bar{\mathcal{E}}_{i,i^*,t}\bar{P}_{k,t}^{Y}}{\bar{\mathcal{E}}_{i,i^*,s}\bar{P}_{k,s}^{Y}}\right)^{\mu_{i,k}^M}\right]^{1-\gamma^M} \frac{P_{i,j,s}^M}{P_{i,j,t}^M}\right\}^{\theta_{i,s}^M-1} \left(\frac{P_{i,j,t}^{M,*}}{P_{i,j,t}^{M}}\right)^{-\theta_{i,s}^M} P_{i,j,s}^M M_{i,j,s}}. \quad (88)$$

This necessary first order condition equates the expected present value of the marginal revenue gained from import supply to the expected present value of the marginal cost incurred from production. Aggregate import price index (84) 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 (87):

$$P_{i,j,t}^{M} = \left\{(1-\omega^M)(P_{i,j,t}^{M,*})^{1-\theta_{i,t}^M} + \omega^M \left\{\left[\left(\frac{P_{i,j,t-1}^{M}}{P_{i,j,t-2}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\mathcal{E}_{i,i^*,t}P_{k,t}^{Y}}{\mathcal{E}_{i,i^*,t-1}P_{k,t-1}^{Y}}\right)^{\mu_{i,k}^M}\right]^{\gamma^M} \left[\left(\frac{\bar{P}_{i,j,t-1}^{M}}{\bar{P}_{i,j,t-2}^{M}}\right)^{1-\mu_i^M} \prod_{k=1}^{M^*}\left(\frac{\bar{\mathcal{E}}_{i,i^*,t}\bar{P}_{k,t}^{Y}}{\bar{\mathcal{E}}_{i,i^*,t-1}\bar{P}_{k,t-1}^{Y}}\right)^{\mu_{i,k}^M}\right]^{1-\gamma^M} P_{i,j,t-1}^{M}\right\}^{1-\theta_{i,t}^M}\right\}^{\frac{1}{1-\theta_{i,t}^M}}. \quad (89)$$

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 economy specific aggregate import price index that prevailed during period $t-1$, rescaled to account for past economy specific import price inflation.

E. Monetary, Fiscal, and Macroprudential Policy

The government consists of a monetary authority, a fiscal authority, and a macroprudential authority. The monetary authority implements monetary policy, while the fiscal authority implements fiscal policy, and the macroprudential authority implements macroprudential policy.

The Monetary Authority

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

$$\begin{aligned} i_{i,t}^{P} - \bar{i}_{i,t}^{P} = \rho_j^i (i_{i,t-1}^{P} - \bar{i}_{i,t-1}^{P}) + (1-\rho_j^i)\Big[\xi_j^{\pi} (\pi_{i,t}^{C} - \bar{\pi}_{i,t}^{C}) + \xi_j^{Y} (\ln Y_{i,t} - \ln \bar{Y}_{i,t}) + \xi_j^{Q} (\ln Q_{i,t} - \ln \bar{Q}_{i,t}) \\ + \xi_j^{i} (i_{k,t}^{P} - \bar{i}_{k,t}^{P}) + \xi_j^{\mathcal{E}} (\ln \mathcal{E}_{i,k,t} - \ln \bar{\mathcal{E}}_{i,k,t}) \Big] + \nu_{i,t}^{i^P}, \end{aligned} \tag{90}$$

where $0 \leq \rho_j^i < 1$, $\xi_j^{\pi} \geq 0$, $\xi_j^{Y} \geq 0$, $\xi_j^{Q} \geq 0$, $\xi_j^{i} \geq 0$ and $\xi_j^{\mathcal{E}} \geq 0$. This rule prescribing the conduct of monetary policy is consistent with achieving some combination of inflation control, output stabilization, and exchange rate stabilization objectives. As specified, the deviation of the nominal policy interest rate from its steady state equilibrium value depends on a weighted average of its past deviation and its desired deviation. Under a flexible inflation targeting regime $j = 0$, and this desired deviation is increasing in the contemporaneous deviation of consumption price inflation from its target value with $\xi_j^{\pi} > 1$, as well as the contemporaneous deviation of output from its steady state equilibrium value with $\xi_j^{Y} > 0$. Under a managed exchange rate regime $j = 1$, and it is also increasing in the contemporaneous deviation of the real effective exchange rate from its steady state equilibrium value with $\xi_j^{Q} > 0$. Under a fixed exchange rate regime $j = 2$, and the deviation of the nominal policy interest rate from its steady state equilibrium value instead tracks the contemporaneous deviation of the nominal policy interest rate for the economy that issues the anchor currency from its steady state equilibrium value one for one with $\xi_j^{i} = 1$, while responding to any contemporaneous deviation of the corresponding nominal bilateral exchange rate from its target value with $\xi_j^{\mathcal{E}} > 0$. For economies belonging to a currency union, the target variables entering into their common monetary policy rule are expressed as output weighted averages across union members. Deviations from this monetary policy rule are captured by mean zero and serially uncorrelated monetary policy shock $\nu_{i,t}^{i^P}$.

The Fiscal Authority

The fiscal authority implements fiscal policy through control of public consumption and the tax rate applicable to the labor income of households and the earnings of intermediate good firms. It can transfer its budgetary resources intertemporally through transactions in the domestic money and bond markets. Considered jointly, the rules prescribing the conduct of this distortionary fiscal policy are countercyclical, representing automatic fiscal stabilizers, and are consistent with achieving a public financial wealth stabilization objective.

Public consumption satisfies an acyclical fiscal expenditure rule exhibiting partial adjustment dynamics of the form

$$\frac{G_{i,t}}{\overline{Y}_{i,t}}-\frac{\overline{G}_{i,t}}{\overline{Y}_{i,t}}=\rho_G\left(\frac{G_{i,t-1}}{\overline{Y}_{i,t-1}}-\frac{\overline{G}_{i,t-1}}{\overline{Y}_{i,t-1}}\right)+(1-\rho_G)\zeta^G\left(\frac{A^G_{i,t+1}}{P^Y_{i,t}Y_{i,t}}-\frac{\overline{A}^G_{i,t+1}}{\overline{P}^Y_{i,t}\overline{Y}_{i,t}}\right)+\nu^G_{i,t}, \tag{91}$$

where $0\leq\rho_G<1$ and $\zeta^G>0$. As specified, the deviation of the ratio of public consumption to steady state equilibrium output from its steady state equilibrium value depends on a weighted average of its past deviation and its desired deviation, which in turn is increasing in the contemporaneous deviation of the ratio of public financial wealth to nominal output from its target value. Deviations from this fiscal expenditure rule are captured by mean zero and serially uncorrelated fiscal expenditure shock $\nu^G_{i,t}$.

The tax rate applicable to the labor income of households and the earnings of intermediate good firms satisfies a countercyclical fiscal revenue rule exhibiting partial adjustment dynamics of the form

$$\tau_{i,t}-\overline{\tau}_{i,t}=\rho_\tau(\tau_{i,t-1}-\overline{\tau}_{i,t-1})-(1-\rho_\tau)\zeta^\tau\left(\frac{A^G_{i,t+1}}{P^Y_{i,t}Y_{i,t}}-\frac{\overline{A}^G_{i,t+1}}{\overline{P}^Y_{i,t}\overline{Y}_{i,t}}\right)+\nu^T_{i,t}, \tag{92}$$

where $0\leq\rho_\tau<1$ and $\zeta^\tau>0$. As specified, the deviation of the tax rate from its steady state equilibrium value depends on a weighted average of its past deviation and its desired deviation, which in turn is decreasing in the contemporaneous deviation of the ratio of public financial wealth to nominal output from its target value. Deviations from this fiscal revenue rule are captured by mean zero and serially uncorrelated fiscal revenue shock $\nu^T_{i,t}$.

The yield to maturity on short term bonds depends on the contemporaneous nominal policy interest rate according to money market relationship

$$i^S_{i,t}=i^P_{i,t}-\zeta^i\frac{A_{i,t+1}}{P^Y_{i,t}Y_{i,t}}+\upsilon^{i^S}_{i,t}, \tag{93}$$

where $\zeta^i>0$. As specified, the spread of the yield to maturity on short term bonds over the nominal policy interest rate is decreasing in the contemporaneous ratio of national financial wealth to nominal output. For economies belonging to a currency block, the ratio of national financial wealth to nominal output is expressed as an output weighted average across block members. Deviations from this money market relationship are captured by mean zero and internationally and serially correlated credit risk premium shock $\upsilon^{i^S}_{i,t}$.

The fiscal authority enters period t in possession of previously accumulated financial wealth $A^G_{i,t}$ which yields return $i^{A^G}_{i,t}$. This financial wealth is distributed across the values of domestic short term bond $B^{S,G}_{i,t}$ and long term bond $B^{L,G}_{i,t}$ portfolios which yield returns $i^S_{i,t-1}$ and $i^{B^{L,G}}_{i,t}$, respectively. It follows that $(1+i^{A^G}_{i,t})A^G_{i,t}=(1+i^S_{i,t-1})B^{S,G}_{i,t}+(1+i^{B^{L,G}}_{i,t})B^{L,G}_{i,t}$, where $(1+i^{B^{L,G}}_{i,t})B^{L,G}_{i,t}$

$= \sum_{k=1}^{t-1} (\Pi_{i,k,t}^{B} + V_{i,k,t}^{B}) B_{i,k,t}^{L,G}$ with $\Pi_{i,k,t}^{B} = i_{i,k}^{L} V_{i,k,k}^{B}$ and $V_{i,k,k}^{B} = 1$. At the end of period t, the fiscal authority levies taxes on the labor income of households and the earnings of industry specific intermediate output good firms at rate $\tau_{i,t}$. In equilibrium, this distortionary tax collection framework corresponds to proportional output taxation, and tax revenues satisfy $T_{i,t} = \tau_{i,t} P_{i,t}^{Y} Y_{i,t}$. The fiscal authority also operates a budget neutral lump sum transfer program which equalizes steady state equilibrium consumption across households, where $\int_0^1 T_i^Z dh = 0$. These sources of public wealth are summed in government dynamic budget constraint:

$$A_{i,t+1}^{G} = (1 + i_{i,t}^{A^G}) A_{i,t}^{G} + \int_0^1 \tau_{i,t} \int_0^1 W_{f,i,t} L_{h,f,i,t} df\, dh + \sum_{k=1}^{M} \int_0^1 \tau_{i,t} (P_{i,k,l,t}^{Y} Y_{i,k,l,t} - W_{i,t} L_{i,k,l,t}) dl - P_{i,t}^{G} G_{i,t}. \tag{94}$$

According to this dynamic budget constraint, at the end of period t, the fiscal authority holds financial wealth $A_{i,t+1}^{G}$, which it allocates between the values of domestic short term bond $B_{i,t+1}^{S,G}$ and long term bond $B_{i,t+1}^{L,G}$ portfolios, that is $A_{i,t+1}^{G} = B_{i,t+1}^{S,G} + B_{i,t+1}^{L,G}$ where $B_{i,t+1}^{L,G} = \sum_{k=1}^{t} V_{i,k,t}^{B} B_{i,k,t+1}^{L,G}$. Finally, the fiscal authority purchases final public consumption good $G_{i,t}$ at price $P_{i,t}^{G}$.

The Macroprudential Authority

The regulatory capital requirement applicable to lending by domestic banks to domestic and foreign firms satisfies a macroprudential policy rule exhibiting partial adjustment dynamics of the form

$$\kappa_{i,t+1}^{R} - \kappa^{R} = \rho_{\kappa}(\kappa_{i,t}^{R} - \kappa^{R}) + (1-\rho_{\kappa}) \left\{ \zeta^{\kappa,B} \left(\frac{B_{i,t+1}^{C,B}}{P_{i,t}^{Y} Y_{i,t}} - \frac{\overline{B}_{i,t+1}^{C,B}}{\overline{P}_{i,t}^{Y} \overline{Y}_{i,t}} \right) - \zeta^{\kappa,i} \left[\mathrm{E}_t (i_{i,t+1}^{A^{A,H}} - \overline{i}_{i,t+1}^{A^{A,H}}) - (i_{i,t}^{S} - \overline{i}_{i,t}^{S}) \right] \right\} + \nu_{i,t}^{\kappa}, \tag{95}$$

where $0 < \kappa^{R} < 1$, $0 \le \rho_{\kappa} < 1$, $\zeta^{\kappa,B} > 0$ and $\zeta^{\kappa,i} > 0$. As specified, the deviation of the regulatory capital requirement from its steady state equilibrium value depends on a weighted average of its past deviation and its desired deviation. This desired deviation is increasing in the contemporaneous deviation of the ratio of bank credit to nominal output from its steady state equilibrium value, and is decreasing in the contemporaneous deviation of the expected excess portfolio return from its steady state equilibrium value, mimicking a countercyclical capital buffer. Deviations from this macroprudential policy rule are captured by mean zero and serially uncorrelated capital requirement shock $\nu_{i,t}^{\kappa}$.

The loan default rate applicable to borrowing by domestic firms from domestic and foreign banks satisfies a default rate relationship exhibiting partial adjustment dynamics of the form

$$\delta_{i,t}^{C} - \delta^{C} = \rho_{\delta}(\delta_{i,t-1}^{C} - \delta^{C}) + (1-\rho_{\delta}) \left\{ \zeta^{\delta,B} \left(\frac{B_{i,t+1}^{C,F}}{P_{i,t}^{Y} Y_{i,t}} - \frac{\overline{B}_{i,t+1}^{C,F}}{\overline{P}_{i,t}^{Y} \overline{Y}_{i,t}} \right) + \zeta^{\delta,i} \left[\mathrm{E}_t (i_{i,t+1}^{A^{A,H}} - \overline{i}_{i,t+1}^{A^{A,H}}) - (i_{i,t}^{S} - \overline{i}_{i,t}^{S}) \right] \right\} + \nu_{i,t}^{\delta}, \tag{96}$$

where $0 < \delta^{C} < 1$, $0 \le \rho_{\delta} < 1$, $\zeta^{\delta,B} > 0$ and $\zeta^{\delta,i} > 0$. As specified, the deviation of the loan default rate from its steady state equilibrium value depends on a weighted average of its past deviation and its attractor deviation. This attractor deviation is increasing in the contemporaneous deviation of the ratio of nonfinancial corporate debt to nominal output from its steady state equilibrium value, as well as the contemporaneous deviation of the expected excess portfolio return from its steady state equilibrium value, proxying for systemic risk. Deviations from this default rate relationship are captured by mean zero and serially uncorrelated loan default shock $\nu_{i,t}^{\delta}$.

F. Market Clearing Conditions

A rational expectations equilibrium in this panel dynamic stochastic general equilibrium model of the world economy consists of state contingent sequences of allocations for the households, firms and banks of all economies which solve their constrained optimization problems given prices and policies, together with state contingent sequences of allocations for the governments of all economies which 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 exports $X_{i,t}$ equal production of the domestic final output good less the total demand of domestic households, firms and the government,

$$X_{i,t} = Y_{i,t} - C_{i,t}^{h} - I_{i,t}^{h} - G_{i,t}^{h}, \tag{97}$$

where $X_{i,t} = \sum_{j=1}^{N} X_{i,j,t}$ and $X_{i,j,t} = M_{j,i,t}$. Clearing of the final import good market requires that imports $M_{i,t}$ equal the total demand of domestic households, firms and the government:

$$M_{i,t} = C_{i,t}^{f} + I_{i,t}^{f} + G_{i,t}^{f}. \tag{98}$$

In equilibrium, combination of these final output and import good market clearing conditions yields output expenditure decomposition,

$$P_{i,t}^{Y} Y_{i,t} = P_{i,t}^{C} C_{i,t} + P_{i,t}^{I} I_{i,t} + P_{i,t}^{G} G_{i,t} + P_{i,t}^{X} X_{i,t} - P_{i,t}^{M} M_{i,t}, \tag{99}$$

where the price of domestic demand satisfies $P_{i,t}^{D} = P_{i,t}^{C} = P_{i,t}^{I} = P_{i,t}^{G}$, while domestic demand satisfies $D_{i,t} = C_{i,t} + I_{i,t} + G_{i,t}$.

Clearing of the final bank loan market requires that loan supply $B_{i,t+1}^{C,B}$ equal the total demand of domestic and foreign firms,

$$B_{i,t+1}^{C,B} = \sum_{j=1}^{N} B_{i,j,t+1}^{C,B}, \tag{100}$$

where $B_{i,j,t+1}^{C,B} = B_{j,i,t+1}^{C,F}$. In equilibrium, clearing of the final bank loan payments system implies that credit loss rate $\delta_{i,t}^{C,E}$ satisfies:

$$(1-\delta_{i,t}^{C,E})(1+i_{i,t-1}^{C}) = \sum_{j=1}^{N} \frac{B_{j,i,t}^{C,F}}{B_{i,t}^{C,B}} (1-\delta_{j,t}^{C})(1+i_{j,t}^{C,E}) \frac{\mathcal{E}_{i,j,t}}{\mathcal{E}_{i,j,t-1}}. \tag{101}$$

The derivation of this result equates the aggregate principal and interest receipts of banks to the aggregate principal and interest payments of domestic and foreign firms.

Let $A_{i,t+1}$ denote the net foreign asset position, which equals the sum of the financial wealth of households $A^H_{i,t+1}$, firms $A^F_{i,t+1}$, banks $A^B_{i,t+1}$ and the government $A^G_{i,t+1}$,

$$A_{i,t+1} = A^H_{i,t+1} + A^F_{i,t+1} + A^B_{i,t+1} + A^G_{i,t+1}, \tag{102}$$

where $A^H_{i,t+1} = B^{D,H}_{i,t+1} + A^{A,H}_{i,t+1}$, $A^F_{i,t+1} = -B^{C,F}_{i,t+1} - V^S_{i,t}$ and $A^B_{i,t+1} = K^B_{i,t+1}$. Imposing equilibrium conditions on government dynamic budget constraint (94) reveals that the increase in public financial wealth equals public saving, or equivalently that the fiscal balance $FB_{i,t} = A^G_{i,t+1} - A^G_{i,t}$ equals the sum of net interest income and the primary fiscal balance $PB_{i,t} = \tau_{i,t} P^Y_{i,t} Y_{i,t} - P^G_{i,t} G_{i,t}$,

$$FB_{i,t} = \left[\frac{B^{S,G}_i}{A^G_i} i^S_{i,t-1} + \frac{B^{L,G}_i}{A^G_i} i^{L,E}_{i,t-1} \right] A^G_{i,t} + PB_{i,t}, \tag{103}$$

where effective long term nominal market interest rate $i^{L,E}_{i,t}$ satisfies $i^{L,E}_{i,t} = \chi^G i^{L,E}_{i,t-1} + (1-\chi^G) i^L_{i,t}$ with $0 \leq \chi^G < 1$. The derivation of this result abstracts from capital gains on long term bond holdings, and imposes restrictions $V^B_{i,k-1,t-1} B^{L,G}_{i,k-1,t} = \chi^G V^B_{i,k,t-1} B^{L,G}_{i,k,t}$, $B^{S,G}_{i,t} / A^G_{i,t} = B^{S,G}_i / A^G_i$ and $B^{L,G}_{i,t} / A^G_{i,t} = B^{L,G}_i / A^G_i$. Imposing equilibrium conditions on household dynamic budget constraint (12), and combining it with government dynamic budget constraint (103), firm dividend payment definition (36), bank dividend payment definition (57), bank balance sheet identity (58), output expenditure decomposition (99), and payments system clearing condition (101) reveals that the increase in net foreign assets equals national saving less investment expenditures, or equivalently that the current account balance $CA_{i,t} = \mathcal{E}_{i*,i,t} A_{i,t+1} - \mathcal{E}_{i*,i,t-1} A_{i,t}$ equals the sum of net international investment income and the trade balance $TB_{i,t} = \mathcal{E}_{i*,i,t} P^X_{i,t} X_{i,t} - \mathcal{E}_{i*,i,t} P^M_{i,t} M_{i,t}$,

$$CA_{i,t} = \left\{ \sum_{j=1}^{N} w^M_j \left[(1 + i^S_{j,t-1}) \frac{\mathcal{E}_{i*,j,t}}{\mathcal{E}_{i*,j,t-1}} - 1 \right] \right\} \mathcal{E}_{i*,i,t-1} A_{i,t} + TB_{i,t}, \tag{104}$$

where world money market capitalization weight w^M_i satisfies $0 < w^M_i < 1$ and $\sum_{i=1}^{N} w^M_i = 1$. The derivation of this result abstracts from bank lending across economies and the cost of regulation, as well as from foreign long term bond and stock holdings, and imposes restriction $\frac{\mathcal{E}_{i,j,t-1} B^S_{i,j,t}}{A_{i,t}} = w^M_j$.

III. The Empirical Framework

Estimation, inference and forecasting are based on a linear state space representation of an approximate multivariate linear rational expectations representation of this panel dynamic stochastic general equilibrium model of the world economy. This multivariate linear rational expectations representation is derived by linearizing the equilibrium conditions of this panel dynamic stochastic general equilibrium model around its stationary deterministic steady state equilibrium, and consolidating them by substituting out intermediate variables. Unless stated otherwise, this steady state equilibrium abstracts from long run balanced growth, and features zero inflation and net financial asset holdings.[2]

In what follows, $\hat{x}_{i,t}$ denotes the deviation of variable $x_{i,t}$ from its steady state equilibrium value, while $\mathrm{E}_t\, x_{i,t+s}$ denotes the rational expectation of variable $x_{i,t+s}$ conditional on information available in period t. Bilateral weights $w_{i,j}^{Z}$ for evaluating the trade weighted average of variable $x_{i,t}$ across the trading partners of economy i are based on exports for $Z = X$, imports for $Z = M$, and their average for $Z = T$. Furthermore, bilateral weights $w_{i,j}^{Z}$ for evaluating the weighted average of domestic currency denominated variable $x_{i,t}$ across the lending destinations and borrowing sources of economy i are based on bank lending for $Z = C$ and nonfinancial corporate borrowing for $Z = F$. In addition, bilateral weights $w_{i,j}^{Z}$ for evaluating the portfolio weighted average of domestic currency denominated variable $x_{i,t}$ across the investment destinations of economy i are based on debt for $Z = B$ and equity for $Z = S$. Finally, world weights w_i^{Z} for evaluating the weighted average of variable $x_{i,t}$ across all economies are based on output for $Z = Y$, money market capitalization for $Z = M$, bond market capitalization for $Z = B$, and stock market capitalization for $Z = S$.

A. Endogenous Variables

Output price inflation $\hat{\pi}_{i,t}^{Y}$ depends on a linear combination of its past and expected future values driven by the contemporaneous labor income share, output, and the internal terms of trade according to output price Phillips curve:

$$\hat{\pi}_{i,t}^{Y} = \frac{\gamma^{Y}}{1+\gamma^{Y}\beta}\hat{\pi}_{i,t-1}^{Y} + \frac{\beta}{1+\gamma^{Y}\beta}\mathrm{E}_t\hat{\pi}_{i,t+1}^{Y} + \frac{(1-\omega^{Y})(1-\omega^{Y}\beta)}{\omega^{Y}(1+\gamma^{Y}\beta)}\left\{\ln\frac{\hat{W}_{i,t}\hat{L}_{i,t}}{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}} + \left[1-\left(1-\frac{X_i}{Y_i}\sum_{k=1}^{M^*}\frac{X_{i,k}}{X_i}\phi_k^{F}\right)^{-1}\right]\ln\hat{Y}_{i,t} + \frac{X_i}{Y_i}\ln\hat{\mathcal{T}}_{i,t}^{X} - \frac{1}{\theta^{Y}-1}\ln\hat{\theta}_{i,t}^{Y}\right\} + \frac{X_i}{Y_i}\mathcal{P}_1(L)\Delta\ln\hat{\mathcal{T}}_{i,t}^{X}. \quad (105)$$

Output price inflation also depends on contemporaneous, past and expected future changes in the internal terms of trade, where polynomial in the lag operator $\mathcal{P}_1(L) = 1 - \frac{\gamma^{Y}}{1+\gamma^{Y}\beta}L - \frac{\beta}{1+\gamma^{Y}\beta}\mathrm{E}_t L^{-1}$. The response coefficients of this relationship vary across economies with their trade openness and commodity export intensities.

Consumption price inflation $\hat{\pi}_{i,t}^{C}$ depends on a linear combination of its past and expected future values driven by the contemporaneous labor income share, output, and the internal terms of trade according to consumption price Phillips curve:

[2] In steady state equilibrium $\mathcal{A}_i = \nu_i^{C} = \nu_i^{I} = \nu_i^{X} = \upsilon_i^{B} = \upsilon_i^{S} = \nu_i^{\mathcal{E}} = 1$, $\nu_i^{i^P} = \upsilon_i^{i^S} = \nu_i^{G} = \nu_i^{T} = \nu_i^{\kappa} = \nu_i^{\delta} = 0$, $\nu_i^{M} = \frac{\theta^{M}}{\theta^{M}-1}$, and $\sigma_{\theta^Y}^2 = \sigma_{\theta^M}^2 = \sigma_{\theta^L}^2 = \sigma_{A}^2 = \sigma_{\nu^C}^2 = \sigma_{\nu^I}^2 = \sigma_{\nu^X}^2 = \sigma_{\nu^M}^2 = \sigma_{\nu^{i,P}}^2 = \sigma_{\nu^{i,S}}^2 = \sigma_{\nu^B}^2 = \sigma_{\nu^S}^2 = \sigma_{\nu^{\mathcal{E}}}^2 = \sigma_{\nu^L}^2 = \sigma_{\nu^G}^2 = \sigma_{\nu^T}^2 = \sigma_{\theta^C}^2 = \sigma_{\nu^\kappa}^2 = \sigma_{\nu^\delta}^2 = \sigma_{\theta^{Y,k}}^2 = 0$.

$$\begin{aligned}\hat{\pi}^C_{i,t} = {} & \frac{\gamma^Y}{1+\gamma^Y\beta}\hat{\pi}^C_{i,t-1} + \frac{\beta}{1+\gamma^Y\beta}\mathrm{E}_t\hat{\pi}^C_{i,t+1} + \frac{(1-\omega^Y)(1-\omega^Y\beta)}{\omega^Y(1+\gamma^Y\beta)}\left\{\ln\frac{\hat{W}_{i,t}\hat{L}_{i,t}}{\hat{P}^Y_{i,t}\hat{Y}_{i,t}}\right. \\ & \left. + \left[1-\left(1-\frac{X_i}{Y_i}\sum_{k=1}^{M^*}\frac{X_{i,k}}{X_i}\phi^F_k\right)^{-1}\right]\ln\hat{Y}_{i,t} + \frac{X_i}{Y_i}\ln\hat{\mathcal{T}}^X_{i,t} - \frac{1}{\theta^Y-1}\ln\hat{\theta}^Y_{i,t}\right\} + \frac{M_i}{Y_i}\mathcal{P}_1(L)\Delta\ln\hat{\mathcal{T}}^M_{i,t}.\end{aligned} \tag{106}$$

Consumption price inflation also depends on contemporaneous, past and expected future changes in the external terms of trade. The response coefficients of this relationship vary across economies with their trade openness and commodity export intensities.

Output $\ln\hat{Y}_{i,t}$ depends on a weighted average of its past and expected future values driven by a weighted average of the contemporaneous real ex ante portfolio return and short term real market interest rate according to output demand relationship:

$$\begin{aligned}\ln\hat{Y}_{i,t} = {} & \frac{\alpha}{1+\alpha}\ln\hat{Y}_{i,t-1} + \frac{1}{1+\alpha}\mathrm{E}_t\ln\hat{Y}_{i,t+1} - \left(1-\frac{X_i}{Y_i}\right)\left\{(1-\phi^C)\frac{C_i}{Y_i}\sigma\frac{1-\alpha}{1+\alpha}\mathrm{E}_t\left[\frac{\phi^A}{1-\phi^C}\hat{r}^{A^{A,H}}_{i,t+1} + \left(1-\frac{\phi^A}{1-\phi^C}\right)\hat{r}^S_{i,t} - \ln\frac{\hat{v}^C_{i,t}}{\hat{v}^C_{i,t+1}}\right]\right. \\ & \left. -\phi^C\mathcal{P}_2(L)\left[\frac{\Pi^S_i}{P^Y_iY_i}\ln\frac{\hat{\Pi}^S_{i,t}}{\hat{P}^C_{i,t}} + (1-\tau_i)\frac{W_iL_i}{P^Y_iY_i}\left(\ln\frac{\hat{W}_{i,t}\hat{L}_{i,t}}{\hat{P}^C_{i,t}} - \frac{1}{1-\tau_i}\hat{\tau}_{i,t}\right)\right] - \mathcal{P}_2(L)\left(\frac{I_i}{Y_i}\ln\hat{I}_{i,t} + \frac{G_i}{Y_i}\ln\hat{G}_{i,t}\right)\right\} \\ & + \frac{X_i}{Y_i}\mathcal{P}_2(L)\sum_{j=1}^{N}w^X_{i,j}\left\{\ln\frac{\hat{v}^M_{i,t}\hat{D}_{j,t}}{\hat{v}^X_{i,t}\hat{v}^M_{j,t}} - \psi^M\left[\left(1-\frac{M_j}{Y_j}\right)\ln\hat{\mathcal{T}}^M_{j,t} - \left(1-\frac{M_i}{Y_i}\right)\ln\hat{\mathcal{T}}^M_{i,t}\right]\right\}.\end{aligned} \tag{107}$$

Reflecting the existence of credit constraints, output also depends on contemporaneous, past and expected future real profit and disposable labor income. In addition, output depends on contemporaneous, past, and expected future investment and public domestic demand. Finally, reflecting the existence of international trade linkages, output depends on contemporaneous, past and expected future export weighted foreign demand, as well as the export weighted average foreign external terms of trade and the domestic external terms of trade. The response coefficients of this relationship vary across economies with the composition of their domestic demand, the size of their government, their labor income share, their trade openness, and their trade pattern.

Domestic demand $\ln\hat{D}_{i,t}$ depends on a weighted average of its past and expected future values driven by a weighted average of the contemporaneous real ex ante portfolio return and short term real market interest rate according to domestic demand relationship:

$$\begin{aligned}\ln\hat{D}_{i,t} = {} & \frac{\alpha}{1+\alpha}\ln\hat{D}_{i,t-1} + \frac{1}{1+\alpha}\mathrm{E}_t\ln\hat{D}_{i,t+1} - (1-\phi^C)\frac{C_i}{Y_i}\sigma\frac{1-\alpha}{1+\alpha}\mathrm{E}_t\left[\frac{\phi^A}{1-\phi^C}\hat{r}^{A^{A,H}}_{i,t+1} + \left(1-\frac{\phi^A}{1-\phi^C}\right)\hat{r}^S_{i,t} - \ln\frac{\hat{v}^C_{i,t}}{\hat{v}^C_{i,t+1}}\right] \\ & +\phi^C\mathcal{P}_2(L)\left[\frac{\Pi^S_i}{P^Y_iY_i}\ln\frac{\hat{\Pi}^S_{i,t}}{\hat{P}^C_{i,t}} + (1-\tau_i)\frac{W_iL_i}{P^Y_iY_i}\left(\ln\frac{\hat{W}_{i,t}\hat{L}_{i,t}}{\hat{P}^C_{i,t}} - \frac{1}{1-\tau_i}\hat{\tau}_{i,t}\right)\right] + \mathcal{P}_2(L)\left(\frac{I_i}{Y_i}\ln\hat{I}_{i,t} + \frac{G_i}{Y_i}\ln\hat{G}_{i,t}\right).\end{aligned} \tag{108}$$

Reflecting the existence of credit constraints, domestic demand also depends on contemporaneous, past and expected future real profit and disposable labor income. Finally, domestic demand depends on contemporaneous, past, and expected future investment and public domestic demand. The response coefficients of this relationship vary across economies with the composition of their domestic demand, the size of their government, and their labor income share.

Consumption $\ln \hat{C}_{i,t}$ depends on a weighted average of its past and expected future values driven by a weighted average of the contemporaneous real ex ante portfolio return and short term real market interest rate according to consumption demand relationship:

$$\ln \hat{C}_{i,t} = \frac{\alpha}{1+\alpha} \ln \hat{C}_{i,t-1} + \frac{1}{1+\alpha} \mathrm{E}_t \ln \hat{C}_{i,t+1} - (1-\phi^C)\sigma \frac{1-\alpha}{1+\alpha} \mathrm{E}_t \left[\frac{\phi^A}{1-\phi^C} \hat{r}^{A^{A,H}}_{i,t+1} + \left(1 - \frac{\phi^A}{1-\phi^C}\right) \hat{r}^S_{i,t} - \ln \frac{\hat{v}^C_{i,t}}{\hat{v}^C_{i,t+1}} \right]$$
$$+\phi^C \left(\frac{C_i}{Y_i}\right)^{-1} \mathcal{P}_2(L) \left[\frac{\Pi^S_i}{P^Y_i Y_i} \ln \frac{\hat{\Pi}^S_{i,t}}{\hat{P}^C_{i,t}} + (1-\tau_i) \frac{W_i L_i}{P^Y_i Y_i} \left(\ln \frac{\hat{W}_{i,t} \hat{L}_{i,t}}{\hat{P}^C_{i,t}} - \frac{1}{1-\tau_i} \hat{\tau}_{i,t} \right) \right]. \tag{109}$$

Reflecting the existence of credit constraints, consumption also depends on contemporaneous, past and expected future real profit and disposable labor income, where polynomial in the lag operator $\mathcal{P}_2(L) = 1 - \frac{\alpha}{1+\alpha} L - \frac{1}{1+\alpha} \mathrm{E}_t L^{-1}$. The response coefficients of this relationship vary across economies with their consumption intensity, the size of their government, and their labor income share.

Investment $\ln \hat{I}_{i,t}$ depends on a weighted average of its past and expected future values driven by the contemporaneous relative shadow price of capital according to investment demand relationship:

$$\ln \hat{I}_{i,t} = \frac{1}{1+\beta} \ln \hat{I}_{i,t-1} + \frac{\beta}{1+\beta} \mathrm{E}_t \ln \hat{I}_{i,t+1} + \frac{1}{\chi(1+\beta)} \ln \left(\hat{v}^I_{i,t} \frac{\hat{Q}_{i,t}}{\hat{P}^C_{i,t}} \right). \tag{110}$$

Reflecting the existence of a financial accelerator mechanism, the relative shadow price of capital $\ln \frac{\hat{Q}_{i,t}}{\hat{P}^C_{i,t}}$ depends on its expected future value, as well as the contemporaneous real ex ante portfolio return, and the contemporaneous real ex ante corporate loan rate net of the expected future loan default rate, according to investment Euler equation:

$$\ln \frac{\hat{Q}_{i,t}}{\hat{P}^C_{i,t}} = \mathrm{E}_t \left\{ \beta(1-\delta) \ln \frac{\hat{Q}_{i,t+1}}{\hat{P}^C_{i,t+1}} - \left[(1-\phi) \hat{r}^{A^{A,H}}_{i,t+1} + \phi\beta \frac{\theta^C}{\theta^C - 1} \frac{1+\kappa^R(1-\beta(1-\chi^B \delta^C))}{\beta} (\hat{r}^{C,E}_{i,t+1} - \lambda^Q \hat{\delta}^C_{i,t+1}) \right] \right.$$
$$\left. + \left[(1-\beta(1-\delta)) + \phi\beta \left(\frac{\theta^C}{\theta^C - 1} \frac{1+\kappa^R(1-\beta(1-\chi^B \delta^C))}{\beta} - \frac{1}{\beta} \right) \right] \left(\eta^K \ln \hat{u}^K_{i,t+1} - \frac{1}{1-\tau_i} \hat{\tau}_{i,t+1} \right) \right\}. \tag{111}$$

The relative shadow price of capital also depends on the expected future capital utilization and tax rates. Auxiliary parameter λ^Q is theoretically predicted to equal one, and satisfies $\lambda^Q \geq 0$. The capital utilization rate $\ln \hat{u}^K_{i,t}$ depends on the contemporaneous real wage according to capital utilization relationship:

$$\ln \hat{u}^K_{i,t} = \frac{1}{\eta^K} \left(\ln \frac{\hat{W}_{i,t}}{\hat{P}^C_{i,t}} - \ln \frac{\hat{u}^K_{i,t} \hat{K}_{i,t}}{\hat{L}_{i,t}} \right). \tag{112}$$

The capital utilization rate also depends on the contemporaneous deviation of utilized capital from employment. The capital stock $\ln \hat{K}_{i,t+1}$ satisfies $\ln \hat{K}_{i,t+1} = (1-\delta)\ln \hat{K}_{i,t} + \delta \ln(\hat{\nu}_{i,t}^{I}\hat{I}_{i,t})$.

Exports $\ln \hat{X}_{i,t}$ depend on contemporaneous export weighted foreign demand, as well as the export weighted average foreign external terms of trade, according to export demand relationship:

$$\ln \hat{X}_{i,t} = \sum_{j=1}^{N} w_{i,j}^{X}\left[\ln \frac{\hat{D}_{j,t}}{\hat{\nu}_{i,t}^{X}\hat{\nu}_{j,t}^{M}} - \psi^{M}\left(1-\frac{M_j}{Y_j}\right)\ln \hat{\mathcal{T}}_{j,t}^{M}\right]. \tag{113}$$

The response coefficients of this relationship vary across economies with their trade pattern and the trade openness of their trading partners. Imports $\ln \hat{M}_{i,t}$ depend on contemporaneous domestic demand, as well as the domestic external terms of trade, according to import demand relationship:

$$\ln \hat{M}_{i,t} = \ln \frac{\hat{D}_{i,t}}{\hat{\nu}_{i,t}^{M}} - \psi^{M}\left(1-\frac{M_i}{Y_i}\right)\ln \hat{\mathcal{T}}_{i,t}^{M}. \tag{114}$$

The response coefficients of this relationship vary across economies with their trade openness.

