Graduate Institute of International and Development Studies
International Economics Department
Working Paper Series

Working Paper No. HEIDWP05-2023

# An Estimated Model of a Commodity-Exporting Economy for the Integrated Policy Framework: Evidence from Mongolia

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# An Estimated Model of a Commodity-Exporting Economy for the Integrated Policy Framework: Evidence from Mongolia*

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March, 2023

**Abstract**

This paper develops an estimated New Keynesian model of a commodity-exporting economy for an integrated policy framework, integrating the full range of policies used in practice and featuring a range of nominal and real rigidities, macro-financial linkages, and transmission channels of external shocks. We jointly examine the optimal conduct of conventional and unconventional monetary policies, macroprudential policy, foreign exchange intervention, capital flow management, and fiscal policy based on the model. The policy analysis framework is applied empirically to Mongolia, a small open, and developing economy highly dependent on imports and commodity exports. We find that an eclectic policy mix improves policy tradeoffs, and a lack of cooperation among policy authorities may result in conflicting policies, hence suboptimal results for overall economic stability. Our optimal policy analysis shows that policy mix adjustments should differ depending on the type of shocks and the policy objectives. The results suggest that the policy analysis framework can help policymakers choose their policy mix adjustments to deal with external shocks in an integrated and optimal way.

**Keywords**: Monetary policy, Macroprudential policy, Foreign exchange intervention, Fiscal policy, Capital flow management, Optimal policy mix, Open economy macroeconomics, External shocks, Bayesian analysis
**JEL:** C11, C32, E32, E43, E52, F41

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* The authors thank Professor Philippe Bacchetta from the University of Lausanne for the academic supervision of this paper. The authors also appreciate Professor Cédric Tille from the Geneva Graduate Institute for International and Development Studies (IHEID) for his helpful comments. This research took place through the coaching program under the Bilateral Assistance and Capacity Building for Central Banks (BCC), financed by SECO, and the Graduate Institute in Geneva. The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the Bank of Mongolia.

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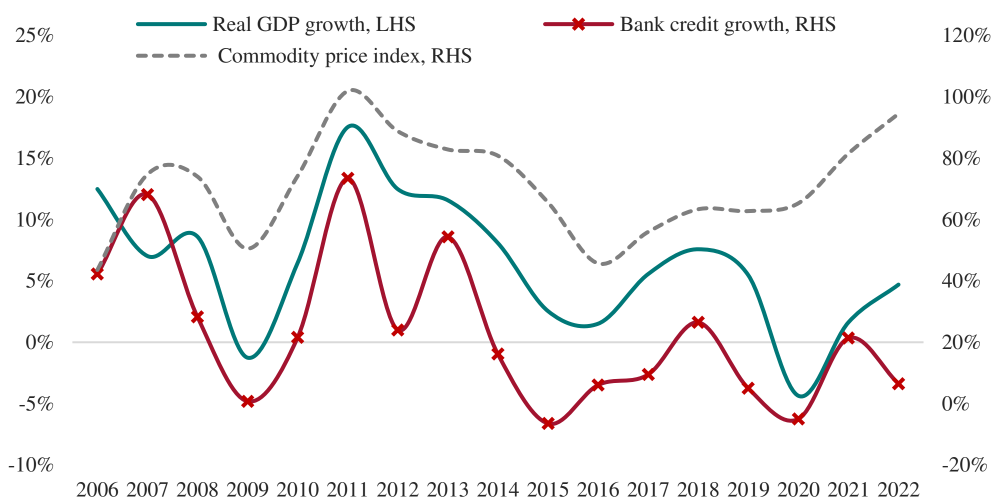
# 1. Introduction

Policymakers employ different strategies and instruments to manage capital flows and achieve economic stabilization objectives. In practice, policymakers use some combination of policies to maintain macroeconomic and financial stability. However, they often face difficult policy tradeoffs, and policy responses vary across countries and over time. The challenges are particularly pronounced in emerging markets and developing economies (EMDEs)[3]. In recent years, IMF-led efforts have formulated a so-called Integrated Policy Framework (IPF)[4], which provides a systematic and analytical approach to analyzing appropriate policy responses and jointly considers the role of policy tools and their interactions with each other and other policies (IMF 2020). Recent global events such as COVID-19 and the war in Ukraine have shown that the outlook for commodity markets is remarkably uncertain, and volatile commodity prices pose significant risks to EMDEs. However, the existing literature and IMF's works on the quantitative models for the IPF have not explicitly addressed the role of IPF policy tools and their optimal mix in dealing with commodity demand and price shocks, which play a crucial role in business and financial cycle fluctuations of commodity-exporting economies such as Mongolia (Figure 1). To address the issues and examine the optimal conduct of a high-dimensional policy mix while internalizing trade-offs, the existing models must be extended by incorporating all policy instruments, relevant shocks, and country characteristics captured in model equations and estimated parameters.

**Figure 1. Mongolian real GDP growth, bank credit growth, and commodity prices**




*Sources:* National Statistical Office of Mongolia, Bank of Mongolia, and FRED Economic Data.

In this context, our paper aims to develop an estimated New Keynesian model of a commodity-exporting economy for the IPF. Using the model, we jointly analyze the transmission mechanisms and the optimal conduct of conventional and unconventional monetary policies, FXI,

[3] In EMDEs, issues such as dominant currency pricing in foreign trade, dollarization in assets and liabilities, maturity and currency mismatch in balance sheets of banks and firms, external financial constraints, and worsening inflation expectations lead to differences in the functioning of the monetary transmission mechanism and policy trade-offs from those in developed economies.

[4] This is in line with what the BIS has called for a long time a Macro-Financial Stability Framework, extended to include also fiscal policy (Borio 2018).

macroprudential policy, CFM, and fiscal policy. Building on Adrian et al. (2020), our model integrates the full range of policy instruments used in practice and features a range of nominal and real rigidities, macro-financial linkages, and transmission channels of external shocks (i.e., commodity export demand, commodity export price, oil price, and risk premium and shocks). The model is estimated using Bayesian methods, and the policy analysis framework is applied empirically to Mongolia, a developing economy highly dependent on imports and commodity exports[5].

This paper contributes to the literature on model-based policy analysis in two distinct ways. First, by capturing the vital role of external shocks and practical policy options in commodity-exporting EMDEs, we suggest an estimated model-based framework for integrated policy analysis. The model-based policy analysis supports understanding better the empirical transmission mechanisms of IPF tools and examining optimal policy mix in dealing with commodity market shocks. Second, as far as we are aware, this paper is the first attempt to quantitatively analyze the optimal joint conduct of the six policies mentioned above by numerically optimizing for both Ramsey optimal policy and response coefficients of simple instrument rules under cases of cooperation and noncooperation among policy authorities in a developing and commodity-exporting economy. Thus, the exercise provides some insights about the importance of policy cooperation and optimal joint policy responses in the wake of risk premiums, commodity export demand, commodity export price, and oil price shocks.

Several papers (i.e., Gopinath 2019, Mano and Sgherri 2020, IMF 2020) have highlighted the need to develop the IPF. The primary motivation for the IPF is two-fold. First, policymakers around the globe have deployed a wider array of policy tools to cope with shocks. In practice, how best to combine these tools when policy tools have overlapping economic effects remains an open question. Therefore, developing the analytical groundwork for the IPF can be regarded as a theory catching up with real-world policy-setting features. Second, the empirical evidence for EMDEs (i.e., dominant currency pricing in foreign trade, dollarization, currency mismatch in balance sheets, and external financial constraints) suggests that the analytical approach needs to fully capture country characteristics, combinations of shocks, and available policy tools. Unlike existing IMF works, Brunnermeier et al. (2020) sketch an IPF for EMDEs that departs from the New Keynesian framework.

Since 2020, various papers, mostly IMF working papers, have developed conceptual or quantitative models for the IPF to support the practice of using multiple policy tools. Basu et al. (2020) build a conceptual model that incorporates many shocks and allows countries to differ across the currency of trade invoicing, degree of currency mismatches, tightness of external and

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[5] In the Mongolian economy, mineral exports account for 80-90 percent of total exports, and the import-to-GDP ratio is quite high (about 65 percent). China is a big trading partner of Mongolia as the trade between the two countries accounts for 80 percent of total exports and 40 percent of imports. Imports from Russia account for about 30 percent of total imports. Other country characteristics of the Mongolian economy are as follows: US dollar invoicing shares of exports and imports are about 75 percent; total external debts to GDP ratio is about 220 percent; above dollarization of bank deposits is about 30 percent; FX markets are shallow; there are sizable balance sheet currency mismatches in both private and public sectors; domestic credit markets are imperfect; both households and companies are highly dependent on bank credits as their credits to GDP ratio is about 25-30 percent, respectively; and inflation expectations are poorly anchored.

domestic borrowing constraints, and depth of foreign exchange markets. Based on the calibrated and three-period model for a small open economy, their analysis maps shocks and country characteristics to optimal policies and yields principles for the IPF tools. Adrian et al. (2020) develop and calibrate an empirically-oriented New Keynesian model that embeds balance sheet channels and includes a range of relevant frictions for EMDEs. They find that FXI and CFM may improve policy tradeoffs under certain conditions, especially for economies with well-anchored inflation expectations and significant foreign currency mismatch. Adrian et al. (2021) present a quantitative micro-founded model to analyze monetary and financial stability issues in open economies with financial fragilities ad weakly anchored inflation expectations. Based on the calibrated exercise, they emphasize the power of FXI to provide domestic stimulus in a liquidity trap. The models of Adrian (2020) and Adrian et al. (2021) only integrate monetary policy, FXI, and CFM. Amatyakul et al. (2021) extend the central bank of Thailand's semi-structural model to provide a coherent framework for conducting integrated policy analysis. Using an estimated medium-scale dynamic stochastic general equilibrium (DSGE) model, Adrian et al. (2022) examine how the policy mix should be adjusted in response to domestic and global financial cycle upturns and downturns. Our model captures the country characteristics and relevant frictions for the EMDEs, and all policy instruments considered in the papers but also includes unconventional monetary policy and commodity market shocks.

A few papers are similar in scope to ours regarding the optimal joint conduct of policy instruments. For example, Basu et al. (2020) conceptually analyze the optimal conduct of policies by solving for the Ramsey optimal policy mix. Adrian et al. (2022) quantitively investigate the optimal joint conduct of monetary policy, macroprudential policy, FXI, CFM, and fiscal policy using another branch of the theoretical optimal policy analysis. Rather than using Ramsey optimal policy setting, they jointly optimize response coefficients of simple instrument rules governing the decentralized conduct of the policies. Using a calibrated small open economy DSGE model with financial frictions, Lama and Medina (2020) jointly optimize simple rules governing the conduct of monetary policy (reserve requirement), macroprudential policy (differentiated reserve requirements), FXI, and capital flow tax. Angelini et al. (2014) also study the interaction of monetary policy and reserve requirements in the cases of cooperation and noncooperation by optimizing simple rules for them. Our paper empirically differs from the existing papers by quantitively analyzing the optimal joint conduct of the expanded range of policies using two branches (i.e., Ramsey policy rule and optimized policy rules) under cooperation and noncooperation cases.

This paper is structured as follows. Section 2 describes our model for the IPF. Section 3 discusses data, estimation, and evaluation of the model, including the goodness of fit, impulse responses, variance, and historical decompositions. Section 4 shows the policy analysis using the model, covering policy transmission mechanisms and optimal policy responses. Finally, section 5 concludes the paper with policy implications.

## 2. The model

Our model builds on a structural and quantitative model for Integrated Policy Framework developed by Adrian et al. (2020). Most equations of the model are derived from a log-linearized version of the micro-founded small open economy DSGE model developed by Adrian et al. (2021)

and have several key characteristics of emerging market economies (EMEs) such as shallow FX markets, sizable balance sheet currency mismatches, and poorly anchored inflation expectations. First, the model incorporates a broader array of real and nominal rigidities and imperfect exchange rate pass-through. The model also allows for producer currency pricing and dominant currency pricing. Second, the model assumes that some agents form inflation expectations adaptability to capture the imperfect credibility of monetary policy[6]. Third, the model assumes incomplete financial markets, with frictions in domestic credit and foreign exchange markets. Fourth, the model allows for discounting primary aggregate demand and supply equations in the spirit of the behavioral New Keynesian model developed by Gabaix (2020).

We extend their model in four main dimensions to help capture critical characteristics of an import-dependent and commodity-exporting economy and to further enrich policy analysis. First, the model of Adrian et al. (2020) has no capital and import components, and the introduction of capital and import components can substantially change the dynamic properties of the model. Therefore, we incorporate investment, capital, and import components, which help introduce additional real rigidities and characteristics of import dependency into the model. Investment and imports are sensitive parts of aggregate demand when capital and imports are introduced. We assume that four final goods (consumption, investment, exports, and government spending) are produced by combining the domestic homogenous good with specific imported inputs. Second, we introduce oil price shock, commodity export demand shock, and commodity export price shock as Mongolia imports 100 percent of its need for petroleum products, and commodity exports significantly affect budget revenue, the balance of payments, and business activities in Mongolia. The inclusions help account for the fact that external shocks play an essential role in the Mongolian business cycles (i.e., Gan-Ochir and Davaajargal 2019). In our specification, oil price, commodity export demand, and commodity export price shocks directly affect output dynamics, net foreign liability, and government budget revenues. Third, we incorporate the capital adequacy ratio (CAR) as a macroprudential prudential policy (MPP) tool that focuses on shaping credit market conditions in a counter-cyclical manner. Including the MPP tool allows the model to capture all standard IPF tools and examine the tools' effectiveness and transmission. Fourth, we introduce unconventional monetary policy (UMP) as EMDEs have started to use the tool during financial stress periods. As government spending is a crucial policy instrument controlled by the government, we incorporate the fiscal sector to examine how fiscal policy interacts with IPF tools and the importance of policy cooperation. The extension will help us to see how these policies can be complemented with the IPF.

After the extension, the model economy consists of households, firms, and a government, which in turn consists of a monetary authority, a macroprudential authority, and a fiscal authority. The monetary authority conducts conventional and unconventional monetary policies and executes

[6] This feature helps to account for how exchange rate changes may have large second round effects on inflation that complicate monetary policy trade-offs in EMEs.

foreign exchange intervention. The macroprudential authority conducts macroprudential policy, and the fiscal authority oversees fiscal policy and capital flow management.

In what follows, we provide an overview of the model and highlight key features of the model.

## 2.1 Aggregate demand

*Resource constraint.* The home economy resource constraint is expressed as a share-weighted average of consumption $c_t$, investment, $in_t$, government spending $g_t$, and export $x_t$ and import $m_t$:

$$y_t = c_y c_t + i_y in_t + g_y g_t + x_y x_t - m_y m_t \tag{1}$$

where $y_t$ is domestic output, $c_y$ is the steady state share of consumption and equals $1 - i_y - g_y - x_y + m_y$, where $i_y$, $g_y$, $x_y$ and $m_y$ are the steady-state investment-output ratio, government spending-output ratio, export-output ratio, and import-output ratio, respectively.

*Modified Euler equation.* Total consumption $(c_t)$ is determined by the Euler equation linking the marginal utility of consumption $\lambda_{c,t}$ to the future marginal utility of consumption and real short-term interest faced by consumers, $r_{b,t}$:

$$\lambda_{c,t} = \delta_c E_t \lambda_{c,t+1} + r_{b,t}$$

where $\delta_c \in [0, 1]$ is a cognitive discount parameter, which has many consequences for macroeconomic dynamics, as Gabaix (2020) discussed. Here, we assume that most households are impatient as they borrow from banks[7].