The nominal ex ante portfolio return $\mathrm{E}_t \hat{i}_{i,t+1}^{A^{A,H}}$ depends on the contemporaneous short term nominal market interest rate according to return function:

$$\mathrm{E}_t \hat{i}_{i,t+1}^{A^{A,H}} = \hat{i}_{i,t}^{S} - \frac{B_i^{L,H}}{A_i^{A,H}}\sum_{j=1}^{N} w_{i,j}^{B}\left(\ln \hat{\upsilon}_{j,t}^{B} - \frac{B_i^{H}}{B_i^{L,H}}\ln \frac{\hat{\nu}_{i,t}^{\mathcal{E}}}{\hat{\nu}_{j,t}^{\mathcal{E}}}\right) - \frac{S_i^{H}}{A_i^{A,H}}\sum_{j=1}^{N} w_{i,j}^{S}\left(\ln \hat{\upsilon}_{j,t}^{S} - \ln \frac{\hat{\nu}_{i,t}^{\mathcal{E}}}{\hat{\nu}_{j,t}^{\mathcal{E}}}\right). \tag{115}$$

Reflecting the existence of internal and external macrofinancial linkages, the nominal ex ante portfolio return also depends on contemporaneous domestic and foreign duration risk premium, equity risk premium, and currency risk premium shocks. The response coefficients of this relationship vary across economies with their domestic and foreign money, bond, and stock market exposures. The real ex ante portfolio return $\mathrm{E}_t \hat{r}_{i,t+1}^{A^{A,H}}$ satisfies $\mathrm{E}_t \hat{r}_{i,t+1}^{A^{A,H}} = \mathrm{E}_t \hat{i}_{i,t+1}^{A^{A,H}} - \mathrm{E}_t \hat{\pi}_{i,t+1}^{C}$.

The nominal policy interest rate $\hat{i}_{i,t}^{P}$ depends on a weighted average of its past and desired values according to monetary policy rule:

$$\hat{i}_{i,t}^{P} = \rho_j^{i}\hat{i}_{i,t-1}^{P} + (1-\rho_j^{i})(\xi_j^{\pi}\hat{\pi}_{i,t}^{C} + \xi_j^{Y}\ln \hat{Y}_{i,t} + \xi_j^{Q}\ln \hat{\mathcal{Q}}_{i,t} + \xi_j^{i}\hat{i}_{k,t}^{P} + \xi_j^{\mathcal{E}}\ln \hat{\mathcal{E}}_{i,k,t}) + \hat{\nu}_{i,t}^{i^{P}}. \tag{116}$$

Under a flexible inflation targeting regime $j=0$, and the desired nominal policy interest rate responds to contemporaneous consumption price inflation and output. Under a managed exchange rate regime $j=1$, and it also responds to the contemporaneous real effective exchange rate. Under a fixed exchange rate regime $j=2$, and the nominal policy interest rate instead tracks the contemporaneous nominal policy interest rate for the economy that issues the anchor currency one for one, while responding to the contemporaneous corresponding nominal bilateral exchange rate. For economies belonging to a currency union, the target variables entering into their common monetary policy rule are expressed as output weighted averages across union members. The real policy interest rate $\hat{r}_{i,t}^{P}$ satisfies $\hat{r}_{i,t}^{P} = \hat{i}_{i,t}^{P} - \mathrm{E}_t \hat{\pi}_{i,t+1}^{C}$.

The short term nominal market interest rate $\hat{i}_{i,t}^{S}$ depends on the contemporaneous nominal policy interest rate and the net foreign asset ratio according to money market relationship,

$$\hat{i}_{i,t}^{S} = \hat{i}_{i,t}^{P} - \zeta^{i} \frac{\hat{A}_{i,t+1}}{P_{i,t}^{Y} Y_{i,t}} + \hat{\upsilon}_{i,t}^{i^S}, \tag{117}$$

where credit risk premium shock $\hat{\upsilon}_{i,t}^{i^S}$ satisfies dynamic factor process $\hat{\upsilon}_{i,t}^{i^S} = \lambda_k^M \sum_{j=1}^{N} w_j^M \hat{v}_{j,t}^{i^S}$ $+(1-\lambda_k^M w_i^M)\hat{v}_{i,t}^{i^S}$. The intensity of international money market contagion varies across economies, with $k=0$ for low debt contagion economies, $k=1$ for medium debt contagion economies, and $k=2$ for high debt contagion economies, where $\lambda_0^M < \lambda_1^M < \lambda_2^M$. For economies belonging to a currency block, the ratio of national financial wealth to nominal output is expressed as an output weighted average across block members. The short term real market interest rate $\hat{r}_{i,t}^{S}$ satisfies $\hat{r}_{i,t}^{S} = \hat{i}_{i,t}^{S} - \mathrm{E}_t \hat{\pi}_{i,t+1}^{C}$.

The long term nominal market interest rate $\hat{i}_{i,t}^{L}$ depends on a weighted average of its expected future value and the contemporaneous short term nominal market interest rate according to bond market relationship,

$$\hat{i}_{i,t}^{L} = \beta \mathrm{E}_t \hat{i}_{i,t+1}^{L} + (1-\beta)(\hat{i}_{i,t}^{S} - \ln \hat{\upsilon}_{i,t}^{B}), \tag{118}$$

where duration risk premium shock $\ln \hat{\upsilon}_{i,t}^{B}$ satisfies dynamic factor process $\ln \hat{\upsilon}_{i,t}^{B}$ $= \lambda_k^B \sum_{j=1}^{N} w_j^B \ln \hat{v}_{j,t}^{B} + (1-\lambda_k^B w_i^B) \ln \hat{v}_{i,t}^{B}$. The intensity of international bond market contagion varies across economies, with $k=0$ for low debt contagion economies, $k=1$ for medium debt contagion economies, and $k=2$ for high debt contagion economies, where $\lambda_0^B < \lambda_1^B < \lambda_2^B$. The long term real market interest rate $\hat{r}_{i,t}^{L}$ satisfies the same bond market relationship, driven by the contemporaneous short term real market interest rate.

The price of equity $\ln \hat{V}_{i,t}^{S}$ depends on its expected future value driven by expected future net profits and the contemporaneous short term nominal market interest rate according to stock market relationship,

$$\ln \hat{V}_{i,t}^{S} = \beta \mathrm{E}_t \ln \hat{V}_{i,t+1}^{S} + (1-\beta)\mathrm{E}_t \ln \hat{\Pi}_{i,t+1}^{S} - (\hat{i}_{i,t}^{S} - \ln \hat{\upsilon}_{i,t}^{S}), \tag{119}$$

where equity risk premium shock $\ln \hat{\upsilon}_{i,t}^{S}$ satisfies dynamic factor process $\ln \hat{\upsilon}_{i,t}^{S}$ $= \lambda_k^S \sum_{j=1}^{N} w_j^S \ln \hat{v}_{j,t}^{S} + (1-\lambda_k^S w_i^S) \ln \hat{v}_{i,t}^{S}$. The intensity of international stock market contagion varies across economies, with $k=0$ for low equity contagion economies, $k=1$ for medium equity contagion economies, and $k=2$ for high equity contagion economies, where $\lambda_0^S < \lambda_1^S < \lambda_2^S$.

Real net profits $\ln \frac{\hat{\Pi}_{i,t}^{S}}{\hat{P}_{i,t}^{Y}}$ depends on contemporaneous output, the labor income share and the tax rate, as well as the deviation of investment from output and the terms of trade, according to profit function:

$$\ln\frac{\hat{\Pi}_{i,t}^{S}}{\hat{P}_{i,t}^{Y}}=\ln\hat{Y}_{i,t}-\left(\frac{\Pi_{i}^{S}}{P_{i}^{Y}Y_{i}}\right)^{-1}\left\{(1-\tau_{i})\frac{W_{i}L_{i}}{P_{i}^{Y}Y_{i}}\ln\frac{\hat{W}_{i,t}\hat{L}_{i,t}}{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}}+\left(1-\frac{W_{i}L_{i}}{P_{i}^{Y}Y_{i}}\right)\hat{\tau}_{i,t}-\lambda^{\Pi}\frac{I_{i}}{Y_{i}}\left\{\frac{\phi}{\delta}\left[\ln\frac{\hat{B}_{i,t+1}^{C,F}}{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}}\right.\right.\right.$$

$$\left.\left.\left.-\frac{\theta^{C}}{\theta^{C}-1}\frac{1+\kappa^{R}(1-\beta(1-\chi^{B}\delta^{C}))}{\beta}\left[\left(\hat{i}_{i,t}^{C,E}-\hat{\delta}_{i,t}^{C}-\ln\frac{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}}{\hat{P}_{i,t-1}^{Y}\hat{Y}_{i,t-1}}\right)+\ln\frac{\hat{B}_{i,t}^{C,F}}{\hat{P}_{i,t-1}^{Y}\hat{Y}_{i,t-1}}\right]\right]-\left(\ln\frac{\hat{I}_{i,t}}{\hat{Y}_{i,t}}-\frac{X_{i}}{Y_{i}}\ln\frac{\hat{\mathcal{T}}_{i,t}^{X}}{\hat{\mathcal{T}}_{i,t}^{M}}\right)\right\}\right\}. \tag{120}$$

Reflecting the existence of a financial accelerator mechanism, real net profits also depends on the contemporaneous and past nonfinancial corporate debt ratio, as well as the contemporaneous nominal corporate loan rate net of the contemporaneous loan default rate and nominal output growth rate. Auxiliary parameter λ^{Π} is theoretically predicted to equal one, and satisfies $\lambda^{\Pi}\geq 0$. The response coefficients of this relationship vary across economies with the size of their government, their labor income share, their investment intensity, and their trade openness.

Reflecting the existence of international bank lending linkages, bank credit $\ln\hat{B}_{i,t+1}^{C,B}$ depends on the contemporaneous bank lending weighted average of domestic currency denominated domestic and foreign nonfinancial corporate debt according to bank credit demand function:

$$\ln\hat{B}_{i,t+1}^{C,B}=\sum_{j=1}^{N}w_{i,j}^{C}\ln\frac{\hat{B}_{j,t+1}^{C,F}}{\hat{\mathcal{E}}_{j,i,t}}. \tag{121}$$

Nonfinancial corporate debt satisfies $\ln\hat{B}_{i,t+1}^{C,F}=\ln\hat{P}_{i,t}^{C}+\ln\hat{K}_{i,t+1}$. Furthermore, the nominal corporate loan rate $\hat{i}_{i,t}^{C,E}$ depends on the nonfinancial corporate borrowing weighted average of past domestic and foreign nominal bank lending rates, adjusted for contemporaneous changes in nominal bilateral exchange rates, according to:

$$\hat{i}_{i,t}^{C,E}=\sum_{j=1}^{N}w_{i,j}^{F}\left(\hat{i}_{j,t-1}^{C}+\ln\frac{\hat{\mathcal{E}}_{i,j,t}}{\hat{\mathcal{E}}_{i,j,t-1}}\right). \tag{122}$$

Finally, the credit loss rate $\hat{\delta}_{i,t}^{C,E}$ depends on the contemporaneous bank lending weighted average of domestic and foreign loan default rates according to:

$$\hat{\delta}_{i,t}^{C,E}=\sum_{j=1}^{N}w_{i,j}^{C}\hat{\delta}_{j,t}^{C}+\lambda^{\delta}\left[\hat{i}_{i,t-1}^{C}-\sum_{j=1}^{N}w_{i,j}^{C}\left(\hat{i}_{j,t}^{C,E}+\ln\frac{\hat{\mathcal{E}}_{i,j,t}}{\hat{\mathcal{E}}_{i,j,t-1}}\right)\right]. \tag{123}$$

The credit loss rate also depends on the past nominal bank lending rate, less the contemporaneous bank lending weighted average of domestic and foreign nominal corporate loan rates, adjusted for contemporaneous changes in nominal bilateral exchange rates. Auxiliary parameter λ^{δ} is theoretically predicted to equal one, and satisfies $\lambda^{\delta}\geq 0$. The real ex ante corporate loan rate $\mathrm{E}_{t}\hat{r}_{i,t+1}^{C,E}$ satisfies $\mathrm{E}_{t}\hat{r}_{i,t+1}^{C,E}=\mathrm{E}_{t}\hat{i}_{i,t+1}^{C,E}-\mathrm{E}_{t}\hat{\pi}_{i,t+1}^{C}$.

The nominal bank lending rate $\hat{i}_{i,t}^{C}$ depends on a weighted average of its past and expected future values driven by the deviation of the past short term nominal market interest rate from the contemporaneous nominal bank lending rate net of the contemporaneous credit loss rate according to lending rate Phillips curve:

$$\hat{i}_{i,t}^{C} = \frac{1}{1+\beta}\hat{i}_{i,t-1}^{C} + \frac{\beta}{1+\beta}\mathrm{E}_t\hat{i}_{i,t+1}^{C} + \frac{(1-\omega^C)(1-\omega^C\beta)}{\omega^C(1+\beta)}\left\{\left[\hat{i}_{i,t-1}^{S} - (\hat{i}_{i,t}^{C} - \hat{\delta}_{i,t}^{C,E})\right]\right.$$
$$\left. - \frac{1-\beta(1-\chi^B\delta^C)}{1+\kappa^R(1-\beta(1-\chi^B\delta^C))}\left[\eta^C(\hat{\kappa}_{i,t} - \hat{\kappa}_{i,t}^{R}) - (\hat{\kappa}_{i,t}^{R} - \kappa^R\hat{i}_{i,t-1}^{S})\right] - \frac{1}{\theta^C-1}\ln\hat{\theta}_{i,t}^{C}\right\}. \tag{124}$$

Reflecting the existence of a regulatory capital requirement, the nominal bank lending rate also depends on the past deviation of the bank capital ratio from its required value, as well as the past deviation of the regulatory bank capital ratio from its funding cost. The real bank lending rate $\hat{r}_{i,t}^{C}$ satisfies $\hat{r}_{i,t}^{C} = \hat{i}_{i,t}^{C} - \mathrm{E}_t\,\hat{\pi}_{i,t+1}^{C}$.

The money stock $\ln\hat{M}_{i,t+1}^{S}$ depends on contemporaneous bank credit and the bank capital stock according to bank balance sheet identity:

$$\ln\hat{B}_{i,t+1}^{C,B} = (1-\kappa^R)\ln\hat{M}_{i,t+1}^{S} + \kappa^R\ln\hat{K}_{i,t+1}^{B}. \tag{125}$$

The bank capital ratio $\hat{\kappa}_{i,t+1}$ satisfies $\hat{\kappa}_{i,t+1} = \kappa^R(\ln\hat{K}_{i,t+1}^{B} - \ln\hat{B}_{i,t+1}^{C,B})$. Retained earnings $\ln\hat{I}_{i,t}^{B}$ depends on a weighted average of its past and expected future values driven by the contemporaneous shadow price of bank capital according to retained earnings relationship:

$$\ln\hat{I}_{i,t}^{B} = \frac{1}{1+\beta}\ln\hat{I}_{i,t-1}^{B} + \frac{\beta}{1+\beta}\mathrm{E}_t\ln\hat{I}_{i,t+1}^{B} + \frac{1}{\chi^C(1+\beta)}\ln\hat{Q}_{i,t}^{B}. \tag{126}$$

The shadow price of bank capital $\ln\hat{Q}_{i,t}^{B}$ depends on its expected future value net of the expected future credit loss rate, as well as the contemporaneous short term nominal market interest rate, according to retained earnings Euler equation:

$$\ln\hat{Q}_{i,t}^{B} = \mathrm{E}_t\left\{\beta(1-\chi^B\delta^C)(\ln\hat{Q}_{i,t+1}^{B} - \hat{\delta}_{i,t+1}^{C,E}) - \left[\hat{i}_{i,t}^{S} + (1-\beta(1-\chi^B\delta^C))\frac{\eta^C}{\kappa^R}(\hat{\kappa}_{i,t+1} - \hat{\kappa}_{i,t+1}^{R})\right]\right\}. \tag{127}$$

Reflecting the existence of a regulatory capital requirement, the shadow price of bank capital also depends on the contemporaneous deviation of the bank capital ratio from its required value. The bank capital stock $\ln\hat{K}_{i,t+1}^{B}$ satisfies $\ln\hat{K}_{i,t+1}^{B} = (1-\chi^B\delta^C)\ln\hat{K}_{i,t}^{B} + \chi^B\delta^C\ln\hat{I}_{i,t}^{B} - \chi^B\hat{\delta}_{i,t}^{C,E}$.

The real wage $\ln\frac{\hat{W}_{i,t}}{\hat{P}_{i,t}^{C}}$ depends on a weighted average of its past and expected future values driven by the contemporaneous unemployment rate according to wage Phillips curve:

$$\ln\frac{\hat{W}_{i,t}}{\hat{P}_{i,t}^{C}} = \frac{1}{1+\beta}\ln\frac{\hat{W}_{i,t-1}}{\hat{P}_{i,t-1}^{C}} + \frac{\beta}{1+\beta}\mathrm{E}_t\ln\frac{\hat{W}_{i,t+1}}{\hat{P}_{i,t+1}^{C}}$$
$$-\frac{(1-\omega^L)(1-\omega^L\beta)}{\omega^L(1+\beta)}\left(\frac{1}{\eta}\hat{u}_{i,t}^{L} + \frac{1}{\theta^L-1}\ln\hat{\theta}_{i,t}^{L}\right) - \frac{1+\gamma^L\beta}{1+\beta}\mathcal{P}_3(L)\hat{\pi}_{i,t}^{C}. \tag{128}$$

The real wage also depends on contemporaneous, past and expected future consumption price inflation, where polynomial in the lag operator $\mathcal{P}_3(L) = 1 - \frac{\gamma^L}{1+\gamma^L\beta}L - \frac{\beta}{1+\gamma^L\beta}\mathrm{E}_t L^{-1}$. The unemployment rate $\hat{u}_{i,t}^{L}$ satisfies $\hat{u}_{i,t}^{L} = \ln\hat{N}_{i,t} - \ln\hat{L}_{i,t}$.

The labor force $\ln \hat{N}_{i,t}$ depends on contemporaneous employment and the after tax real wage according to labor supply relationship:

$$\ln \hat{N}_{i,t} = \frac{\eta}{\iota} \ln \hat{L}_{i,t} + \eta \left[\ln \frac{\hat{W}_{i,t}}{\hat{P}^C_{i,t}} - \frac{1}{1-\tau_i} \hat{\tau}_{i,t} - \ln \hat{v}^L_{i,t} \right]. \tag{129}$$

Employment $\ln \hat{L}_{i,t}$ depends on contemporaneous output and the utilized capital stock according to production function:

$$\ln \hat{Y}_{i,t} = \left(1 - \frac{X_i}{Y_i} \sum_{k=1}^{M*} \frac{X_{i,k}}{X_i} \phi^F_k - \frac{\theta^Y}{\theta^Y - 1} \frac{W_i L_i}{P^Y_i Y_i} \right) \ln(\hat{u}^K_{i,t} \hat{K}_{i,t}) + \frac{\theta^Y}{\theta^Y - 1} \frac{W_i L_i}{P^Y_i Y_i} \ln(\hat{\mathcal{A}}_{i,t} \hat{L}_{i,t}). \tag{130}$$

The response coefficients of this relationship vary across economies with their labor income share, their trade openness, and their commodity export intensities.

The nominal bilateral exchange rate $\ln \hat{\mathcal{E}}_{i,i^*,t}$ depends on its expected future value driven by the contemporaneous short term nominal market interest rate differential according to foreign exchange market relationship:

$$\ln \hat{\mathcal{E}}_{i,i^*,t} = \mathrm{E}_t \ln \hat{\mathcal{E}}_{i,i^*,t+1} - \left[(\hat{i}^S_{i,t} - \hat{i}^S_{i^*,t}) + \ln \frac{\hat{v}^{\mathcal{E}}_{i,t}}{\hat{v}^{\mathcal{E}}_{i^*,t}} \right]. \tag{131}$$

For economies belonging to a currency union, the variables entering into their common foreign exchange market relationship are expressed as output weighted averages across union members. The real bilateral exchange rate $\ln \hat{\mathcal{Q}}_{i,i^*,t}$ satisfies $\ln \hat{\mathcal{Q}}_{i,i^*,t} = \ln \hat{\mathcal{E}}_{i,i^*,t} + \ln \hat{P}^Y_{i^*,t} - \ln \hat{P}^Y_{i,t}$.[3]

The internal terms of trade $\ln \hat{\mathcal{T}}^X_{i,t}$ depends on the contemporaneous relative domestic currency denominated prices of energy and nonenergy commodities according to internal terms of trade function:

$$\ln \hat{\mathcal{T}}^X_{i,t} = \left(1 - \frac{X_i}{Y_i} \sum_{k=1}^{M*} \frac{X_{i,k}}{X_i} \right)^{-1} \sum_{k=1}^{M*} \frac{X_{i,k}}{X_i} \ln \frac{\hat{\mathcal{E}}_{i,i^*,t} \hat{P}^Y_{k,t}}{\hat{P}^Y_{i,t}}. \tag{132}$$

The response coefficients of this relationship vary across economies with their trade openness and commodity export intensities.

The change in the external terms of trade $\ln \hat{\mathcal{T}}^M_{i,t}$ depends on a linear combination of its past and expected future values driven by the contemporaneous deviation of the import weighted average real bilateral exchange rate from the external terms of trade according to import price Phillips curve:

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[3] The nominal effective exchange rate $\ln \hat{\mathcal{E}}_{i,t}$ satisfies $\ln \hat{\mathcal{E}}_{i,t} = \ln \hat{\mathcal{E}}_{i,i^*,t} - \sum_{j=1}^{N} w^T_{i,j} \ln \hat{\mathcal{E}}_{j,i^*,t}$, while the real effective exchange rate $\ln \hat{\mathcal{Q}}_{i,t}$ satisfies $\ln \hat{\mathcal{Q}}_{i,t} = \ln \hat{\mathcal{Q}}_{i,i^*,t} - \sum_{j=1}^{N} w^T_{i,j} \ln \hat{\mathcal{Q}}_{j,i^*,t}$.

$$\Delta \ln \hat{\mathcal{T}}_{i,t}^{M} = \frac{\gamma^{M}(1-\mu_{i}^{M})}{1+\gamma^{M}\beta(1-\mu_{i}^{M})}\Delta \ln \hat{\mathcal{T}}_{i,t-1}^{M} + \frac{\beta}{1+\gamma^{M}\beta(1-\mu_{i}^{M})}\mathrm{E}_{t}\Delta \ln \hat{\mathcal{T}}_{i,t+1}^{M}$$
$$+\frac{(1-\omega^{M})(1-\omega^{M}\beta)}{\omega^{M}(1+\gamma^{M}\beta(1-\mu_{i}^{M}))}\left\{\sum_{j=1}^{N} w_{i,j}^{M}\left[\ln\frac{\hat{\mathcal{Q}}_{i,j,t}}{\hat{\mathcal{T}}_{i,t}^{M}} + \frac{X_{i}}{Y_{i}}\ln \hat{\mathcal{T}}_{i,t}^{X} + \left(1-\frac{X_{j}}{Y_{j}}\right)\ln \hat{\mathcal{T}}_{j,t}^{X}\right] - \frac{1}{\theta^{M}-1}\ln \hat{\theta}_{i,t}^{M}\right\} \quad (133)$$
$$-\mathcal{P}_{4}(L)\left(\hat{\pi}_{i,t}^{Y} - \frac{X_{i}}{Y_{i}}\Delta \ln \hat{\mathcal{T}}_{i,t}^{X}\right) + \frac{\gamma^{M}(1+\beta)}{1+\gamma^{M}\beta(1-\mu_{i}^{M})}\mathcal{P}_{5}(L)\sum_{k=1}^{M*}\mu_{i,k}^{M}\ln(\hat{\mathcal{E}}_{i,i*,t}\hat{P}_{k,t}^{Y}).$$

The change in the external terms of trade also depends on the contemporaneous domestic and import weighted average foreign internal terms of trade. In addition, the change in the external terms of trade depends on contemporaneous, past and expected future output price inflation and the change in the internal terms of trade, where polynomial in the lag operator $\mathcal{P}_4(L) = 1 - \frac{\gamma^M(1-\mu_i^M)}{1+\gamma^M\beta(1-\mu_i^M)}L - \frac{\beta}{1+\gamma^M\beta(1-\mu_i^M)}\mathrm{E}_t L^{-1}$. Finally, the change in the external terms of trade depends on the contemporaneous, past and expected future domestic currency denominated prices of energy and nonenergy commodities. The response coefficients of this relationship vary across economies with their trade openness, their trade pattern, and their commodity import intensities.

Public domestic demand $\ln \hat{G}_{i,t}$ depends on a weighted average of its past and desired values according to fiscal expenditure rule:

$$\ln \hat{G}_{i,t} = \rho_G \ln \hat{G}_{i,t-1} + (1-\rho_G)\zeta^G\left(\frac{G_i}{Y_i}\right)^{-1}\frac{\hat{A}_{i,t+1}^{G}}{P_{i,t}^{Y}Y_{i,t}} + \left(\frac{G_i}{Y_i}\right)^{-1}\hat{v}_{i,t}^{G}. \quad (134)$$

Desired public domestic demand responds to the contemporaneous net government asset ratio. The tax rate $\hat{\tau}_{i,t}$ depends on a weighted average of its past and desired values according to fiscal revenue rule:

$$\hat{\tau}_{i,t} = \rho_\tau \hat{\tau}_{i,t-1} - (1-\rho_\tau)\zeta^\tau \frac{\hat{A}_{i,t+1}^{G}}{P_{i,t}^{Y}Y_{i,t}} + \hat{v}_{i,t}^{T}. \quad (135)$$

The desired tax rate responds to the contemporaneous net government asset ratio. The response coefficients of the former relationship vary across economies with the size of their government.

The regulatory bank capital ratio $\hat{\kappa}_{i,t+1}^{R}$ depends on a weighted average of its past and desired values according to macroprudential policy rule:

$$\hat{\kappa}_{i,t+1}^{R} = \rho_\kappa \hat{\kappa}_{i,t}^{R} + (1-\rho_\kappa)\left[\zeta^{\kappa,B}\frac{B_i^{C,B}}{P_i^Y Y_i}\ln\frac{\hat{B}_{i,t+1}^{C,B}}{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}} - \zeta^{\kappa,i}(\mathrm{E}_t \hat{i}_{i,t+1}^{A^{A,H}} - \hat{i}_{i,t}^{S})\right] + \hat{v}_{i,t}^{\kappa}. \quad (136)$$

The desired regulatory bank capital ratio responds to the contemporaneous bank credit ratio, as well as the contemporaneous expected excess portfolio return. The loan default rate $\hat{\delta}_{i,t}^{C}$ depends on a weighted average of its past and attractor values according to default rate relationship:

$$\hat{\delta}_{i,t}^{C} = \rho_\delta \hat{\delta}_{i,t-1}^{C} + (1-\rho_\delta)\left[\zeta^{\delta,B}\frac{B_i^{C,F}}{P_i^Y Y_i}\ln\frac{\hat{B}_{i,t+1}^{C,F}}{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}} + \zeta^{\delta,i}(\mathrm{E}_t \hat{i}_{i,t+1}^{A^{A,H}} - \hat{i}_{i,t}^{S})\right] + \hat{v}_{i,t}^{\delta}. \quad (137)$$

The attractor loan default rate responds to the contemporaneous nonfinancial corporate debt ratio, as well as the contemporaneous expected excess portfolio return. The response coefficients of these relationships vary across economies with the size of their bank credit exposures and nonfinancial corporate debt loads.

The fiscal balance ratio $\frac{\widehat{FB}_{i,t}}{P_{i,t}^{Y}Y_{i,t}}$ depends on a weighted average of the past short term nominal market interest rate and the effective long term nominal market interest rate, as well as the past net government asset ratio, and the contemporaneous growth rate of nominal output and the primary fiscal balance ratio, according to government dynamic budget constraint:

$$\frac{\widehat{FB}_{i,t}}{P_{i,t}^{Y}Y_{i,t}}=\frac{1}{\beta}\frac{1}{1+g}\left[\frac{A_i^G}{P_i^YY_i}\left(\frac{B_i^{S,G}}{A_i^G}\hat{i}_{i,t-1}^{S}+\frac{B_i^{L,G}}{A_i^G}\hat{i}_{i,t-1}^{L,E}\right)+(1-\beta)\left(\frac{\hat{A}_{i,t}^G}{P_{i,t-1}^{Y}Y_{i,t-1}}-\frac{A_i^G}{P_i^YY_i}\ln\frac{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}}{\hat{P}_{i,t-1}^{Y}\hat{Y}_{i,t-1}}\right)\right]+\frac{\widehat{PB}_{i,t}}{P_{i,t}^{Y}Y_{i,t}}. \quad (138)$$

In addition, the primary fiscal balance ratio $\frac{\widehat{PB}_{i,t}}{P_{i,t}^{Y}Y_{i,t}}$ depends on the contemporaneous tax rate and the deviation of public domestic demand from output, as well as the terms of trade, according to:

$$\frac{\widehat{PB}_{i,t}}{P_{i,t}^{Y}Y_{i,t}}=\hat{\tau}_{i,t}-\frac{G_i}{Y_i}\left(\ln\frac{\hat{G}_{i,t}}{\hat{Y}_{i,t}}-\frac{X_i}{Y_i}\ln\frac{\hat{\mathcal{T}}_{i,t}^{X}}{\hat{\mathcal{T}}_{i,t}^{M}}\right). \quad (139)$$

Furthermore, the net government asset ratio $\frac{\hat{A}_{i,t+1}^G}{P_{i,t}^{Y}Y_{i,t}}$ depends on its past value, as well as the contemporaneous growth rate of nominal output and the fiscal balance ratio, according to:

$$\frac{\hat{A}_{i,t+1}^G}{P_{i,t}^{Y}Y_{i,t}}=\frac{1}{1+g}\left(\frac{\hat{A}_{i,t}^G}{P_{i,t-1}^{Y}Y_{i,t-1}}-\frac{A_i^G}{P_i^YY_i}\ln\frac{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}}{\hat{P}_{i,t-1}^{Y}\hat{Y}_{i,t-1}}\right)+\frac{\widehat{FB}_{i,t}}{P_{i,t}^{Y}Y_{i,t}}. \quad (140)$$

Finally, the effective long term nominal market interest rate $\hat{i}_{i,t}^{L,E}$ depends on a weighted average of its past value and the contemporaneous long term nominal market interest rate according to $\hat{i}_{i,t}^{L,E}=\chi^G\hat{i}_{i,t-1}^{L,E}+(1-\chi^G)\hat{i}_{i,t}^{L}$. The linearization of these relationships accounts for long run balanced growth at nominal rate g. Their response coefficients vary across economies with their public financial wealth, the size of their government, and their trade openness.

The current account balance ratio $\frac{\widehat{CA}_{i,t}}{\mathcal{E}_{i*,i,t}P_{i,t}^{Y}Y_{i,t}}$ depends on the contemporaneous quotation currency denominated world money market portfolio return, as well as the past net foreign asset ratio, and the contemporaneous growth rate of world nominal output and the trade balance ratio, according to national dynamic budget constraint:

$$\frac{\widehat{CA}_{i,t}}{\mathcal{E}_{i*,i,t}P_{i,t}^{Y}Y_{i,t}}=\frac{1}{\beta}\frac{1}{1+g}\left[\frac{A_i}{P_i^YY_i}\sum_{j=1}^{N}w_j^M\left(\hat{i}_{j,t-1}^{S}+\ln\frac{\hat{\mathcal{E}}_{i*,j,t}}{\hat{\mathcal{E}}_{i*,j,t-1}}\right)+(1-\beta)\left(\frac{\hat{A}_{i,t}}{P_{i,t-1}^{Y}Y_{i,t-1}}-\frac{A_i}{P_i^YY_i}\ln\frac{\hat{P}_t^{Y}\hat{Y}_t}{\hat{P}_{t-1}^{Y}\hat{Y}_{t-1}}\right)\right]+\frac{\widehat{TB}_{i,t}}{\mathcal{E}_{i*,i,t}P_{i,t}^{Y}Y_{i,t}}. \quad (141)$$

Furthermore, the trade balance ratio $\frac{\widehat{TB}_{i,t}}{\mathcal{E}_{i*,i,t}P_{i,t}^{Y}Y_{i,t}}$ depends on the contemporaneous deviation of exports from imports and the terms of trade according to:

$$\frac{\widehat{TB}_{i,t}}{\mathcal{E}_{i*,i,t}P_{i,t}^{Y}Y_{i,t}}=\frac{X_i}{Y_i}\ln\frac{\hat{\mathcal{T}}_{i,t}^{X}\hat{X}_{i,t}}{\hat{\mathcal{T}}_{i,t}^{M}\hat{M}_{i,t}}. \quad (142)$$

Finally, the net foreign asset ratio $\frac{\hat{A}_{i,t+1}}{P_{i,t}^{Y}Y_{i,t}}$ depends on its past value, as well as the contemporaneous growth rate of world nominal output and the current account balance ratio, according to:

$$\frac{\hat{A}_{i,t+1}}{P_{i,t}^{Y}Y_{i,t}} = \frac{1}{1+g}\left(\frac{\hat{A}_{i,t}}{P_{i,t-1}^{Y}Y_{i,t-1}} - \frac{A_i}{P_i^Y Y_i}\ln\frac{\hat{P}_t^Y\hat{Y}_t}{\hat{P}_{t-1}^Y\hat{Y}_{t-1}}\right) + \frac{\widehat{CA}_{i,t}}{\mathcal{E}_{i*,i,t}P_{i,t}^{Y}Y_{i,t}}. \tag{143}$$

The linearization of these relationships accounts for long run balanced growth at nominal rate g. Their response coefficients vary across economies with their national financial wealth and their trade openness.

The price of commodities $\ln\hat{P}_{k,t}^{Y}$ depends on a weighted average of its past and expected future values driven by the contemporaneous world output weighted average labor income share, output, and the relative domestic currency denominated price of commodities according to commodity price Phillips curve:

$$\begin{aligned}\ln\hat{P}_{k,t}^{Y} &= \frac{1}{1+\beta}\ln\hat{P}_{k,t-1}^{Y} + \frac{\beta}{1+\beta}\mathrm{E}_t\ln\hat{P}_{k,t+1}^{Y} + \frac{(1-\omega_k^Y)(1-\omega_k^Y\beta)}{\omega_k^Y(1+\beta)}\sum_{i=1}^{N}w_i^Y\left\{\ln\frac{\hat{W}_{i,t}\hat{L}_{i,t}}{\hat{P}_{i,t}^{Y}\hat{Y}_{i,t}}\right.\\ &\left.+\left[\frac{1}{1-\phi_k^F}-\left(1-\frac{X_i}{Y_i}\sum_{k=1}^{M*}\frac{X_{i,k}}{X_i}\phi_k^F\right)^{-1}\right]\ln\hat{Y}_{i,t} - \ln\frac{\hat{\mathcal{E}}_{i,i*,t}\hat{P}_{k,t}^{Y}}{\hat{P}_{i,t}^{Y}} - \frac{1}{\theta^Y-1}\ln\hat{\theta}_{k,t}^{Y}\right\} - \mathcal{P}_5(L)\sum_{i=1}^{N}w_i^Y\ln\hat{\mathcal{E}}_{i,i*,t}.\end{aligned} \tag{144}$$

The price of commodities also depends on the contemporaneous, past and expected future world output weighted average nominal bilateral exchange rate, where polynomial in the lag operator $\mathcal{P}_5(L) = 1 - \frac{1}{1+\beta}L - \frac{\beta}{1+\beta}\mathrm{E}_t L^{-1}$. The response coefficients of this relationship vary across commodity markets $1 \le k \le M*$, with $k=1$ for energy commodities and $k=2$ for nonenergy commodities.

B. Exogenous Variables

The productivity $\ln\hat{\mathcal{A}}_{i,t}$, labor supply $\ln\hat{\nu}_{i,t}^{L}$, consumption demand $\ln\hat{\nu}_{i,t}^{C}$, investment demand $\ln\hat{\nu}_{i,t}^{I}$, export demand $\ln\hat{\nu}_{i,t}^{X}$, and import demand $\ln\hat{\nu}_{i,t}^{M}$ shocks follow stationary first order autoregressive processes:

$$\ln\hat{\mathcal{A}}_{i,t} = \rho_{\mathcal{A}}\ln\hat{\mathcal{A}}_{i,t-1} + \varepsilon_{i,t}^{\mathcal{A}},\ \varepsilon_{i,t}^{\mathcal{A}} \sim \text{iid } \mathcal{N}(0,\sigma_{\mathcal{A}}^2), \tag{145}$$

$$\ln\hat{\nu}_{i,t}^{L} = \rho_{\nu^L}\ln\hat{\nu}_{i,t-1}^{L} + \varepsilon_{i,t}^{\nu^L},\ \varepsilon_{i,t}^{\nu^L} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^L}^2), \tag{146}$$

$$\ln\hat{\nu}_{i,t}^{C} = \rho_{\nu^C}\ln\hat{\nu}_{i,t-1}^{C} + \varepsilon_{i,t}^{\nu^C},\ \varepsilon_{i,t}^{\nu^C} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^C}^2), \tag{147}$$

$$\ln\hat{\nu}_{i,t}^{I} = \rho_{\nu^I}\ln\hat{\nu}_{i,t-1}^{I} + \varepsilon_{i,t}^{\nu^I},\ \varepsilon_{i,t}^{\nu^I} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^I}^2), \tag{148}$$

$$\ln\hat{\nu}_{i,t}^{X} = \rho_{\nu^X}\ln\hat{\nu}_{i,t-1}^{X} + \varepsilon_{i,t}^{\nu^X},\ \varepsilon_{i,t}^{\nu^X} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^X}^2), \tag{149}$$

$$\ln\hat{\nu}_{i,t}^{M} = \rho_{\nu^M}\ln\hat{\nu}_{i,t-1}^{M} + \varepsilon_{i,t}^{\nu^M},\ \varepsilon_{i,t}^{\nu^M} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^M}^2). \tag{150}$$

In addition, the credit risk premium $\hat{\nu}_{i,t}^{i^S}$, duration risk premium $\ln\hat{\nu}_{i,t}^{B}$, equity risk premium $\ln\hat{\nu}_{i,t}^{S}$, currency risk premium $\ln\hat{\nu}_{i,t}^{\mathcal{E}}$, and lending rate markup $\ln\hat{\theta}_{i,t}^{C}$ shocks follow stationary first order autoregressive processes:

$$\hat{\nu}_{i,t}^{i^S} = \rho_{\nu^{i,S}}\hat{\nu}_{i,t-1}^{i^S} + \varepsilon_{i,t}^{\nu^{i,S}},\ \varepsilon_{i,t}^{\nu^{i,S}} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^{i,S}}^2), \tag{151}$$

$$\ln\hat{\nu}_{i,t}^{B} = \rho_{\nu^B}\ln\hat{\nu}_{i,t-1}^{B} + \varepsilon_{i,t}^{\nu^B},\ \varepsilon_{i,t}^{\nu^B} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^B}^2), \tag{152}$$

$$\ln\hat{\nu}_{i,t}^{S} = \rho_{\nu^S}\ln\hat{\nu}_{i,t-1}^{S} + \varepsilon_{i,t}^{\nu^S},\ \varepsilon_{i,t}^{\nu^S} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^S}^2), \tag{153}$$

$$\ln\hat{\nu}_{i,t}^{\mathcal{E}} = \rho_{\nu^{\mathcal{E}}}\ln\hat{\nu}_{i,t-1}^{\mathcal{E}} + \varepsilon_{i,t}^{\nu^{\mathcal{E}}},\ \varepsilon_{i,t}^{\nu^{\mathcal{E}}} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^{\mathcal{E}}}^2), \tag{154}$$

$$\ln\hat{\theta}_{i,t}^{C} = \rho_{\theta^C}\ln\hat{\theta}_{i,t}^{C} + \varepsilon_{i,t}^{\theta^C},\ \varepsilon_{i,t}^{\theta^C} \sim \text{iid } \mathcal{N}(0,\sigma_{\theta^C}^2). \tag{155}$$

Furthermore, the output price markup $\ln\hat{\theta}_{i,t}^{Y}$, import price markup $\ln\hat{\theta}_{i,t}^{M}$, wage markup $\ln\hat{\theta}_{i,t}^{L}$, and commodity price markup $\ln\hat{\theta}_{k,t}^{Y}$ shocks follow white noise processes:

$$\ln\hat{\theta}_{i,t}^{Y} = \varepsilon_{i,t}^{\theta^Y},\ \varepsilon_{i,t}^{\theta^Y} \sim \text{iid } \mathcal{N}(0,\sigma_{\theta^Y}^2), \tag{156}$$

$$\ln\hat{\theta}_{i,t}^{M} = \varepsilon_{i,t}^{\theta^M},\ \varepsilon_{i,t}^{\theta^M} \sim \text{iid } \mathcal{N}(0,\sigma_{\theta^M}^2), \tag{157}$$

$$\ln\hat{\theta}_{i,t}^{L} = \varepsilon_{i,t}^{\theta^L},\ \varepsilon_{i,t}^{\theta^L} \sim \text{iid } \mathcal{N}(0,\sigma_{\theta^L}^2), \tag{158}$$

$$\ln\hat{\theta}_{k,t}^{Y} = \varepsilon_{k,t}^{\theta^Y},\ \varepsilon_{k,t}^{\theta^Y} \sim \text{iid } \mathcal{N}(0,\sigma_{\theta^{Y,k}}^2). \tag{159}$$

Finally, the monetary policy $\hat{\nu}_{i,t}^{i^P}$, fiscal expenditure $\hat{\nu}_{i,t}^{G}$, fiscal revenue $\hat{\nu}_{i,t}^{T}$, capital requirement $\hat{\nu}_{i,t}^{\kappa}$, and default rate $\hat{\nu}_{i,t}^{\delta}$ shocks follow white noise processes:

$$\hat{\nu}_{i,t}^{i^P} = \varepsilon_{i,t}^{\nu^{i,P}},\ \varepsilon_{i,t}^{\nu^{i,P}} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^{i,P}}^2), \tag{160}$$

$$\hat{\nu}_{i,t}^{G} = \varepsilon_{i,t}^{\nu^G},\ \varepsilon_{i,t}^{\nu^G} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^G}^2), \tag{161}$$

$$\hat{\nu}_{i,t}^{T} = \varepsilon_{i,t}^{\nu^T},\ \varepsilon_{i,t}^{\nu^T} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^T}^2), \tag{162}$$

$$\hat{\nu}_{i,t}^{\kappa} = \varepsilon_{i,t}^{\nu^\kappa},\ \varepsilon_{i,t}^{\nu^\kappa} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^\kappa}^2), \tag{163}$$

$$\hat{\nu}_{i,t}^{\delta} = \varepsilon_{i,t}^{\nu^\delta},\ \varepsilon_{i,t}^{\nu^\delta} \sim \text{iid } \mathcal{N}(0,\sigma_{\nu^\delta}^2). \tag{164}$$

As an identifying restriction, all innovations are assumed to be independent, which combined with our distributional assumptions implies multivariate normality.

IV. Estimation

The traditional econometric interpretation of an approximate linear state space representation of this panel dynamic stochastic general equilibrium model of the world economy regards it as a representation of the joint probability distribution of the data. We employ a Bayesian maximum likelihood estimation procedure which respects this traditional econometric interpretation while conditioning on prior information concerning the generally common values of parameters across economies. In addition to mitigating potential model misspecification and identification problems, exploiting this additional information may be expected to yield efficiency gains in estimation.

A. Transformation of the Data Set

Estimation of the parameters of our panel dynamic stochastic general equilibrium model is based on the estimated cyclical components of a total of 661 endogenous variables observed for forty economies over the sample period 1999Q1 through 2014Q3. The advanced and emerging economies under consideration are Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, the Czech Republic, Denmark, Finland, France, Germany, Greece, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, New Zealand, Norway, the Philippines, Poland, Portugal, Russia, Saudi Arabia, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, the United Kingdom, and the United States. The observed macroeconomic and financial market variables under consideration are the price of output, the price of consumption, the quantity of output, the quantity of private consumption, the quantity of exports, the quantity of imports, the nominal policy interest rate, the short term nominal market interest rate, the nominal bank lending interest rate, the long term nominal market interest rate, the price of equity, the nominal wage, the unemployment rate, employment, the nominal bilateral exchange rate, the quantity of public domestic demand, the fiscal balance ratio, and the prices of nonrenewable energy and nonenergy commodities. For a detailed description of this multivariate panel data set, refer to Appendix A.

We estimate the cyclical components of all of the observed endogenous variables under consideration with the generalization of the filter described in Hodrick and Prescott (1997) due to Vitek (2014), which parameterizes the difference order associated with the penalty term determining the smoothness of the trend component. For the price of output, the price of consumption, the quantity of output, the quantity of private consumption, the quantity of exports, the quantity of imports, the price of equity, the nominal wage, employment, the nominal bilateral exchange rate, the quantity of public domestic demand, and the prices of energy and nonenergy commodities, we set the difference order to two and the smoothing parameter to 16,000. For the nominal policy interest rate, the short term nominal market interest rate, the nominal bank lending interest rate, the long term nominal market interest rate, the unemployment rate, and the fiscal balance ratio, we set the difference order to one and the smoothing parameter to 400.

B. Prior and Posterior Parameter Distributions

We estimate the parameters of an approximate linear state space representation of our panel dynamic stochastic general equilibrium model by Bayesian maximum likelihood, conditional on prior information concerning their generally common values across economies. We justify these cross-economy equality restrictions, which are necessary for our estimation procedure to be computationally feasible, by interpreting these parameters as structural and assuming that they do not vary too much across economies. Inference on these parameters is based on an asymptotic normal approximation to the posterior distribution around its mode, which is calculated by numerically maximizing the logarithm of the posterior density kernel with a customized implementation of the differential evolution algorithm due to Storn and Price (1997). We assume a multivariate normal prior distribution, which implies that the mode of the posterior distribution equals its mean. For a detailed discussion of this estimation procedure, refer to Vitek (2014).

The marginal prior distributions of parameters are centered within the range of estimates reported in the existing empirical literature, where available. The conduct of monetary policy is represented by a flexible inflation targeting regime in Australia, Canada, Chile, the Czech Republic, the Euro Area, Israel, Japan, Mexico, New Zealand, Norway, Poland, Sweden, the United Kingdom and the United States, by a managed exchange rate regime in Argentina, Brazil, China, Colombia, India, Indonesia, Korea, Malaysia, the Philippines, Russia, South Africa, Switzerland, Thailand and Turkey, and by a fixed exchange rate regime in Denmark and Saudi Arabia, consistent with IMF (2013). The high debt contagion economies are Argentina, Brazil, Colombia, Indonesia, Mexico, the Philippines, Poland, Russia, South Africa, Thailand and Turkey, while the low debt contagion economies are Chile, China, India and Malaysia. The high equity contagion economies are Argentina, Brazil, Colombia, India, Indonesia, Mexico, the Philippines, Poland, Russia, South Africa, Thailand and Turkey, while the low equity contagion economies are Chile, China and Malaysia. The quotation currency for transactions in the foreign exchange market is issued by the United States. All macroeconomic and financial great ratios are calibrated to match their observed values in 2012. The same is true of all bilateral trade, bank lending, nonfinancial corporate borrowing, portfolio debt investment, and portfolio equity investment weights. All weights are normalized to sum to one across economies, where applicable.

Parameter estimation results based on effective sample period 1999Q3 through 2014Q3 are reported in Table 1 of Appendix B. The posterior means of most parameters are close to their prior means, reflecting the imposition of tight priors to preserve empirically plausible impulse response functions. Nevertheless, the data are quite informative regarding some of these parameters, as evidenced by substantial updates from prior to posterior, which collectively result in substantial updates to impulse responses.

V. Policy Analysis

We analyze the interaction between business cycle dynamics in the world economy, and the systematic and unsystematic components of monetary, fiscal and macroprudential policy, within the framework of our estimated panel dynamic stochastic general equilibrium model. In particular, we quantify dynamic interrelationships among key instrument, indicator and target variables with estimated impulse response functions. We also identify the structural determinants of these instrument, indicator and target variables with historical decompositions.

A. Impulse Response Functions

Impulse response functions measure the dynamic effects of selected structural shocks on endogenous variables. The estimated impulse responses of macroeconomic and financial variables to a variety of structural shocks are plotted in Figure 1 through Figure 30 of Appendix B. The macroeconomic variables under consideration are consumption price inflation, output, private consumption, private investment, the nominal policy interest rate, the real effective exchange rate, the unemployment rate, the fiscal balance ratio, and the current account balance ratio. The financial variables under consideration are the short term nominal market interest rate, the long term nominal market interest rate, the relative price of equity, the real money stock, real bank credit, the nominal bank lending rate, the bank capital ratio, and the credit loss rate. The structural shocks under consideration are domestic productivity, domestic labor supply, domestic consumption demand, domestic investment demand, domestic monetary policy, domestic credit risk premium, domestic duration risk premium, domestic equity risk premium, domestic fiscal expenditure, domestic fiscal revenue, domestic lending rate markup, domestic capital requirement, domestic loan default, and world energy and nonenergy commodity price markup shocks.

In response to a domestic productivity shock which generates a persistent hump shaped increase in inflation, there arises a persistent hump shaped contraction of output. Facing a monetary policy tradeoff, the central bank generally raises the nominal policy interest rate to control inflation, and the currency appreciates in real effective terms. The fiscal balance usually deteriorates due to the fall in output and rise in debt service costs, whereas the current account balance tends to improve reflecting the rise in the terms of trade. In response to a domestic labor supply shock which generates a persistent increase in the labor force, there arises a persistent hump shaped expansion of output, accompanied by a persistent hump shaped decrease in inflation. Facing a monetary policy tradeoff, the central bank generally cuts the nominal policy interest rate to stimulate inflation, and the currency usually depreciates in real effective terms. The fiscal balance typically improves due to the rise in output and fall in debt service costs, whereas the current account balance tends to deteriorate reflecting the fall in the terms of trade.

In response to a domestic consumption demand shock which generates a persistent hump shaped increase in consumption, there arises a persistent hump shaped expansion of output, generally accompanied by a persistent hump shaped increase in inflation. Not facing a monetary policy tradeoff, the central bank raises the nominal policy interest rate to stabilize inflation and output, usually appreciating the currency in real effective terms. The fiscal balance improves due to the rise in nominal output in spite of higher debt service costs, whereas the current account balance deteriorates commensurate with the larger rise in domestic demand. In response to a domestic investment demand shock which generates a persistent hump shaped increase in investment, there arises a persistent hump shaped expansion of output, generally accompanied by a persistent hump shaped increase in inflation. Not facing a monetary policy tradeoff, the central bank raises the nominal policy interest rate to stabilize inflation and output, typically appreciating the currency in real effective terms. The fiscal balance improves due to the rise in nominal output in spite of higher debt service costs, whereas the current account balance deteriorates commensurate with the larger rise in domestic demand.

In response to a domestic monetary policy shock which generates a persistent increase in the nominal policy interest rate except under a fixed exchange rate regime, the currency appreciates in real effective terms. Reflecting the interest rate and exchange rate channels of monetary transmission, there arises a persistent hump shaped contraction of output, accompanied by a persistent decrease in inflation. In particular, in response to a one percentage point increase in the nominal policy interest rate, the median peak contraction of output is 0.4 percent across economies within a range of 0.1 to 0.6 percent, while the median peak decrease in inflation is 0.3 percentage points within a range of 0.2 to 0.3 percentage points, and the median peak increase in the unemployment rate is 0.2 percentage points within a range of 0.1 to 0.2 percentage points. The fiscal balance deteriorates due to the fall in nominal output and rise in debt service costs, whereas the current account balance improves commensurate with the larger fall in domestic demand. Under a fixed exchange rate regime, a domestic monetary policy shock which generates a transient increase in the nominal policy interest rate only induces a transient appreciation of the currency in real effective terms.

In response to a domestic credit risk premium shock which generates a persistent increase in the short term nominal market interest rate, the currency appreciates in real effective terms except perhaps under a currency union, and there arises a persistent hump shaped contraction of output, accompanied by a persistent decrease in inflation. In particular, in response to a one percentage point increase in the short term nominal market interest rate, the median peak contraction of output is 0.4 percent across economies, within a range of 0.0 to 0.6 percent. The central bank cuts the nominal policy interest rate to stabilize inflation and output, but the fiscal balance deteriorates due to the fall in nominal output and rise in debt service costs, whereas the current account balance improves reflecting the larger fall in domestic demand. In response to a domestic duration risk premium shock which generates a persistent increase in the long term nominal market interest rate, there arises a persistent hump shaped contraction of output, generally accompanied by a persistent hump shaped decrease in inflation. In particular, in response to a one percentage point increase in the long term nominal market interest rate, the median peak contraction of output is 0.5 percent across economies, within a range of 0.0 to 0.9 percent. The central bank usually cuts the nominal policy interest rate to stabilize inflation and output, and the currency depreciates in real effective terms. The credit loss rate rises as systemic risk materializes, reducing the bank capital ratio. The fiscal balance deteriorates due to the fall in nominal output and rise in debt service costs, whereas the current account balance improves commensurate with the larger fall in domestic demand. In response to a domestic equity risk premium shock which generates a persistent increase in the price of equity, there arises a persistent hump shaped expansion of output, generally accompanied by a persistent hump shaped increase in inflation. In particular, in response to a ten percent increase in the price of equity, the median peak expansion of output is 0.2 percent across economies, within a range of 0.0 to 0.4 percent. The central bank raises the nominal policy interest rate to stabilize inflation and output, and the currency appreciates in real effective terms. The credit loss rate falls as systemic risk accumulates, raising the bank capital ratio. The fiscal balance improves due to the rise in nominal output in spite of higher debt service costs, whereas the current account balance deteriorates reflecting the larger rise in domestic demand.

In response to a domestic fiscal expenditure shock which generates a persistent improvement in the fiscal balance, there arises a persistent contraction of output, accompanied by a persistent hump shaped decrease in inflation. In particular, in response to a one percentage point increase in the ratio of the primary fiscal balance to nominal output, the median peak contraction of output is 0.8 percent within a range of 0.0 to 1.3 percent, and generally decreases across economies with their trade openness. The central bank cuts the nominal policy interest rate to stabilize inflation and output, crowding in investment and depreciating the currency in real effective terms. The current account balance improves, reflecting the larger fall in domestic demand than in output. In response to a domestic fiscal revenue shock which generates a persistent improvement in the fiscal balance, there arises a persistent contraction of output, generally accompanied by a persistent hump shaped decrease in inflation. In particular, in response to a one percentage point increase in the ratio of the primary fiscal balance to nominal output, the median peak contraction of output is 0.4 percent within a range of 0.0 to 0.5 percent, and usually decreases across economies with their trade openness. The central bank cuts the nominal policy interest rate to stabilize inflation and output, which tends to crowd in investment and depreciate the currency in real effective terms. The current account balance improves, commensurate with the larger fall in domestic demand than in output.

In response to a domestic lending rate markup shock which generates a persistent increase in the nominal bank lending rate, there arises a persistent hump shaped investment driven output contraction, generally accompanied by a persistent hump shaped decrease in inflation. The central bank cuts the nominal policy interest rate to stabilize inflation and output, but the fiscal balance deteriorates due to the fall in nominal output, whereas the current account balance improves reflecting the larger fall in domestic demand. In response to a domestic capital requirement shock which generates a persistent increase in the regulatory bank capital ratio, there arises a persistent increase in the spread of the nominal bank lending rate over the short term nominal market interest rate to gradually close the bank capital ratio shortfall. This induces a persistent hump shaped investment driven output contraction, generally accompanied by a persistent hump shaped decrease in inflation. The central bank cuts the nominal policy interest rate to stabilize inflation and output, but the fiscal balance deteriorates due to the fall in nominal output, whereas the current account balance improves reflecting the larger fall in domestic demand. In response to a domestic loan default shock which generates a persistent increase in the loan default rate, there arises a persistent increase in the spread of the nominal bank lending rate over the short term nominal market interest rate to compensate for a higher credit loss rate and gradually close the bank capital ratio shortfall. This induces a persistent hump shaped investment driven output contraction, generally accompanied by a persistent hump shaped decrease in inflation. The central bank cuts the nominal policy interest rate to stabilize inflation and output, but the fiscal balance deteriorates due to the fall in nominal output, whereas the current account balance improves reflecting the larger fall in domestic demand.

In response to a world energy or nonenergy commodity price markup shock which generates an increase in the price of energy or nonenergy commodities, inflation increases and the central bank raises the nominal policy interest rate. For net exporters of energy or nonenergy commodities, the currency generally appreciates in real effective terms, inducing terms of trade driven expansions of consumption and investment mitigated by monetary policy tightening, which translate into an expansion of output in spite of terms of trade driven expenditure switching. The fiscal and current account balances usually improve, reflecting the rise in the terms of trade. In contrast, for net importers of energy or nonenergy commodities, the currency typically depreciates in real effective terms, inducing terms of trade driven contractions of consumption and investment amplified by monetary policy tightening, which translate into a contraction of output in spite of terms of trade driven expenditure switching. The fiscal and current account balances tend to deteriorate, reflecting the fall in the terms of trade.

B. Historical Decompositions

Historical decompositions measure the time varying contributions of disjoint sets of structural shocks to the realizations of endogenous variables. The estimated historical decompositions of consumption price inflation and output growth are plotted in Figure 31 and Figure 32. The sets of structural shocks under consideration are domestic supply, foreign supply, domestic demand, foreign demand, world monetary policy, domestic fiscal policy, foreign fiscal policy, domestic financial, foreign financial, and world terms of trade shocks.

Our estimated historical decompositions of inflation attribute deviations from trend rates primarily to economy specific combinations of supply and demand shocks, together with terms of trade shocks. The contribution of domestic relative to foreign demand shocks is generally decreasing across economies with their trade openness and increasing with their monetary policy autonomy. Trend inflation rates have typically stabilized at relatively low levels in advanced economies, particularly those with well established flexible inflation targeting regimes such as Australia, Canada, the Czech Republic, Israel, Korea, New Zealand, Norway, Sweden, and the United Kingdom. Estimated historical decompositions of output growth attribute business cycle dynamics around relatively stable trend growth rates primarily to economy specific combinations of demand shocks, and to a lesser extent supply and financial shocks. Business cycle fluctuations in major deficit economies such as the United Kingdom and the United States have been primarily driven by domestic demand shocks, whereas those in major surplus economies such as China and Germany have been primarily driven by foreign demand shocks. In both groups of economies, these business cycle fluctuations have generally been amplified by financial shocks and mitigated by fiscal policy shocks. Trend output growth rates have typically stabilized at relatively low levels in advanced economies, and at relatively high levels in emerging economies.

During the build up to the global financial crisis, positive demand shocks contributed to a synchronized global expansion, generally amplified by financial shocks. This synchronized global expansion was reflected in a synchronized global rise in inflation, typically amplified by world terms of trade shocks. During the global financial crisis, negative demand shocks, amplified and accelerated by financial shocks, generated a synchronized global recession. This synchronized global recession was mitigated by countercyclical unsystematic monetary or fiscal policy interventions. It was reflected in a synchronized global fall in inflation, generally amplified by terms of trade shocks. Since the global financial crisis, positive demand shocks, typically amplified by financial shocks, have contributed to a synchronized global recovery. In the Euro Area periphery, this recovery was derailed by financial shocks, which necessitated procyclical unsystematic fiscal policy interventions.

VI. Spillover Analysis

Within the framework of our estimated panel dynamic stochastic general equilibrium model, the dynamic effects of macroeconomic and financial shocks are transmitted throughout the world economy via trade, financial and commodity price linkages, necessitating monetary, fiscal and macroprudential policy responses to spillovers. With respect to financial linkages, macroeconomic shocks are transmitted via cross-border bank lending, portfolio debt and portfolio equity exposures, while financial shocks are also transmitted via contagion effects.

We analyze spillovers from macroeconomic and financial shocks in systemic economies to the rest of the world with simulated conditional betas and estimated impulse response functions. The systemic economies under consideration are China, the Euro Area, Japan, the United Kingdom and the United States, consistent with IMF (2013). The macroeconomic shocks under consideration are productivity, labor supply, consumption demand, investment demand, monetary policy, fiscal expenditure, and fiscal revenue shocks. The financial shocks under consideration are credit risk premium, duration risk premium, equity risk premium, lending rate markup, capital requirement, and loan default shocks.

A. Simulated Conditional Betas

Simulated conditional betas measure contemporaneous comovement between endogenous variables driven by selected structural shocks, on average over the business cycle. They are ordinary least squares estimates of slope coefficients in bivariate regressions of endogenous variables on contemporaneous endogenous variables, averaged across a large number of simulated paths for the world economy. The simulated betas of output with respect to contemporaneous output in systemic economies, conditional on macroeconomic or financial shocks in each of these systemic economies, are plotted in Figure 33. They measure causality as opposed to correlation, because they abstract from structural shocks originating in other economies.

On average over the business cycle, output spillovers from systemic economies to the rest of the world in our estimated panel dynamic stochastic general equilibrium model are primarily generated by macroeconomic shocks, which contribute more to business cycle fluctuations than financial shocks. This implies weak international business cycle comovement beyond close trading partners. However, during episodes of financial stress in systemic economies, such as during the global financial crisis, international business cycle comovement is more uniformly strong due to the prevalence of financial shocks, which also propagate via elevated contagion effects.

Output spillovers generated by macroeconomic shocks are generally small but concentrated in our estimated panel dynamic stochastic general equilibrium model. The pattern of international business cycle comovement driven by macroeconomic shocks primarily reflects bilateral trade relationships, and therefore exhibits gravity. That is, output spillovers generated by macroeconomic shocks are typically concentrated among geographically close trading partners, which tend to have strong bilateral trade relationships due in part to transportation costs. However, this pattern is diluted by supply shocks, which are primarily transmitted internationally via terms of trade shifts, unlike other macroeconomic shocks which are primarily transmitted internationally via domestic demand shifts.

Output spillovers generated by financial shocks are generally large and diffuse in our estimated panel dynamic stochastic general equilibrium model. The pattern of international business cycle comovement driven by financial shocks transcends bilateral bank lending and portfolio investment relationships, which are typically weak outside of currency blocks reflecting relationship banking and portfolio home bias. Output spillovers generated by financial shocks are primarily transmitted via international comovement in financial asset prices. Given that bilateral trade relationships tend to be weak beyond close trading partners, accounting for strong international comovement in financial asset prices requires strong international comovement in asset risk premia. The intensity of these contagion effects varies across source and recipient economies. They are uniquely strong from the United States, commensurate with the depth of its money, bond and stock markets. They are strong to internationally financially integrated emerging economies, moderate to advanced economies, and weak to internationally financially unintegrated emerging economies.

B. Impulse Response Functions

Peak impulse response functions measure the maximum effects of selected structural shocks on endogenous variables. The estimated peak impulse responses of consumption price inflation, output, the real effective exchange rate, the fiscal balance ratio, and the current account balance ratio to a variety of structural shocks are plotted in Figure 34 through Figure 46. The structural shocks under consideration are foreign productivity, foreign labor supply, foreign consumption demand, foreign investment demand, foreign monetary policy, foreign credit risk premium, foreign duration risk premium, foreign equity risk premium, foreign fiscal expenditure, foreign fiscal revenue, foreign lending rate markup, foreign capital requirement, and foreign loan default shocks.

In response to a productivity shock which generates an increase in inflation and contraction of output in a systemic economy, the currencies of recipient economies generally depreciate in real effective terms. There usually arise terms of trade driven increases in inflation and expansions of output in recipient economies, in spite of lower foreign demand. As a result, their fiscal and current account balances tend to improve. In response to a labor supply shock which generates a decrease in inflation and expansion of output in a systemic economy, the currencies of recipient economies generally appreciate in real effective terms. There typically arise terms of trade driven decreases in inflation and contractions of output in recipient economies, in spite of higher foreign demand. As a result, their fiscal and current account balances tend to deteriorate.

In response to a consumption demand shock which generates an increase in inflation and expansion of output in a systemic economy, there generally arise foreign demand driven increases in inflation and expansions of output in recipient economies, amplified by depreciations of their currencies in real effective terms. As a result, their fiscal and current account balances usually improve. In response to an investment demand shock which generates an increase in inflation and expansion of output in a systemic economy, there generally arise foreign demand driven increases in inflation and expansions of output in recipient economies, amplified by depreciations of their currencies in real effective terms. As a result, their fiscal and current account balances typically improve.

In response to a monetary policy shock which generates an increase in the nominal policy interest rate in a systemic economy, the currencies of recipient economies generally depreciate in real effective terms. There usually arise foreign demand driven decreases in inflation and contractions of output in recipient economies, mitigated by terms of trade deteriorations. As a result, their fiscal and current account balances tend to deteriorate.

In response to a credit risk premium shock which generates an increase in the short term nominal market interest rate in a systemic economy, the short term nominal market interest rates of recipient economies also generally increase, reflecting international money market contagion effects. As a result, there usually arise decreases in inflation and contractions of output in recipient economies, accompanied by deteriorations of their fiscal and current account balances. In response to a duration risk premium shock which generates an increase in the long term nominal market interest rate in a systemic economy, the long term nominal market interest rates of recipient economies also generally increase, reflecting international bond market contagion effects. As a result, there typically arise decreases in inflation and contractions of output in recipient economies, accompanied by deteriorations of their fiscal and current account balances. In response to an equity risk premium shock which generates an increase in the price of equity in a systemic economy, the prices of equity in recipient economies also generally increase, reflecting international stock market contagion effects. As a result, there tend to arise increases in inflation and expansions of output in recipient economies, accompanied by improvements in their fiscal and current account balances.

In response to a fiscal expenditure shock which generates an improvement in the fiscal balance in a systemic economy, there generally arise foreign demand driven decreases in inflation and contractions of output in recipient economies. As a result, their fiscal and current account balances usually deteriorate. In response to a fiscal revenue shock which generates an improvement in the fiscal balance in a systemic economy, there generally arise foreign demand driven decreases in inflation and contractions of output in recipient economies. As a result, their fiscal and current account balances typically deteriorate.

In response to a lending rate markup shock which generates an increase in the nominal bank lending rate in a systemic economy, the nominal corporate loan rates of recipient economies also generally increase, reflecting cross-border bank lending linkages. As a result, there usually arise decreases in inflation and contractions of output in recipient economies, accompanied by deteriorations of their fiscal and current account balances. In response to a capital requirement shock which generates an increase in the regulatory bank capital ratio in a systemic economy, the nominal corporate loan rates of recipient economies also generally increase, reflecting cross-border bank lending linkages. As a result, there typically arise decreases in inflation and contractions of output in recipient economies, accompanied by deteriorations of their fiscal and current account balances. In response to a loan default shock which generates an increase in the loan default rate in a systemic economy, the nominal bank lending rates and nominal corporate loan rates of recipient economies also generally increase, reflecting cross-border bank lending linkages. As a result, there tend to arise decreases in inflation and contractions of output in recipient economies, accompanied by deteriorations of their fiscal and current account balances.

VII. Forecasting

We analyze the predictive accuracy of our estimated panel dynamic stochastic general equilibrium model of the world economy for consumption price inflation and output growth with sequential unconditional forecasts in sample. The results of this forecast performance evaluation exercise are plotted in Figure 47 through Figure 49.

We measure the dynamic forecasting performance of our estimated panel dynamic stochastic general equilibrium model relative to that of a driftless random walk over holdout sample period 2005Q2 through 2014Q3 at the one through eight 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 our estimated panel dynamic stochastic general equilibrium model generally dominates a random walk in terms of predictive accuracy for inflation and output growth. Indeed, over the holdout sample under consideration, the root mean squared prediction error is 43 percent lower for inflation and 44 percent lower for output growth, on average across economies and horizons.

Visual inspection of our sequential unconditional forecasts of inflation and output growth indicates that our estimated panel dynamic stochastic general equilibrium model is capable of predicting business cycle turning points. Indeed, these sequential unconditional forecasts suggest that a synchronized global moderation was overdue by the time of the global financial crisis. However, the model generally underpredicted the severity of this synchronized global recession.

VIII. Conclusion

This paper develops a structural macroeconometric model of the world economy, disaggregated into forty national economies. This panel dynamic stochastic general equilibrium model features a range of nominal and real rigidities, extensive macrofinancial linkages, and diverse spillover transmission channels. A variety of monetary policy analysis, fiscal policy analysis, macroprudential policy analysis, spillover analysis, and forecasting applications of the estimated model are demonstrated. These include quantifying the monetary, fiscal and macroprudential transmission mechanisms with impulse response functions, accounting for business cycle fluctuations with historical decompositions, and generating relatively accurate sequential unconditional forecasts of inflation and output growth.

This estimated panel dynamic stochastic general equilibrium model consolidates much existing theoretical and empirical knowledge concerning business cycle dynamics in the world economy, provides a framework for a progressive research strategy, and suggests explanations for its own deficiencies. The sensitivity of consumption to changes in financial conditions varies significantly across its nondurables versus durables components, as does that of investment across its residential versus business components. Moreover, the financing of durables and housing stock accumulation by households, and of capital stock accumulation by firms, varies considerably with respect to the mix of bank versus capital market based intermediation. Extending the model along these dimensions remains an objective for future research.

Appendix A. Description of the Data Set

Estimation is based on quarterly data on a variety of macroeconomic and financial market variables observed for forty economies over the sample period 1999Q1 through 2014Q3. The economies under consideration are Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, the Czech Republic, Denmark, Finland, France, Germany, Greece, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, New Zealand, Norway, the Philippines, Poland, Portugal, Russia, Saudi Arabia, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, the United Kingdom, and the United States. Where available, this data was obtained from the GDS and WEO databases compiled by the International Monetary Fund. Otherwise, it was extracted from the IFS database produced by the International Monetary Fund.

The macroeconomic variables under consideration are the price of output, the price of consumption, the quantity of output, the quantity of private consumption, the quantity of exports, the quantity of imports, the nominal wage, the unemployment rate, employment, the quantity of public domestic demand, the fiscal balance ratio, and the prices of nonrenewable energy and nonenergy commodities. The price of output is measured by the seasonally adjusted gross domestic product price deflator, while the price of consumption is proxied by the seasonally adjusted consumer price index. The quantity of output is measured by seasonally adjusted real gross domestic product, while the quantity of private consumption is measured by seasonally adjusted real private consumption expenditures. The quantity of exports is measured by seasonally adjusted real export revenues, while the quantity of imports is measured by seasonally adjusted real import expenditures. The nominal wage is derived from the quadratically interpolated annual labor income share, while the unemployment rate is measured by the seasonally adjusted share of total unemployment in the total labor force, and employment is measured by quadratically interpolated annual total employment. The quantity of public domestic demand is measured by the sum of quadratically interpolated annual real consumption and investment expenditures of the general government, while the fiscal balance is measured by the quadratically interpolated annual overall fiscal balance of the general government. The prices of energy and nonenergy commodities are proxied by broad commodity price indexes denominated in United States dollars.

The financial market variables under consideration are the nominal policy interest rate, the short term nominal market interest rate, the nominal bank lending interest rate, the long term nominal market interest rate, the price of equity, and the nominal bilateral exchange rate. The nominal policy interest rate is measured by the central bank policy rate, the short term nominal market interest rate is measured by a reference bank deposit rate, the nominal bank lending interest rate is measured by a reference bank lending rate, and the long term nominal market interest rate is measured by a long term government bond yield. In cases where these interest rates are not reported, the closest available substitute is used. The price of equity is proxied by a broad stock price index denominated in domestic currency units, while the nominal bilateral exchange rate is measured by the domestic currency price of one United States dollar. All of these financial market variables are expressed as period average values.

Calibration is based on annual data obtained from databases compiled by the International Monetary Fund where available, and from the Bank for International Settlements or the World Bank Group otherwise. Macroeconomic great ratios are derived from the WEO and WDI databases, while financial great ratios are also derived from the IFS and BIS databases. Bilateral trade weights are derived for goods on a cost, insurance and freight basis from the DOTS database. Bank lending and nonfinancial corporate borrowing weights are derived on a consolidated ultimate risk basis from the BIS database. Portfolio debt and equity investment weights are derived from the CPIS, BIS, and WDI databases.