The first order condition (FOC) of household optimization implies that the marginal utility of consumption varies inversely with current consumption but rises with past consumption, with the latter reflecting habit persistence in consumption:

$$\lambda_{c,t} = -\frac{1}{\sigma(1-\varkappa_c)}\left(c_t - \varkappa_c c_{t-1} - \varepsilon_{c,t}\right)$$

where $\sigma$ is the elasticity of intertemporal substitution, $\varkappa_c \in (0,1)$ measures the importance of external consumption habit, and $\varepsilon_{c,t}$ is an exogenous shock to preference, assumed to follow a first-order autoregressive process with an IID-Normal error term.

Combining these equations implies that consumption demand depends on a real borrowing rate, $r_{b,t}$:

$$c_t - \varkappa_c c_{t-1} - \varepsilon_{c,t} = \delta_c\left(E_t c_{t+1} - \varkappa_c c_t - E_t \varepsilon_{c,t+1}\right) - \frac{1}{\sigma(1-\varkappa_c)} r_{b,t} \tag{2}$$

*Borrowing rate.* In addition to discounting, the model also assumes that the borrowing rate facing home consumers includes a time-varying "private borrowing spread", $\psi_t$:

[7] The assumption is broadly consistent with the case of Mongolia in the sense that there are 1.6 million credit accounts at banks, equivalent to 73 percent of adults, 18 years or older.

$$r_{b,t} = (i_t - E_t\pi_{c,t+1}) + (i_{b,t} - i_t) = r_t + \psi_t \quad (3)$$

where $r_t = i_t - E_t\pi_{c,t+1}$ is the short-term real interest rate, $i_t$ is the policy rate, $E_t\pi_{c,t+1}$ is expected consumer price inflation, and $\psi_t$ is the interest rate spread between the nominal borrowing rate, $i_{b,t}$ and policy rate, $i_t$.

*The private borrowing spread.* The borrowing spread, $\psi_t$, is assumed to be a function of the real exchange rate, $q_t$, and the function is upward-sloping and locally convex (i.e., logistic functional form), allowing for the possibility that depreciations above a certain threshold[8] may exert significant nonlinear effects on financial conditions even while small depreciations may have only minimal effects. The linearized representation is given by

$$\psi_t = \rho_\psi \psi_{t-1} + \rho_q(q_{c,t} - \varepsilon_{\bar{q},t}) + \rho_{car} car_t + \rho_{npl} npl_t - \rho_{CB} cr_{CB,t} \quad (4)$$

where $\rho_q$ is a parameter governing the effect of the real exchange rate on the spread, and $\varepsilon_{\bar{q},t}$ is a risk appetite shock. Therefore, equation (4) allows the incorporation of the financial channel of the exchange rate, macroprudential policy, and unconventional monetary policy. The positive relationship between the spread and the real exchange rate (i.e., the spread rises when the real exchange rate depreciates) captures the financial channel of the exchange rate. As highlighted by Aghion et al. (2001), if nominal prices are 'sticky', a currency depreciation leads to an increase in firms' and households' foreign currency debt repayment obligations, thereby deteriorating their balance sheets. It reduces the borrowing capacity of firms and households (tightens financial condition), especially when a substantial part of borrowing represents unhedged foreign currency debt, and therefore investment, consumption, and output in a credit-constrained economy, which in turn reduces the demand for the domestic currency and leads to depreciation.

Following Quint and Rabanal (2013), we introduce a MPP tool, the capital adequacy ratio (CAR) on banks, $car_t$. Since the regulation adds extra costs for banks, we assume that it increases the borrowing spread. The term, $\rho_{car} car_t$, can be called a "regulation premium". Within the CAR requirement, banks will pass the cost of not being able to lend the total amount of funds to their customers. Hence, a tightening of credit conditions following higher CAR will increase the spread[9]. In line with Aguirre and Blanco (2015), we assume that the non-performing loan ratio ($npl_t$) will positively affect the borrowing spread since the bank will include the cost of credit risk.

The central bank of Mongolia (BOM) has implemented unconventional monetary policy (UMP) measures primarily focused on increasing banks' lending by providing subsidized financing to banks since 2012. Under the UMP, banks receiving financing from the BOM are obliged to issue loans to households and firms at a subsidized interest rate (much lower than market lending rates). Therefore, the expansion in domestic assets of the BOM balance sheet (central bank's claims on

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[8] Threshold real exchange rate is assumed as $\bar{q}_{c,t} \equiv \bar{q}_c + \varepsilon_{\bar{q},t}$, where $\bar{q}_c$ is constant steady state real exchange rate and $\varepsilon_{\bar{q},t}$ is a stochastic risk appetite shock. A higher value of $\bar{q}_c$ implies that even a substantial real exchange rate depreciation relative to the steady state will not induce much of a rise in the private borrowing spread unless the stochastic shock, $\varepsilon_{\bar{q},t}$ is also sufficiently negative so that $\bar{q}_c \leq q_{c,t}$.

[9] Theoretical foundation on how CAR affect the borrowing rate is well documented by Angelini et al. (2014).

banks), $cr_{CB,t}$, has lowered the lending rate-policy rate spread, $\psi_t$, and increased newly issued loans from banks, $cr_t$.

*Oil and core consumption.* We introduce oil price and consumption into the model consistent with Medina and Soto (2005). Domestic households consume oil and non-oil (core) goods, which consist of domestically produced goods (home goods) and imported differentiated goods (foreign goods). All three types of goods (oil, home, and foreign) are imperfect substitutes in the consumption basket. Households' cost minimization of consumption basket yields demands for oil and core consumptions (i.e., demands for domestically produced and imported goods). The total consumption, $c_t$, is a bundle of oil consumption, $o_{c,t}$, and core consumption, $\bar{c}_t$, and demands for these consumptions are given by

$$o_{c,t} = c_t - \eta^{o,\bar{c}}\gamma_t^{o,c} \tag{5}$$

$$\bar{c}_t = c_t - \eta^{o,\bar{c}}\gamma_t^{\bar{c},c} \tag{6}$$

where $\eta^{o,\bar{c}}$ is the elasticity of substitution between oil and core consumption, $\gamma_t^{o,c} \equiv p_{o,t} - p_{c,t}$ is the price of oil consumption ($p_{o,t}$) relative to that of a total consumption basket ($p_{c,t}$), and $\gamma_t^{\bar{c},c} \equiv p_{\bar{c},t} - p_{c,t}$ is the price of core consumption ($p_{\bar{c},t}$) relative to that of the total consumption basket ($p_{c,t}$).

The core consumption, $\bar{c}_t$, is a bundle of domestically produced goods and imported goods, and demand for the imported goods, $\bar{c}_{m,t}$, are given by

$$\bar{c}_{m,t} = \bar{c}_t - \eta^{m,\bar{c}}\gamma_t^{m,\bar{c}} \tag{7}$$

where $\eta^{m,\bar{c}}$ is the elasticity of substitution between domestically produced and imported goods for core consumption, and $\gamma_t^{m,\bar{c}} \equiv p_{m,t} - p_{\bar{c},t}$ is the price of non-oil imported goods ($p_{m,t}$) relative to that of the core consumption basket ($p_{\bar{c},t}$).

*Investment.* As in Agénor and Silva (2017), capital good producer owns the capital stock, which is rented out to the domestic producers at a given rental rate of $r_t^k$. To produce these goods, the capital good firm spends $in_t$ on the final good. It must pay for these goods in advance, therefore capital goods producers must borrow from banks. We assume that $\alpha_{in}$ percent of credit issued in the current period and $(1 - \alpha_{in})$ percent of credit issued in the last period transformed into the current period's investment. Thus, investment goods ($in_t$) is determined by

$$in_t = \alpha_{in}cr_t + (1 - \alpha_{in})cr_{t-1} + \varepsilon_{in,t} \tag{8}$$

where $cr_t$ is real bank credit and $e_{in,t}$ represents the marginal efficiency of investment (MEI) shock, assumed to follow a first-order autoregressive process with an IID-Normal error term.

The demand for imported investment goods is given by

$$in_{m,t} = in_t - \eta^{m,in}\gamma_t^{m,h} \tag{9}$$

where $\eta^{m,in}$ is the elasticity of substitution between domestically produced and imported goods for investment, and $\gamma_t^{m,h} \equiv p_{m,t} - p_t$ is the price of non-oil imported goods ($p_{m,t}$) relative to that of domestically produced goods ($p_t$).

The real bank credit ($cr_t$) is modeled as employed by Aguirre and Balanco (2015). The credit is a function of output, $y$, borrowing rate, $r_{b,t}^L$, and CAR, $car_t$:

$$cr_t = \rho_{cr} cr_{t-1} - \theta_r r_{b,t}^L - \theta_{car} car_t + \theta_{CB} cr_{CB,t} + \varepsilon_{cr,t} \tag{10}$$

where $\varepsilon_{cr,t}$ is a shock to bank credits assumed to follow a first-order autoregressive process with an IID-Normal error term. The first two variables, $y$ and $r_{b,t}^L$, are key determinants of bank credit demand. MPP authority can affect the bank credit supply and interest rate spread by imposing higher capital adequacy requirements (CAR). Within the measure, banks are only allowed to lend a proportion of their loanable funds; therefore, tightening the CAR will decrease the bank credit. To reflect the effects of UMP measures, we also include banks' borrowing from the central bank (i.e., central bank's claims on banks) ($cr_{CB,t}$) into equation (10). The specification highlighting the effects of borrowing from the central bank on the banks' credit is consistent with Agénor and Silva (2017).

The non-performing loan ratio ($npl_t$) is defined as a function of lagged value, economic activity, exchange rate variability, and own shock:

$$npl_t = \xi_{npl} npl_{t-1} - \xi_y y_t + \xi_{\Delta e} \Delta e_t + \varepsilon_{npl,t} \tag{11}$$

where $e_t$ is the nominal exchange rate, $\varepsilon_{npl,t}$ is a NPL ratio shock assumed to follow a first-order autoregressive process with an IID-Normal error term. We included the change in nominal exchange rate into the equation since borrowers who loan out in foreign currency but earn revenue in domestic currency face exchange rate risk.

*Exports.* Total exports, $x_t$, consist of non-commodity, $x_{ncom,t}$, and commodity exports, $x_{com,t}$, and their demands are modelled differently. In real (volume) terms:

$$x_y x_t = x_{ncom,y} x_{ncom,t} + x_{com,y} x_{com,t} \tag{12}$$

where $x_{ncom,y}$ and $x_{com,y}$ are shares of non-commodity and commodity exports in total output, and $x_y = x_{ncom,y} + x_{com,y}$ is the share of exports in the output.

Non-commodity export demand, $x_{ncom,t}$, rises with foreign output, $y_t^*$, and falls with the relative price of non-commodity exported goods produced by home exporters to that of their foreign competitors, $p_{ncx,t} - p_t^*$, where $p_{ncx,t} = p_t - e_t$, $p_t^*$ is foreign price, and $e_t$ is nominal exchange rate. As Chen et al. (2008) documented, commodity markets are mainly independent of developments in individual exporting countries. In line with the empirical fact, demand for commodity export is modelled as it depends on foreign output and the demand shock ($\varepsilon_{com,t}$), capturing variations in resource exports that are unrelated to the relative cost of export goods and level of foreign output. Thus, non-commodity and commodity exports are specified as

$$x_{ncom,t} = y_t^* - \eta^x(p_{ncx,t} - p_t^*) = y_t^* + \eta^x q_t \tag{13}$$

$$x_{com,t} = y_t^* + \varepsilon_{com,t} \tag{14}$$

where $\eta^x$ is the relative price elasticity of non-commodity export demand, and $q_t$ is domestic price-based real exchange rate.

The demand for imported inputs for export goods is given by

$$x_{m,t} = x_t - \eta^{m,x}\gamma_t^{m,h} \tag{15}$$

where $\eta^{m,x}$ is the elasticity of substitution between domestically produced and imported goods for the export goods.

*Exchange rates.* By definition, the consumption-based real exchange rate ($q_{c,t}$) and domestic price based real exchange rate ($q_t$) are defined as

$$q_{c,t} = p_t^* + e_t - p_{c,t} \equiv q_{c,t-1} + \pi_t^* + \Delta e_t - \pi_{c,t} \tag{16}$$

$$q_t = p_t^* + e_t - p_t \equiv q_{t-1} + \pi_t^* + \Delta e_t - \pi_t \tag{17}$$

where $\pi_t^*$ is foreign inflation, $\pi_{c,t}$ is headline inflation, and $\pi_t$ is domestically produced good inflation.

*Risk-augmented UIP*. In the model, banks borrow in domestic and foreign currencies (i.e., taking deposits or issuing bonds), but issue loans in domestic currency and this generates currency mismatch in their balance sheets. They pay a risk premium on foreign currency borrowing because of the default risk. Thus, we assume that the UIP does not hold in the short run. The UIP risk premium $\phi_t(d_t, \bar{d}_t, b_t)$ and a tax on capital outflows $\tau_t$ are included. The risk-augmented UIP is specified as

$$e_t = E_t e_{t+1} + i_t^* - i_t + \phi_t - \tau_t \tag{18}$$

where $i_t^*$ is foreign short term interest rate. The UIP equation implies the real exchange rate depreciates (i.e., $q_t$ rises) when the foreign real interest rate rises relative to the domestic real interest rate, or if the UIP risk premium $\phi_t$ increases; conversely, it appreciates in response to a tax on capital outflows, $\tau_t$, the policy instrument moderating the exchange rate risk by limiting excessive capital flights. A theoretical foundation supporting the inclusion of such capital control measures, $\tau_t$, in the UIP equation is provided by Bacchetta et al. (2013), who analyze optimal policy in a semi-open economy, where the Ramsey planner is a central bank with access to international capital markets. They find that the accumulation of reserves combined with capital controls gives a higher welfare than full capital mobility, especially it is optimal to impose capital controls so that the domestic interest rate can differ from the foreign rate. As empirical support, Bacchetta et al. (2023) show that capital controls can eliminate the adverse impact of low US interest rates and effectively reduce firms' vulnerability to exchange rate fluctuations using firm-level data on corporate bond issuances in 16 EMEs.

*UIP risk premium.* Time-varying UIP risk premium $\phi_t(d_t, \bar{d}_t, b_t)$ implies that investors require higher expected returns if the home economy's net foreign liabilities $d_t$ rise relative to a threshold level of $\bar{d}_t$ and in times of market stress[10]. The government may reduce this UIP risk premium using foreign exchange intervention (FXI). Foreign exchange sales ($b_t$) strengthen the demand for home currency and thus may reduce the risk premium. As employed by Adrian et al. (2020), a nonlinear function of the UIP risk premium is considered, and linearized representation is given by

$$\phi_t = \rho_\phi \phi_{t-1} + \phi_d d_t - \phi_b b_t - k_d \phi_b \varepsilon_{\bar{d},t} - (\phi_{e,1} E_t \Delta e_{t+1} + \phi_{e,2} \Delta e_t) + \varepsilon_{\phi,t} \tag{19}$$

where $\varepsilon_{\bar{d},t}$ is a debt limit shock, $\varepsilon_{\phi,t}$ is a risk premium shock, and both shocks are assumed to follow a first order autoregressive process with an IID-Normal error terms. In line with Bacchetta and Wincoop (2021), the expected changes in the nominal exchange rate, $E_t \Delta e_{t+1}$ and $\phi_{e,2} \Delta e_t$ are included in the risk premium function to account for the delayed overshooting puzzle. The risk-augmented UIP (18) and UIP risk premium (19) equations allow us to include the transmission mechanisms of CFM and FXI.

*Imports.* Total import expands as oil consumption and inputs, core consumption, investment, and government spending rise and fall in response to an increase in their relative prices so that import demand is given by

$$m_y m_t = m_{o,y} o_t + m_{\bar{c},y} \bar{c}_{m,t} + m_{in,y} in_{m,t} + m_{g,y} g_{m,t} + m_{x,y} x_{m,t} \tag{20}$$

where $m_{o,y} = m_{o_c,y} + m_{o_y,y}$, $m_{\bar{c},y}$, $m_{in,y}$, $m_{x,y}$, and $m_{g,t} = m_y - m_{o,y} - m_{\bar{c},y} - m_{in,y} - m_{x,y}$ are the steady-state oil import-output ratio, core consumption import-output ratio, investment import-output ratio, export input import-output ratio, and government spending good import-output ratio, respectively. The imported oil is given by $m_{o,y} o_t = m_{o_c,y} o_{c,t} + m_{o_y,y} o_{y,t}$, where $m_{o_c,y}$ is the steady-state ratio of oil consumption to output, $m_{o_y,y}$ is the steady-state ratio of oil input in production to output, $o_{y,t}$ is oil input used in domestic production defined by equation (30), and $g_{m,t}$ is import demand for government spending goods given by

$$g_{m,t} = in_t - \eta^{m,g} \gamma_t^{m,h} \tag{21}$$

where $\eta^{m,g}$ is the elasticity of substitution between domestically produced and imported goods for the government spending goods.

*Net foreign liabilities.* As the home country is assumed to be restricted to borrowing (or lending) abroad in foreign currency, its net foreign liabilities (i.e., the share of GDP), $d_t \equiv \frac{e_t D_t}{\bar{Y} P_t}$, evolve according to

[10] Threshold net foreign liability level is assumed as $\bar{d}_t \equiv \bar{d} + \varepsilon_{\bar{d},t}$, where $\bar{d}$ is constant steady state level and $\varepsilon_{\bar{d},t}$ is a stochastic debt limit shock.

$$d_t = (1+r_d)d_{t-1} - x_{ncom,y}x_{ncom,t} - x_{com,y}\left(x_{com,t} + \gamma_t^{com,*} + q_t\right) + m_{o_c,y}\left(o_{c,t} + \gamma_t^{o,*} + q_t\right) + m_{o_y,y}\left(o_{y,t} + \gamma_t^{o,*} + q_t\right) + m_{\bar{c},y}\left(\bar{c}_{m,t} + q_t\right) + m_{in,y}\left(in_{m,t} + q_t\right) + m_{g,y}\left(g_{m,t} + q_t\right) + m_{x,y}\left(x_{m,t} + q_t\right) \quad (22)$$

where $r_d$ is the steady-state real interest rate on net foreign liabilities, $\gamma_t^{com,*} \equiv p_{com,t} - p_t^*$ is the relative price of commodity in foreign currency received by domestic exporters, $\gamma_t^{o,*} \equiv p_{o,t}^* - p_t^*$ is the relative price of oil in foreign currency paid by domestic importers.

## 2.2 Aggregate supply

*Modified Phillips curve*. Turning to the supply side, the price-setting equation for domestically produced goods takes the form of a modified New Keynesian Phillips curve:

$$\pi_t - \iota_d\pi_{t-1} = \beta\delta_\pi(E_t\pi_{t+1} - \iota_d\pi_t) + \kappa_{mc}\left(mc_t + \varepsilon_{\pi,t}\right) \quad (23)$$

This specification is based on a Calvo-style price setting with the sensitivity of inflation, $\pi_t$, on domestically produced goods to real marginal cost, $mc_t$, determined by the slope coefficient, $\kappa_{mc} = \frac{(1-\xi)(1-\beta\xi)}{\xi}$, where $\beta$ is the discount factor and $\xi$ is the Calvo price-stickiness parameter. $\varepsilon_{\pi,t}$ denotes a domestic price markup shock, assumed to follow a first-order autoregressive process with an IID-Normal error term. The indexation parameter determines some structural persistence in inflation, $\iota_d$. This persistence can be interpreted as inflation expectations with an adaptive component as highlighted by Clarida et al. (1999). In such sense, the parameter reflects the role of imperfect central bank credibility and the ability of the central bank to anchor inflation expectations. The indexation parameter can also reflect that cost shocks exert a highly persistent "second-round" effect on inflation. Moreover, as in Euler equation (2), the Phillips curve also allows for cognitive discounting parameter, $\delta_\pi \in [0,1]$, which dumps the effect of future marginal cost on current inflation. The traditional, rational model corresponds to $\delta_c = \delta_\pi = 1$, but our model generates $\delta_c$ and $\delta_\pi$ strictly less than 1. We will test which assumption is supported by data and examine the implication of the discounting for macroeconomic dynamics in the empirical analysis section.

*Domestic producer's marginal cost*. The real marginal cost, $mc_t$, rises with an increase in the producer real wage, $\xi_t$, or capital rental rate, $r_t^k$, or domestic currency real price of oil, $p_{o,t} - p_t$:

$$mc_t = (1 - \Omega_k - \Omega_o)\xi_t + \Omega_k r_t^k + \Omega_o\gamma_t^{o,h} - \varepsilon_{a,t} \quad (24)$$

where $\varepsilon_{a,t}$ is a stationary, country-specific shock to the level of technology, the parameters, $\Omega_k$ and $\Omega_o$, capture the shares of capital and oil in production, and $\gamma_t^{o,h} \equiv p_{o,t} - p_t$ is the price of oil consumption ($p_{o,t}$) relative to that of domestically produced goods ($p_t$).

*Production function.* In line with Bjørnland et al. (2018), we assume that domestic output goods, $y_t$, are produced using capital, oil, and labor, according to a Cobb-Douglas function:

$$y_t = \Omega_k k_t^s + \Omega_o o_{y,t} + (1 - \Omega_k - \Omega_o)n_t + \varepsilon_{a,t} \quad (25)$$

where $k_t^s$ is capital services, $o_{y,t}$ is oil input used in production, and $n_t$ is employment.

*Capital accumulation.* The capital producers can increase the supply of rental services from capital ($k_t^s$) either by investing in additional capital, which takes one period to be installed ($k_{t-1}$) or by changing the utilization rate ($u_t$) of already installed capital:

$$k_t^s = k_{t-1} + u_t \tag{26}$$

The accumulation of installed capital ($k_t$) is a function of the investment, $i_t$:

$$k_t = (1 - \delta_k)k_{t-1} + \delta_k\big(in_t + \varepsilon_{in,t}\big) \tag{27}$$

where $\delta_k$ is the depreciation rate of capital, and $\varepsilon_{in,t}$ denotes the marginal efficiency of investment (MEI) shock that affects how investment is transformed into capital.

We assume that the capital good firm chooses only the utilization rate, $u_t$, to maximize its intertemporal objective function, and the optimality condition with respect to capital utilization implies that the degree of capital utilization is a positive function of the rental rate of capital, $r_t^k$:

$$u_t = u_a r_t^k \tag{28}$$

where $u_a = (1 - \kappa)/\kappa$ and $\kappa$ is a positive function of the elasticity of the capital utilization adjustment cost function and is normalized to be between zero and one. When $\kappa$ is closer to one, it is incredibly costly to change the utilization of capital, thus, it remains constant.

*Rental rate of capital.* Cost minimization by domestic firms implies that the rental rate of capital, $r_t^k$ is negatively related to the capital-labor ratio and positively to the real wage, $\xi_t$:

$$r_t^k = -\frac{1}{\varsigma}(k_t^s - n_t) + \xi_t \tag{29}$$

where $\varsigma$ is the elasticity of substitution among inputs (capital, labor, and oil) used in production.

*Demand for imported oil input.* Cost minimization by domestic firms implies that the oil input demand, $o_{y,t}$ is negatively related to the real oil price and positively to the real wage, $\xi_t$ and employment (all with unit elasticity):

$$o_{y,t} = n_t + \varsigma\big(\xi_t - \gamma_t^{o,h}\big) \tag{30}$$

*Labor supply.* Sticky wage and unemployment rates are introduced in the model based on the framework of Galí et al. (2011). The utility function with preference shifter employed by Galí et al. (2011) does not change the model's main features, and the preference allows us to parameterize the strength of short-run wealth effects on labor supply. In this setting, the marginal rate of substitution, $mrs_t$, between consumption and leisure, which determines the cost of working an additional hour in terms of consumption goods is given by

$$mrs_t = \chi n_t + z_t + \varepsilon_{n,t} \tag{31}$$

where $\chi$ is the inverse of the Frisch labor elasticity, $\varepsilon_{n,t}$ is a labor supply shock, assumed to follow a first-order autoregressive process with an IID-Normal error term, and $z_t$ is endogenous reference shifter ($z_t$), determined as follows:

$$z_t = (1 - \vartheta_z)\, z_{t-1} - \vartheta_z \lambda_{c,t} \tag{32}$$

*Wage Phillips curve.* Nominal wages are sticky and set in Calvo-style wage contracts, and the wage Phillips curve takes the following form

$$\omega_t - \iota_\omega \pi^L_{c,t} = \beta \delta_\pi E_t\big(\omega_{t+1} - \iota_\omega \pi^L_{c,t+1}\big) + \kappa_\omega\big(mrs_t - \xi_{c,t} + \varepsilon_{\omega,t}\big) \tag{33}$$

where $\kappa_\omega = \frac{(1-\xi_\omega)(1-\beta\xi_\omega)}{\xi_\omega(1+\theta_\omega\chi)}$ and $\xi_\omega$ is the Calvo wage-stickiness parameter, $\theta_\omega = \frac{\mathcal{M}_\omega}{\mathcal{M}_\omega - 1}$ is wage elasticity of labor demand, and $\mathcal{M}_\omega$ is the steady-state wage markup. Nominal wage inflation, $\omega_t$, depends on future wage inflation and the gap between the marginal cost of work ($mrs_t$) and the consumption real wage ($\xi_{c,t}$). $\varepsilon_{\omega,t}$ denotes a wage markup shock, assumed to follow a first-order autoregressive process with an IID-Normal error term.

This setup allows for a flexible specification of wage indexation in which the relevant inflation measure indexing wages is a long moving average of either past realized inflation or of exchange rate changes:

$$\pi^L_{c,t} = (1 - \Phi)\pi^L_{c,t-1} + \Phi\big(v\pi_{c,t-1} + (1 - v)\Delta q_{c,t-1}\big) \tag{34}$$

The dependence of wage inflation on past exchange rate changes[11], $\Delta q_{c,t-1}$, allows for substantial "second-round" effects through a wage channel. In the case of $\Phi = 1$ and $v = 1$, the wage inflation equation (33) is the same as the standard wage Phillips curve.

*Unemployment and labor force*. In the framework of Galí et al. (2011), the wage markup ($\mu_{\omega,t}$) is equal to the difference between the real wage ($\omega_t$) and the marginal rate of substitution between working and consuming ($mrs_t$), which is also equal to a linear function of unemployment ($un_t$)[12]:

$$\mu_{\omega,t} = \xi_{c,t} - mrs_t \tag{35}$$

$$un_t = \frac{\mu_{\omega,t}}{\chi} \tag{36}$$

where $\chi$ is the elasticity of labor supply in the household utility function.

By definition, the labor force ($l_t$) is given as

$$l_t = n_t + un_t \tag{37}$$

*Real wages.* The producer real wage, $\xi_t$, is determined by the identity:

$$\xi_t = \xi_{t-1} + \omega_t - \pi_t \tag{38}$$

The consumption real wage, $\xi_{c,t}$, is given by

[11] The potential channel explaining how exchange rate affects wages is as follows: exchange rate depreciation increases the relative price of imported goods, causing households to demand a higher real wage in terms of the consumer good, $\xi_{c,t}$, to keep their purchasing power intact as required to induce them to work the same number of hours and leave their $mrs_t$unchanged.

[12] As explained by Gali et al. (2011), directly observing unemployment rate allows us to correctly identify both wage markup shock and labor supply shock.

$$\xi_{c,t} = \xi_{c,t-1} + \omega_t - \pi_{c,t} \tag{39}$$

where $\pi_{c,t}$ is the consumer price inflation.

*Phillips curve for import price inflation*. The model allows for deviations from the law of one price in the import sector. The Phillips curve determining import prices is derived from Calvo-style pricing assumptions. Specifically, the price-setting is given by

$$\pi_{m,t} - \iota_m \pi_{m,t-1} = \beta \delta_\pi \left( E_t \pi_{m,t+1} - \iota_m \pi_{m,t} \right) + \kappa_{mc_m} \left( mc_{m,t} + \varepsilon_{\pi_m,t} \right) \tag{40}$$

where $\kappa_{mc_m} = \frac{(1-\xi_m)(1-\beta\xi_m)}{\xi_m}$, $\iota_m$ is the indexation parameter reflecting the weight on the dynamic (lagged) inflation component, $\xi_m$ is the Calvo price-stickiness parameter, $mc_{m,t}$ denotes the real marginal cost of importing firms and $\varepsilon_{\pi_m,t}$ denotes an import price markup shock, assumed to follow a first-order autoregressive process with an IID-Normal error term.

*Importing firms' marginal costs.* Real marginal costs of import sectors are defined as

$$mc_{m,t} = p_t^* + e_t - p_{m,t} = q_{c,t} - \gamma_t^{\bar{c},c} - \gamma_t^{m,\bar{c}} \tag{41}$$

*Relative prices and inflations.* Relative prices are given by

$$\gamma_t^{o,c} \equiv p_{o,t} - p_{c,t} \equiv \gamma_{t-1}^{o,c} + \pi_{o,t} - \pi_{c,t} \tag{42}$$

$$\gamma_t^{\bar{c},c} \equiv p_{\bar{c},t} - p_{c,t} \equiv \gamma_{t-1}^{\bar{c},c} + \pi_{\bar{c},t} - \pi_{c,t} \tag{43}$$

$$\gamma_t^{m,\bar{c}} \equiv p_{m,t} - p_{\bar{c},t} \equiv \gamma_{t-1}^{m,\bar{c}} + \pi_{m,t} - \pi_{\bar{c},t} \tag{44}$$

$$\gamma_t^{m,h} \equiv p_{m,t} - p_t \equiv \gamma_{t-1}^{m,h} + \pi_{m,t} - \pi_t \tag{45}$$

$$\gamma_t^{o,h} \equiv p_{o,t} - p_t \equiv \gamma_{t-1}^{o,h} + \pi_{o,t} - \pi_t \tag{46}$$

$$\gamma_t^{com,*} \equiv p_{com,t} - p_t^* \equiv \gamma_{t-1}^{com,*} + \pi_{com,t} - \pi_t^* \tag{47}$$

$$\gamma_t^{o,*} \equiv p_{o,t}^* - p_t^* \equiv \gamma_{t-1}^{o,*} + \pi_{o,t} - \pi_t^* \tag{48}$$

Headline price inflation ($\pi_{c,t}$) and core consumption inflation ($\pi_{\bar{c},t}$) are defined as

$$\pi_{c,t} = m_o \pi_{o,t} + (1 - m_o) \pi_{\bar{c},t} \tag{49}$$

$$\pi_{\bar{c},t} = m_m \pi_{m,t} + (1 - m_m) \pi_t \tag{50}$$

$$\pi_{o,t} = p_{o,t} - p_{o,t-1} \tag{51}$$

$$\pi_{com,t} = p_{com,t} - p_{com,t-1} \tag{52}$$

where $m_o$ is share of oil consumption in the total consumption basket, and $m_m$ is the share of imported goods in the core consumption basket.

## 2.3 Monetary, macroprudential, FX intervention, CFM, and fiscal policies

The central bank is assumed to follow a Taylor-style policy rule:

$$i_t = \gamma_i i_{t-1} + (1-\gamma_i)\left[\gamma_\pi E_t \pi_{c,t}^A + \gamma_y y_t\right] + \varepsilon_{i,t} \tag{53}$$

where $\gamma_i$ allows for interest rate smoothing, and $\varepsilon_{i,t}$ is a policy rate shock, assumed to follow a first-order autoregressive process with an IID-Normal error term. The rule specifies that the central bank considers the four-quarter change in CPI in setting the policy rate, and the annual inflation is defined as

$$\pi_{c,t}^A = \left(\pi_{c,t} + \pi_{c,t-1} + \pi_{c,t-2} + \pi_{c,t-3}\right)/4 \tag{54}$$

It also takes domestic output, $y_t$, into account.