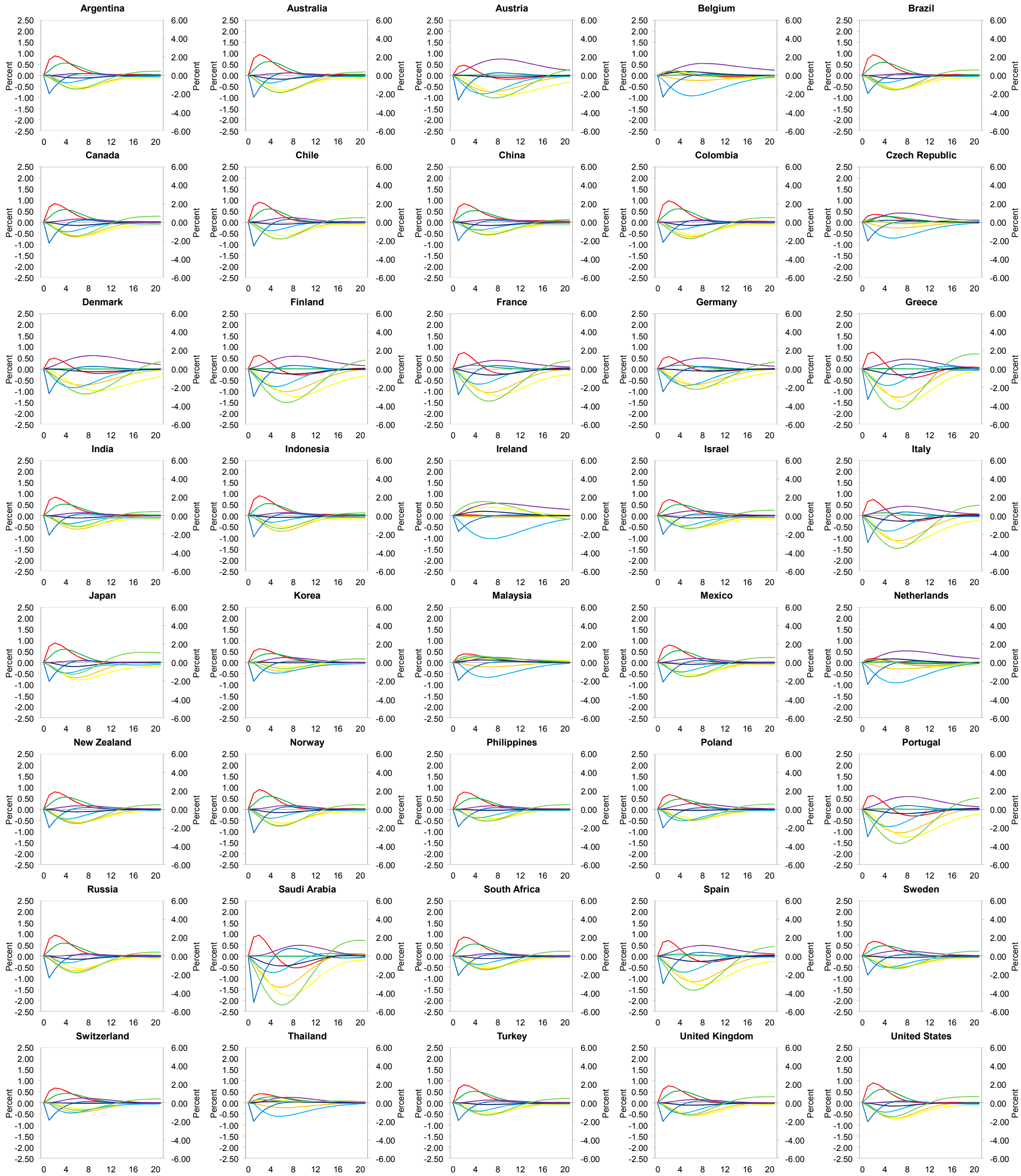
Appendix B. Tables and Figures

Table 1. Parameter Estimation Results

	Prior Mean	Prior SD	Posterior Mean		Prior Mean	Prior SD	Posterior Mean
α	0.9000	0.0900	0.8762	ζ^G	0.0025	0.0000	…
β	0.9756	0.0000	…	ζ^τ	0.0250	0.0000	…
χ	2.2500	0.2250	2.0775	$\zeta^{\kappa,B}$	0.0625	0.0000	…
χ^B	10.0000	1.0000	10.6072	$\zeta^{\kappa,i}$	0.1250	0.0000	…
χ^C	1.1250	0.1125	1.2115	$\zeta^{\delta,B}$	0.0156	0.0000	…
χ^G	0.9639	0.0000	…	$\zeta^{\delta,i}$	0.1250	0.0000	…
δ	0.0250	0.0000	…	λ_0^M	0.5409	0.0541	0.5044
δ^C	0.0063	0.0000	…	λ_1^M	1.0817	0.1082	0.9922
η	0.0500	0.0050	0.0476	λ_2^M	1.6226	0.1623	1.6199
η^K	0.5000	0.0500	0.5004	λ_0^B	0.5409	0.0541	0.5394
η^C	0.5000	0.0500	0.5101	λ_1^B	1.0817	0.1082	1.0410
γ^Y	0.5000	0.0500	0.4914	λ_2^B	1.6226	0.1623	1.5839
γ^M	0.5000	0.0500	0.5223	λ_0^S	0.6649	0.0665	0.6405
γ^L	0.5000	0.0500	0.5278	λ_1^S	1.3297	0.1330	1.3220
ι	0.0800	0.0080	0.0834	λ_2^S	1.9946	0.1995	2.0544
κ^R	0.1000	0.0000	…	$\rho_{\mathcal{A}}$	0.7500	0.0750	0.7715
μ^M	0.2500	0.0250	0.2590	$\rho_{\nu,C}$	0.5000	0.0500	0.5231
ω^Y	0.8750	0.0875	0.8717	$\rho_{\nu,I}$	0.5000	0.0500	0.5270
ω^M	0.8750	0.0875	0.8803	$\rho_{\nu,X}$	0.7500	0.0750	0.7134
ω^L	0.8750	0.0875	0.8558	$\rho_{\nu,M}$	0.7500	0.0750	0.7536
ω^C	0.3333	0.0333	0.3334	$\rho_{\nu,i,S}$	0.7500	0.0750	0.7449
ω_1^Y	0.3333	0.0333	0.3227	$\rho_{\nu,B}$	0.7500	0.0750	0.8017
ω_2^Y	0.3333	0.0333	0.3534	$\rho_{\nu,S}$	0.7500	0.0750	0.7658
ϕ	0.8000	0.0800	0.7975	ρ_{θ^C}	0.5000	0.0500	0.4945
ϕ^A	0.1000	0.0100	0.0977	$\rho_{\nu,L}$	0.7500	0.0750	0.7437
ϕ^C	0.4500	0.0450	0.4359	$\rho_{\nu,\varepsilon}$	0.7500	0.0750	0.7347
ϕ_1^F	0.9000	0.0900	0.9255	$\sigma^2_{\theta^Y}$	$7.31\times10^{+4}$	$7.31\times10^{+3}$	$7.29\times10^{+4}$
ϕ_2^F	0.8000	0.0800	0.8225	$\sigma^2_{\theta^M}$	$1.30\times10^{+5}$	$1.30\times10^{+4}$	$1.35\times10^{+5}$
ψ^M	1.5000	0.1500	1.5422	$\sigma^2_{\mathcal{A}}$	4.59×10^{-1}	4.59×10^{-2}	4.59×10^{-1}
ρ^i	0.7500	0.0750	0.7755	$\sigma^2_{\nu,C}$	$1.07\times10^{+1}$	$1.07\times10^{+0}$	$9.79\times10^{+0}$
ρ_G	0.7500	0.0750	0.7727	$\sigma^2_{\nu,I}$	$1.77\times10^{+0}$	1.77×10^{-1}	$1.76\times10^{+0}$
ρ_τ	0.7500	0.0750	0.7666	$\sigma^2_{\nu,X}$	$6.19\times10^{+0}$	6.19×10^{-1}	$6.30\times10^{+0}$
ρ_κ	0.7500	0.0000	…	$\sigma^2_{\nu,M}$	$8.36\times10^{+0}$	8.36×10^{-1}	$8.56\times10^{+0}$
ρ_δ	0.7500	0.0000	…	$\sigma^2_{\nu,i,P}$	2.89×10^{-1}	2.89×10^{-2}	2.91×10^{-1}
σ	6.0000	0.6000	6.0322	$\sigma^2_{\nu,i,S}$	3.26×10^{-2}	3.26×10^{-3}	3.20×10^{-2}
θ^Y	7.6667	0.0000	…	$\sigma^2_{\nu,B}$	2.61×10^{-1}	2.61×10^{-2}	2.64×10^{-1}
θ^M	7.6667	0.0000	…	$\sigma^2_{\nu,S}$	$4.03\times10^{+0}$	4.03×10^{-1}	$3.96\times10^{+0}$
θ^L	7.6667	0.0000	…	$\sigma^2_{\theta^C}$	$1.15\times10^{+4}$	$1.15\times10^{+3}$	$1.17\times10^{+4}$
θ^C	161.0000	0.0000	…	$\sigma^2_{\theta^L}$	$3.47\times10^{+5}$	$3.47\times10^{+4}$	$3.50\times10^{+5}$
ξ_0^π	1.5000	0.1500	1.5381	$\sigma^2_{\nu,L}$	$2.14\times10^{+1}$	$2.14\times10^{+0}$	$2.18\times10^{+1}$
ξ_1^π	1.5000	0.1500	1.4182	$\sigma^2_{\nu,\varepsilon}$	6.02×10^{-2}	6.02×10^{-3}	5.96×10^{-2}
ξ_0^Y	0.1250	0.0125	0.1257	$\sigma^2_{\nu,G}$	8.20×10^{-2}	8.20×10^{-3}	7.73×10^{-2}
ξ_1^Y	0.1250	0.0125	0.1244	$\sigma^2_{\nu,T}$	4.33×10^{-1}	4.33×10^{-2}	4.44×10^{-1}
ξ_1^Q	0.0313	0.0031	0.0305	$\sigma^2_{\nu,\kappa}$	1.57×10^{-1}	1.57×10^{-2}	1.53×10^{-1}
$\xi_2^{\mathcal{E}}$	1.2500	0.0000	…	$\sigma^2_{\nu,\delta}$	1.07×10^{-3}	1.07×10^{-4}	1.09×10^{-3}
ζ^i	0.0000	0.0000	…	$\sigma^2_{\theta^{Y,k}}$	$7.52\times10^{+3}$	$7.52\times10^{+2}$	$7.83\times10^{+3}$

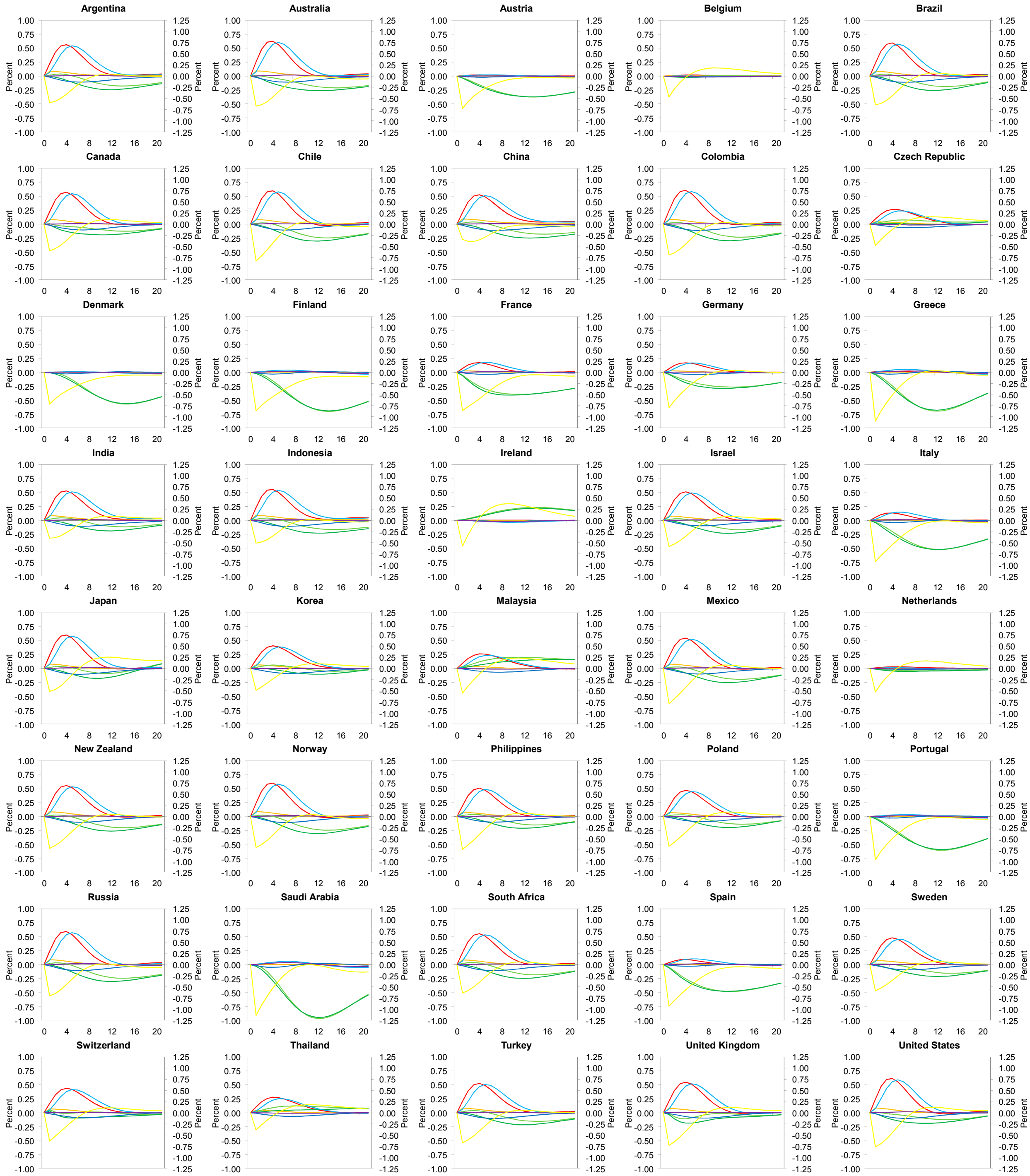
Note: All priors are normally distributed, while all posteriors are asymptotically normally distributed. All auxiliary parameters have degenerate priors with mean zero.

Figure 1. IRFs of Macro Variables to a Domestic Productivity Shock



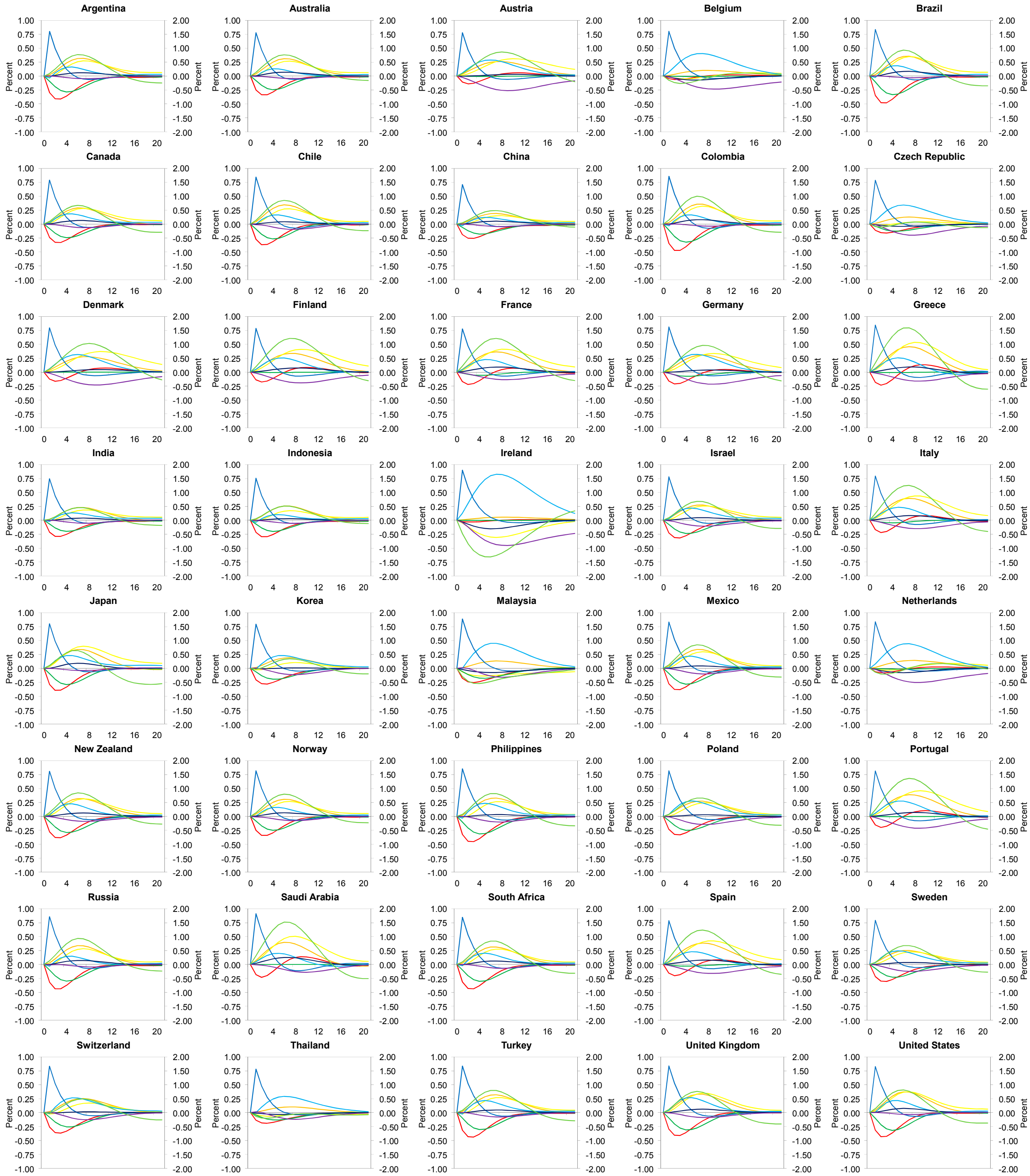
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic productivity shocks which raise output price inflation by one percentage point. All variables are annualized, where applicable.

Figure 2. IRFs of Financial Variables to a Domestic Productivity Shock



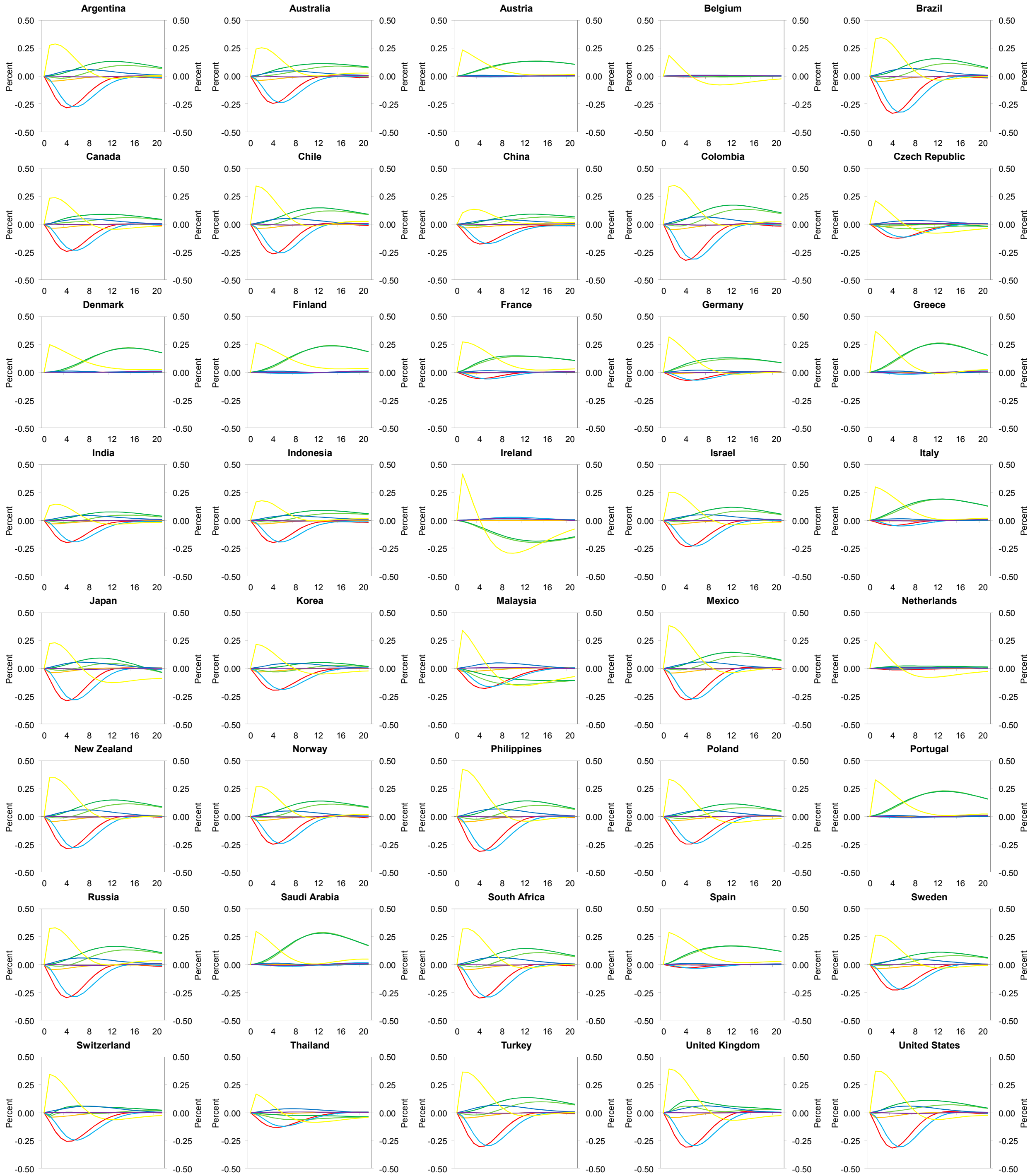
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic productivity shocks which raise output price inflation by one percentage point. All variables are annualized, where applicable.

Figure 3. IRFs of Macro Variables to a Domestic Labor Supply Shock



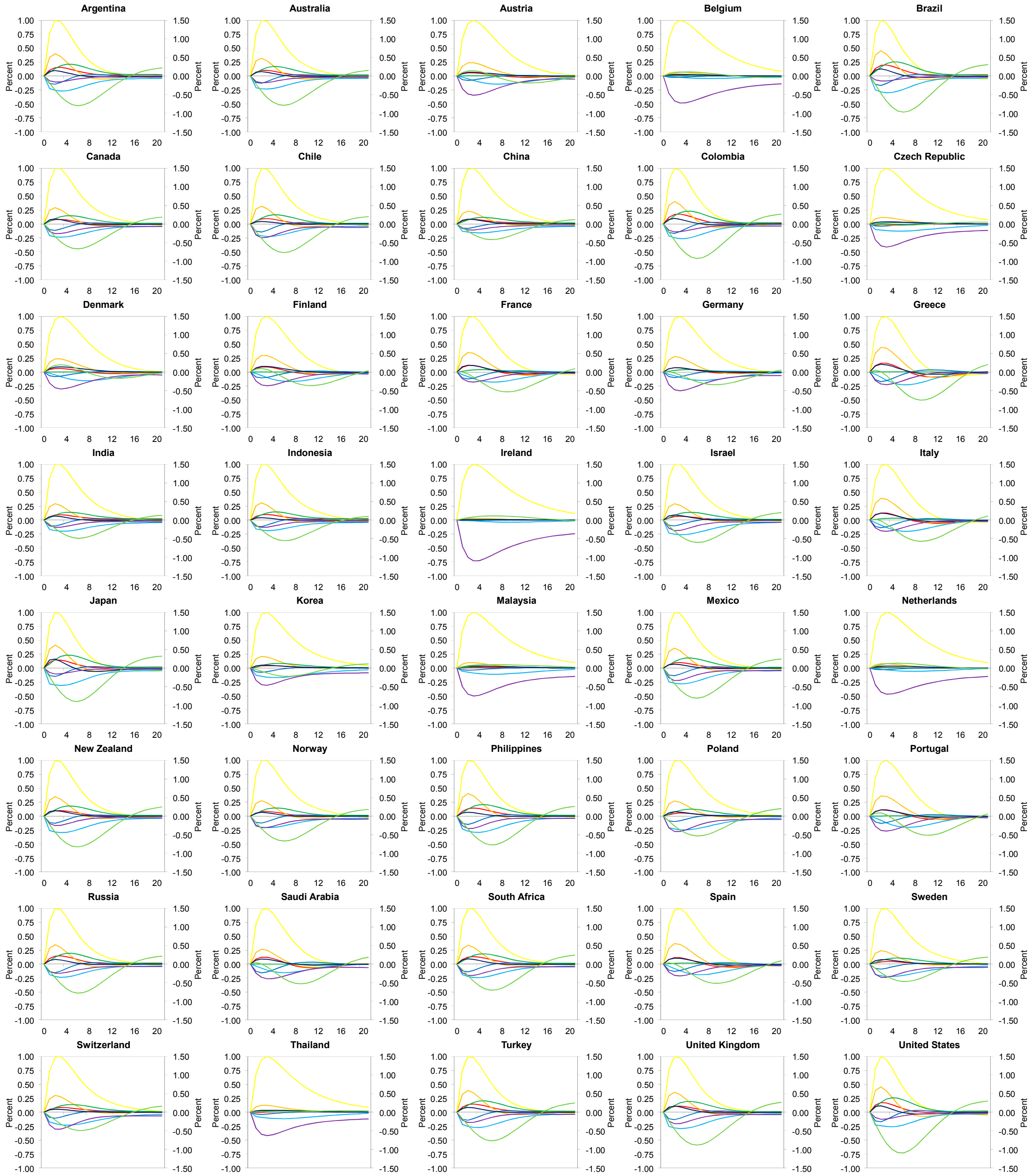
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic labor supply shocks which raise the labor force by one percent. All variables are annualized, where applicable.

Figure 4. IRFs of Financial Variables to a Domestic Labor Supply Shock



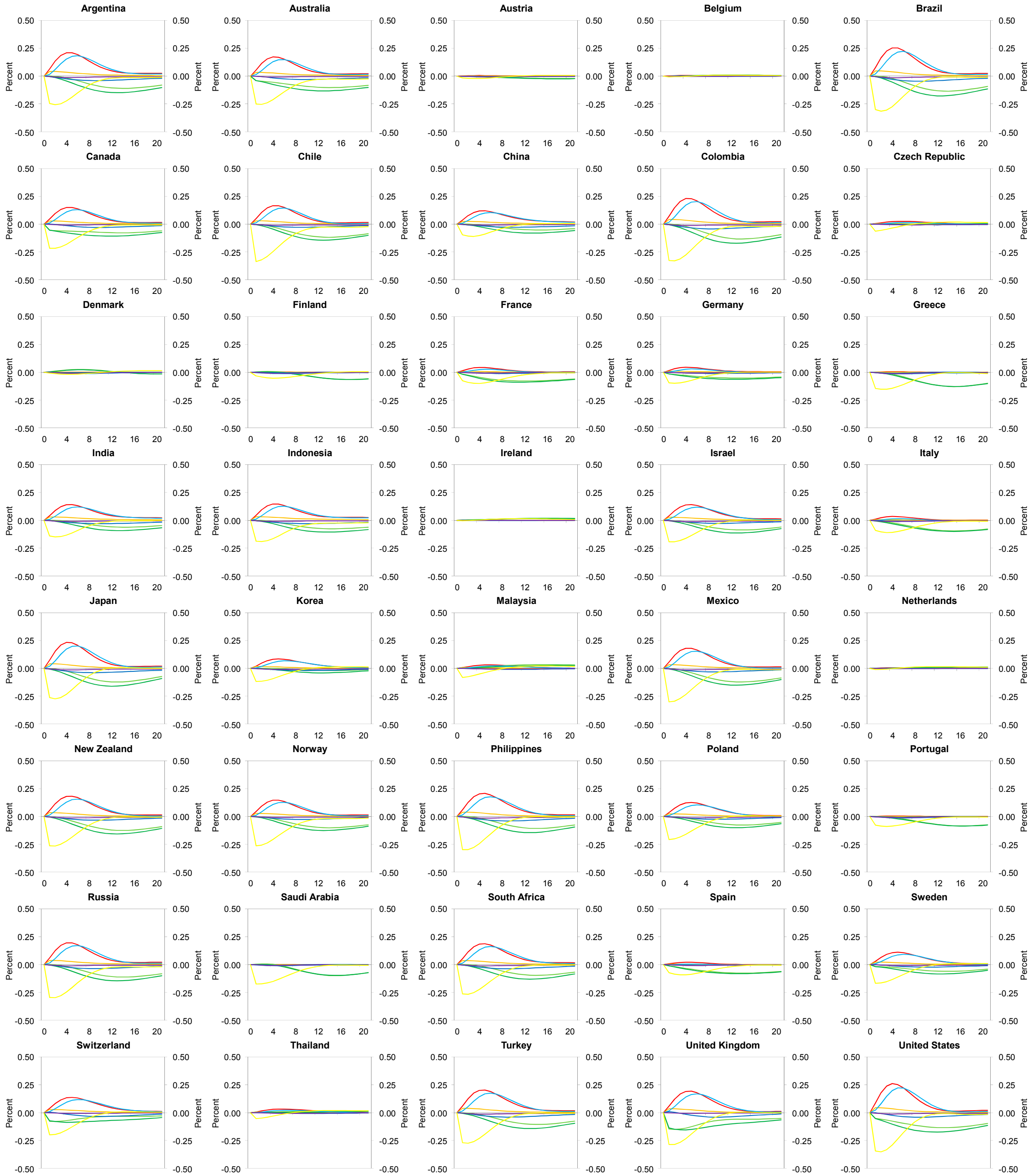
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic labor supply shocks which raise the labor force by one percent. All variables are annualized, where applicable.

Figure 5. IRFs of Macro Variables to a Domestic Consumption Demand Shock



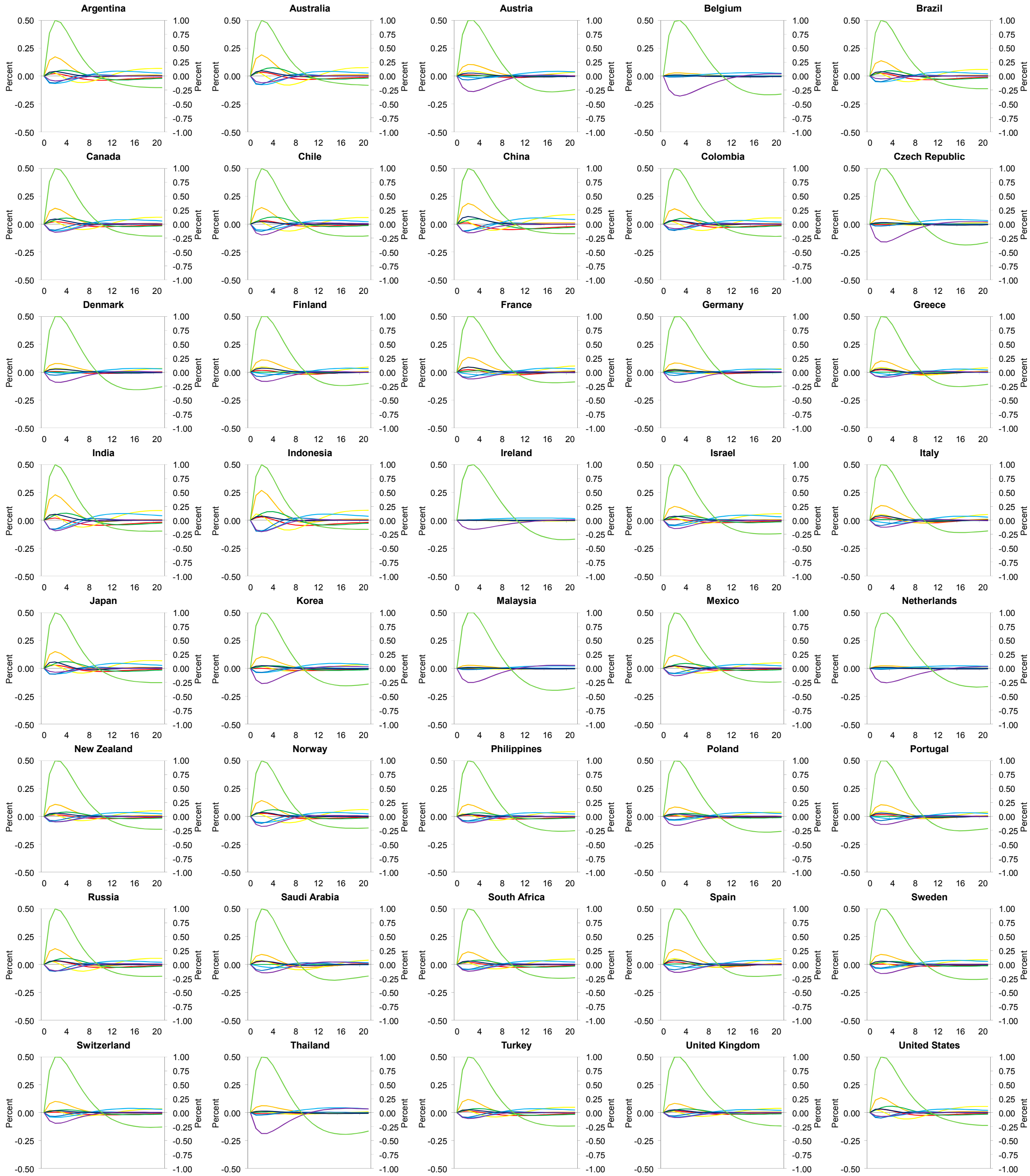
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic consumption demand shocks which raise private consumption by one percent. All variables are annualized, where applicable.

Figure 6. IRFs of Financial Variables to a Domestic Consumption Demand Shock



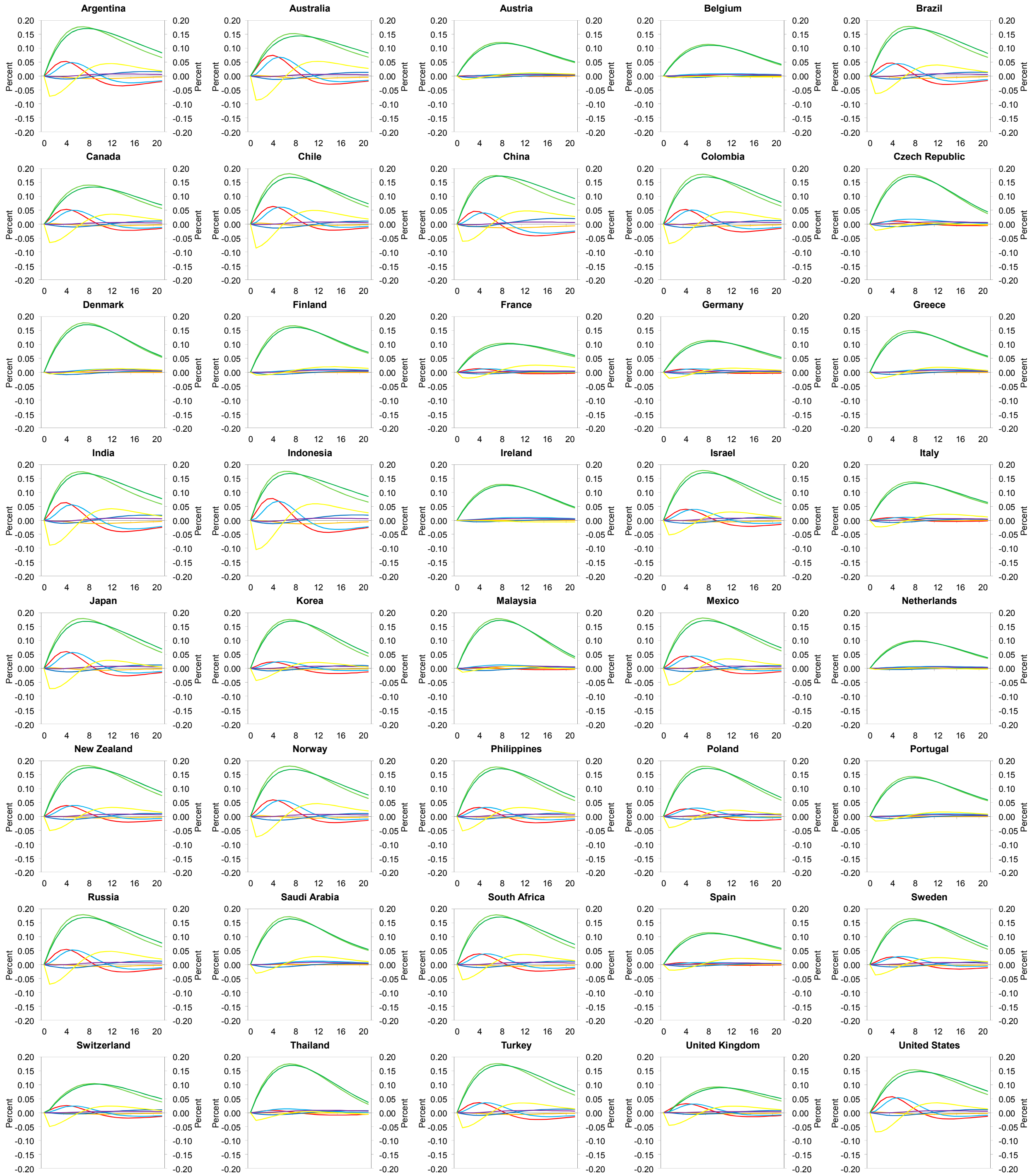
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic consumption demand shocks which raise private consumption by one percent. All variables are annualized, where applicable.

Figure 7. IRFs of Macro Variables to a Domestic Investment Demand Shock



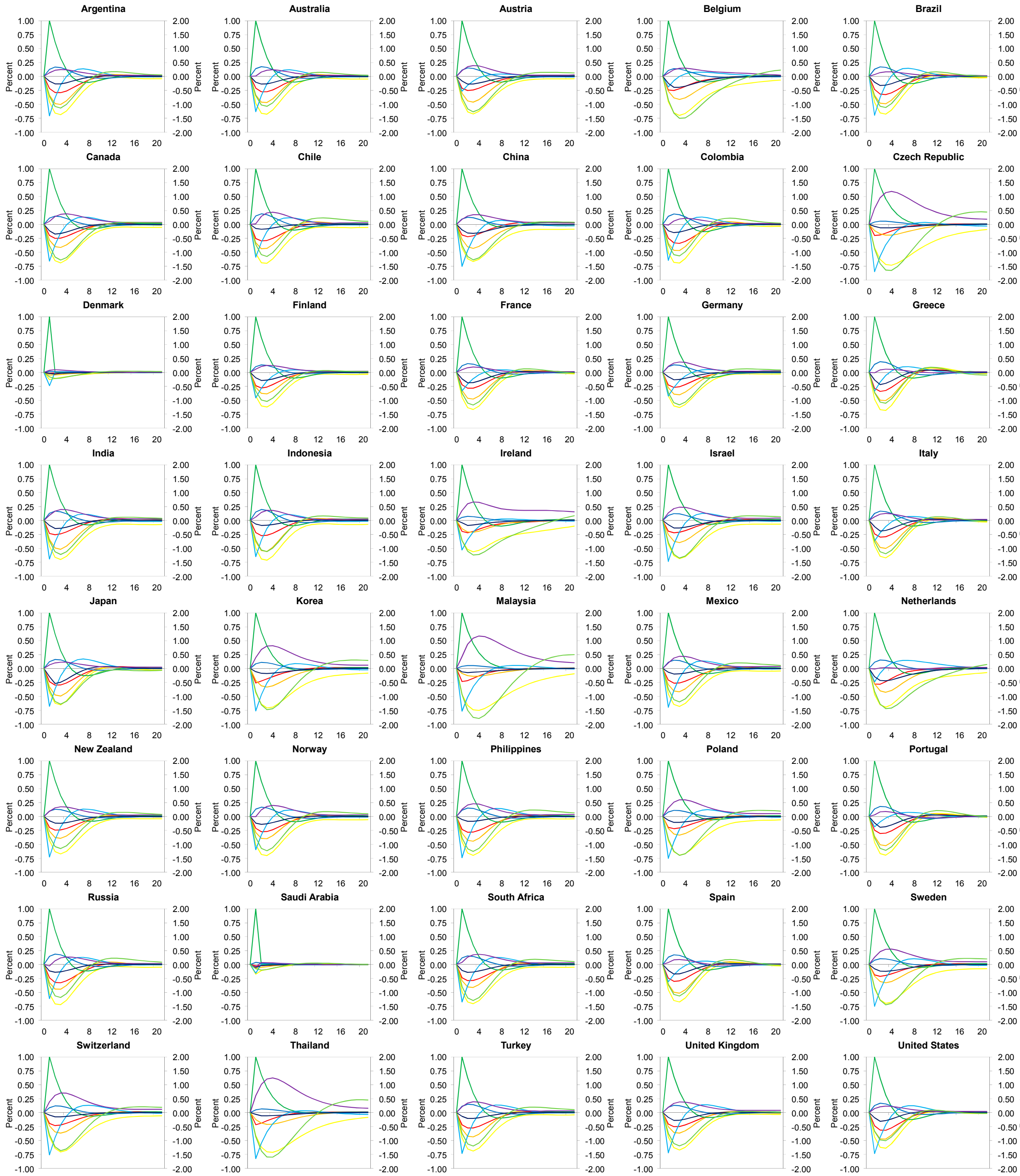
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic investment demand shocks which raise private investment by one percent. All variables are annualized, where applicable.