UMP is assumed to follow a rule:

$$cr_{CB,t} = \varrho_{cr_{CB}} cr_{CB,t-1} - \left(1-\varrho_{cr_{CB}}\right)\left(\varrho_y y_t + \varrho_{cr} cr_t\right) + e_{cr_{CB},t} \tag{55}$$

where $\varrho_{cr_{CB}}$ allows for central bank credit smoothing, and $e_{cr_{CB},t}$ is a shock to central bank credit to banks, assumed to be i.i.d. and $N\left(0, \sigma_{cr_{CB}}^2\right)$. The policy parameters $\varrho_y$ and $\varrho_{cr}$ are both positive, implying that a decrease in bank credit, $d_t$, and GDP, $y_t$, triggers higher central bank credits to banks, $cr_{CB,t}$.

MPP authority is assumed to follow a CAR rule:

$$car_t = \varpi_{car} car_{t-1} + (1-\varpi_{car})\left(\varpi_y y_t + \varpi_{cr} cr_t\right) + \varepsilon_{car,t} \tag{56}$$

where$\varpi_{car}$ allows for CAR smoothing, and $\varepsilon_{car,t}$ is a shock to capital requirement, assumed to follow a first-order autoregressive process with an IID-Normal error term. According to the CAR rule, the MPP authority aims to stabilize output and bank credit fluctuations by gradually adjusting the policy-controlled prudential measure, $car_t$Other studies have employed similar rules (Angelini et al. 2014 and Aguirre and Blanco 2015). The rule allows us to examine the effectiveness of MPP tools. Angelini et al. (2014) describe the reasons why the time-varying CAR is a macroprudential instrument.

For foreign asset purchases by the BOM, $b_t$, we assume the following FXI rule:

$$b_t = b_b b_{t-1} - (1-b_b)\left[b_q\left(q_{c,t} - \varepsilon_{\bar{q},t}\right) + b_d\left(d_t - \varepsilon_{\bar{d},t}\right)\right] + \varepsilon_{b,t} \tag{57}$$

where $b_b$ allows for foreign asset purchases/sales smoothing, $\varepsilon_{b,t}$ is a foreign asset purchase/sale shock, assumed to follow a first-order autoregressive process with an IID-Normal error term. The term $q_{c,t} - \varepsilon_{\bar{q},t}$ measures the deviation of the real exchange rate from its threshold level (i.e., exchange rate misalignment), the key driver of the private borrowing spread, and $d_t - \varepsilon_{\bar{d},t}$ measures the deviation of net foreign liability from its threshold level, the key driver of the sovereign risk premium. The policy parameters $b_q$ and $b_d$ are both positive, implying that an increase in $d_t$ (or a decrease in $\varepsilon_{\bar{d},t}$) triggers lower $b_t$ (i.e., foreign asset sales). The rationale behind the rule is that the central bank intervenes in the foreign exchange market to sell its currency reserves if either the private borrowing spread or the risk premium on government bonds issued in foreign currency rises. The specification implies that the central bank does not attempt to offset all fluctuations in the UIP risk premium.

For the tax on capital outflows, $\tau_t$, we assume the following CFM rule:

$$\tau_t = \tau_\tau \tau_{t-1} + (1-\tau_\tau)\left[\tau_q\left(q_{c,t} - \varepsilon_{\bar{q},t}\right) + \tau_\phi\left(\phi_t - \rho_\phi \phi_{t-1}\right)\right] + e_{\tau,t} \tag{58}$$

where $\tau_\tau$ allows for foreign asset purchases/sales smoothing, $e_{\tau,t}$ is a foreign asset purchase/sale shock, assumed to be i.i.d. and $N(0,\sigma_\tau^2)$. The term $\phi_t - \rho_\phi \phi_{t-1}$ is the counterpart of risk premium affected by net foreign liabilities, central bank's foreign asset purchases, debt limit shock, and risk premium shock. The policy parameters $\tau_q$ and $\tau_\phi$ are both positive. Therefore, the rule implies that excessive depreciation in the real exchange rate triggers an increase in the capital outflow tax to reduce incentives to sell the domestic currency. The rationale behind the second term is that the authorities attempt to use CFMs to change the exchange value of its currency so that they respond to any changes in the non-smoothing component of the risk premium on government bonds.

The government collects tax revenues from the capital, $\tau_k$, labor, $\tau_l$, consumption, $\tau_c$, commodity export, $\tau_x$, and import taxes, $\tau_m$, and sells the bond portfolio (i.e., the share of GDP), $d_{g,t} \equiv \frac{D_{g,t}}{\bar{Y}P_t}$, to finance its interest payments and expenditure, $g_t$. Fiscal choices satisfy the identify

$$\begin{aligned} &d_{g,t} + \tau_k kr_y\left(k_t^s + r_t^k\right) + \tau_l l\xi_y(n_t + \xi_t) + \tau_c c_y\left(c_t - \gamma_t^{\bar{c},c} - \gamma_t^{m,\bar{c}} + \gamma_t^{m,h}\right) + \\ &\tau_x\left(x_{ncom,y}x_{ncom,t} + x_{com,y}\left(x_{com,t} + \gamma_t^{com,*} + q_t\right)\right) + \tau_m\Big(m_{o_c,y}\left(o_{c,t} + \gamma_t^{o,*} + q_t\right) + \\ &m_{o_y,y}\left(o_{y,t} + \gamma_t^{o,*} + q_t\right) + m_{\bar{c},y}\left(\bar{c}_{m,t} + q_t\right) + m_{in,y}\left(in_{m,t} + q_t\right) + m_{g,y}\left(g_{m,t} + q_t\right) + \\ &m_{x,y}\left(x_{m,t} + q_t\right)\Big) = (1 + r^L)d_{g,t-1} + g_y g_t \end{aligned} \tag{59}$$

where $kr_y$ is steady state ratios of capital income to GDP, $l\xi_y$ is labor income to GDP ratio and $r^L$ is the steady-state real interest rate on government debt.

As employed by Leeper et al. (2017), the fiscal rule is set as government expenditure, $g_t$, respond to $d_{g,t-1}$ and domestic output, $y_t$, as follows:

$$g_t = \vartheta_g g_{t-1} - \left(1 - \vartheta_g\right)\left[\vartheta_y y_t + \vartheta_d d_{g,t-1}\right] + e_{g,t} \tag{60}$$

where $\vartheta_g$ allows for government expenditure smoothing, $e_{g,t}$ is a government spending shock, assumed to be i.i.d. and $N\left(0,\sigma_g^2\right)$. According to the fiscal rule, the fiscal authority has two objectives: output stabilization and government debt stabilization. The policy parameters $\vartheta_y$ and $\vartheta_d$ are both positive, implying that the fiscal policy is pro-cyclical as an increase in $y_t$ (or a rise in $d_{g,t}$) triggers lower government spending, $g_t$.

### 2.4 Foreign variables

The foreign currency commodity price that domestic commodity exporters take ($p_{com,t}$) is given by

$$p_{com,t} = \mu_{com} p^*_{com,t} + (1 - \mu_{com}) p_{com,t-1} \tag{61}$$

where $p^*_{com,t}$ is the commodity price in the foreign currency determined in world markets and is unaffected by economic developments in the domestic economy. In the long run, we assume that the law of one price holds for commodities. However, following Rees et al. (2016), we allow for a delay in the short-term pass-through into the prices that domestic commodity exporters face. We do this to account for real-world friction in that a portion of commodity exports is sold according to predetermined price contracts. We assume that $100 \times \mu_{com}$ percent of any changes in overseas commodity prices feeds into domestic commodity prices within the same quarter of the price change. The assumption also aligns with the dominant currency pricing paradigm where export prices are sticky in a dominant currency (i.e., dollar invoicing shares are above 80 percent), highlighted by Gopinath et al. (2020). The domestic currency oil price that importers sell is given by

$$p_{o,t} = p^*_{o,t} + e_t \tag{62}$$

where $p^*_{o,t}$ is the oil price in the foreign currency determined in world markets. In line with Medina and Soto (2005), we assume there is no delay in the pass-through from the world oil prices to the domestic retail prices.

In the model, the foreign output, $y^*_t$, foreign inflation, $\pi^*_t$, and foreign nominal interest rate, $i^*_t$, the world oil price, $p^*_{o,t}$, and the world commodity price, $p^*_{com,t}$, are assumed to follow AR(1) process:

$$y^*_t = \rho_{y^*} y^*_{t-1} + e_{y^*,t} \tag{63}$$

$$\pi^*_t = \rho_{\pi^*} \pi^*_{t-1} + e_{\pi^*,t} \tag{64}$$

$$i^*_t = \rho_{i^*} i^*_{t-1} + e_{i^*,t} \tag{65}$$

$$p^*_{o,t} = \rho_{p^*_o} p^*_{o,t-1} y^*_t + e_{p^*_o,t} \tag{66}$$

$$p^*_{com,t} = \rho_{p^*_{com}} p^*_{com,t-1} + \rho_{com,y^*} y^*_t + e_{p^*_{com},t} \tag{67}$$

where $e_{y^*,t}$ is foreign output shock, $e_{\pi^*,t}$ is foreign inflation shock, $e_{i^*,t}$ is foreign interest rate shock, $e_{p^*_o,t}$ is global oil price shock, $e_{p^*_{com},t}$ is global commodity price shock, and these exogenous shocks are assumed to be i.i.d. and $N(0, \sigma^2_k)$, $k = \{y^*, \pi^*, i^*, p^*_{o,t}, p^*_{com}\}$. Here we assume that foreign output (the rest of the world's output) positively affects world commodity prices.

## 2.5 Shock dynamics

To capture the link between private and country borrowing spreads[13], the risk appetite shock $\varepsilon_{\bar{q},t}$ in private borrowing, the spread is assumed to be influenced by the private debt limit shock $\varepsilon_{\bar{d},t}$. We also assume that $\varepsilon_{\bar{q},t}$ has an idiosyncratic component, $\varepsilon_{p,t}$, so that

$$\varepsilon_{\bar{q},t} = \varepsilon_{p,t} + \gamma_{\varepsilon_{\bar{d}}}\varepsilon_{\bar{d},t}, \tag{68}$$

The other exogenous shocks $s_t = \{\varepsilon_{p,t}, \varepsilon_{\bar{d},t}, \varepsilon_{c,t}, \varepsilon_{a,t}, \varepsilon_{in,t}, \varepsilon_{cr,t}, \varepsilon_{npl,t}, \varepsilon_{com,t}, \varepsilon_{\phi,t}, \varepsilon_{n,t}, \varepsilon_{\pi,t}, \varepsilon_{\pi_m,t}, \varepsilon_{\omega,t}, \varepsilon_{\psi,t}, \varepsilon_{i,t}, \varepsilon_{car,t}, \varepsilon_{b,t}\}$ are assumed to follow AR(1) processes:

$$s_t = \rho_s s_{t-1} + e_{s,t},\ e_{s,t} \sim i.i.d.\ N(0, \sigma_s^2) \tag{69}$$

Equations (1)-(69) determine 69 endogenous variables. The stochastic behavior of the system of rational expectations equations is driven by 24 exogenous shocks.

# 3. Data, estimation, and empirical results

## 3.1 Data

The model is estimated using 21 quarterly data from 2005Q1 to 2022Q2, the longest available times series as the quarterly data for GDP and its components are only available since 2005Q1. For the domestic economy (Mongolia), the following 16 variables are observed: log-differences of seasonally adjusted (s.a.) real GDP (constant 2015 prices in MNT) ($dlgdp_t$), s.a. real household consumption (constant 2015 prices in MNT) ($dlcon_t$), s.a. real government spending (constant 2015 prices in MNT) ($dlgsp_t$), s.a. real commodity export (constant 2015 prices in MNT) ($dlcx_t$), central bank claims on banks ($dcrcb_t$), real wage (ratio of nominal wage to CPI) ($dlrw_t$), the nominal exchange rate (1 USD to MNT) ($dlner_t$), employment ($dlemp_t$), real bank credits (bank credit to CPI) ($dlbcr_t$), consumer price index ($dlcpi_t$), price index of domestically produced goods ($dldcpi_t$), unemployment rate ($unr_t$), (annual) policy rate ($prate_t$), NPL ratio ($npl_t$), capital adequacy ratio ($car_t$), and foreign exchange sale to foreign reserve ratio ($fxi_t$).

For the foreign economy and market, taken to represent the rest of the world, the following 5 variables are used in the estimation: log-differences of world oil (Brent Crude) price ($dlpoil_t^*$), world coal price (2016 = 100, includes Australian and South African Coal) index ($dlpcom_t^*$), China's GDP index ($dlgdp_t^*$), the US CPI ($dlcpi_t^*$), and (annual) Federal funds rate ($fedr_t^*$). Mongolia has a close trade link with China as exports to China account for about 90 percent of total export, and coal exports, which only go to China, account for 40-50 percent of total exports. Therefore, we assume that the Chinese economy influences Mongolian external demand. China's GDP is used as a proxy for foreign output, and coal price is collected as a proxy for commodity export price. However, the Mongolian economy is financially linked with the Western world as its external debts are mainly in US dollar.

[13] Adrian et al. (2020) document that in their sample of EME countries, the median correlation between corporate and sovereign spreads is about 0.4.

Moreover, a large share of Mongolian trade is still priced and invoiced primarily in the US dollar (i.e., dominant currency pricing) rather than the exporter's or the importer's currency. For instance, the US dollar accounts for 70-75 percent of export revenues, import payments and foreign exchange transactions in Mongolia. Statistics on foreign exchange transactions show that RMB's share is less than 15 percent. To reflect the financial linkage, the US interest rate and the US CPI are observed as proxies for foreign interest rate and foreign inflation, respectively, and the exchange rate of MNT against USD is used in the model estimation. As the foreign variables are modeled as an exogenous AR(1) process, using observable foreign variables from different countries does not violate the setting of the model.

Exchange rate, bank credit, central bank claims, NPL ratio, policy rate, CAR, and FXI are observed from the Bank of Mongolia, while all other domestic variables are directly collected from the database of the National Statistical Office of Mongolia (www.1212.mn). In addition, world oil and coal prices are taken from the IMF Primary Commodity Prices, the China GDP index is calculated based on Chinese annual growth data from Bloomberg, the US CPI is observed from Bloomberg, and the Federal funds rate is collected from the FRED database of Federal Reserve Bank of St. Louis.

Prior to empirical analysis, the data is transformed as follows: all variables, including log-differenced (scaled by 100 to convert into percent) and series in level, are demeaned separately in order to ensure that the series used in the estimation are stationary as they represent the business cycle-related part of the original variables. The corresponding measurement equation is:

$$Y_t = \begin{bmatrix} dlgdp_t \\ dlcon_t \\ dlgsp_t \\ dcrcb_t \\ dlcx_t \\ dlrw_t \\ dlner_t \\ dlemp_t \\ dlbcr_t \\ dlcpi_t \\ dldcpi_t \\ unr_t \\ prate_t \\ npl_t \\ car_t \\ fxi_t \\ dlpoil_t^* \\ dlpcom_t^* \\ dlgdp_t^* \\ dlcpi_t^* \\ fedr_t^* \end{bmatrix} = \begin{bmatrix} d\bar{y} \\ d\bar{c} \\ d\bar{g} \\ d\bar{cr}_{CB} \\ d\bar{x}_{com} \\ d\bar{\xi}_c \\ d\bar{e} \\ d\bar{n} \\ d\bar{cr} \\ \bar{\pi}_c \\ \bar{\pi} \\ \bar{u} \\ 4*\bar{\imath} \\ \overline{npl} \\ \overline{car} \\ \bar{b} \\ d\bar{p}_o^* \\ d\bar{p}_{com}^* \\ d\bar{y}^* \\ \bar{\pi}^* \\ 4*\bar{\imath}^* \end{bmatrix} + \begin{bmatrix} y_t - y_{t-1} \\ c_t - c_{t-1} \\ g_t - g_{t-1} \\ cr_{CB,t} - cr_{CB,t} \\ x_{com,t} - x_{com,t-1} \\ \xi_{c,t} - \xi_{c,t-1} \\ e_t - e_{t-1} \\ n_t - n_{t-1} \\ cr_t - cr_{t-1} \\ \pi_{c,t} \\ \pi_t \\ u_t \\ 4*i_t \\ npl_t \\ car_t \\ b_t \\ p_{o,t}^* - p_{o,t-1}^* \\ p_{com,t}^* - p_{com,t-1}^* \\ y_t^* - y_{t-1}^* \\ \bar{\pi}^* \\ 4*\bar{\imath}^* \end{bmatrix} \quad (70)$$

where $dl$ stands for 100 times log difference. The variables with the bar in equations stand for the steady state values, the historical average of the corresponding series.