Figure 8. IRFs of Financial Variables to a Domestic Investment Demand Shock



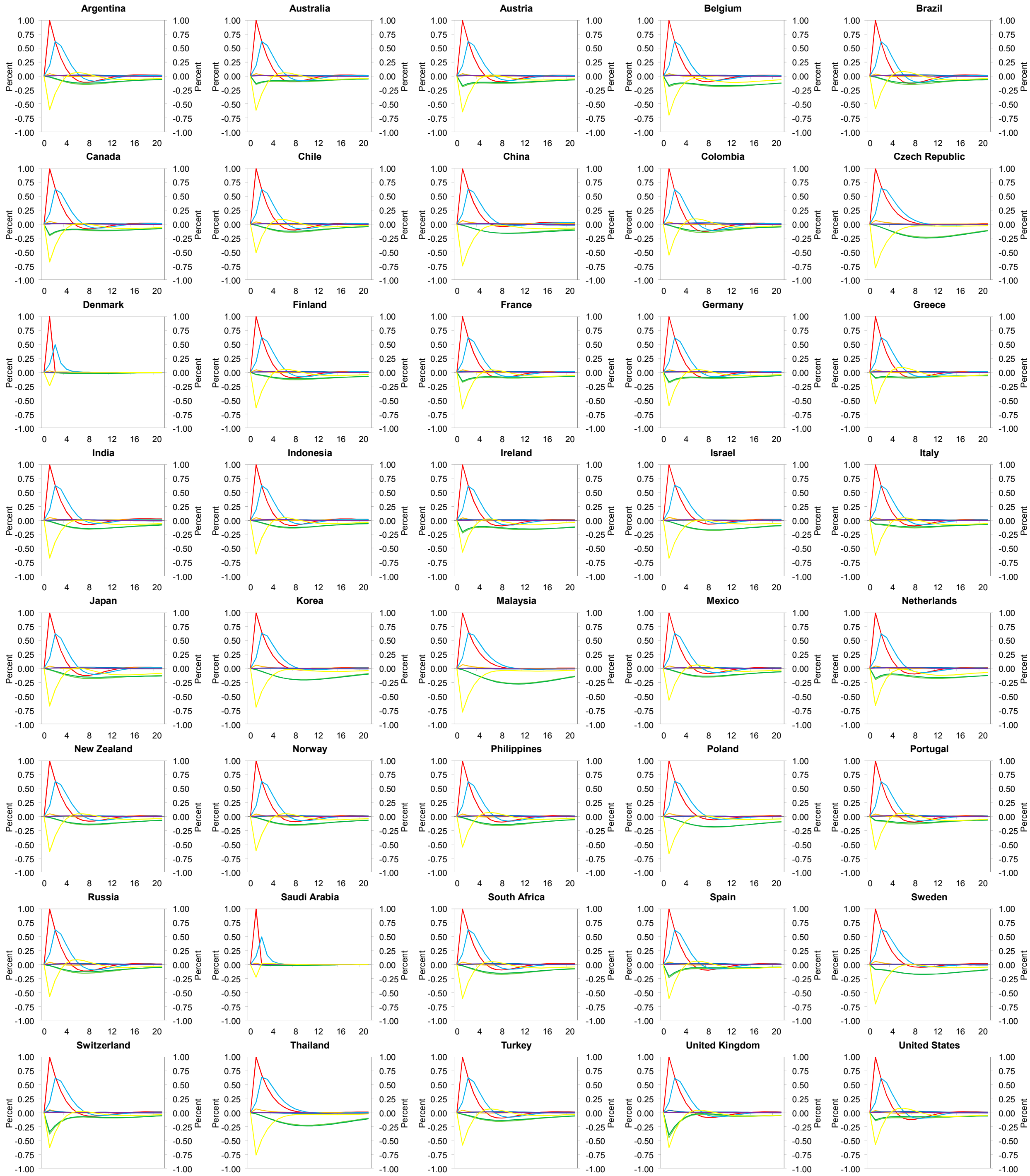
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic investment demand shocks which raise private investment by one percent. All variables are annualized, where applicable.

Figure 9. IRFs of Macro Variables to a Domestic Monetary Policy Shock



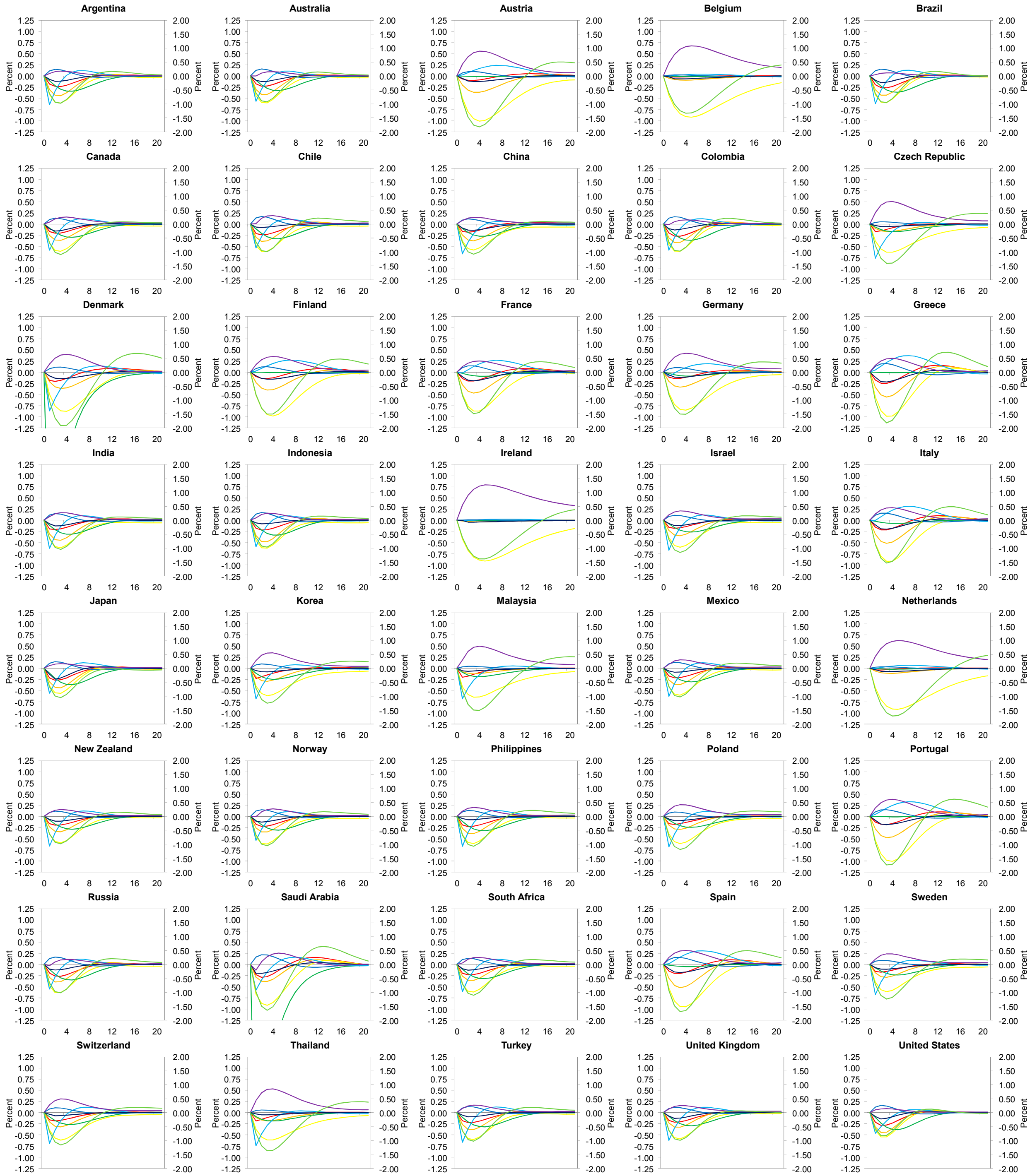
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic monetary policy shocks which raise the nominal policy interest rate by one percentage point. All variables are annualized, where applicable.

Figure 10. IRFs of Financial Variables to a Domestic Monetary Policy Shock



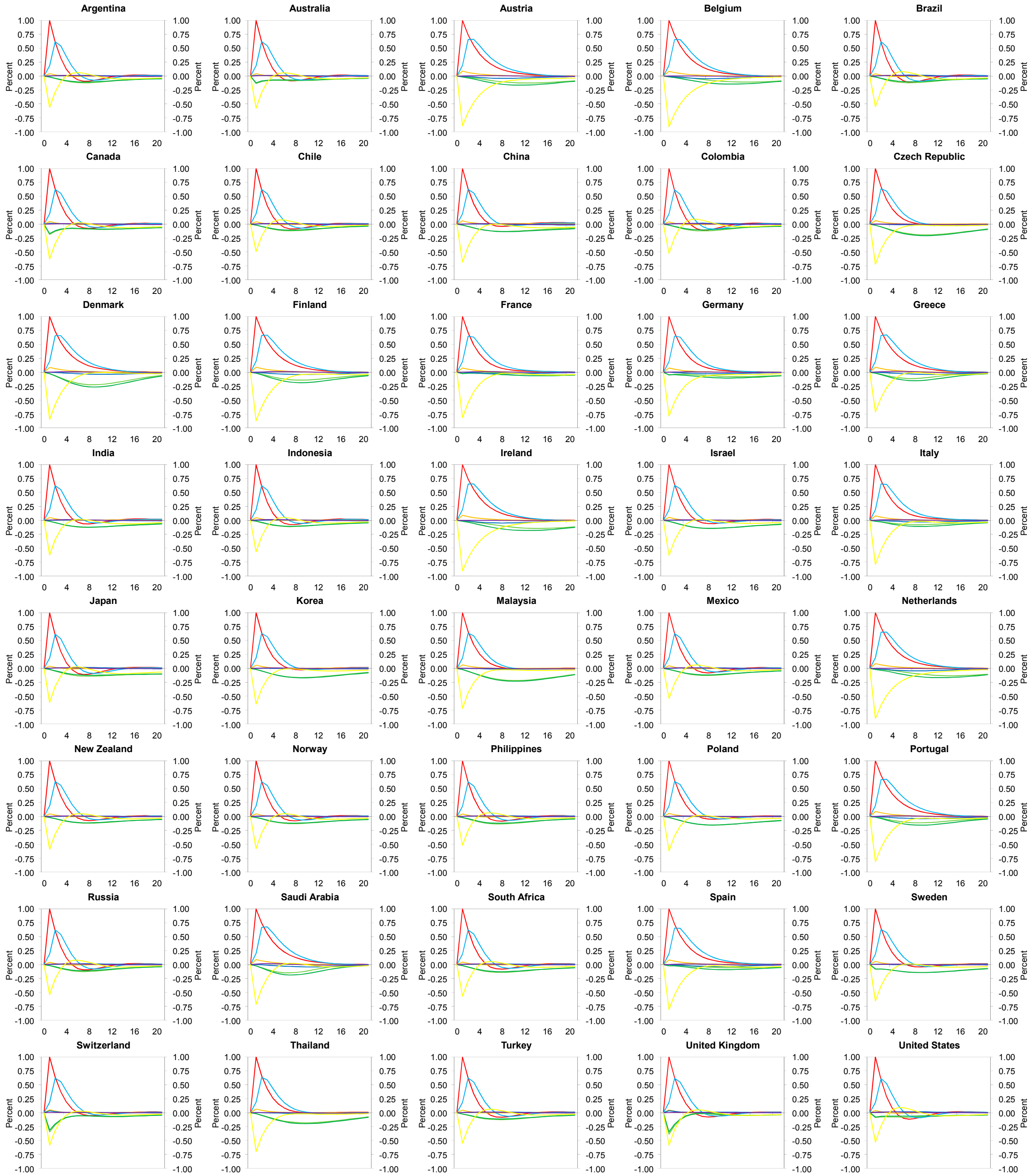
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic monetary policy shocks which raise the nominal policy interest rate by one percentage point. All variables are annualized, where applicable.

Figure 11. IRFs of Macro Variables to a Domestic Credit Risk Premium Shock



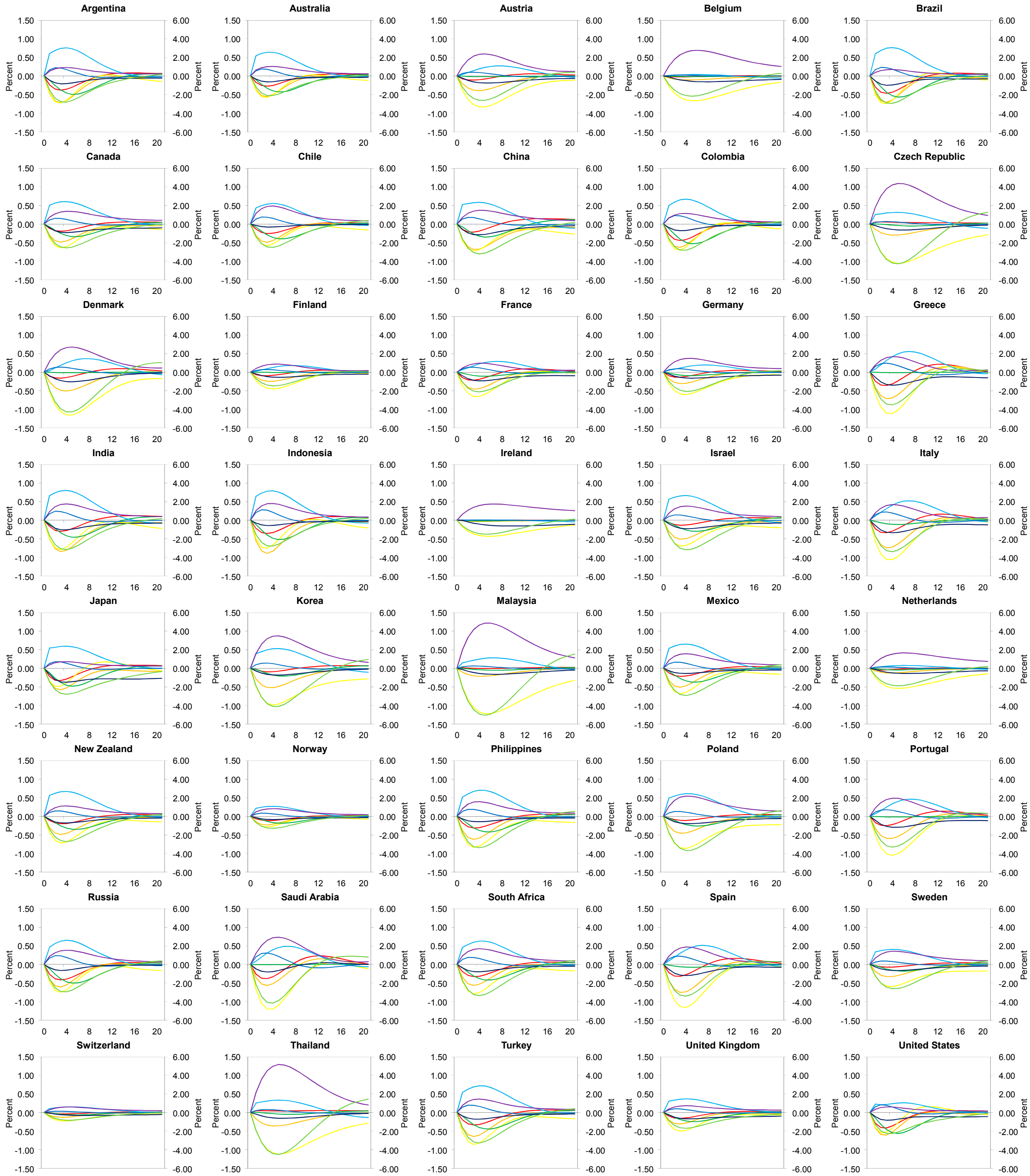
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic credit risk premium shocks which raise the short term nominal market interest rate by one percentage point. All variables are annualized, where applicable.

Figure 12. IRFs of Financial Variables to a Domestic Credit Risk Premium Shock



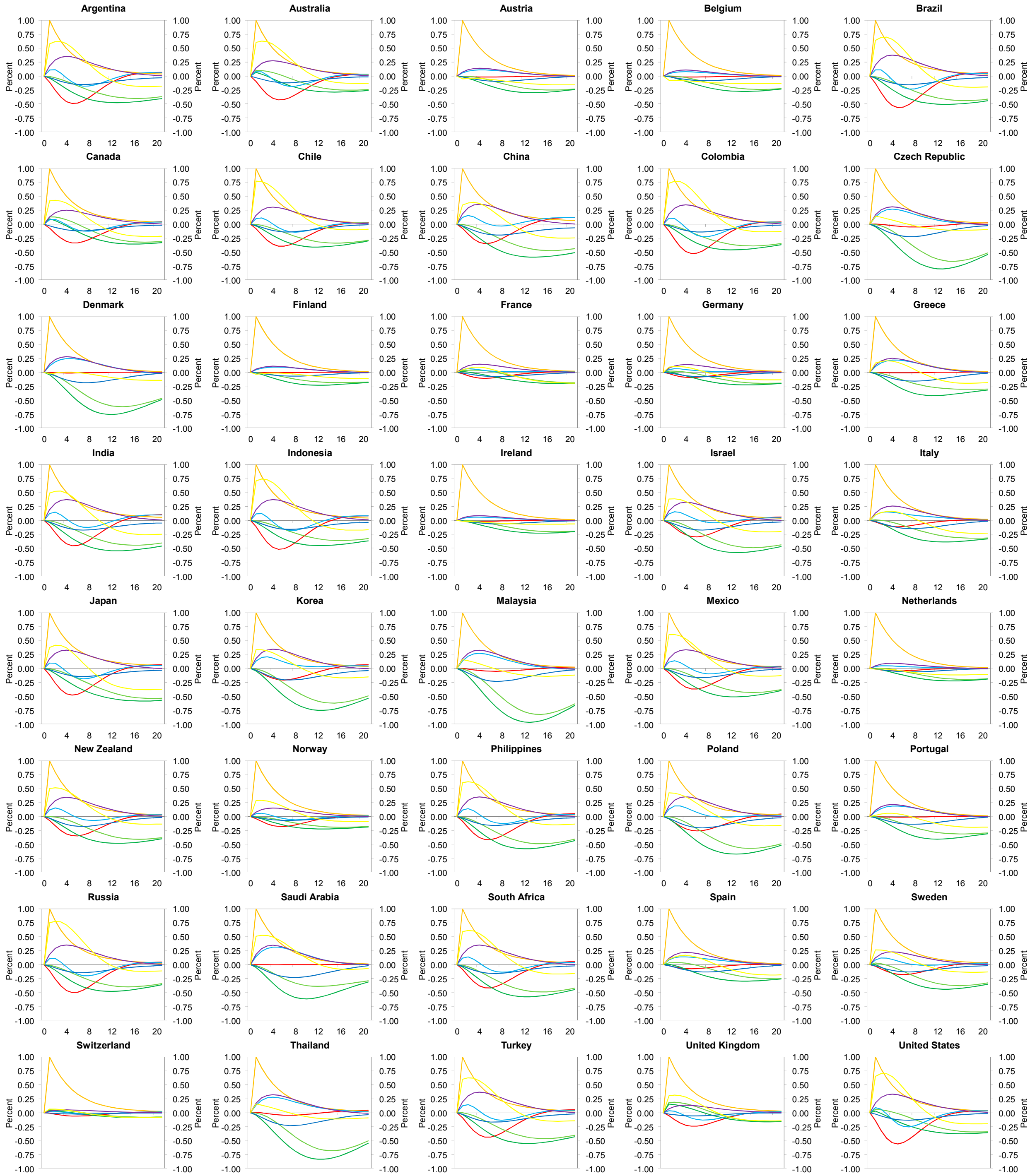
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic credit risk premium shocks which raise the short term nominal market interest rate by one percentage point. All variables are annualized, where applicable.

Figure 13. IRFs of Macro Variables to a Domestic Duration Risk Premium Shock



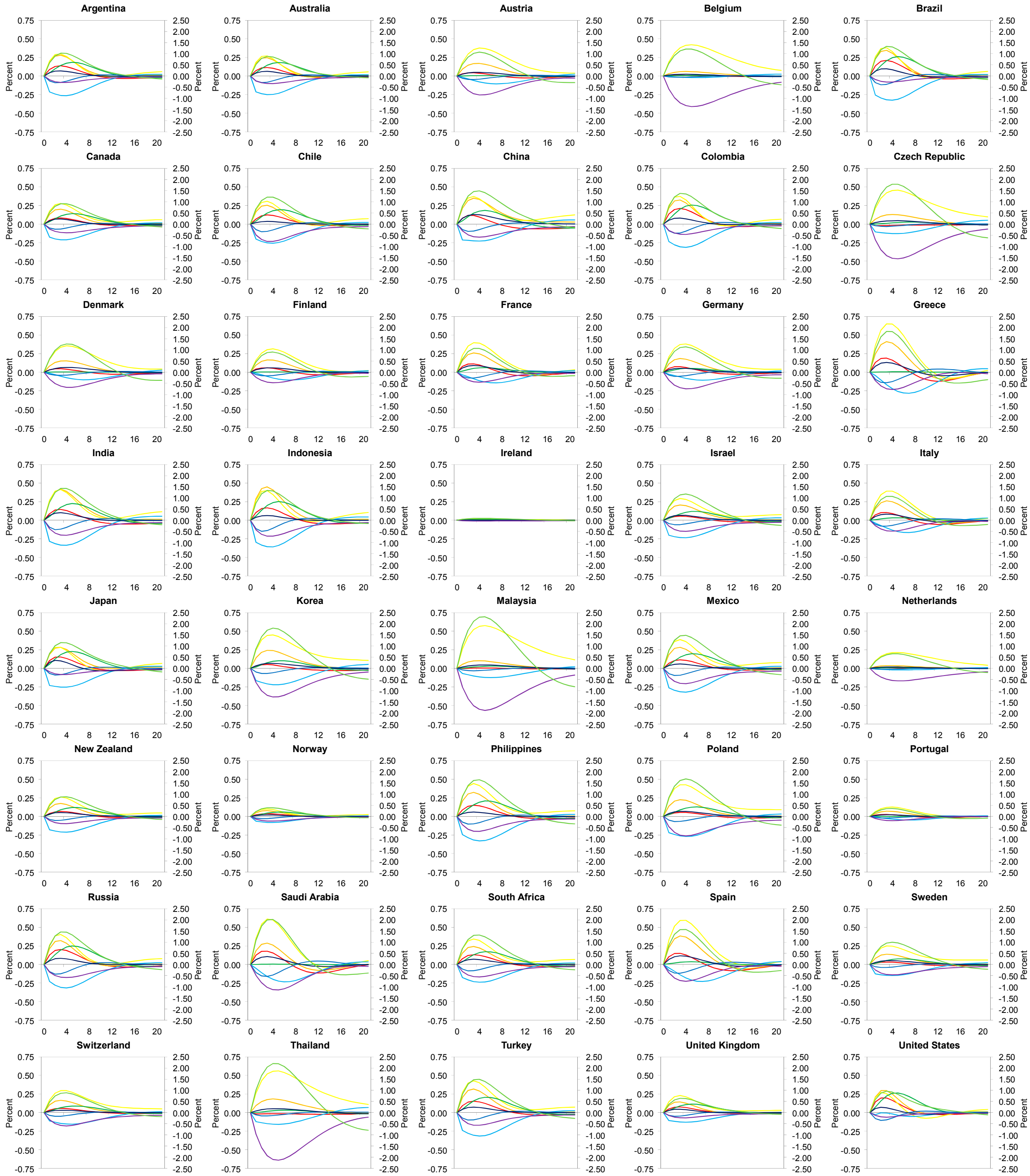
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic duration risk premium shocks which raise the long term nominal market interest rate by one percentage point. All variables are annualized, where applicable.

Figure 14. IRFs of Financial Variables to a Domestic Duration Risk Premium Shock



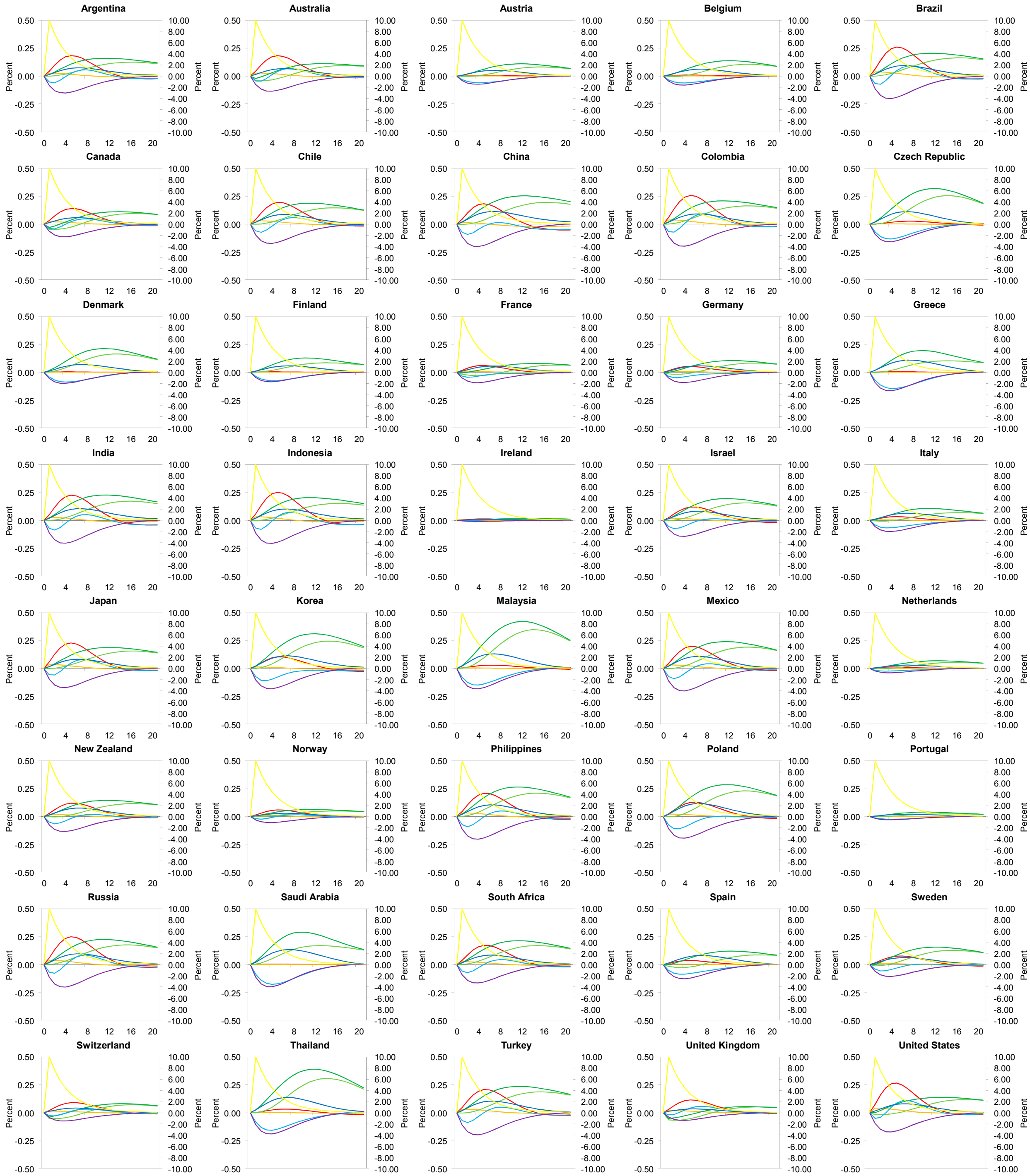
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic duration risk premium shocks which raise the long term nominal market interest rate by one percentage point. All variables are annualized, where applicable.

Figure 15. IRFs of Macro Variables to a Domestic Equity Risk Premium Shock



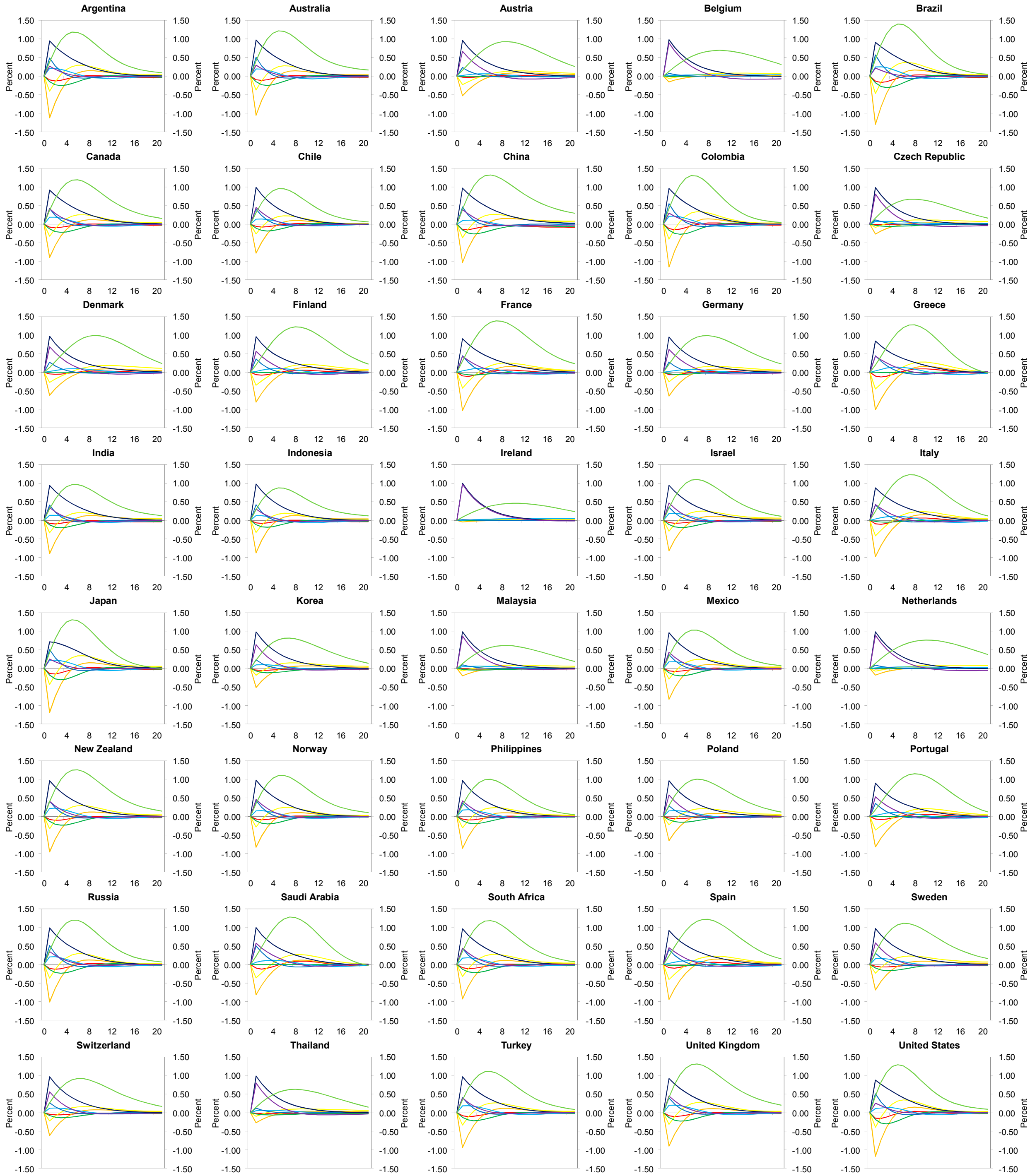
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic equity risk premium shocks which raise the price of equity by ten percent. All variables are annualized, where applicable.

Figure 16. IRFs of Financial Variables to a Domestic Equity Risk Premium Shock



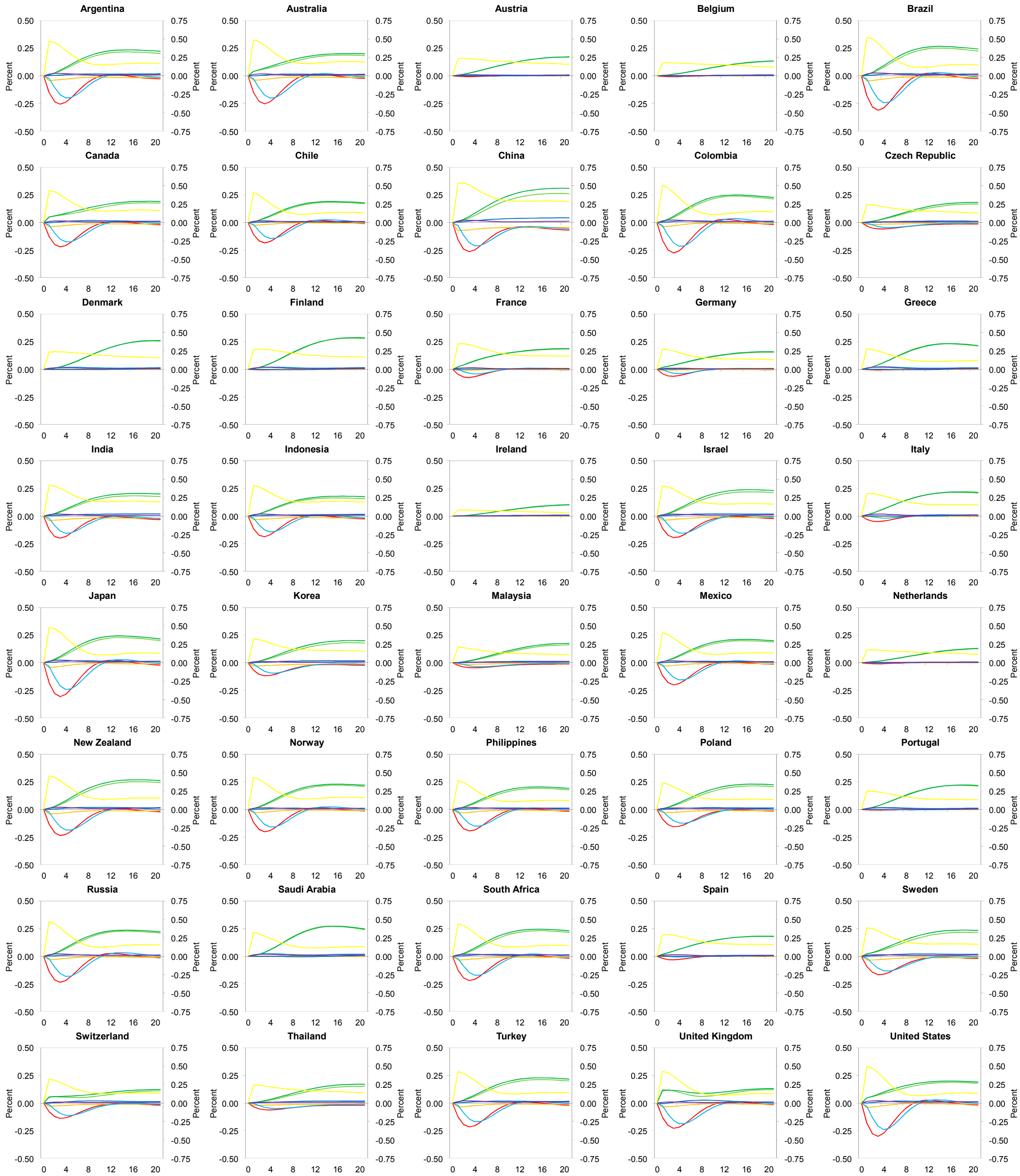
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic equity risk premium shocks which raise the price of equity by ten percent. All variables are annualized, where applicable.

Figure 17. IRFs of Macro Variables to a Domestic Fiscal Expenditure Shock



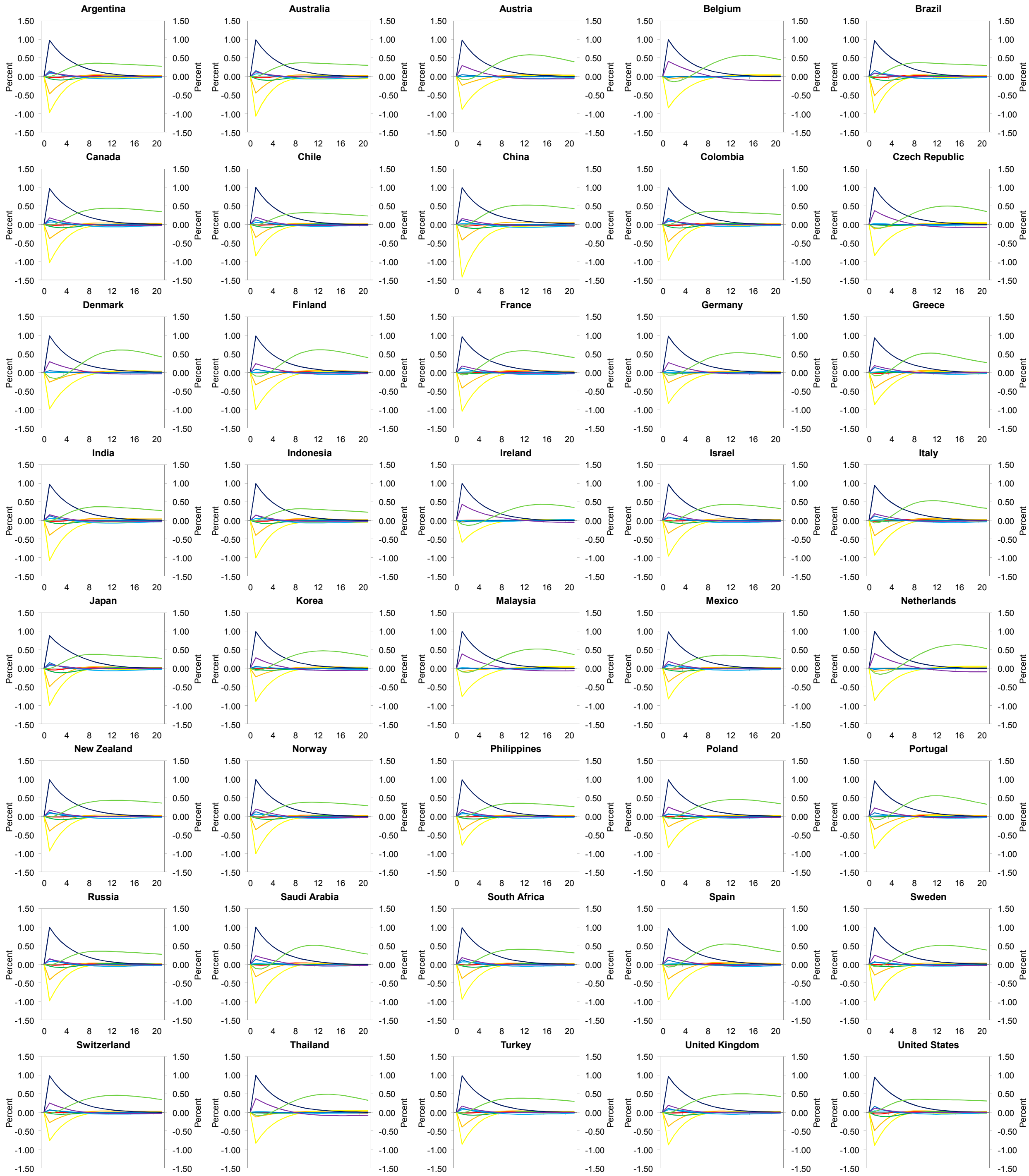
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic fiscal expenditure shocks which raise the primary fiscal balance ratio by one percentage point. All variables are annualized, where applicable.

Figure 18. IRFs of Financial Variables to a Domestic Fiscal Expenditure Shock



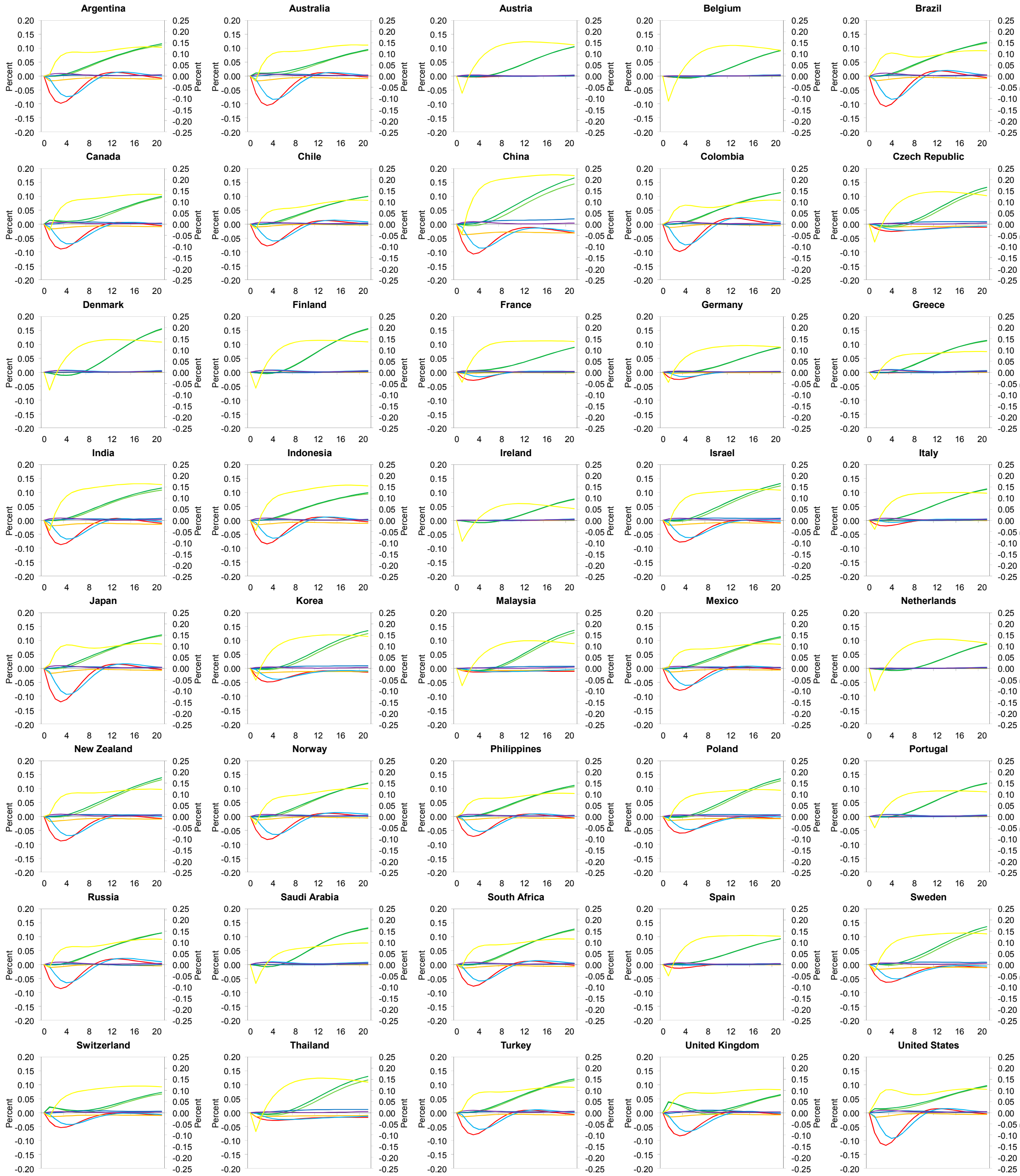
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic fiscal expenditure shocks which raise the primary fiscal balance ratio by one percentage point. All variables are annualized, where applicable.

Figure 19. IRFs of Macro Variables to a Domestic Fiscal Revenue Shock



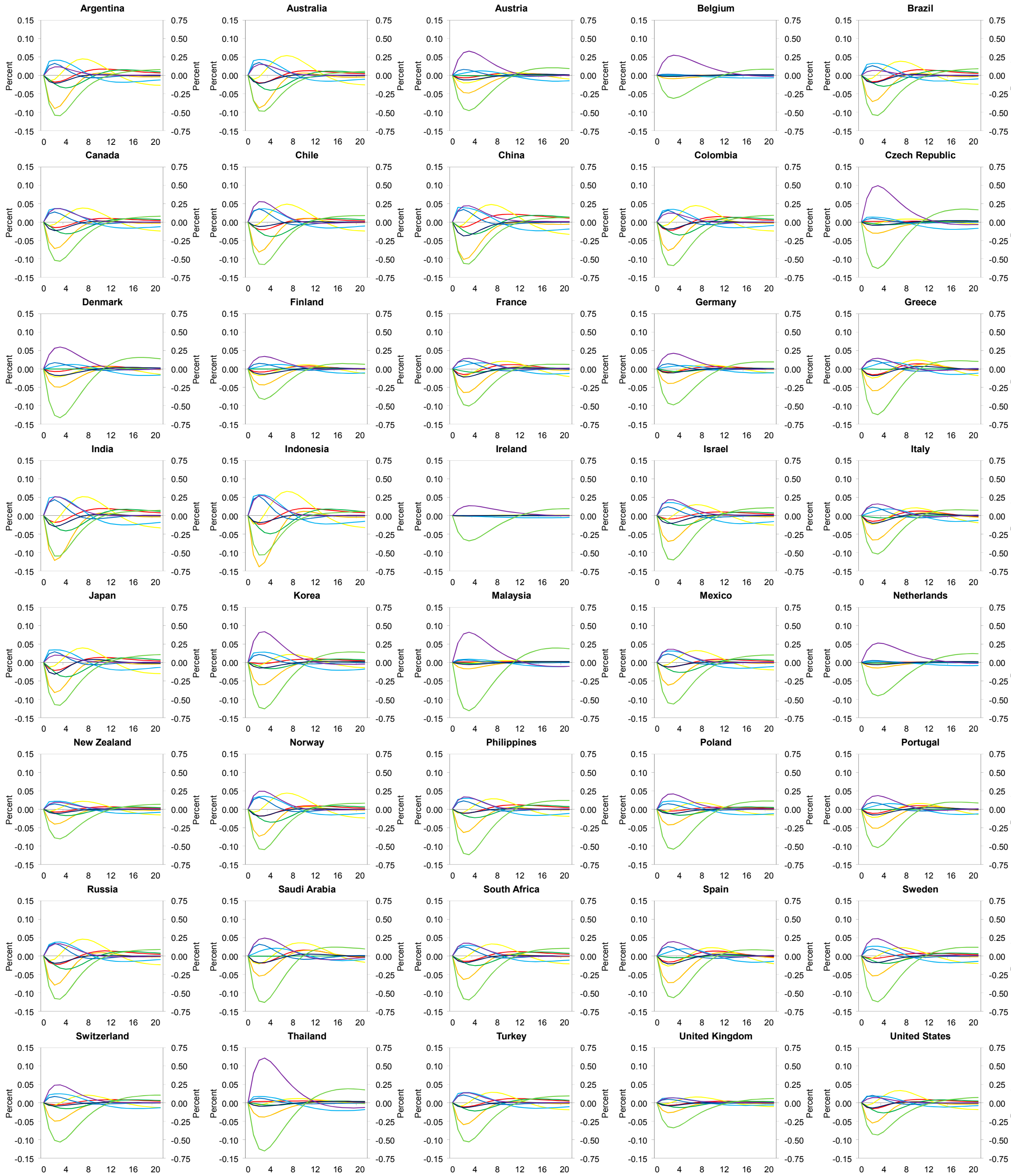
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic fiscal revenue shocks which raise the primary fiscal balance ratio by one percentage point. All variables are annualized, where applicable.

Figure 20. IRFs of Financial Variables to a Domestic Fiscal Revenue Shock



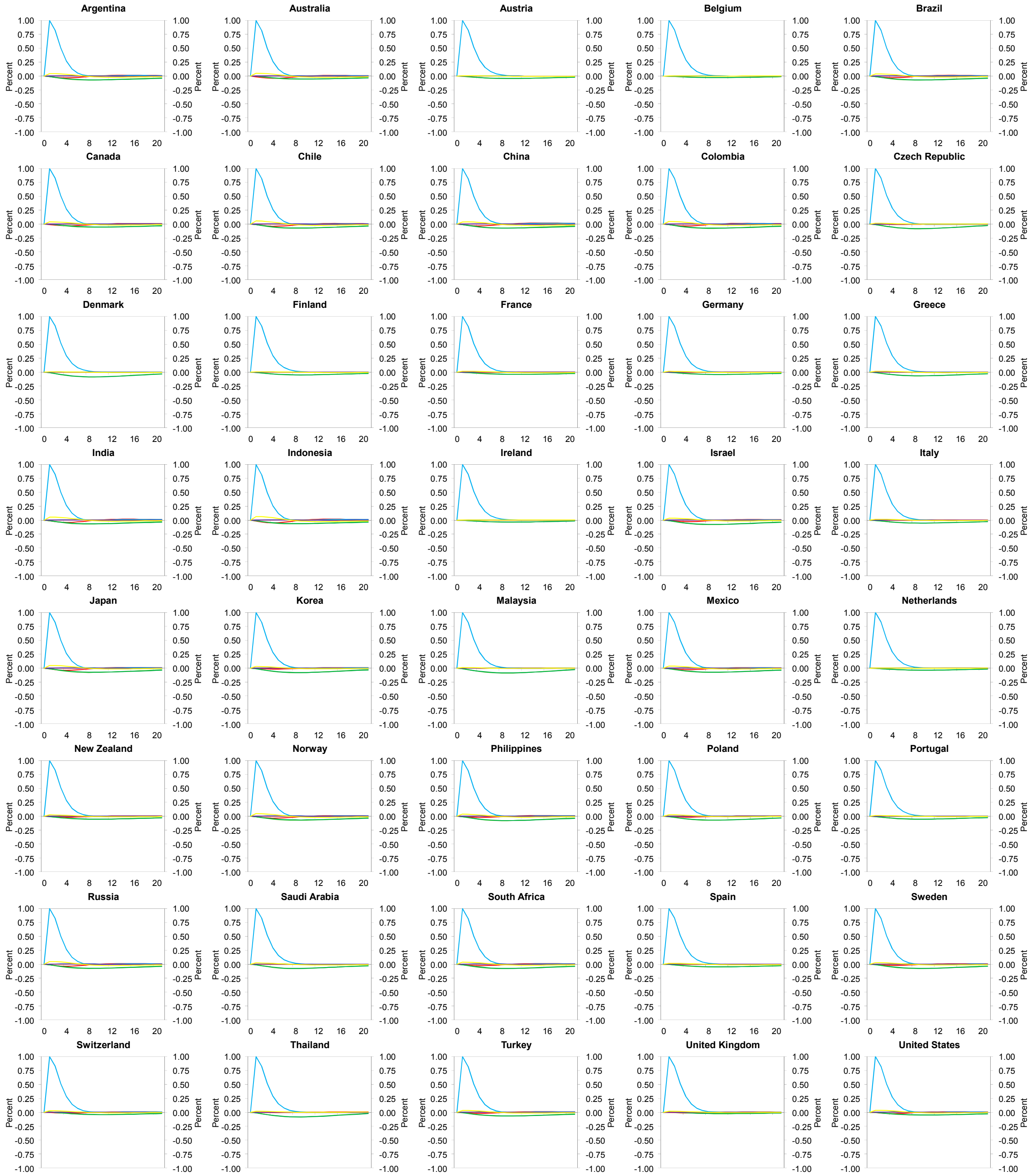
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic fiscal revenue shocks which raise the primary fiscal balance ratio by one percentage point. All variables are annualized, where applicable.

Figure 21. IRFs of Macro Variables to a Domestic Lending Rate Markup Shock



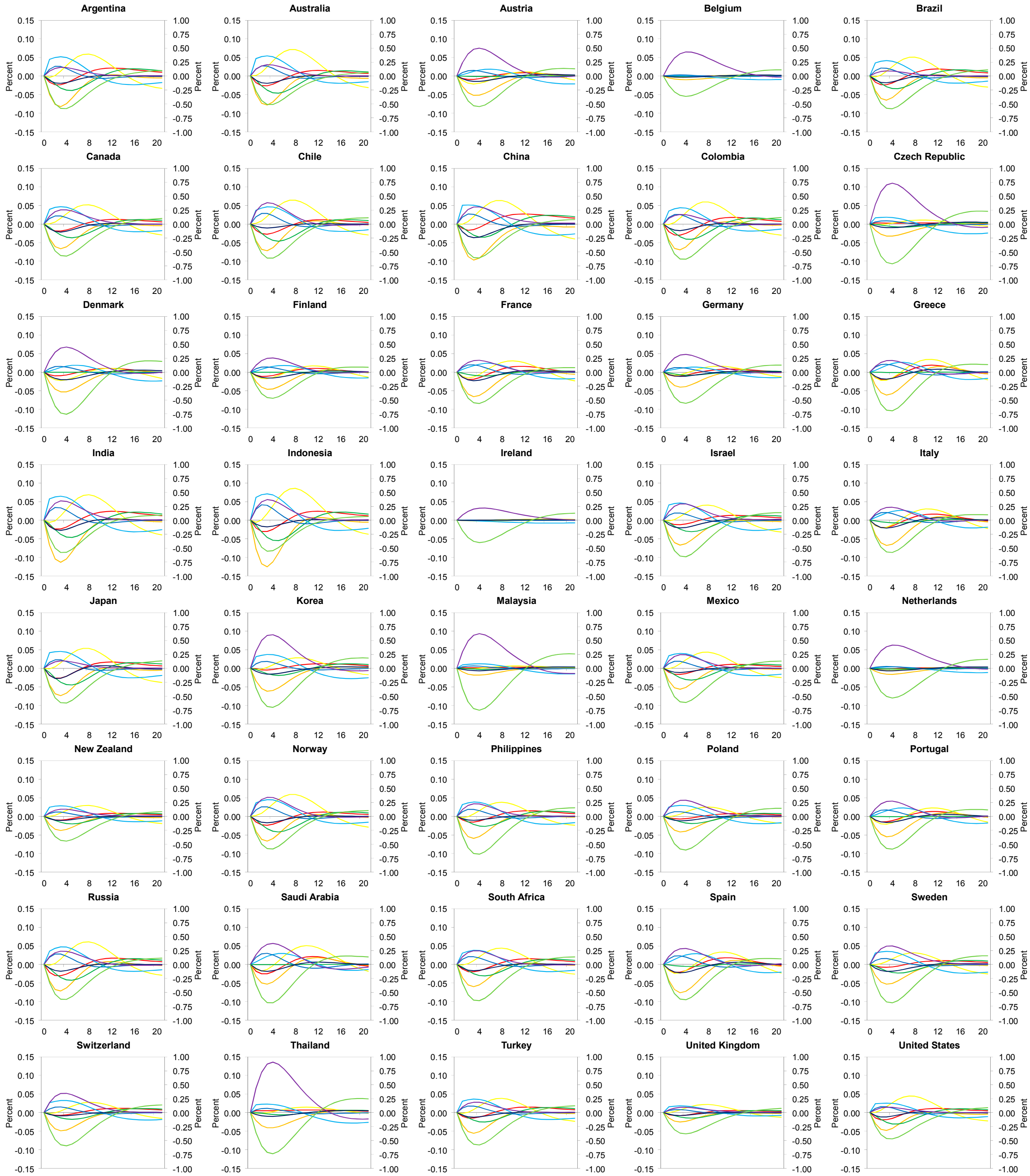
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic lending rate markup shocks which raise the nominal bank lending rate by one percentage point. All variables are annualized, where applicable.

Figure 22. IRFs of Financial Variables to a Domestic Lending Rate Markup Shock



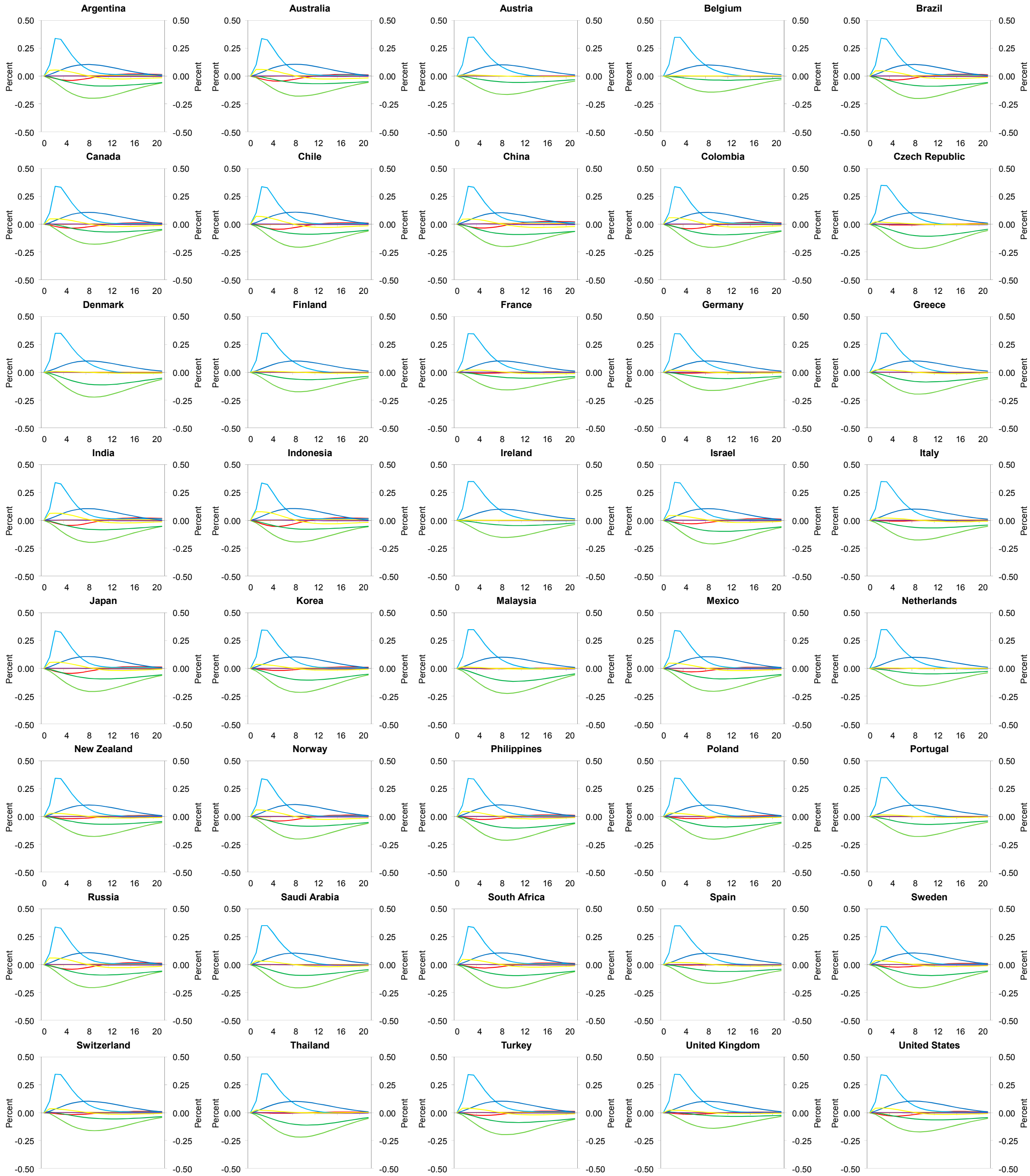
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic lending rate markup shocks which raise the nominal bank lending rate by one percentage point. All variables are annualized, where applicable.

Figure 23. IRFs of Macro Variables to a Domestic Capital Requirement Shock



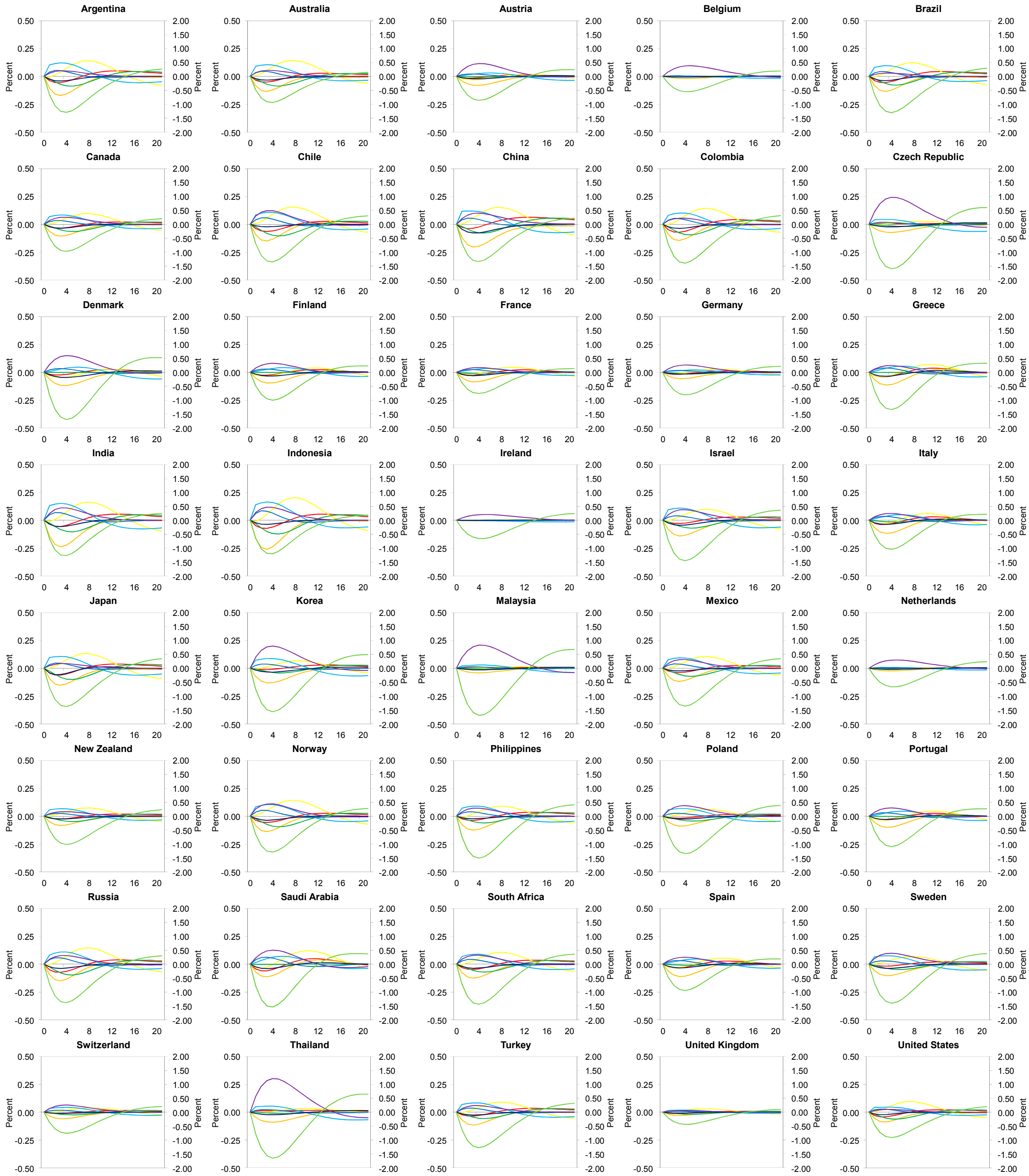
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic capital requirement shocks which raise the regulatory bank capital ratio by one percentage point. All variables are annualized, where applicable.

Figure 24. IRFs of Financial Variables to a Domestic Capital Requirement Shock



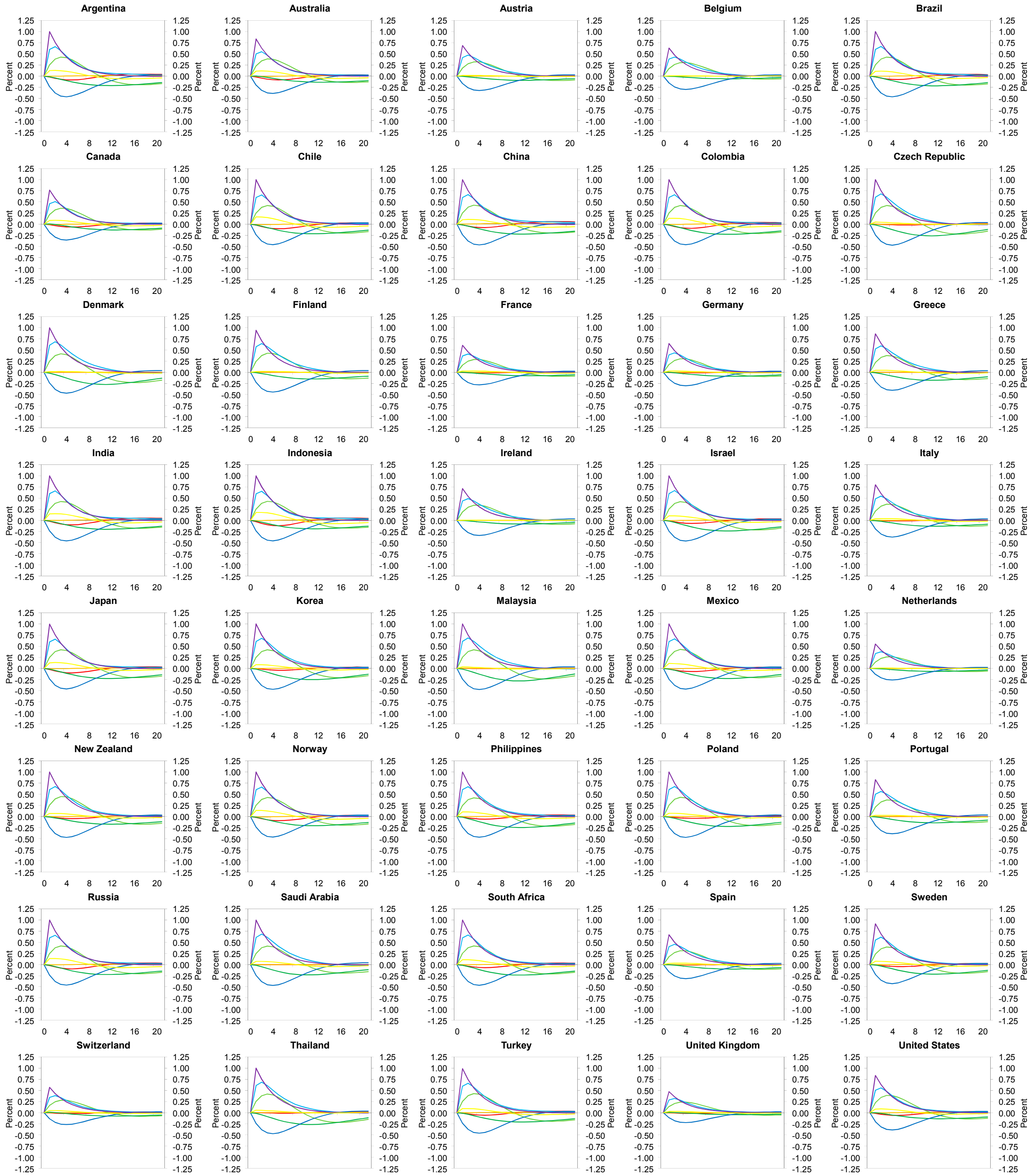
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic capital requirement shocks which raise the regulatory bank capital ratio by one percentage point. All variables are annualized, where applicable.

Figure 25. IRFs of Macro Variables to a Domestic Loan Default Shock



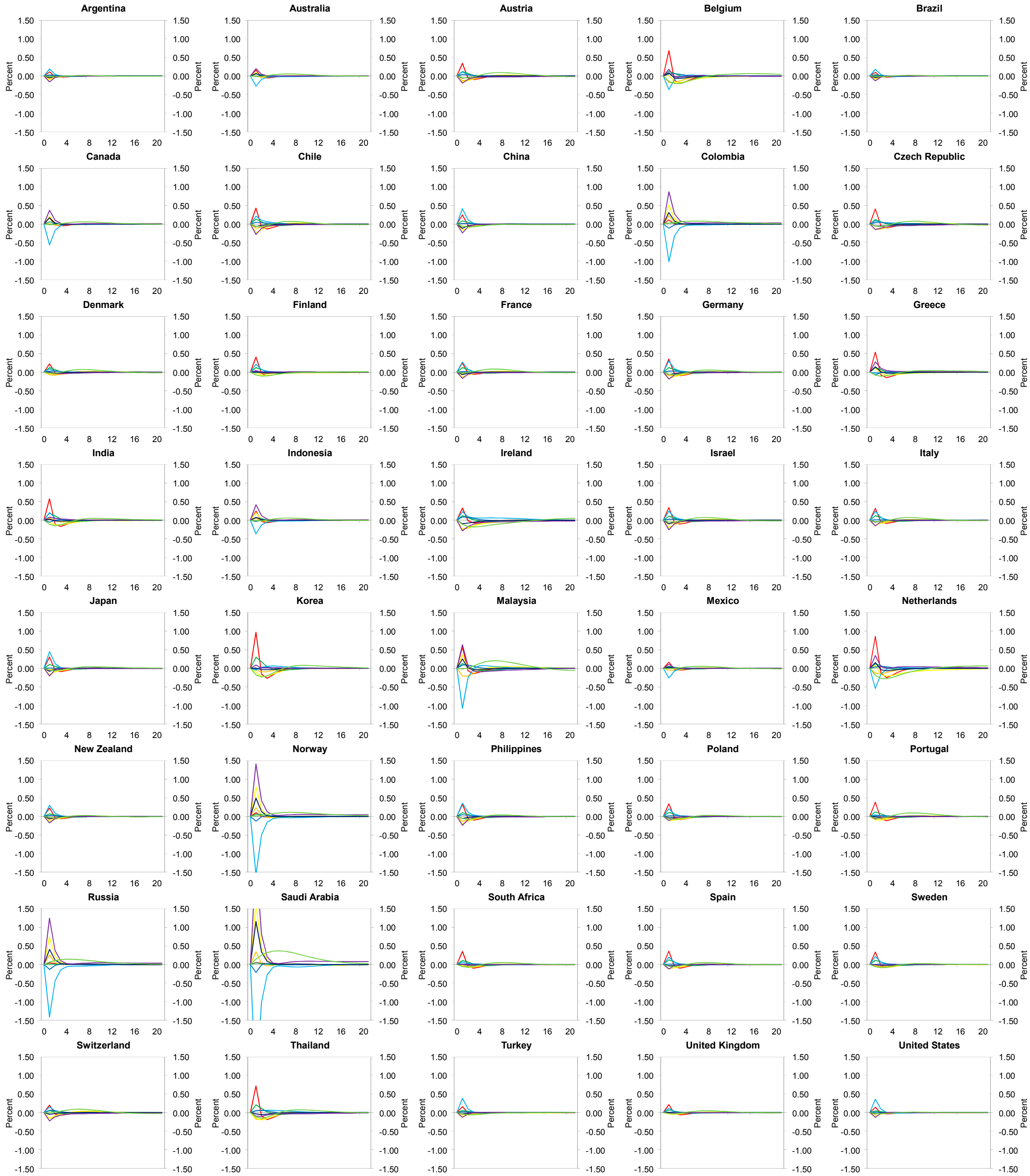
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to domestic loan default shocks which raise the loan default rate by one percentage point. All variables are annualized, where applicable.

Figure 26. IRFs of Financial Variables to a Domestic Loan Default Shock



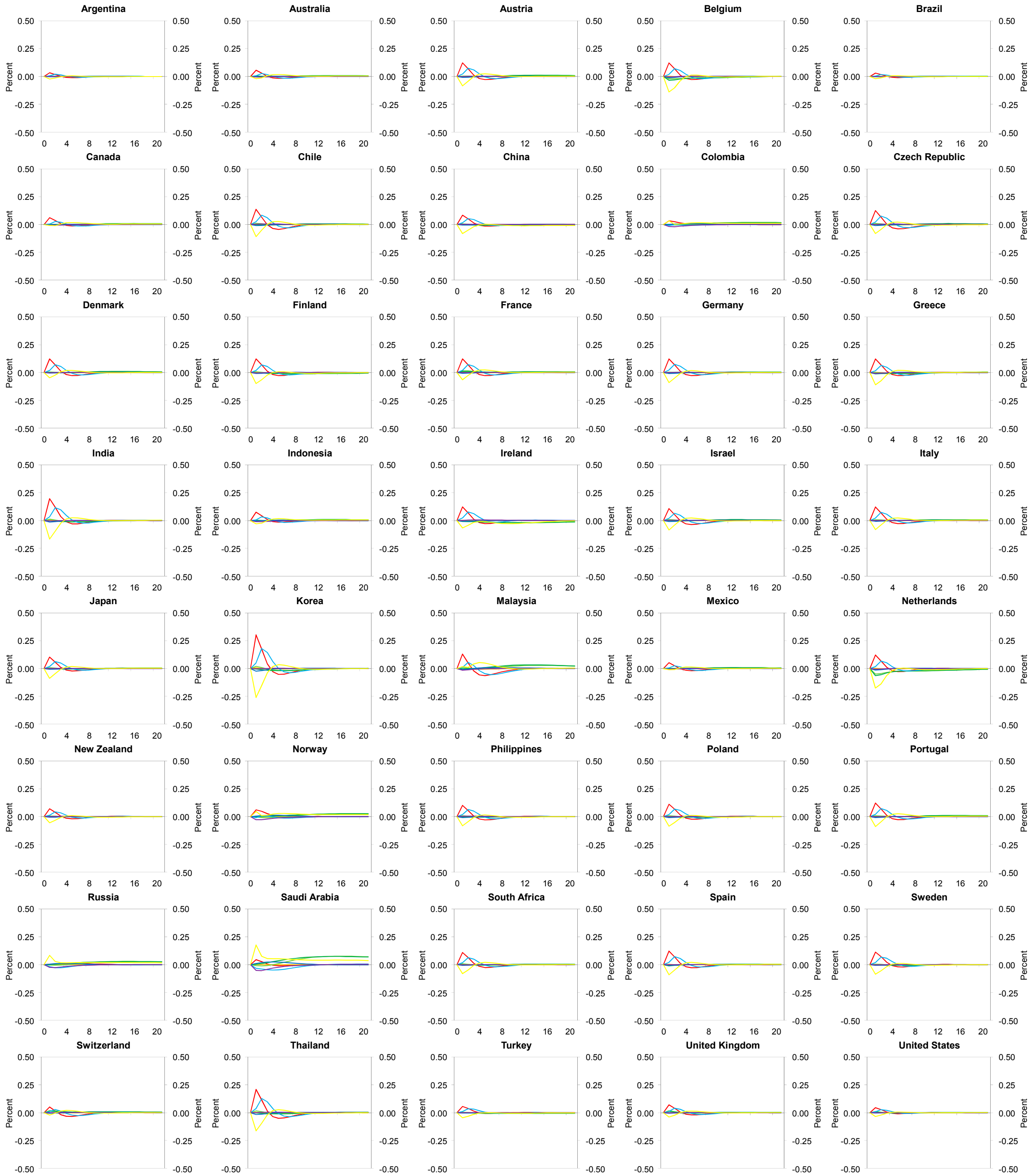
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to domestic loan default shocks which raise the loan default rate by one percentage point. All variables are annualized, where applicable.