## 3.2 Prior distributions and calibrated parameters

As our model is a medium-scale model, we estimate and evaluate the model using Bayesian techniques, which help deal with cross-equation restrictions by dealing with misspecification and identification problems, well will help resolve identification and misspecification problems. As the prior is based on 'non-sample' information, the Bayesian techniques provide an ideal framework for combining different sources of information (Del Negro and Schorfheide 2011). We estimate the mode of the posterior distribution by maximizing the log posterior function. In the next step, the Random Walk Metropolis (RWM) algorithm is used to get the posterior distribution and evaluate the model's marginal likelihood. All numerical estimations, evaluations, and simulations in this paper are done using Dynare 4.5.7.

Christopher Sims's 'csminwel' optimization routine is used to obtain the posterior mode and to compute the Hessian matrix at the mode. To test the presence of the identification problem, more than 20 optimization runs are launched, and all optimization routines converge to the same mode value. As a unique mode for the model is found, the Hessian from the optimization routine is used as a proposal density, properly scaled ($c = 0.16$) to attain an acceptance rate of about 25 percent. For the RWM results, two independent chains are generated with 500,000 draws each, of which 200,000 are used as an initial burn-in phase. Convergence of the chains is monitored using both the univariate and the multivariate convergence diagnostics variants of Brooks and Gelman (1998).

There are two sets of model parameters. The first set includes parameters that are calibrated. The discount factor for Mongolia ($\beta$) is set to 0.9925, which is slightly lower than the calibrated values for advanced economies, and (quarterly) steady-state real interest rate on net foreign liabilities ($r_d$) is calibrated to 0.75 percent (i.e., the annualized rate is 3 percent), consistent with the sample average of the spread between the nominal interest rate on total external debts and foreign inflation. The (quarterly) steady-state real interest rate on government debt ($r^L$) is set to 0.25 percent as most government debt is concessional loans from international financial institutions (i.e., ADB, World Bank, JICA, and EBRD) and donor countries. In the spirit of Gabaix (2020), we allow for discounting in the Euler equation of consumption and price-setting equations by setting $\delta_c = 0.96$ and $\delta_\pi = 0.97$, in line with the calibrated values of Adrin et al. (2020). The share of oil in the CPI basket ($m_o$) is set to 0.08, consistent with the average share in the basket. The share of imported goods in the core consumption basket ($m_m$) is calibrated to 0.45, which is the fact that the sample average share of imported goods in the CPI is about 40 percent (i.e., $(1 - 0.08) \cdot 0.45 = 0.41$). The steady-state value of the labor income to output ratio ($l\xi_y$) is fixed at 0.27, which is the average ratio from 2005 to 2021. The steady-state value of the rent income to output ratio ($kr_y$) is fixed at 0.2, consistent with the sample average ratio. Capital depreciation rate ($\delta_k$) is assigned a value of 0.04 (on a quarterly basis), which is chosen to be slightly higher than the values used in advanced countries.

The steady-state values of investment to GDP ratio ($i_y$), import to GDP ratio ($m_y$), the government spending to GDP ratio ($g_y$), commodity export to GDP ratio ($xr_y$) and non-commodity export to

GDP ratio ($xnr_y$) are respectively calibrated to $i_y = 0.36$, $m_y = 0.61$, $g_y = 0.14$, $xr_y = 0.46$, $xnr_y = 0.02$, which are the sample average values of the ratios calculated using statistics on the expenditure approach of GDP and foreign trade statistics. The import to GDP ratio in the economy is much higher than the calibrated value in Adrian et al. (2022). The shares of import components are calibrated to $m_{o_c,y} = 0.06$, $m_{o_y,y} = 0.02$, $m_{in,y} = 0.21$, $m_{\bar{c},y} = 0.165$, and $m_{x,y} = 0.1$ based on the sample average of the import data published by the Mongolian Customs General Administration. Following Adrian et al. (2020), we set $\gamma_{\varepsilon_{\bar{d}}} = 0.5$.

Finally, tax rates such as $\tau_k$, $\tau_l$, $\tau_c$, $\tau_x$, and $\tau_m$ are fixed at 10 percent since Mongolia has kept its current 10 percent tax rate for most of the income, including employment income, operating income, capital gains, passive income of dividends, interest and royalties, and other indirect income for resident tax payers for the sample period.

The second set of 107 parameters to be estimated and their prior distributions are listed in the first panel of Table X.1 of the Appendix. Priors for parameters of macroeconomic relationships are selected consistent with those used in the literature (e.g., Smets and Wouters 2007, Adolfson et al. 2007, Galí et al. 2011, and Gan-Ochir and Undral 2018). Prior distributions of parameters in bank credit, NPL, and private borrowing spread equations are based on Aguirre and Blanco (2015) and Adrian et al. (2020). Priors for the parameters due to the inclusion of oil prices are chosen in line with Medina and Soto (2005).

We set diffuse priors for parameters in CAR, FXI, CFM, and Fiscal policy rules in line with Quent and Rabanal (2013) and Adrian et al. (2022). As a common choice, the inverse gamma distribution is selected for all standard deviations of shocks, and prior variances are chosen as diffuse priors reflecting the volatility in the observed series for structural shocks.

### 3.3 Posterior estimates of the parameters

The last two columns in Table X.1 of the Appendix report the posterior mode, mean, and 90 percent probability interval of the posterior distribution of estimated parameters. The data regarding the estimated parameters is very informative as the posteriors significantly shift from the priors. It implies that the estimated model reflects specific characteristics of the Mongolian economy. The estimated parameters of macroeconomic relationships and macro-financial linkages align with those found in existing studies (i.e., Gan-Ochir and Undral 2016) that estimate structural model for Mongolia using Bayesian techniques. Focusing on the novel results for the Mongolian economy, we only discuss selected parameters at the posterior mean.

The estimated parameters of private borrowing spread imply that there exists evidence financial channel of exchange rate passing through the costs of credit ($\rho_q = 0.07$), but MPP and UMP measures can directly affect the cost of credit ($\rho_{car} = 0.38$ and $\rho_{CB} = 0.013$).

The values of the elasticity of substitution between oil and core consumption ($\eta^{o,\bar{c}}$), the share of oil in production ($\Omega_o$), and the elasticity of substitution among production inputs ($\varsigma$) is estimated to be around 0.3, 0.17, and 0.94, respectively. The result supports the argument that oil plays a vital role in the consumption and production of the economy. Compared to the results found by

Medina and Soto (2006) for the Chilean economy, $\eta^{o,\bar{c}}$ is estimated as a lower value, but $\varsigma$ is estimated in a higher value.

The data also supports the delayed effects of bank credit on investment. For instance, the estimated share of current-period bank credit on the current investment ($\alpha_{in}$) is estimated at 0.61, implying that 39 percent of last quarter's bank credit transformed into the current investment. The risk premium parameters, $\phi_{e,1}$ and $\phi_{e,2}$, representing the degree of impact of expected and current depreciation on the risk premium, are estimated at 0.67 and 0.84, respectively. The result supports the empirical fact that the risk premium negatively correlates with the expected depreciation. As highlighted by Bacchetta and Wincoop (2021), the modified UIP with $\phi_{e,1}$ and $\phi_{e,2}$ will help us replicate the long-standing empirical evidence (or resolve the delayed overshooting puzzle) that raises in the interest rate leads to gradual appreciation, followed by a gradual depreciation.

The elasticity of non-commodity export with respect to relative price is estimated at a high value of 1.43, implying that non-commodity export is very elastic to changes in the relative price. Since the share of non-commodity export in total export is less than 10 percent, total export can be less sensitive to changes in relative price and real exchange rate. The elasticities of imports with respect to relative price are estimated as $\eta^{m,g} = 1$, $\eta^{m,\bar{c}} = 0.8$, $\eta^{m,in} = 1.13$, and $\eta^{m,x} = 1.05$, implying that imported goods for government spending, investment, and export are very elastic to changes in relative price and real exchange rate. The estimated parameter on the commodity price adjustment ($\mu_{com}$) suggests that 67 percent of changes in world commodity export price feed commodity export prices that domestic companies receive within the same quarter.

Degrees of smoothing in interest rate, UMP, CAR, and fiscal rules are estimated at the high values of $\gamma_i = 0.91$, $\varrho_{cr_{CB}} = 0.89$, $\varpi_{car} = 0.94$, and $\vartheta_g = 0.59$, respectively, which is consistent with the literature. However, degrees of smoothing in FXI and CFM rules are estimated at relatively low values. The estimated interest rate rule implies that the Bank of Mongolia gives more focus on the anti-inflation policy ($\gamma_\pi = 1.59$), but also considers output ($\gamma_y$=0.07) when setting the policy rate. The estimated policy parameters suggest that the CAR strongly responds to the output compared to the policy rate, FXI firmly reacts to the real exchange rate, and CFM can be effective way to respond to changes in risk premium.

The data also contains a large amount of information about the parameters of the shock process. In particular, standard deviations of bank credit, central bank credit, investment, domestic price markup, commodity export demand, world commodity export price, world oil price, and government spending shocks are estimated in relatively high values, capturing the fluctuations in the observed variables.

## 3.4 Fitness of the model

Figure X.1 of the Appendix reports the actual data, and the Kalman-filtered, one-sided estimate[14] of the observed variables, computed using the posterior mean, to assess the in-sample fit of the

[14] The Kalman filter estimates are also called as one step ahead predictions and can be interpreted as the fitted value of a regression.

estimated model. In the figure, green lines represent actual values, and black lines correspond to model fit values.

The in-sample fit of the estimated model appears to be reasonably well since the model somewhat replicates the general movements of most variables. In particular, the model fits the actual data reasonably well in the second half of the sample. The in-sample fit is good for variables with low fluctuations but weak for high ones.

## 3.5 Impulse responses to external shocks

Impulse responses of the estimated model to external shocks are shown in green lines with '+' marker of Figures X.2-X.5 of the Appendix. In this section, the discussion only focuses on the impulse responses of the estimated model.

The transmission of commodity export demand shock is presented in Figure X.2. The results align with empirical findings obtained by Gan-Ochir et al. (2022) using a VAR model for a small open and commodity-exporting economy (Mongolia). According to the estimated model, the demand shock of a 10 percent increase in commodity export transfers to 9 percent growth in real total export, leading to 2.5 and 3.5 percent rises in employment and output on impact, respectively. The higher export increases the import demand, and FXI and CFM measures are adjusted to reduce the appreciation pressure. Consequently, the real exchange rate gradually appreciates. The appreciation reduces the imported goods inflation while the domestic output increases the pressure on wages, causing domestically produced goods' inflation. Responding to the CPI inflation and output rises, the authority raises the CAR, which crowds out private consumption and investment.

An increase in commodity export price boosts domestic demand, as shown in Figure X.3. Even with FXI and CFM measures, the shock gradually appreciates the real exchange rate, leading to decreased net export (i.e., enormously increased import and slightly decreased export) and falls in imported good inflation and private borrowing spread. The domestic demand increases the pressure on the inflation of domestically produced goods, hence the CPI inflation. The decline in the real borrowing rate increases private consumption and investment, boosting output. The results are consistent with the empirical evidence on the effects of copper and coal prices in the Mongolian economy found by Gan-Ochir and Davaajargal (2019), who employed a large Bayesian VAR approach.

As a novel result for the Mongolian economy, Figure X.4 shows that the risk premium shock generates a difficult policy trade-off. The shock causes investors to be less willing to hold bonds issued by the home economy or to demand a higher expected return, which leads to the depreciation of the domestic currency. The real exchange rate depreciation stimulates real net export (i.e., slightly increases export and strongly reduces import). Total export is less responsive to changes in the exchange rate since the share of commodity export (prices are sticky and set in the world market) is relatively high in the economy. As inflation expectations are less well anchored and the share of imported goods in the CPI basket, the depreciation has significant and persistent effects on inflation, inducing the central bank to tighten monetary policy. However, the real policy rate remains negative for the first five quarters since the central bank does not fully follow the Taylor principle and is relatively slow to respond to inflation. The depreciation gradually increases the private borrowing spread through the financial channel of the exchange rate. Since the rise in the borrowing spread dominates the fall in the short-term interest rate, the real borrowing rate gradually rises, crowding out private consumption and investment. As highlighted by Adrian et al. (2020) and Adrian et al. (2021), output contracts while net export and inflation rise in parallel, highlighting the potential problems associated with exchange rate depreciations for economics with these characteristics. With FXI and CFM measures, the exchange rate is stabilized over time. Quantitatively, a 1 percentage point rise in risk premium depreciates the real exchange rate by 0.45 percent peak after 5 quarters, increases CPI inflation by 0.12 percentage point peak after 2 quarters, and contracts output by 0.05 percent peak after 2 quarters.

The macroeconomic and financial effects of the oil price shock on the Mongolian economy are shown in Figure X.5. The results are qualitatively like those obtained by Bjørnland et al. (2018), who used a Markov Switching New Keynesian DSGE model to analyze the role of oil price volatility in the US economy. The 10 percent surge in world oil price raises the CPI inflation by 1.3 percentage points on impact and gradually declines output by 0.6 percent within 2 years as the cost of production increases. The decline in the import mainly drives the initial short-lived rise in output. Higher fuel prices and CPI inflation decline fuel and core consumption, leading to a fall in demand for imported oil and consumption goods. In responding to inflation, the central bank raises the nominal policy rate. Because of the high inflation, the real exchange rate appreciates, and the real short-term interest rate falls. The appreciation amplifies the fall in the real borrowing rate by lowering the private borrowing spread on the impact period. The lower borrowing rate temporarily supports the investment. However, the investment quickly declines as the persistent fall in output reduces bank credit and investment. With an increased cost of production, firms want to substitute with labor; employment increases (and unemployment falls), pushing up real wages rapidly by 1.1 percent. The wage growth heightens the pressure on CPI inflation as well.

## 3.6 Variance and historical decompositions

Having examined the impulse responses, we are now interested in the forecast error variance decomposition (FEVD) to investigate the role of structural shocks in driving fluctuations of crucial macro and financial variables. Table X.2 of the Appendix displays the FEVD of selected variables (at period 20) computed at the posterior mean.

The variance decomposition analysis confirms that external shocks play vital roles in Mongolian economic fluctuations. For instance, external shocks account for above 40 percent of the 20-quarter ahead fluctuations in GDP, household consumption, CPI inflation, real wage, and exchange rates. The result is entirely in line with the empirical facts from vector autoregression (VAR) models found by Gan-Ochir and Davaajargal (2019) and Gan-Ochir et al. (2022). Within the external shocks, commodity export demand and price shocks are essential for variances of output, consumption, exchange rates, NPL ratio, real wage, employment, CAR, and FXI. However, oil price and risk premium shocks explain the CPI inflation, exchange rates, and interest rate fluctuations. The analysis also shows that oil price and domestic supply shocks are vital drivers of inflation, exchange rate fluctuations, real wage, and interest rate. In addition to external shocks, fluctuations in the labor market are driven by domestic demand shocks such as MEI, preference, and bank credit shocks.