Figure 27. IRFs of Macro Variables to an Energy Commodity Price Markup Shock



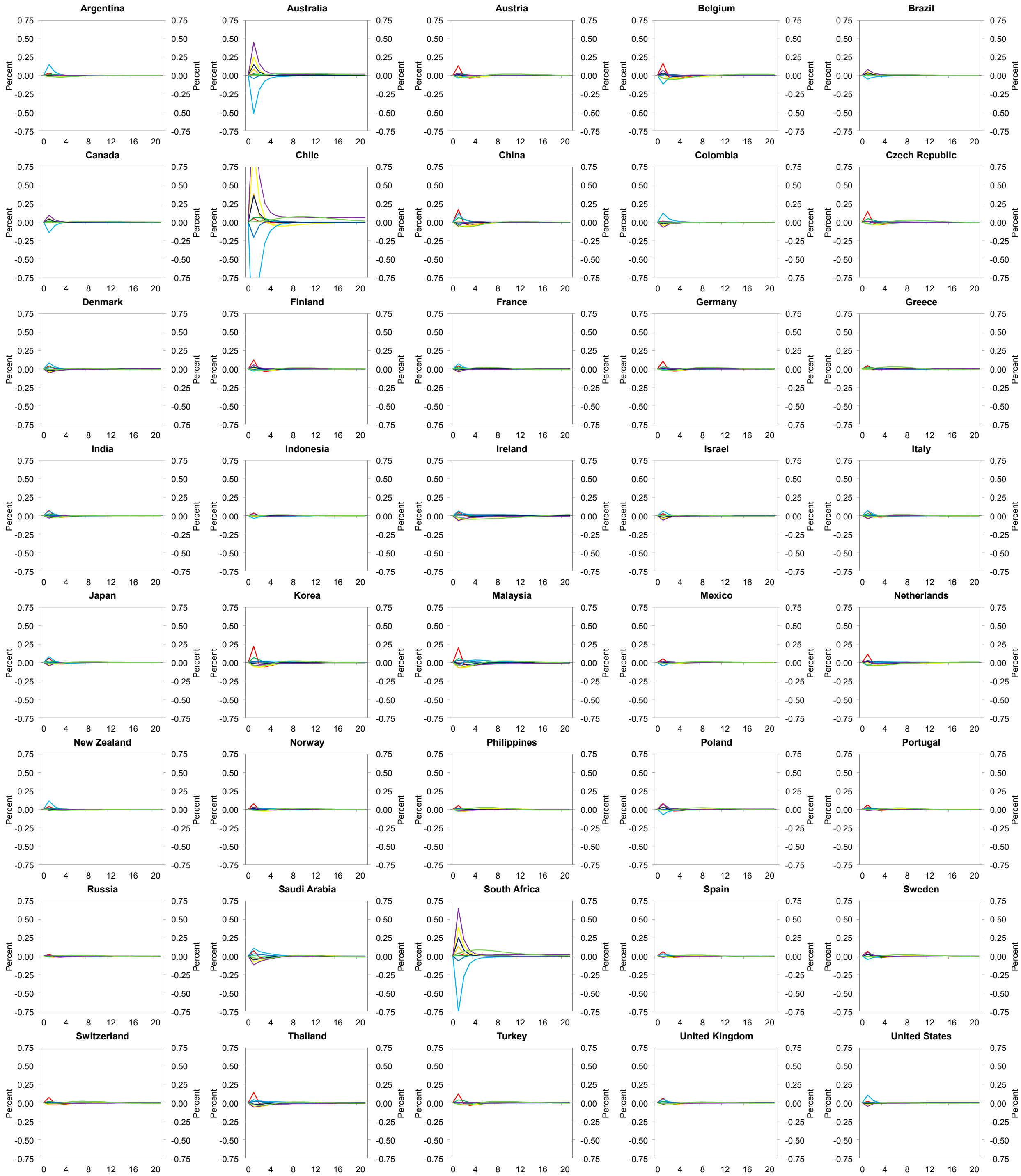
Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to a world energy commodity price markup shock which raises the price of energy commodities by ten percent. All variables are annualized, where applicable.

Figure 28. IRFs of Financial Variables to an Energy Commodity Price Markup Shock



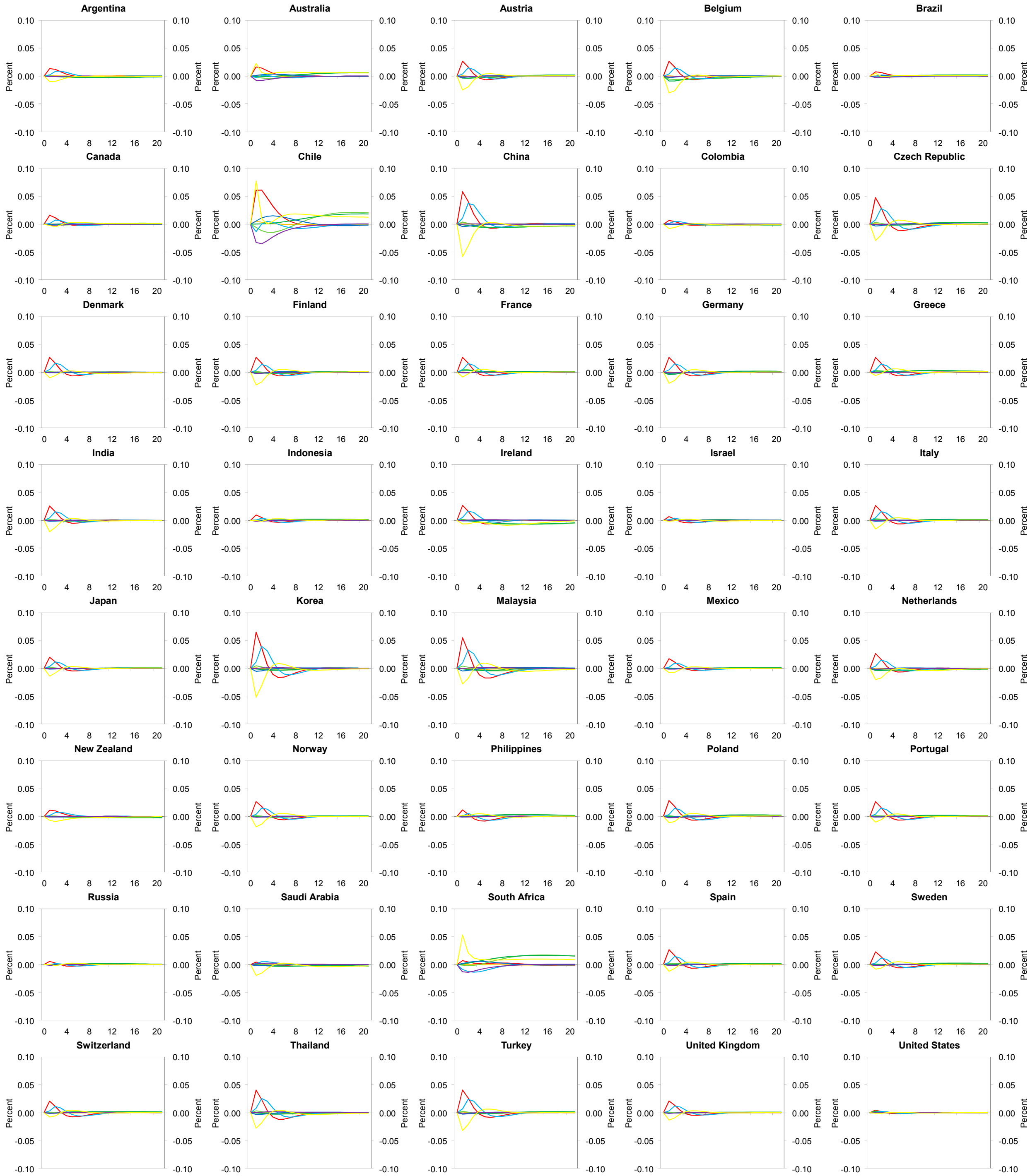
Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to a world energy commodity price markup shock which raises the price of energy commodities by ten percent. All variables are annualized, where applicable.

Figure 29. IRFs of Macro Variables to a Nonenergy Commodity Price Markup Shock



Note: Depicts the impulse responses of consumption price inflation ■ (lhs), output ■ (lhs), private consumption ■ (lhs), private investment ■ (rhs), the nominal policy interest rate ■ (lhs), the real effective exchange rate ■ (lhs), the unemployment rate ■ (lhs), the fiscal balance ratio ■ (lhs), and the current account balance ratio ■ (lhs) to a world nonenergy commodity price markup shock which raises the price of nonenergy commodities by ten percent. All variables are annualized, where applicable.

Figure 30. IRFs of Financial Variables to a Nonenergy Commodity Price Markup Shock

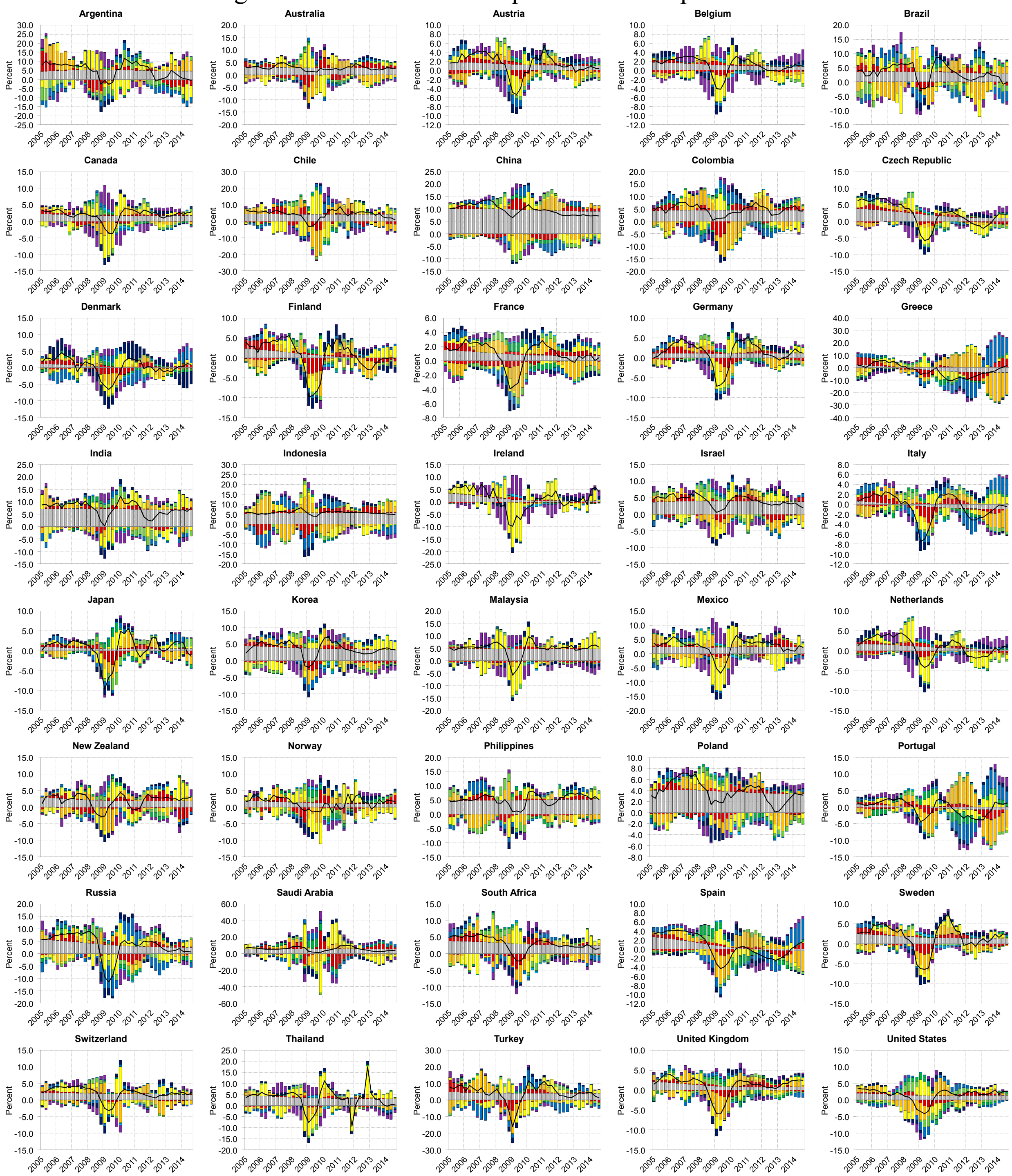


Note: Depicts the impulse responses of the short term nominal market interest rate ■ (lhs), the long term nominal market interest rate ■ (lhs), the relative price of equity ■ (rhs), the real money stock ■ (lhs), real bank credit ■ (lhs), the nominal bank lending rate ■ (lhs), the bank capital ratio ■ (lhs), and the credit loss rate ■ (lhs) to a world nonenergy commodity price markup shock which raises the price of nonenergy commodities by ten percent. All variables are annualized, where applicable.

Figure 31. Historical Decompositions of Consumption Price Inflation

Note: Decomposes observed consumption price inflation ■ as measured by the seasonal logarithmic difference of the price of consumption into the sum of a trend component ■ and contributions from domestic supply ■, foreign supply ■, domestic demand ■, foreign demand ■, world monetary policy ■, domestic fiscal policy ■, foreign fiscal policy ■, domestic financial ■, foreign financial ■, and world terms of trade ■ shocks.

Figure 32. Historical Decompositions of Output Growth

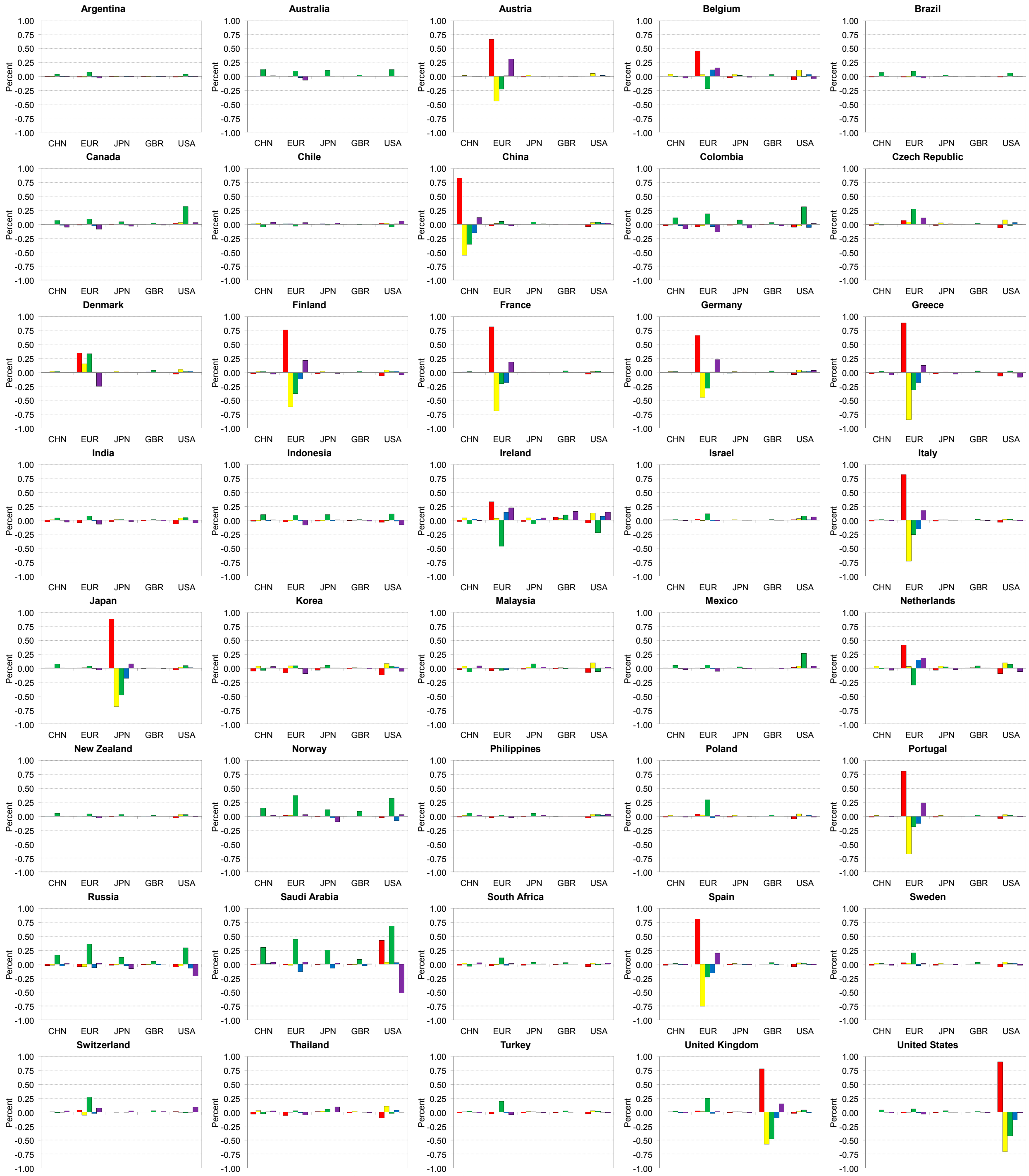


Note: Decomposes observed output growth ■ as measured by the seasonal logarithmic difference of output into the sum of a trend component ■ and contributions from domestic supply ■, foreign supply ■, domestic demand ■, foreign demand ■, world monetary policy ■, domestic fiscal policy ■, foreign fiscal policy ■, domestic financial ■, foreign financial ■, and world terms of trade ■ shocks.

Figure 33. Simulated Conditional Betas of Output

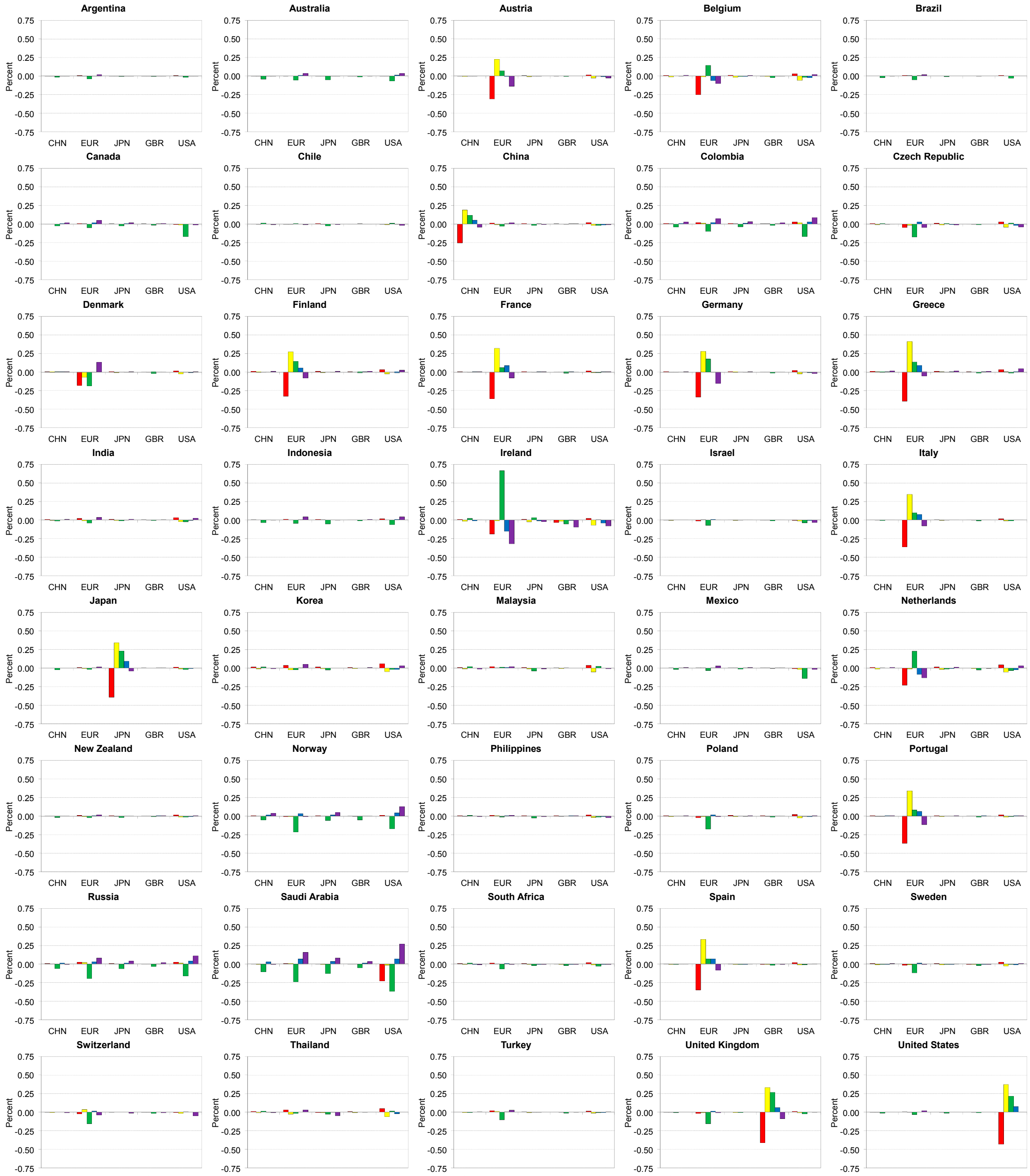
Note: Depicts the betas of output with respect to contemporaneous output in systemic economies conditional on selected macroeconomic and financial shocks ■, selected macroeconomic shocks ■, and selected financial shocks ■ in each of these systemic economies. These betas are calculated with a Monte Carlo simulation with 999 replications for $2T$ periods, discarding the first T simulated observations to eliminate dependence on initial conditions, where T denotes the observed sample size.

Figure 34. Peak IRFs to Foreign Productivity Shocks



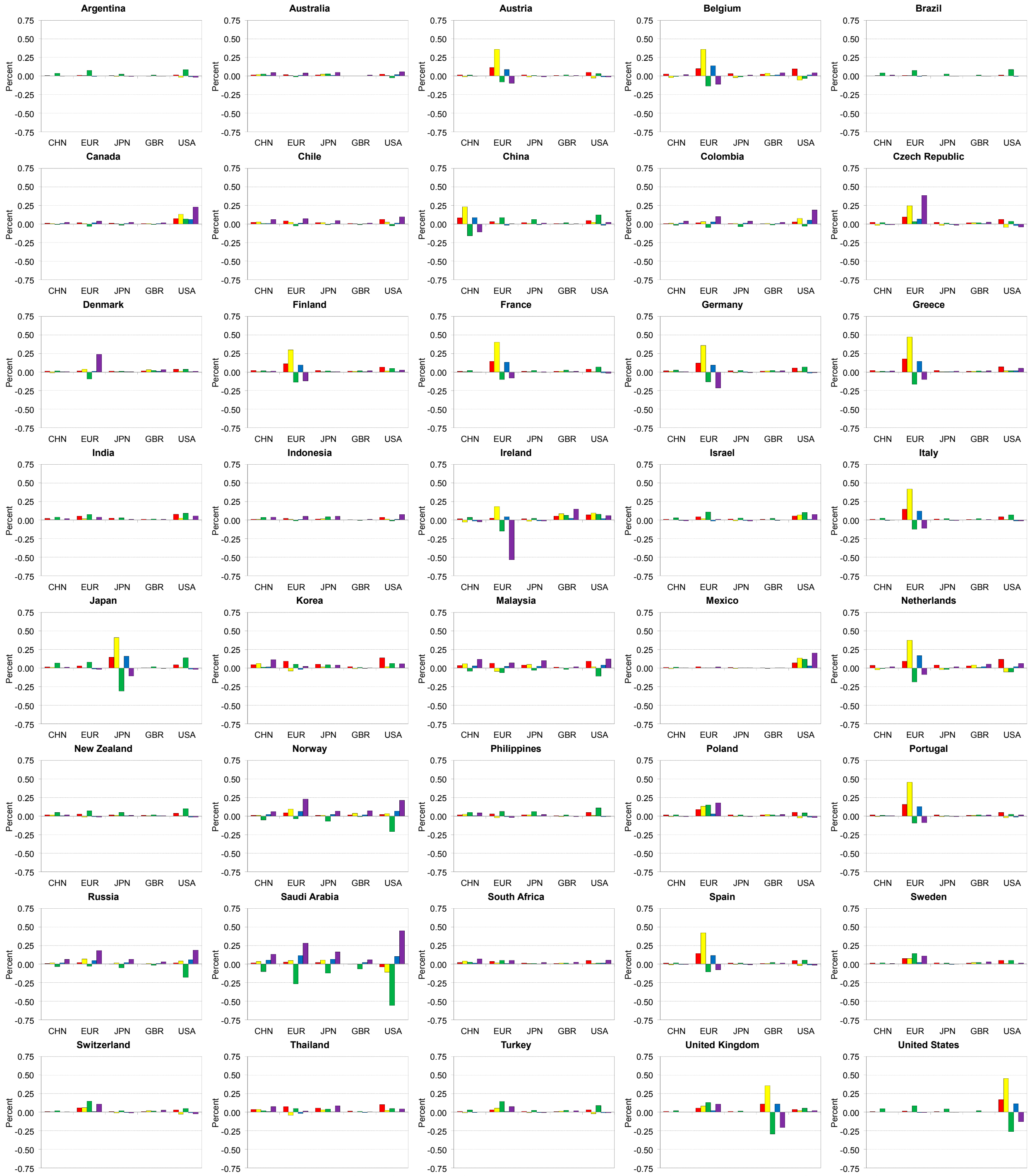
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to productivity shocks in systemic economies which raise their output price inflation by one percentage point. All variables are annualized, where applicable.

Figure 35. Peak IRFs to Foreign Labor Supply Shocks



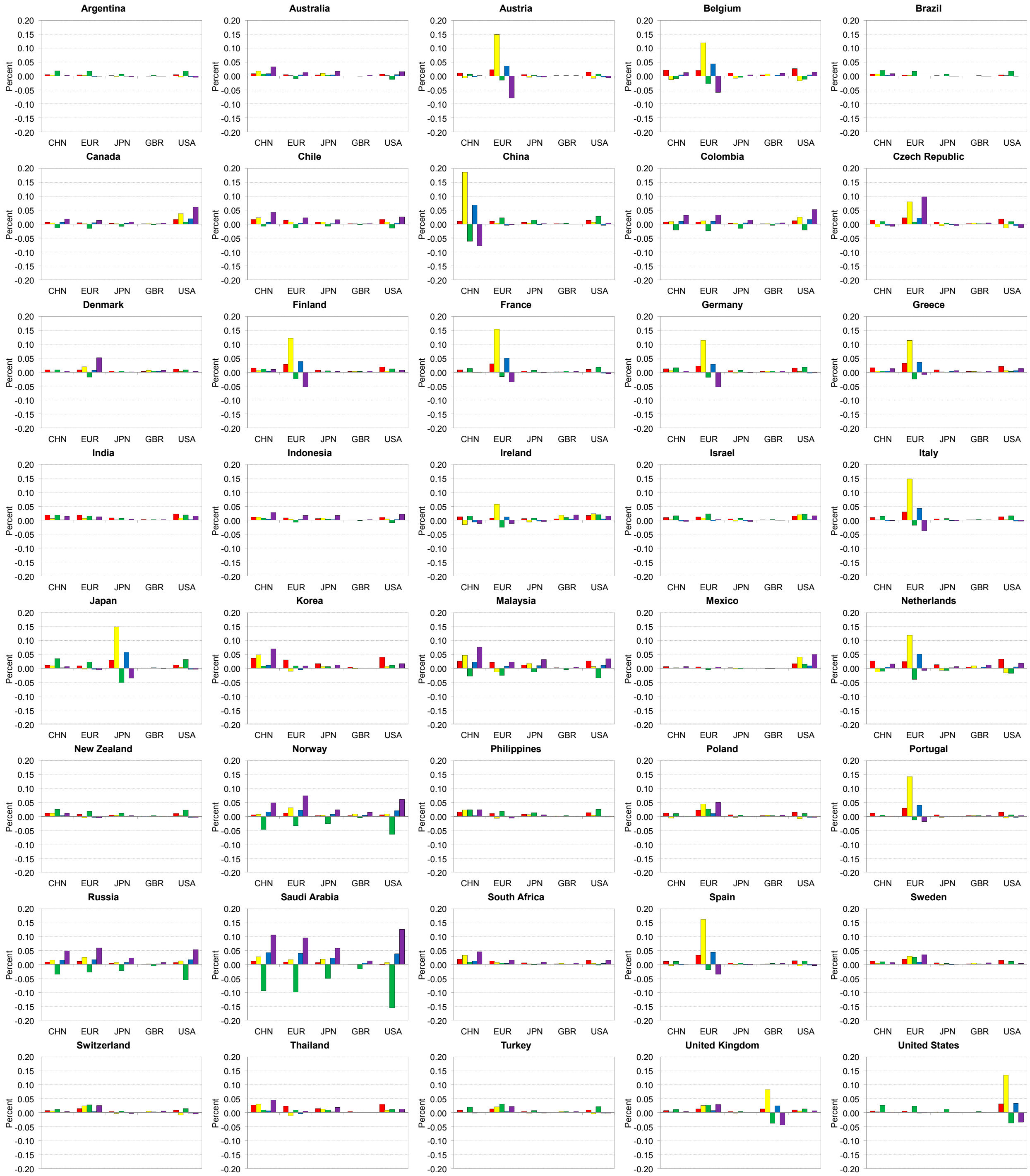
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to labor supply shocks in systemic economies which raise their labor force by one percent. All variables are annualized, where applicable.

Figure 36. Peak IRFs to Foreign Consumption Demand Shocks



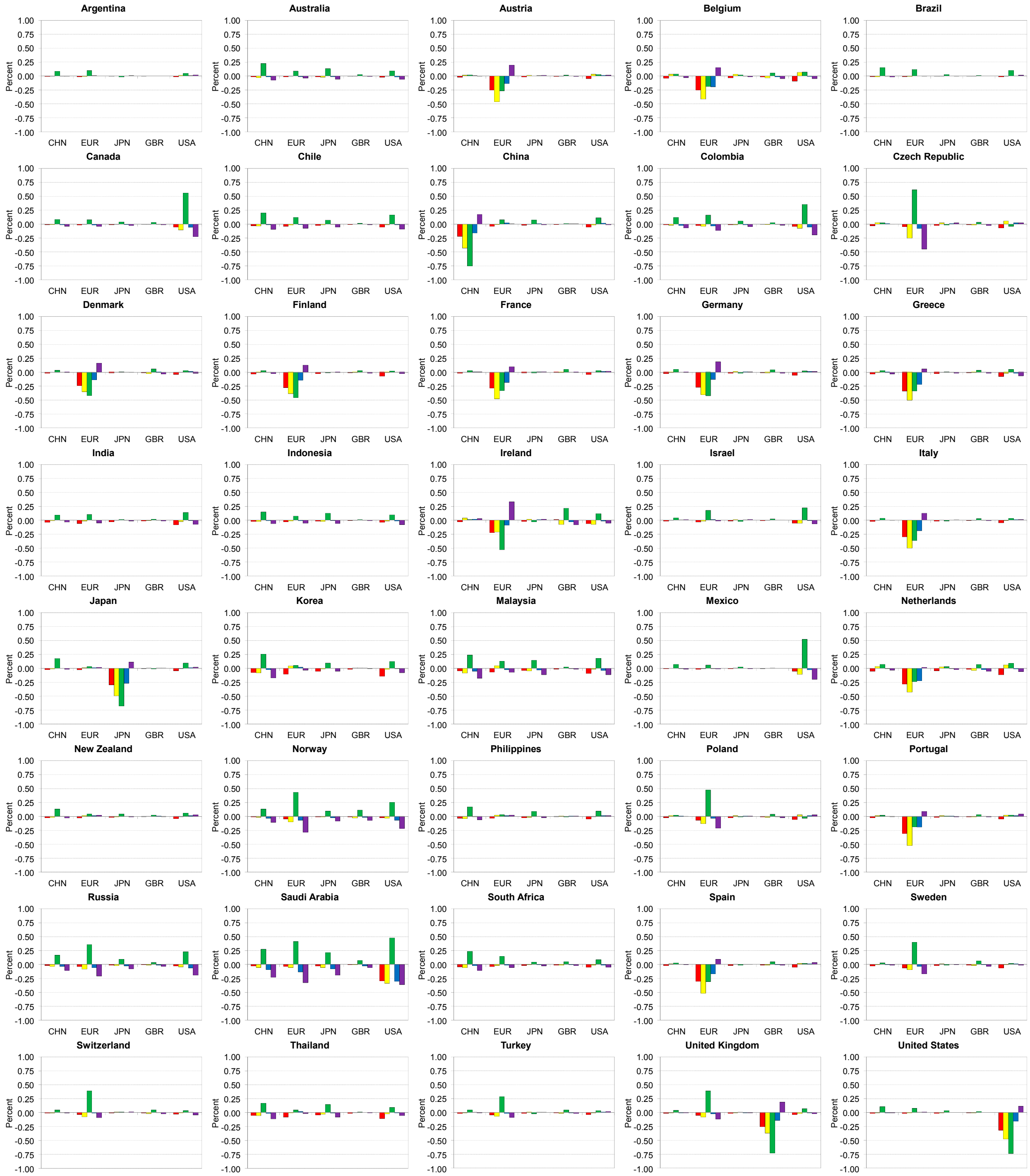
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to consumption demand shocks in systemic economies which raise their private consumption by one percent. All variables are annualized, where applicable.

Figure 37. Peak IRFs to Foreign Investment Demand Shocks



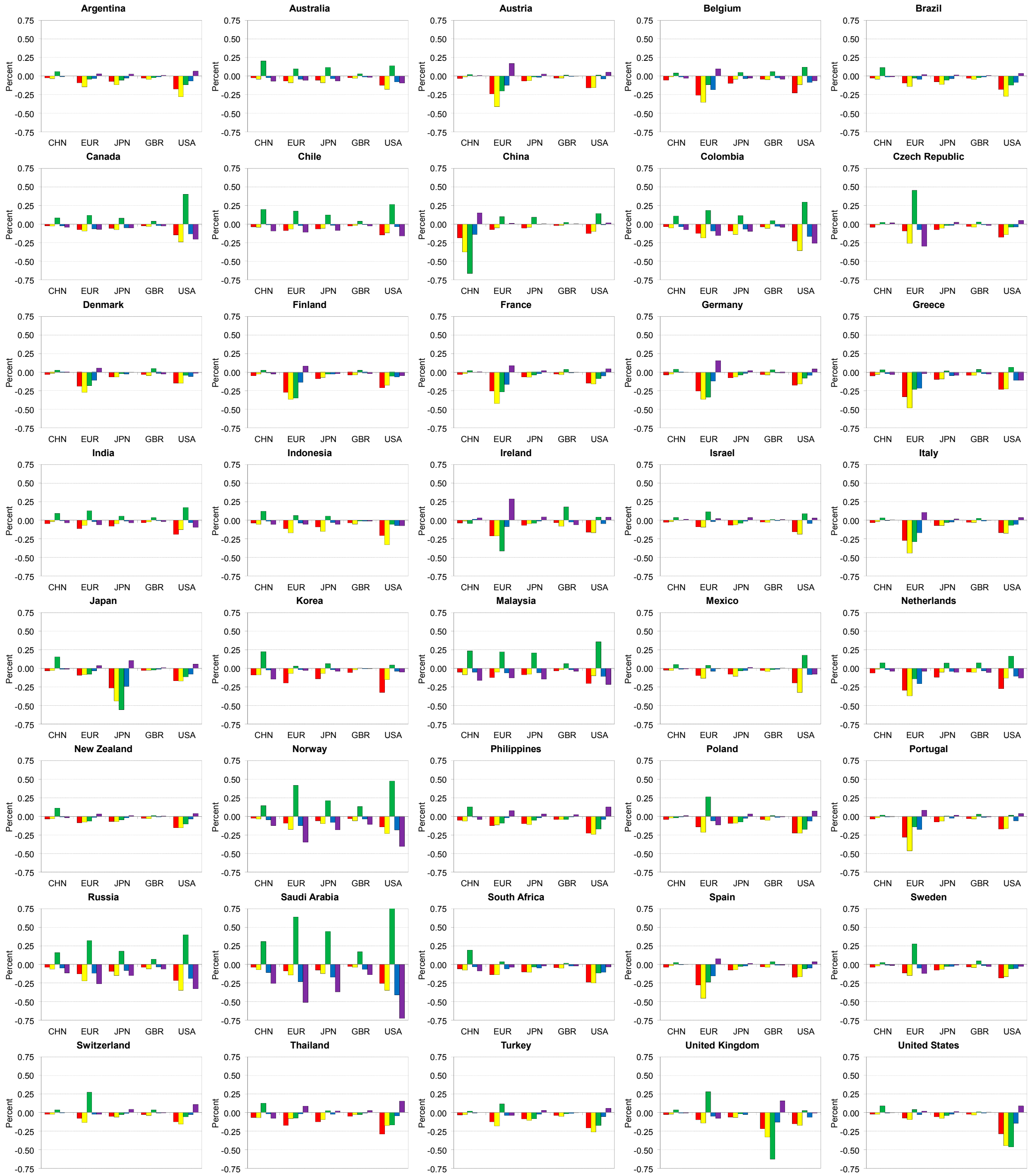
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to investment demand shocks in systemic economies which raise their private investment by one percent. All variables are annualized, where applicable.

Figure 38. Peak IRFs to Foreign Monetary Policy Shocks



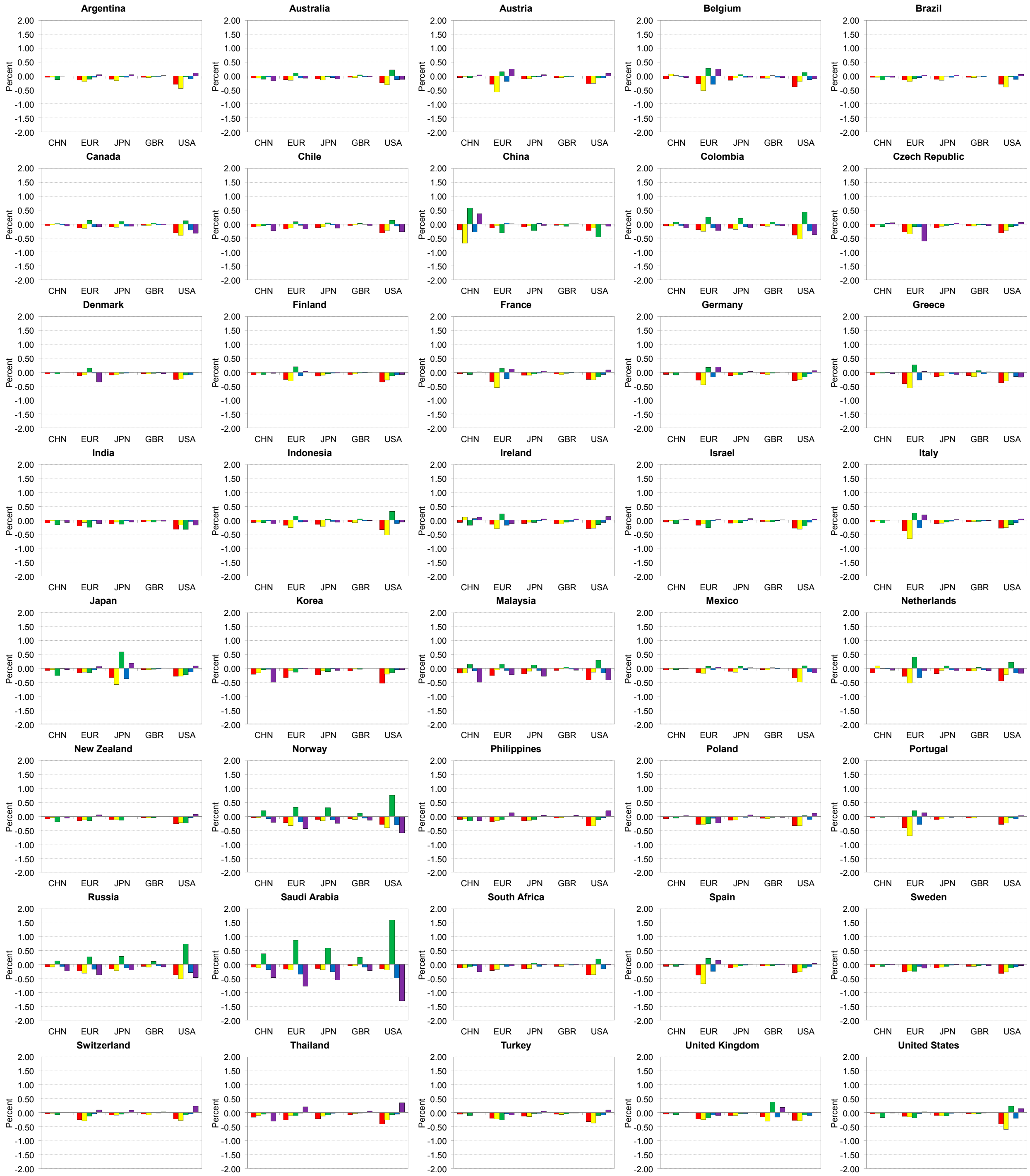
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to monetary policy shocks in systemic economies which raise their nominal policy interest rate by one percentage point. All variables are annualized, where applicable.