In line with the existing literature, contributions of unanticipated policy shocks to macroeconomic fluctuations are negligible. However, it does not imply that systematic policy actions are less effective in stabilizing the whole economy.

We also assess the historical decomposition to answer the question of how much of the changes in key macroeconomic variables are due to external shocks. Figure X.6 of the Appendix reports the historical decompositions of selected variables explained by external shocks. In the figure, black lines are the stochastic components of the actual series, and the green bars are contributions of external shocks.

The shock decompositions confirm that external shocks have been the primary source of changes in the selected vital variables. For instance, the recent recession during the COVID-19 pandemic (e.g., annual GDP growth and annual CPI inflation for 2020 were -4.6 percent and 2.3 percent, respectively) has been mainly driven by external shocks. The result is consistent with findings obtained by Gan-Ochir (2022), who analyzes macroeconomic effects and transmission of the pandemic on the Mongolian economy. Moreover, external shocks have mainly led to cycles of change in the nominal exchange rate, changes in the real wage, and the short-term interest rate. The crucial role of external shocks implies that policymakers can achieve macroeconomic and financial stability by implementing an optimal policy mix, which aims to minimize the adverse effects of the shocks.

Overall, the above empirical results based on the model are entirely in line with the empirical facts found for the Mongolian economy.

## 4. Policy analysis

Having verified that our estimated model provides a plausible model fit and reasonably replicates empirical facts on the effects of external shocks on the economy (i.e., the results of impulse responses, variance, and historical decompositions), we conduct policy analysis using the estimated model. In this section, we quantify transmission mechanisms of CMP, UPM, FXI, MPP, CFM, and fiscal policy and examine the optimal policy mix (i.e., the jointly optimized responses of these policies) under Ramsey policy and optimized policy rules.

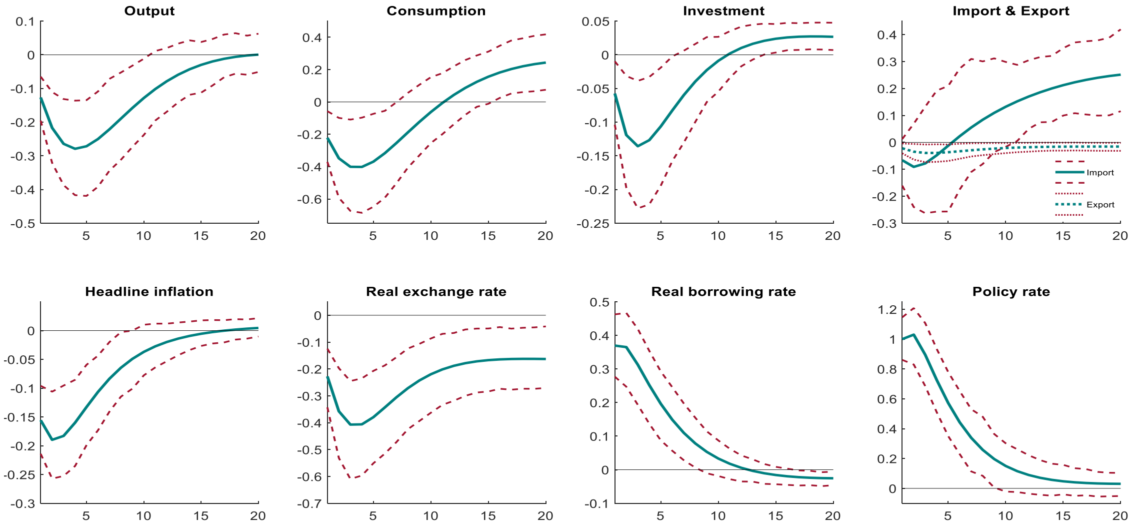
### 4.1 Policy transmission mechanisms

As our model features extensive interactions among transmission mechanisms of policies, here we examine these policy transmission mechanisms with impulse responses. Here we show impulse responses of main variables to unanticipated changes in policy instruments. Figure 2 shows key macro and financial variables' impulse responses to unanticipated policy instrument changes. The solid green lines are the mean impulse responses of posterior distributions, while the dashed red lines represent the 90 percent posterior probability interval.

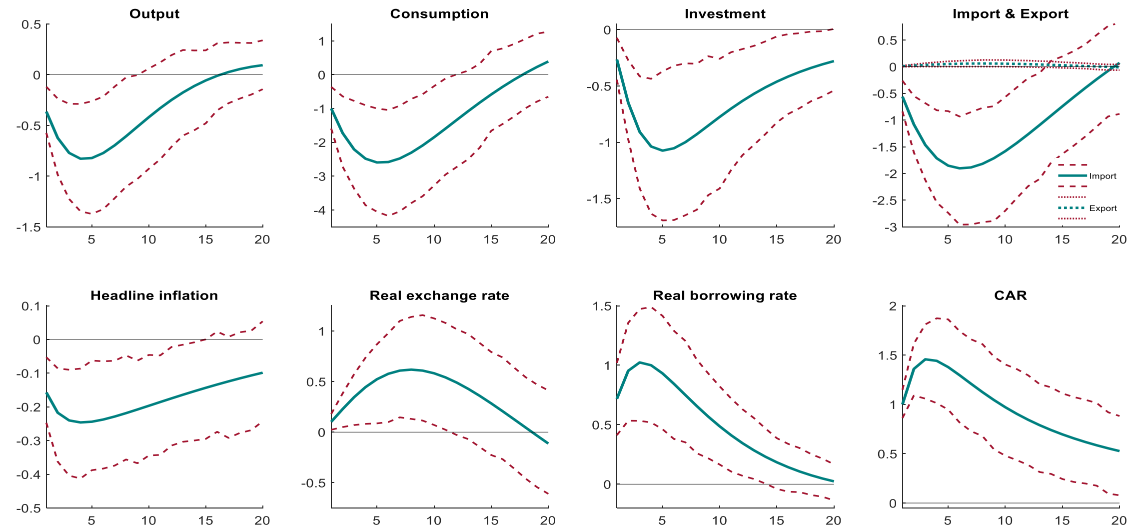
Figure 2.A presents the transmission mechanism of a monetary policy tightening through a policy rate hike (CFM). A policy rate hike increases the real borrowing rate, and the resultant tightening of financial conditions reduces consumption, investment, export, and output. As a result, the domestic currency appreciates in nominal and real terms, initially stimulating the imports in the medium term. The lower output decreases the inflation of domestically produced goods.

## Figure 2. Transmission mechanisms of policy instruments

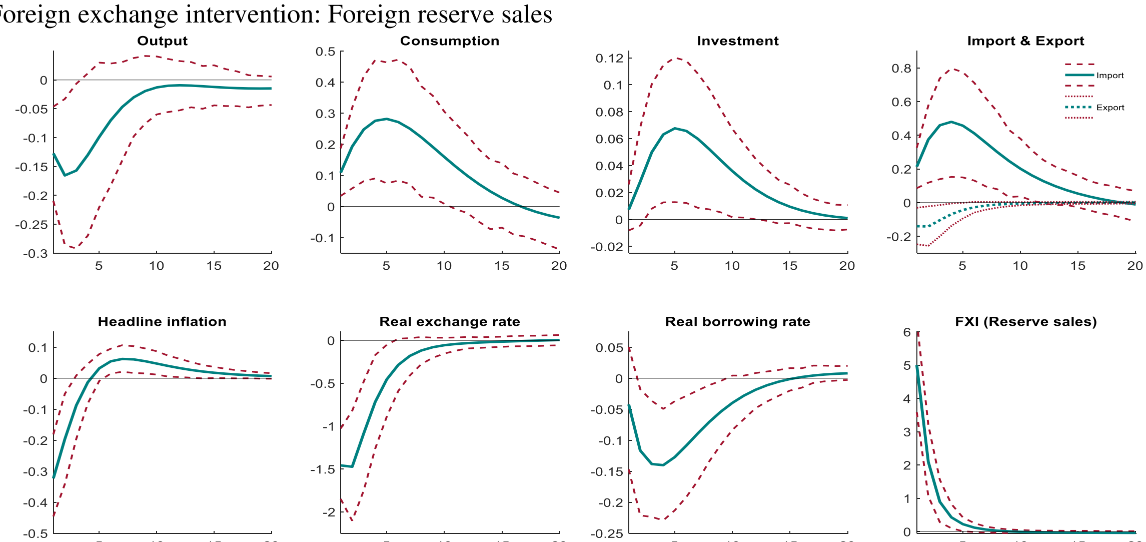
A. Conventional monetary policy tightening: An increase in interest rate



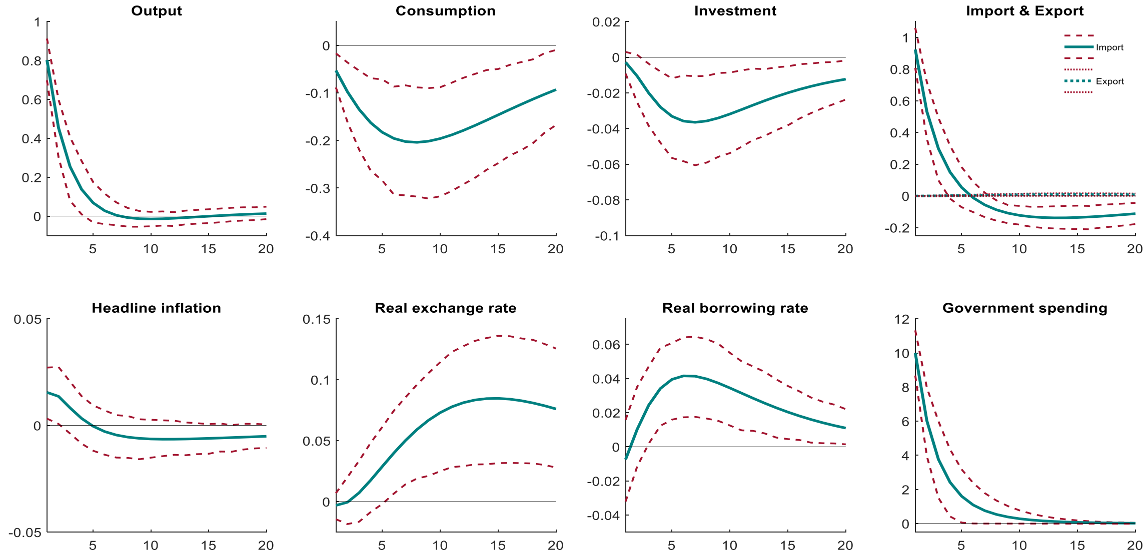

B. Macroprudential policy tightening: An increase in CAR



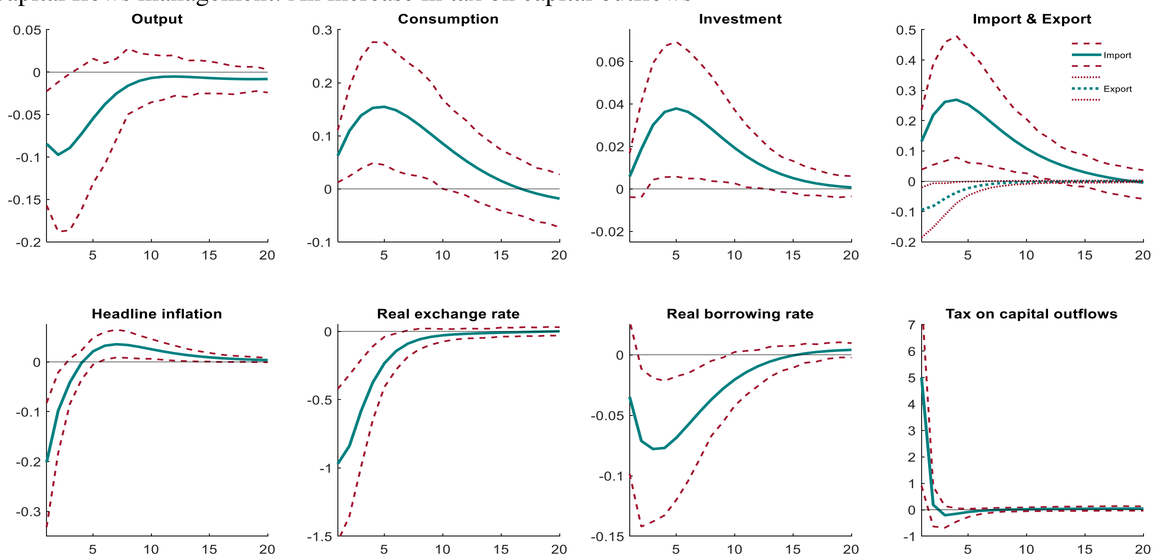

C. Foreign exchange intervention: Foreign reserve sales



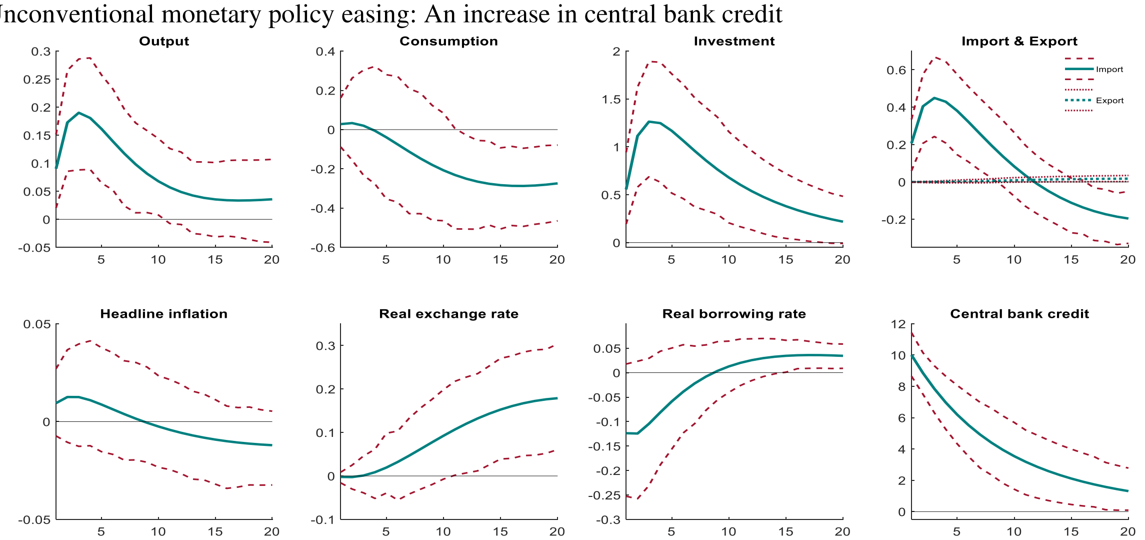
D. Fiscal policy easing: An increase in government spending




E. Capital flows management: An increase in tax on capital outflows




F. Unconventional monetary policy easing: An increase in central bank credit



The currency appreciation also reduces import price inflation and oil price inflation, amplifying and accelerating the fall in CPI inflation. Numerically, increasing the policy rate by 1 percentage point lowers output by 0.3 percent peak after 4 quarters, CPI inflation by 0.2 percentage points peak after 2-3 quarters, and appreciates the currency by 0.4 percent peak after 4 quarters. The estimated effects on inflation and output are relatively weak compared to findings obtained for advanced economies.