Figure 39. Peak IRFs to Foreign Credit Risk Premium Shocks



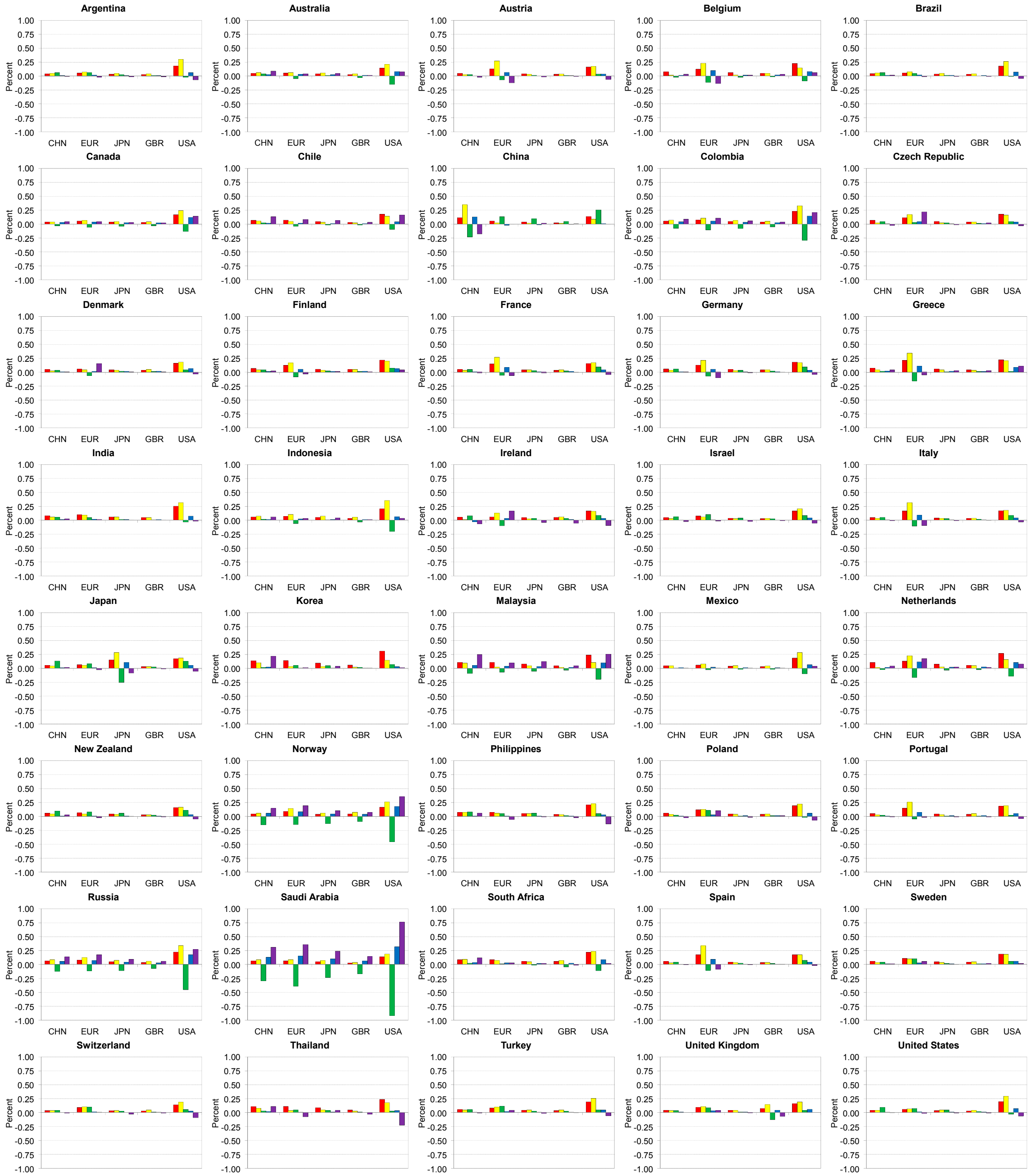
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to credit risk premium shocks in systemic economies which raise their short term nominal market interest rate by one percentage point. All variables are annualized, where applicable.

Figure 40. Peak IRFs to Foreign Duration Risk Premium Shocks



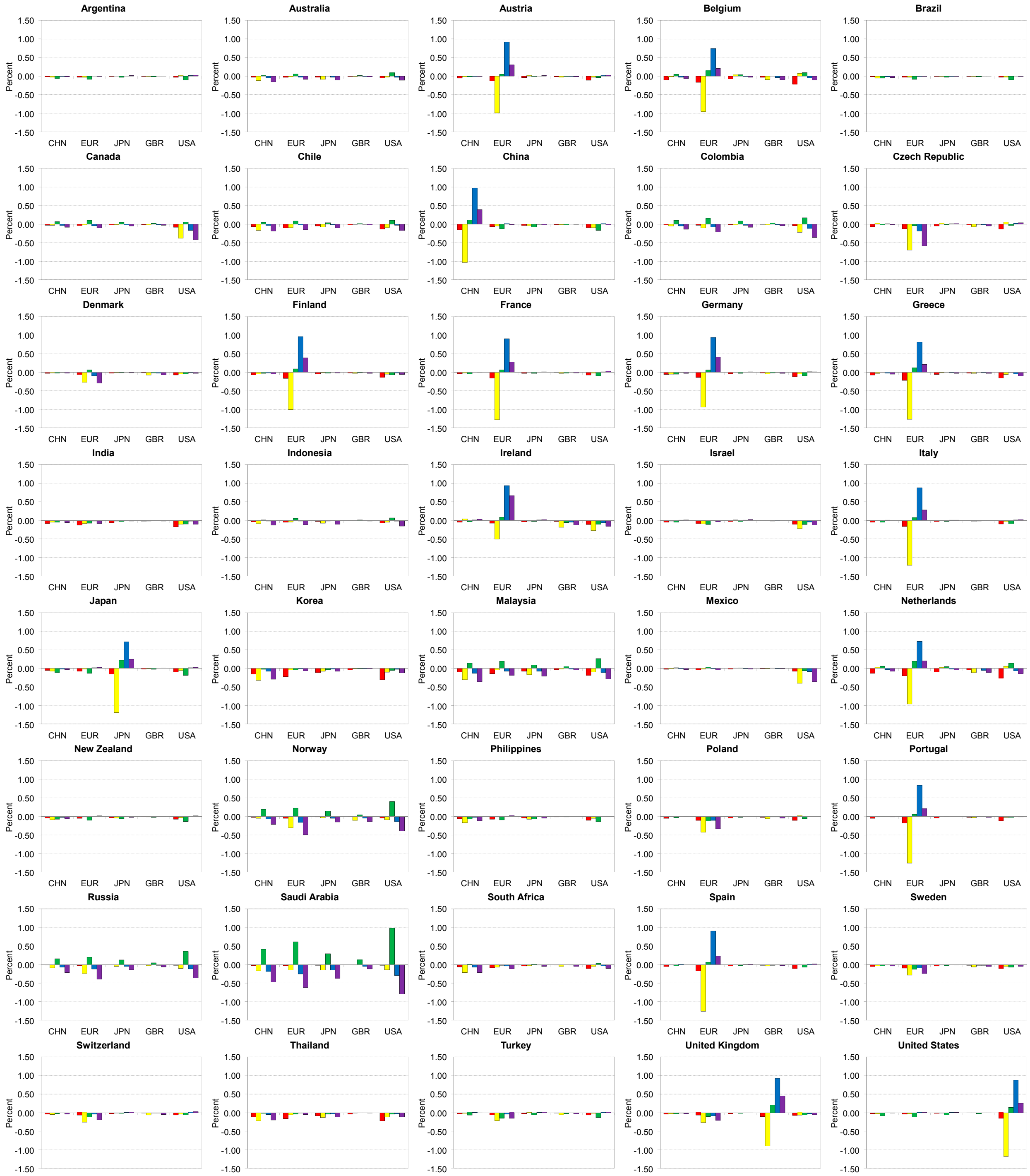
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to duration risk premium shocks in systemic economies which raise their long term nominal market interest rate by one percentage point. All variables are annualized, where applicable.

Figure 41. Peak IRFs to Foreign Equity Risk Premium Shocks



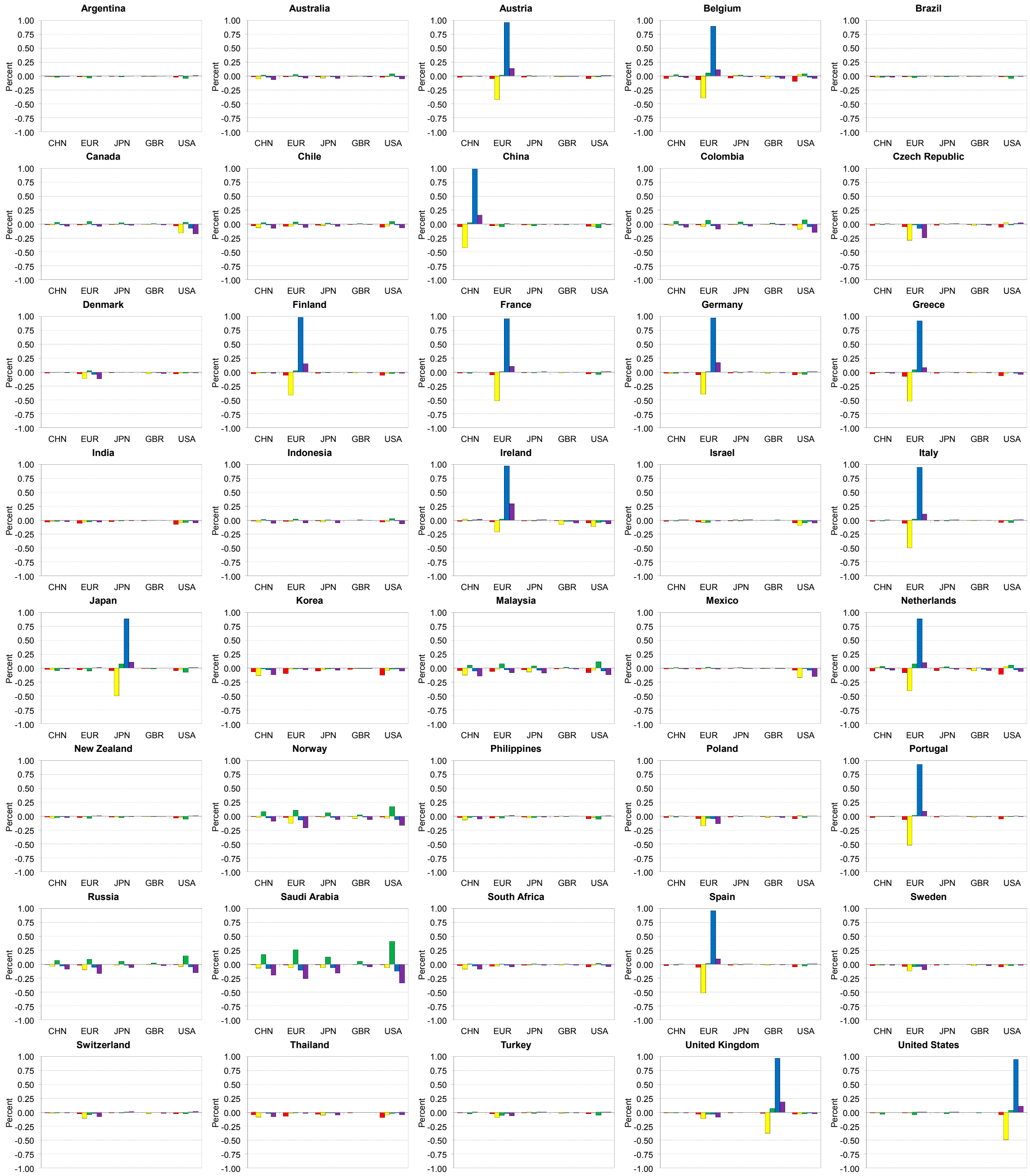
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to equity risk premium shocks in systemic economies which raise their price of equity by ten percent. All variables are annualized, where applicable.

Figure 42. Peak IRFs to Foreign Fiscal Expenditure Shocks



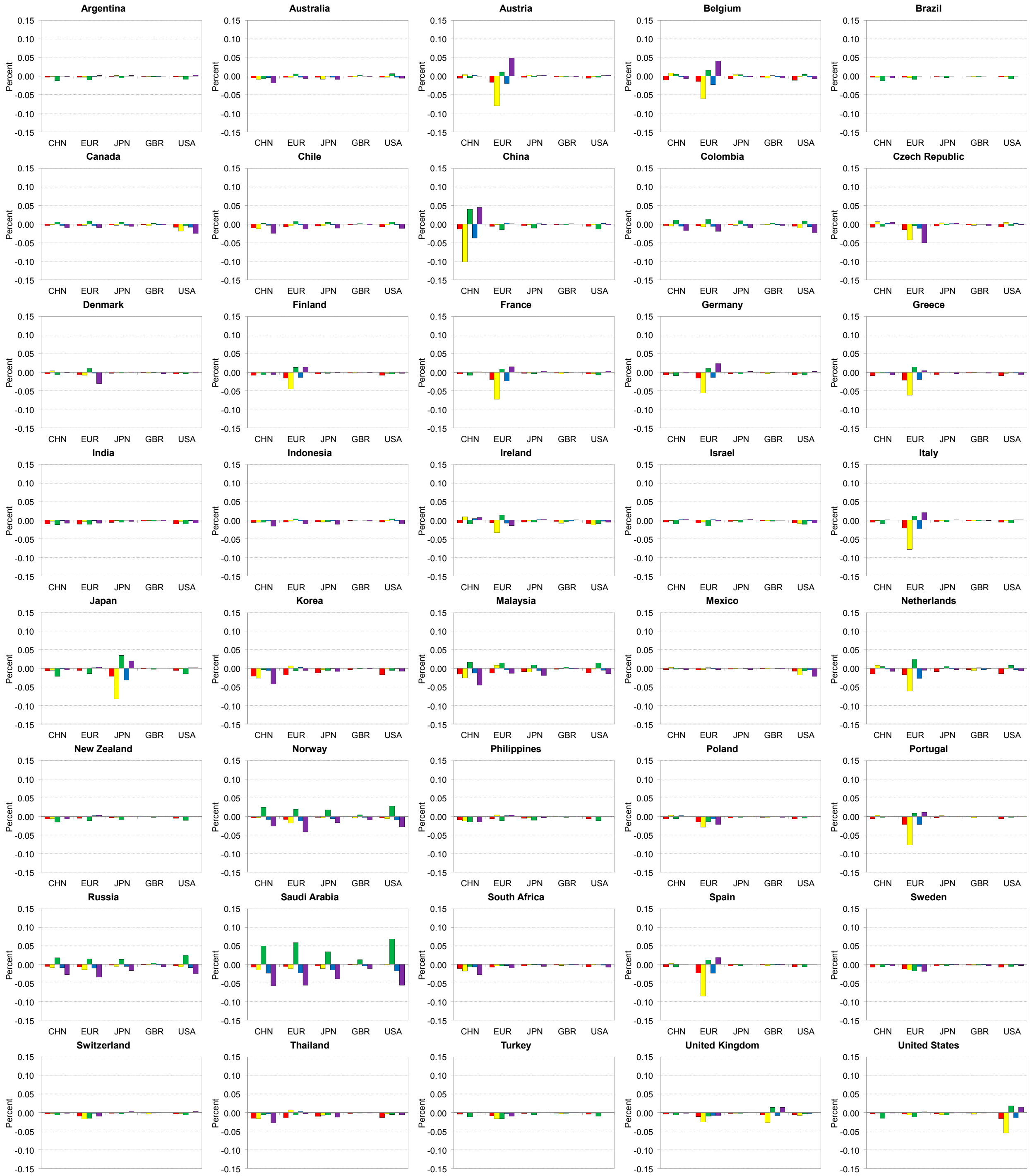
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to fiscal expenditure shocks in systemic economies which raise their primary fiscal balance ratio by one percentage point. All variables are annualized, where applicable.

Figure 43. Peak IRFs to Foreign Fiscal Revenue Shocks



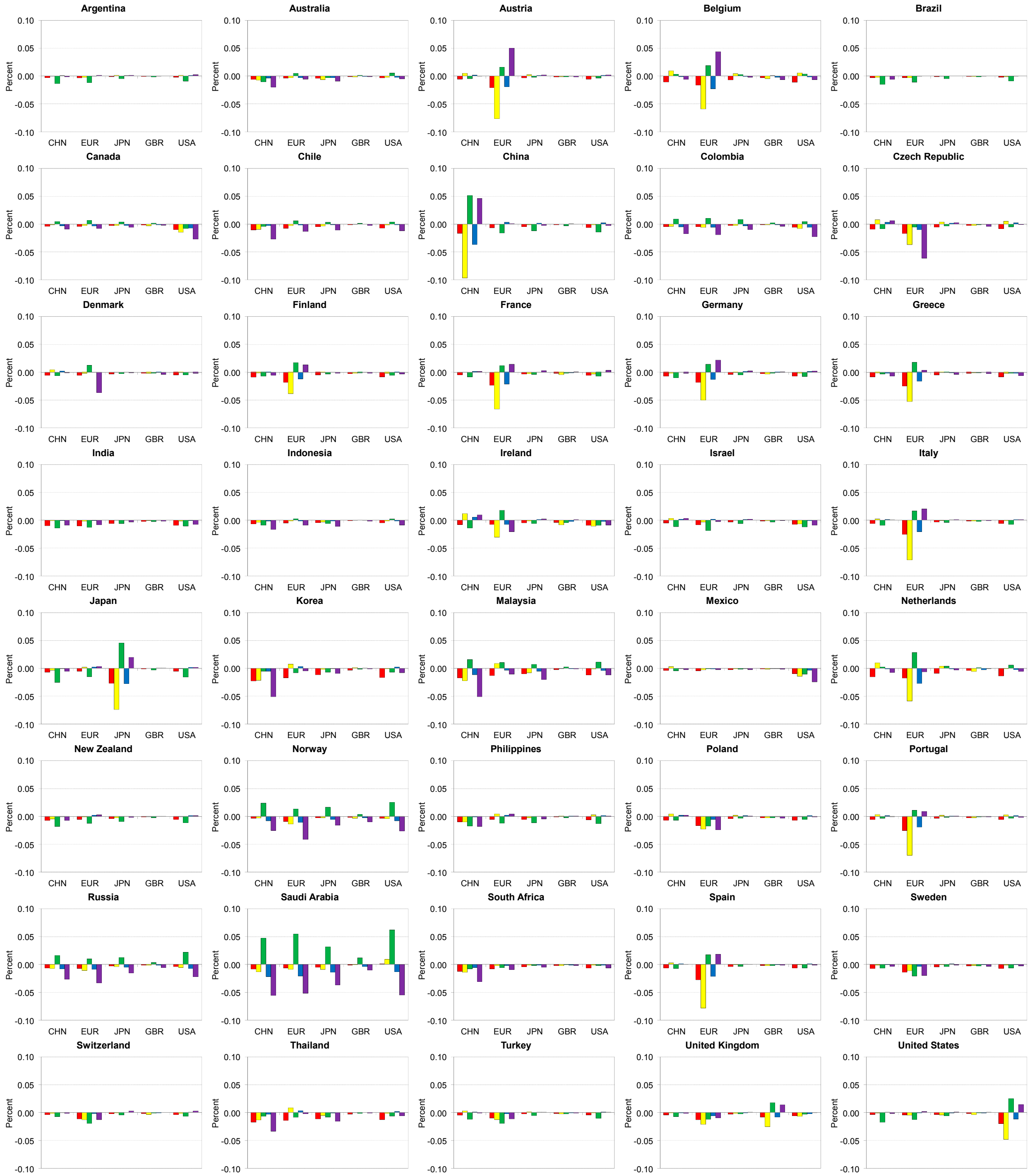
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to fiscal revenue shocks in systemic economies which raise their primary fiscal balance ratio by one percentage point. All variables are annualized, where applicable.

Figure 44. Peak IRFs to Foreign Lending Rate Markup Shocks



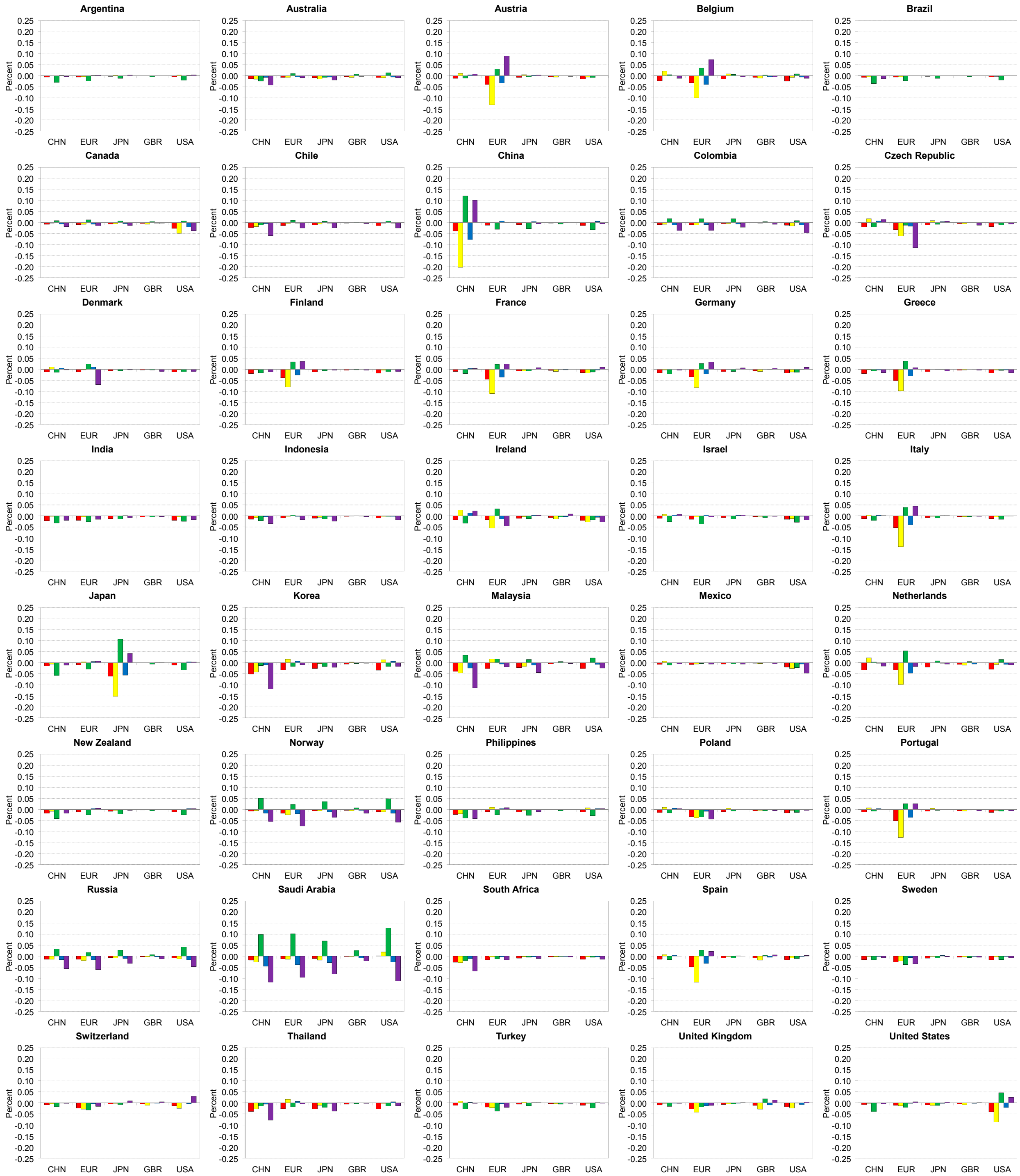
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to lending rate markup shocks in systemic economies which raise their nominal bank lending rate by one percentage point. All variables are annualized, where applicable.

Figure 45. Peak IRFs to Foreign Capital Requirement Shocks



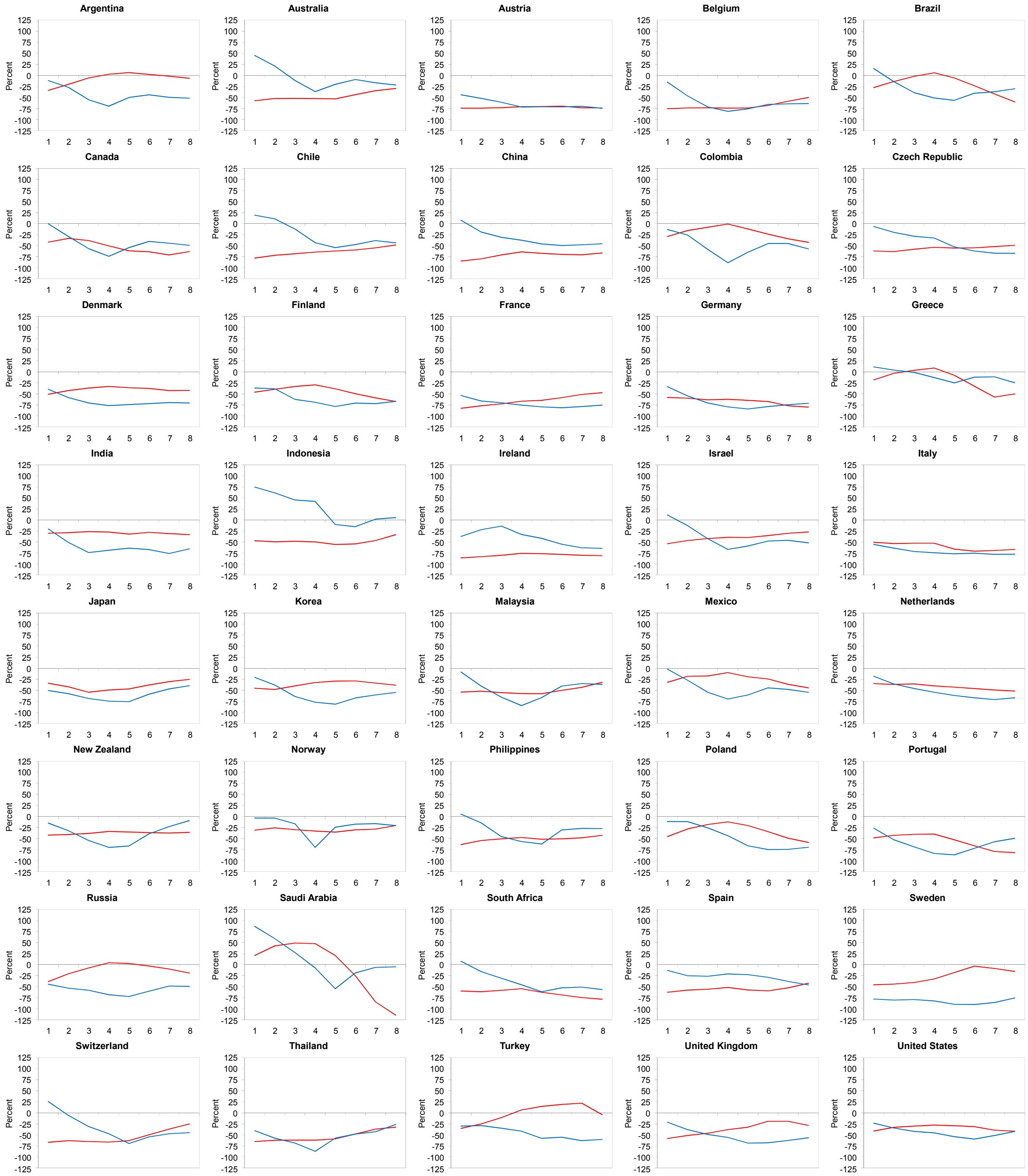
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to capital requirement shocks in systemic economies which raise their regulatory bank capital ratio by one percentage point. All variables are annualized, where applicable.

Figure 46. Peak IRFs to Foreign Loan Default Shocks



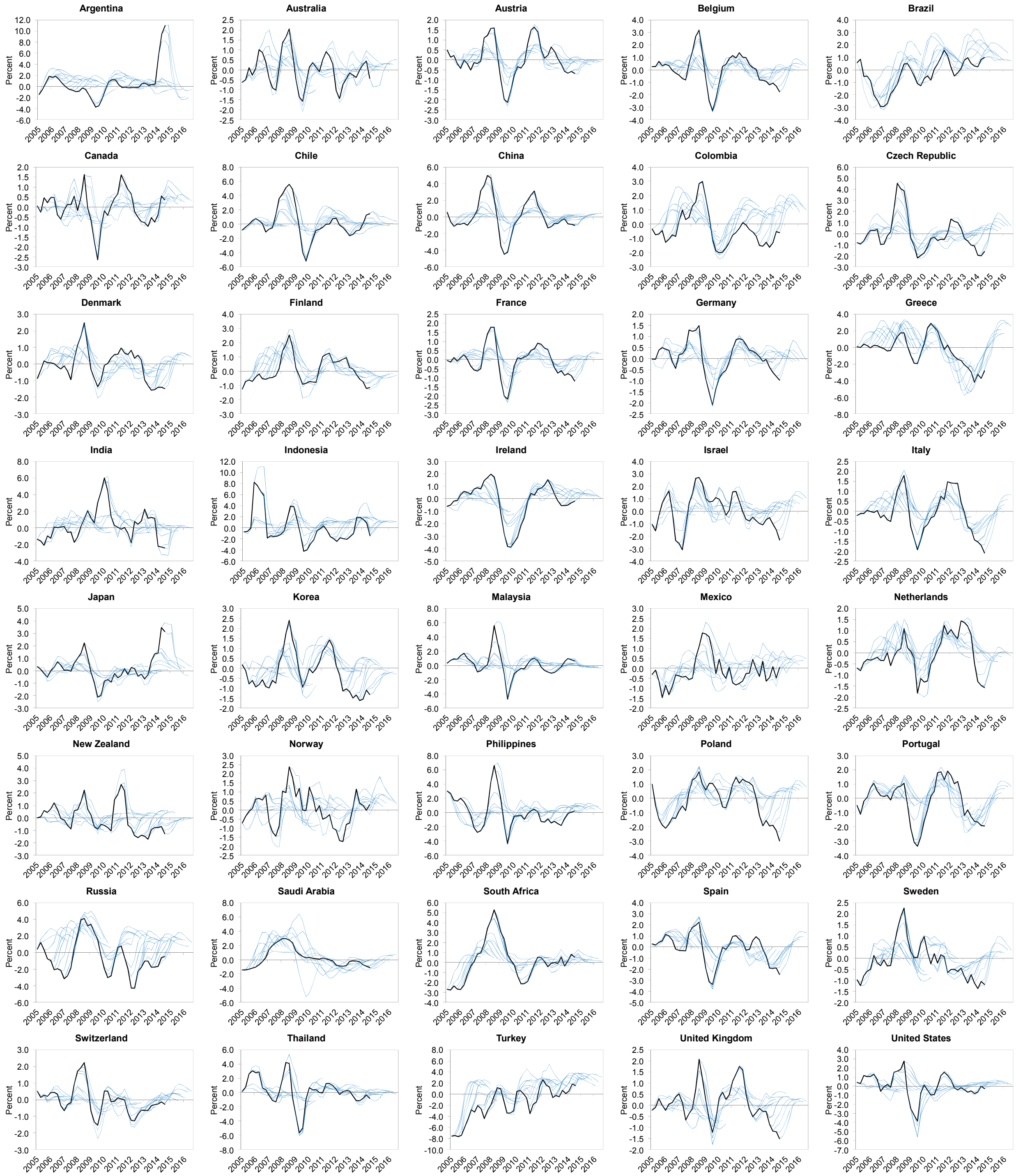
Note: Depicts the peak impulse responses of consumption price inflation ■, output ■, the real effective exchange rate ■, the fiscal balance ratio ■, and the current account balance ratio ■ to loan default shocks in systemic economies which raise their loan default rate by one percentage point. All variables are annualized, where applicable.

Figure 47. Forecast Performance Evaluation Statistics



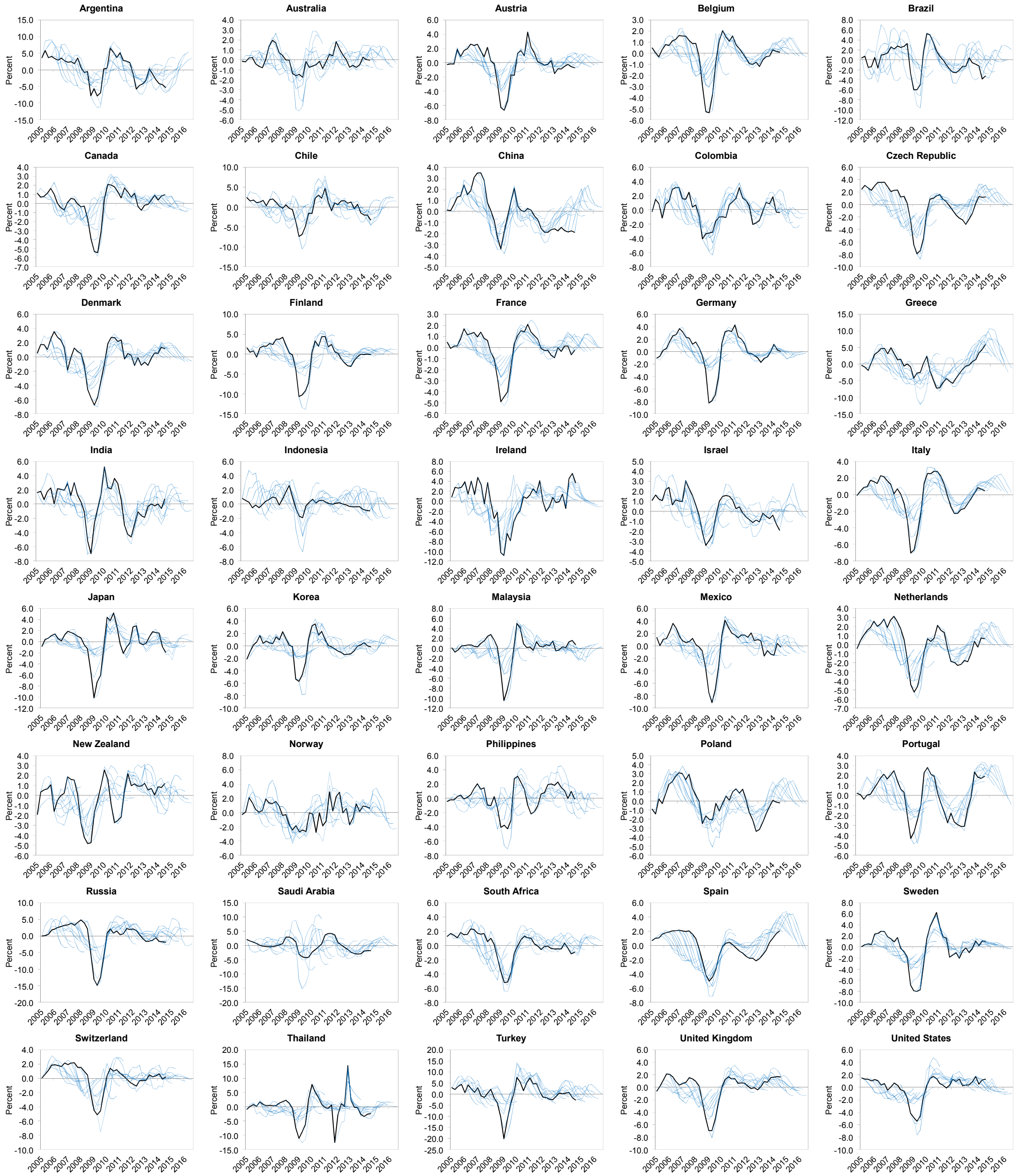
Note: Depicts the horizon dependent logarithmic root mean squared prediction error ratio for consumption price inflation ■ and output growth ■ relative to a random walk, expressed in percent.

Figure 48. Sequential Unconditional Forecasts of Consumption Price Inflation



Note: Depicts the cyclical component of observed consumption price inflation ■ as measured by the seasonal difference of the cyclical component of the logarithm of the price of consumption versus sequential unrestricted forecasts ■.

Figure 49. Sequential Unconditional Forecasts of Output Growth



Note: Depicts the cyclical component of observed output growth ■ as measured by the seasonal difference of the cyclical component of the logarithm of output versus sequential unrestricted forecasts ■.

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