Figure 2.B shows that macroprudential tightening through a rise in CAR (MPP) increases the real borrowing rate and reduces the bank credit. The rise in borrowing rate lowers consumption and amplifies the fall in the bank credit, thereby, investment. As a result, output falls, and the trade balance ratio increases, reflecting lower imports. The lower output reduces CPI inflation. The central bank cuts the policy rate to mitigate CPI inflation and output falls. Reduced inflation and policy rate lead to domestic currency depreciation in both nominal and real terms. Quantitatively, rising CAR by 1 percentage point lowers output by 0.8 percent peak after 4 quarters, inflation by 0.25 percent peak after 3-4 quarters, and depreciates the currency by 0.6 percent peak after 7 quarters. Compared to a tightening monetary policy, a tighter macroprudential policy can reduce inflation and output components without leading to a real exchange rate appreciation. The result suggests that a tighter macroprudential policy can complement monetary policy to stabilize the whole economy by providing more freedom to focus on its objectives (i.e., to stabilize growth and prices).

Figure 2.C reports the transmission mechanism of FXI through reserve sales. An increase in foreign exchange sales to foreign reserve ratio appreciates the real exchange rate, slightly decreases export, and strongly raises imports. As a result, the currency appreciation reduces the CPI inflation, allowing room to decrease the policy rate. Moreover, through the financial channel of the exchange rate, the appreciation also narrows the borrowing spread, which stimulus the bank credit, consumption, and investment. On the other hand, the decrease in net export dominates the rise in domestic demand; hence output falls. Quantitively, increasing the foreign exchange sale ratio by 5 percentage points (i.e., around 150 million USD as of the end of 2022) appreciates the real exchange rate by 1.5 percent, reduces CPI inflation by 0.3 percentage points on impact, and falls output by 0.16 percent peak after 2 quarters.

Figure 2.D displays the transmission mechanism of a fiscal policy easing through a rise in government spending. A surge in government spending boosts public demand, thereby expanding output. As expected, public consumption or investment crowds out private consumption and investment. The fiscal expansion also increases imports, leading to currency depreciation. The depreciation passes to the higher CPI inflation and wider borrowing spread, which amplifies the crowding-out effects. Numerically, increasing government spending by 10 percent raises the output by 0.8 percent and imports by 0.9 percent on impact.

Figure 2.E reveals that CFM measure can effectively stabilize the economy through a tax rate on capital outflows. This measure raises the cost of cross-border transactions from the domestic market to abroad. Raising the tax appreciates the currency in nominal and real terms, slightly reducing exports and increasing imports. The currency appreciation also decreases the CPI inflation and the real borrowing rate, stimulating private consumption and investment. However, the resultant rise in import is higher than the fall in consumption and investment, hence the output

falls. As a result, the central bank cuts the policy rate to mitigate the falls in inflation and output. Like the FXI, the CFM measure supports monetary autonomy by allowing the central bank to focus on the economy's internal stability solely. Quantitively, raising the tax rate by 5 percentage points appreciates the real exchange rate by 1 percent and decreases output by 0.1 percent and inflation by 0.2 percentage points.

Figure 2.F shows the transmission mechanism of a monetary policy tightening through the central bank balance sheet expansion. The rise in the central bank credit to banks increases bank credit and lowers the borrowing rate spread on impact, thereby boosting private. In addition, the higher investment raises demand for imported goods and depreciates the currency. Consequently, the 10 percent increase in central bank credit expands the output by 0.2 percentage points peaking after 3 quarters. The results are qualitatively consistent with empirical estimates of Gan-Ochir and Davaasukh (2022) based on a sign and zero restricted VAR model for CMP and UMP analysis in Mongolia.

## 4.2 The interaction between policies and optimal policy responses

This section examines the interaction among policies and optimal policy mix under Ramsey policy and optimized policy rules. In the analysis, we use our model calibrated at the posterior mode values of the estimated parameters.

### 4.2.1 Policy objectives

Suppose that the government has preferences defined economic stabilization objectives as well as instrument smoothing objectives, represented by an intertemporal loss function,

$$\mathcal{L}_t = E_t \sum_{s=t}^{\infty} (1-\beta)\beta^{s-t}\, \ell(\boldsymbol{x}_s, \boldsymbol{z}_s) \tag{71}$$

Where $\beta$ is the planner's discount rate, $\boldsymbol{x}_s$ is a set of objective variables, and $\boldsymbol{z}_s$ is a set of policy instruments. Following existing papers (i.e., Debortoli et al. 2019 and Adrian et al. 2022), we assume that the intertemporal loss function, $\ell(\boldsymbol{x}_s, \boldsymbol{z}_s)$, quadratically penalizes the deviation of objective variables and policy instruments from their steady-state equilibrium values,

$$\ell(\boldsymbol{x}_s, \boldsymbol{z}_s) = \sum_{j=1}^{M} \lambda_j \left(\boldsymbol{x}_{j,s}\right)^2 + \sum_{i=1}^{N} \lambda_i \left(\boldsymbol{z}_{i,s}\right)^2$$

where $\lambda_j, \lambda_i \geq 0$ for all $j = 0, \ldots, M$ and $i = 0, \ldots, N$, and the preference parameters $\lambda_j$ and $\lambda_i$ characterize the policymaker's preferences over objective and policy instrument variables, respectively. In the case, the value of $\lambda_i$ controls the degree of instruemtnt smoothing. Using a canonical New Keynesian DSGE model, Debortoli et al. (2019) analytically show that the quadratic approximation to the household utility around a non-distorted steady state results in a similar generalized loss function with optimal weights, quadratically penalizes the deviation of objective variables from the equilibrium values.

In specifying the intertemporal loss function, we assume that the considered 6 policies' loss functions must be consistent with policy rules in our model. For the CMP, the central bank stabilizes inflation and output growth by selecting the policy rate for Ramsey policy or the parameters of the policy rate rule (53) for the optimized policy rules to minimize the following loss function[15],

$$\ell_{CMP}(\pi_c, \Delta y, \Delta i) \equiv (\pi_c)^2 + \lambda_{cmp,y}(\Delta y)^2 + \lambda_{\Delta i}(\Delta i)^2 \tag{72}$$

where $\lambda_{cmp,y} \geq 0$, $\lambda_{\Delta i} \geq 0$.

For the UMP, the central bank aims to stabilize the credit growth and output growth by choosing the central bank credit or the parameters of the UMP rule (55) to minimize the following loss function,

$$\ell_{UMP}(\Delta cr, \Delta y, \Delta cr_{CB}) \equiv \lambda_{ump,cr}(\Delta cr)^2 + \lambda_{ump,y}(\Delta y)^2 + \lambda_{\Delta cr_{CB}}(\Delta cr_{CB})^2 \tag{73}$$

where $\lambda_{ump,cr} \geq 0$, $\lambda_{ump,y} \geq 0$, $\lambda_{\Delta cr_{CB}} \geq 0$.

The macroprudential authority is also concerned with the variability of credit growth, output, and the chosen policy instrument. Following Angelini et al. (2014), we accordingly assume that the authority selects CAR or parameters of the CAR rule (56) to minimize the loss function,

$$\ell_{MPP}(\Delta cr, \Delta y, \Delta car) \equiv \lambda_{mpp,cr}(\Delta cr)^2 + \lambda_{mpp,y}(\Delta y)^2 + \lambda_{\Delta car}(\Delta car)^2 \tag{74}$$

where $\lambda_{mpp,cr} \geq 0$, $\lambda_{mpp,y} \geq 0$, $\lambda_{\Delta car} \geq 0$. The positive value for $\lambda_{ump,y}$ implies a countercyclical policy: banks must hold more capital for a given amount of loans in good times, but CAR decreases in recessions.

In line with the policy rules of FXI set by Adrian et al. (2020) and Adrian et al. (2021), we assume that the central bank chooses the amount of FXI or parameters of the FXI rule (57) to minimize the following loss function,

$$\ell_{FXI}(\Delta q_c, \Delta d, \Delta b) \equiv \lambda_{fxi,q}(\Delta q_c)^2 + \lambda_{fxi,d}(\Delta d)^2 + \lambda_{\Delta b}(\Delta b)^2 \tag{75}$$

where $\lambda_{fxi,q} \geq 0$, $\lambda_{fxi,d} \geq 0$, $\lambda_{\Delta b} \geq 0$.

In the same way, CFM authority selects the tax on capital outflows or parameters of the CFM rule (58) to minimize the following loss function,

$$\ell_{CFM}(\Delta q_c, \Delta \phi, \Delta \tau) \equiv \lambda_{cfm,q}(\Delta q_c)^2 + \lambda_{cfm,\phi}(\Delta \phi)^2 + \lambda_{\Delta \tau}(\Delta \tau)^2 \tag{76}$$

where $\lambda_{cfm,q} \geq 0$, $\lambda_{cfm,d} \geq 0$, $\lambda_{\Delta \tau} \geq 0$.

Following Leeper et al. (2017), we assume that the fiscal authority selects the government spending or parameters of the fiscal rule (60) to minimize the loss function,

$$\ell_{FP}(\Delta y, \Delta d_g, \Delta g) \equiv \lambda_{fp,y}(\Delta y)^2 + \lambda_{fp,d}\left(\Delta d_g\right)^2 + \lambda_{\Delta g}(\Delta g)^2 \tag{77}$$

where $\lambda_{fp,y} \geq 0$, $\lambda_{fp,d} \geq 0$, $\lambda_{\Delta g} \geq 0$.

[15] The loss function could be obtained by taking a second-order approximation of the utility function of households and entrepreneurs, as in Woodford (2003) in the case of optimal policy.

Positive values for $\lambda_{\Delta i}$, $\lambda_{\Delta cr_{CB}}$, $\lambda_{\Delta car}$, $\lambda_{\Delta b}$, $\lambda_{\Delta\tau}$ and $\lambda_{\Delta g}$ are warranted by the need to keep movements in the policy instruments "reasonable" since it is well known that if there is no cost for adjusting them, optimal policies tend to generate excessive volatility in the policy instruments.

We examine the interaction between policies in two different cases. In the case of cooperation, the policies are chosen jointly and optimally by a single authority with 6 instruments. A single authority sets values of policy instruments or parameters in policy rules to minimize the sum of the loss functions (72), (73), (74), (75), (76), and (77):

$$\ell = \ell_{CMP} + \ell_{UMP} + \ell_{MPP} + \ell_{FXI} + \ell_{CFM} + \ell_{FP} \tag{78}$$

In the second case, we assume that policy authorities do not cooperate: each policy authority minimizes its loss function, taking the other policies' rules as given.

### 4.2.2 Ramsey optimal policy

In the case of cooperation, a single authority minimizes (78) by jointly choosing all 6 policy instruments and taking into account the equilibrium conditions of the economy:

$$\min_{\{i_s^c, cr_{CB,s}^c, car_s^c, b_s^c, \tau_s^c, g_s^c\}_{s=t}^{\infty}} \mathcal{L}_t \tag{79}$$

subject to the model equations except for policy rules, and where $\ell(\boldsymbol{x}_s, \boldsymbol{z}_s)$ is given by equation (78), $\boldsymbol{x}_s = (\pi_{c,s}, \Delta y_s, \Delta q_{c,s}, \Delta cr_s, \Delta d_s, \Delta\phi_s, \Delta d_{g,s})$ and $\boldsymbol{z}_s = (i_s, cr_{CB,s}, car_s, b_s, \tau_s, g_s)$. The superscript $c$ denotes the case of cooperation.

In the case of non-cooperation, the Ramsey optimization of each policy authority is as follows:

$$\min_{\{I_{p,s}^n\}_{s=t}^{\infty}} \mathcal{L}_{t,p} \tag{80}$$

subject to the model equations except for the policy rule of $I_{p,s}^n$, which is a chosen policy instrument from the set $(i_s, cr_{CB,s}, car_s, b_s, \tau_s, g_s)$. $\mathcal{L}_{t,p}$ is the intertemporal loss function with $\ell_p$ given by (72)-(77), and $p$ stands for names of policies such as $(CMP, UMP, MPP, FXI, CFM, FP)$. For example, when $p = CMP$, $I_{p,s}^n = i_s$ and $\ell_{CMP}$ are used in the minimization. The superscript $n$ denotes the case of non-cooperation: in practice, the policy chosen by each authority is optimal, taking the other's existing policies as given. We also assume that households and firms are passive in both cases, taking policies as given.

We compare the outcomes of the two cases with different combinations of the preference parameters. In this exercise, we assume that the preference parameters of the same objective variables in different policy loss functions are equal and the preference parameter for policy instrument variables are equal: $\lambda_{k,y} = \lambda_{cmp,y} = \lambda_{ump,y} = \lambda_{mpp,y} = \lambda_{fp,y}$; $\lambda_{j,cr} = \lambda_{ump,cr} = \lambda_{mpp,cr}$; $\lambda_{l,q} = \lambda_{fxi,q} = \lambda_{cfm,q}$; $\lambda_d = \lambda_{fxi,d} = \lambda_{cfm,\phi} = \lambda_{fp,d}$; $\lambda_i = \lambda_{\Delta i} = \lambda_{\Delta cr_{CB}} = \lambda_{\Delta car} = \lambda_{\Delta b} = \lambda_{\Delta\tau} = \lambda_{\Delta g}$. As values of lost functions may vary depending on the choice of the preference parameters, we consider 6 combinations of the preference parameters set as shown in Table 1. For example, the choices of $\lambda_{k,y} = 0.125$, $\lambda_{j,cr} = 0.01$, $\lambda_{l,q} = 0.01$, $\lambda_d = 0.01$ and $\lambda_i = 0.1$ are broadly in line with the values used by Angelini et al. (2014). The figures of $\lambda_{k,y} = 0.125$, $\lambda_{j,cr} =$

0.01, $\lambda_{l,q} = 0.01$, $\lambda_d = 0.01$ and $\lambda_i = 1$ for the authorities' preferences are consistent with the values Adrian et al. (2022) employed in the search for optimized policy rules. These cases imply that the government solely focuses on inflation and output growth stabilization and the smoothing of instruments, in line with the inflation targeting literature. These settings are somehow in line with the finding obtained by Debortoli et al. (2019), simple loss functions should feature a high weight on measure of economic activity as stabilizing activity also stabilizes other welfare relevant variables. In the second row of Table 1, we increase the values of $\lambda_{j,cr}$, $\lambda_{l,q}$ and $\lambda_d$ to make the weight of each variable in the loss function (78) equal to 0.5, implying that a single authority (in the case of cooperation) gives the highest preference for inflation with the weight of 1 and the same preference for the volatility of each other variable. It represents that the authorities consider all variables in policy rules or loss functions (i.e., aiming to stabilize other loss relevant variables) when implementing policies. In the third row of Table 1, we consider a case that a single authority gives equal preference for inflation, output growth, credit growth, and change in exchange rate with the weight of 1 and a slight preference for smoothing of instruments. To find out the sensitivity of the result regarding the change in $\lambda_d$, we select different values for the parameter. In particular, the case of $\lambda_d = 0.01$ implies that the government solely focuses on macroeconomic and financial stability.

In this exercise, we consider a situation where all shocks simultaneously hit the economy and choose standard deviations of the shocks as at the posterior mode. Table 1 reports the values of intertemporal loss functions for the different combinations of the preference parameters under cooperative and uncooperative cases. The results under all considered combinations of preference parameters show that coordinated policies lead to much lower joint loss, computed as the sum of the separate losses. It indicates that the authorities stand to benefit from cooperation in whatever objective functions (i.e., preference parameters) they have. The robust result suggests that authorities must fully cooperate to ensure overall economic stability under the integrated policy framework.

Our analysis also reveals that the choice of preference parameter for instruments matters for the loss ratio between cooperative and noncooperative cases. For instance, in the case of the first row, the joint loss of noncooperation is 11.3 percent worse than with cooperation when $\lambda_i = 1$. If we consider much higher values, such as $\lambda_i = 0.1$, the loss worsens by 19.9 percent. This finding is also robust for choices of the preference parameters in the second row. It suggests that the joint and higher smoothing of instruments may help stabilize the whole economy though policies are conducted in a non-cooperative way. However, once the government focuses on macroeconomic and financial stability, additional benefits from including other variables such as external debt, government debt, and risk premium in the loss function are limited. For instance, there is a minor difference between ratios of noncooperative and cooperative losses in the two cases of the third row (44.6 percent and 42.8 percent).

## Table 1. Intertemporal loss function values under Ramsey optimal policy: all shocks

| Preference parameters[a] | | | Loss functions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Conventional Monetary policy, $\mathcal{L}_{CMP}$ | Unconventional monetary policy, $\mathcal{L}_{UMP}$ | Macroprudential policy, $\mathcal{L}_{MPP}$ | FX intervention, $\mathcal{L}_{FXI}$ | Fiscal policy, $\mathcal{L}_{FP}$ | Capital flow management, $\mathcal{L}_{CFM}$ | Joint loss[b], $\mathcal{L}$ |
| $\lambda_{k,y} = 0.125, \lambda_{j,cr} = 0.01$ $\lambda_{l,q} = 0.01, \lambda_d = 0.01$ | $\lambda_i = 0.1$ | Cooperative | | | | | | | 12175.0 |
| | | Noncooperative | 3778.9 | 3324.7 | 2620.0 | 1662.1 | 3023.4 | 194.2 | 14603.3 |
| | | Noncoop./Coop. (%) | | | | | | | 19.9 |
| | $\lambda_i = 1.0$ | Cooperative | | | | | | | 14585..0 |
| | | Noncooperative | 4705.7 | 3325.7 | 2964.3 | 1968.5 | 3052.1 | 215.9 | 16232.2 |
| | | Noncoop./Coop. (%) | | | | | | | 11.3 |
| $\lambda_{k,y} = 0.125, \lambda_{j,cr} = 0.25$ $\lambda_{l,q} = 0.25, \lambda_d = 0.125$ | $\lambda_i = 0.1$ | Cooperative | | | | | | | 34560.0 |
| | | Noncooperative | 3778.9 | 10992 | 8572.6 | 17310 | 3415.2 | 1926.7 | 45995.4 |
| | | Noncoop./Coop. (%) | | | | | | | 33.1 |
| | $\lambda_i = 1.0$ | Cooperative | | | | | | | 43492.0 |
| | | Noncooperative | 4705.7 | 11161.0 | 10439.0 | 20799.0 | 3567.0 | 3286.4 | 53958.1 |
| | | Noncoop./Coop. (%) | | | | | | | 24.1 |
| $\lambda_{k,y} = 0.25, \lambda_{j,cr} = 0.5$ $\lambda_{l,q} = 0.5, \lambda_i = 0.1$ | $\lambda_d = 0.01$ | Cooperative | | | | | | | 36255.0 |
| | | Noncooperative | 6716.4 | 21625.0 | 15278 | 1360.6 | 5904.4 | 901.4 | 51785.8 |
| | | Noncoop./Coop. (%) | | | | | | | 42.8 |
| | $\lambda_d = 0.25$ | Cooperative | | | | | | | 60071.0 |
| | | Noncooperative | 6716.4 | 21625.0 | 15278.0 | 33216.0 | 6720.6 | 3333.9 | 86889.9 |
| | | Noncoop./Coop. (%) | | | | | | | 44.6 |

*Notes*: [a] Preference parameters in the loss functions: $\lambda_{k,y} = \lambda_{cmp,y} = \lambda_{ump,y} = \lambda_{mpp,y} = \lambda_{fp,y}$; $\lambda_{j,cr} = \lambda_{ump,cr} = \lambda_{mpp,cr}$; $\lambda_{l,q} = \lambda_{fxi,q} = \lambda_{cfm,q}$; $\lambda_d = \lambda_{fxi,d} = \lambda_{cfm,\phi} = \lambda_{fp,d}$; $\lambda_i = \lambda_{\Delta i} = \lambda_{\Delta cr_{CB}} = \lambda_{\Delta car} = \lambda_{\Delta b} = \lambda_{\Delta \tau} = \lambda_{\Delta g}$; see equations (72)-(77) in the text. [b] For cooperative case, value of $\mathcal{L}_t$ calculated using (78); for noncooperative, sum of values of $\mathcal{L}_{t,p}$ calculated using (72)-(77).

Our results suggest that when many objective variables are included in the loss functions, cooperation among policies/authorities is essential as losses under non-cooperation (compared to cooperation case) increase.

We now investigate how the policy mix should be optimally adjusted in response to fundamental external shocks, the main drivers of cyclical fluctuations in the Mongolian economy. In the Ramsey optimal policy response analysis, we rely on the cooperative case using the preference parameters of $\lambda_{k,y} = 0.125$, $\lambda_{j,cr} = 0.01$, $\lambda_{l,q} = 0.01$, $\lambda_d = 0.01$ and $\lambda_i = 0.1$, shown in the first row of Table 1. Impulse responses under the Ramsey policy to external shocks are shown in red lines with the 'o' marker of Figures X.2-X.5 of the Appendix, offering some insights into the key variables' dynamics.

Under the Ramsey policy, the impulse responses to a positive commodity export demand shock suggest a substantial tightening of monetary and fiscal policies and solid FXI and CFM measures to stabilize output and inflation. A moderate reduction in CAR and a loose UMP are recommended to offset the destabilizing effects of the tight macroeconomic policies partly. Fiscal policy can complement monetary policy and assist the central bank in pursuing its objectives. With such policy mix, the headline inflation quickly stabilized and initially declined instead of rising, which is observed in the response of the estimated model. The real exchange rate depreciated over time as inflation declined and stabilized well. Because of the tight policies, the real borrowing rate increases and consumption and investment fall, leading to reduce imports and diminishing effects on the output. As the output is stabilized quickly, volatilities of employment, real wage, and NPL ratio are also lowered (Figure X.2). In terms of both risk premium and commodity export demand shocks, FXI and CFM enhance monetary autonomy by stabilizing inflation. Since there is no boundary for changes in the policy rate, FXI and CFM measures, the prescribed substantial adjustments to the policy instruments can be outside of the conventional discrete response thresholds. As raised by Adrian et al. (2022), this ignorance of institutional realities may impede a high degree of policy coordination in practice.

Regarding positive commodity export price shocks, Ramsey optimal policy suggests a gradual but continuous FXI (to buy foreign currency), CFM action, and a tightening monetary policy. However, gradual fiscal, unconventional monetary and macroprudential policy actions offset the tight policies' effects on output. As a result, the policy mix stabilizes inflation better but slightly amplifies the effects on real variables in the medium term (Figure X.3).

Compared to the estimated impulse responses, the responses of Ramsey policy recommend a more aggressive policy rate hike with a more substantial FXI measure when positive risk premium shocks hit the economy. The strong monetary tightening is partially offset by easing macroprudential (CAR) and fiscal policies. As an FXI to sell foreign reserves is suggested, the need for higher tax on capital outflow is reduced. With the policy mix, headline inflation and real exchange rate are stabilized well, and the timing of peak adverse effect the output is shortened, but the output is stabilized within 20 quarters. In line with the output stabilization, volatilities in consumption, investment, import, export, employment, real wage, and NPL ratio are significantly reduced (Figure X.4).

Even with the Ramsey policy, oil price shocks create difficult policy trade-offs as inflation rises and output drops simultaneously. The policy suggests an aggressive hike of policy rate together with somehow tighter fiscal policy, supporting to the reduction of both domestically produced and imported goods inflations. Under the policy, FXI to buy foreign currency and reduction in tax on capital outflows initially lower the appreciation pressures on the real exchange rate. To reduce the effects of policy rate on consumption and investment, easing of UMP are also suggested, and the CAR is initially increased and subsequently lowered. In this policy mix, inflation is stabilized much quicker at the cost of the drop in output. In particular, the combination of policies changes the dynamics of real borrowing rate, CFM measure, and investment compared to their estimated impulse responses (Figure X.5).

Overall, our findings support general principles suggested by Adrian et al. (2022) for economies with larger international trade and financial exposures. For instance, monetary policy plays the central role in stabilizing headline inflation and output when external shocks hit the economy. FXI and CFM play a supporting role in stabilizing the import inflation, through alleviating the volatility in the exchange rate as exchange rate pass-through is reasonably high. Fiscal and macroprudential policies help to offset the destabilizing effects of policy rate, tax on capital outflow and FXI on the real variables.

### 4.2.2 Optimized policy rules

In this section, we assume that the government minimizes its intertemporal loss function under long-run commitment to its policy rules with respect to their response coefficients, subject to the economy's structure as represented by the estimated model. Note that this constrained minimization problem takes as given out postulated functional dependence of policy instruments on key target variables.

In the case of cooperation, the solution of the constrained minimization yields a tuple of policy rule parameters $(\gamma_i^{c*}, \gamma_\pi^{c*}, \gamma_y^{c*}; \varrho_{cr_{CB}}^{c*}, \varrho_y^{c*}, \varrho_{cr}^{c*}; \varpi_{car}^{c*}, \varpi_y^{c*}, \varpi_{cr}^{c*}; b_b^{c*}, b_d^{c*}, b_q^{c*}; \tau_\tau^{c*}, \tau_q^{c*}, \tau_\phi^{c*}; \vartheta_g^{c*}, \vartheta_y^{c*}, \vartheta_d^{c*})$ such that:

$$(\gamma_i^{c*}, \gamma_\pi^{c*}, \gamma_y^{c*}; \varrho_{cr_{CB}}^{c*}, \varrho_y^{c*}, \varrho_{cr}^{c*}; \varpi_{car}^{c*}, \varpi_y^{c*}, \varpi_{cr}^{c*}; b_b^{c*}, b_d^{c*}, b_q^{c*}; \tau_\tau^{c*}, \tau_q^{c*}, \tau_\phi^{c*}; \vartheta_g^{c*}, \vartheta_y^{c*}, \vartheta_d^{c*}) = \arg\min \mathcal{L}_t\,(\gamma_i, \gamma_\pi, \gamma_y; \varrho_{cr_{CB}}, \varrho_y, \varrho_{cr}; \varpi_{car,}\varpi_{y,}\varpi_{cr}; b_b, b_d, b_q; \tau_\tau, \tau_q, \tau_\phi; \vartheta_g, \vartheta_y, \vartheta_d), \quad (81)$$

subject to the model. The superscript $c$ denotes the case of cooperation.

In the case of non-cooperation, the solutions of the optimizations yield a tuple $(\gamma_i^{n*}, \gamma_\pi^{n*}, \gamma_y^{n*}; \varrho_{cr_{CB}}^{n*}, \varrho_y^{n*}, \varrho_{cr}^{n*}; \varpi_{car}^{n*}, \varpi_y^{n*}, \varpi_{cr}^{n*}; b_b^{n*}, b_d^{n*}, b_q^{n*}; \tau_\tau^{n*}, \tau_q^{n*}, \tau_\phi^{n*}; \vartheta_g^{n*}, \vartheta_y^{n*}, \vartheta_d^{n*})$ such that:

$$(\gamma_i^{n*}, \gamma_\pi^{n*}, \gamma_y^{n*}) = \arg\min \mathcal{L}_{t,CMP}\,(\gamma_i, \gamma_\pi, \gamma_y; \hat{k}_{CMP}), \quad (82)$$

subject to the model.

$$(\varrho_{cr_{CB}}^{n*}, \varrho_y^{n*}, \varrho_{cr}^{n*}) = \arg\min \mathcal{L}_{t,UMP}\,(\varrho_{cr_{CB}}, \varrho_y, \varrho_{cr}; \hat{k}_{UMP}), \quad (83)$$

subject to the model.

$$(\varpi_{car}^{n*}, \varpi_y^{n*}, \varpi_{cr}^{n*}) = \arg\min \mathcal{L}_{t,MPP}\,(\varpi_{car,}\varpi_{y,}\varpi_{cr}; \hat{k}_{MPP}), \quad (84)$$

subject to the model.

$$(b_b^{n*}, b_d^{n*}, b_q^{n*}) = \arg\min \mathcal{L}_{t,FXI}\ (b_b, b_d, b_q; \hat{k}_{FXI}), \quad (85)$$

subject to the model.

$$(\tau_\tau^{c*}, \tau_q^{c*}, \tau_\phi^{c*}) = \arg\min \mathcal{L}_{t,CFM}\ (\tau_\tau, \tau_q, \tau_\phi; \hat{k}_{CFM}), \quad (86)$$

subject to the model.

$$(\vartheta_g^{n*}, \vartheta_y^{n*}, \vartheta_d^{n*}) = \arg\min \mathcal{L}_{t,FP}\ (\vartheta_g, \vartheta_y, \vartheta_d; \hat{k}_{FP}), \quad (87)$$

subject to the model. The superscript $n$ denotes the case of noncooperation. $\mathcal{L}_{t,p}$ is the intertemporal loss function with $\ell_p$ given by (72)-(77), and $p$ stands for names of policies such as $(CMP, UMP, MPP, FXI, CFM, FP)$. $\hat{k}_p$ is a set of other policy rules' parameters at the estimated values, implying that other policies are implemented as before (i.e., according to the estimated rules).

We also compare the outcomes of the cooperation and noncooperation cases with different combinations of the preference parameters. In this exercise, we set 3 combinations of the preference parameters, which are also used in the Ramsey policy analysis: i) $\lambda_{k,y} = 0.125$, $\lambda_{j,cr} = 0.01$, $\lambda_{l,q} = 0.01$, $\lambda_d = 0.01$ and $\lambda_i = 1$, shown in the first column panel and similar to the case used by Adrian et al. (2022); ii) $\lambda_{k,y} = 0.25$, $\lambda_{j,cr} = 0.5$, $\lambda_{l,q} = 0.5$, $\lambda_d = 0.01$ and $\lambda_i = 0.1$, shown in the second column panel; and iii) $\lambda_{k,y} = 0.25$, $\lambda_{j,cr} = 0.5$, $\lambda_{l,q} = 0.125$, $\lambda_d = 0.125$ and $\lambda_i = 0.1$, shown in the third column panel. In this exercise, we also consider a situation in which all shocks simultaneously hit the economy and choose standard deviations of the shocks as at the posterior mode. With such preference parameters and shocks, we numerically minimize the intertemporal loss functions, jointly (for cooperation) and separately (for noncooperation) with respect to the response parameters of the relevant policy rules, subject to the model constraints.

The optimized policy rule parameters and the loss values for cooperative and noncooperative cases under different combinations of preference parameters are shown in Table 2. The comparison of values of the loss functions under different preference parameters also implies that a lack of cooperation may result in suboptimal results for overall economic stability. The results in Table 2 also imply that the optimized rule parameters are sensitive to changes in preference parameters and the form of cooperation. For instance, in the case of cooperation with the preference parameters shown in the first column (i.e., the pursuit of inflation and output stabilization objectives), the optimized policy rule parameters are positive except for only one parameter, $\vartheta_d$, much closer to zero. It is not the case for the other combination of preference parameters. The optimized smoothing parameters of the CAR, FXI and CPF rules take negative values depending on the preference parameters and the form of cooperation. The findings suggest that the setting of the objective function and the cooperation among the authorities are extremely important when authorities aim to formulate and implement an optimal policy mix under the IPF. However, there are some general tendencies for the economy: the policy rate should respond aggressively to expected future headline inflation and moderately to the output, especially under cooperation; the optimized parameters of UMP rule implies that the policy should be less responsive to the output and bank credit; and CAR should be always counter-cyclical in both business and financial cycles.

**Table 2. Optimized policy rule coefficients: all shocks**

| | Parameters & Loss value | $\lambda_{k,y}=0.125$, $\lambda_{j,cr}=0.01$ $\lambda_{l,q}=0.01$, $\lambda_d=0.01$, $\lambda_i=1$ | | $\lambda_{k,y}=0.25$, $\lambda_{j,cr}=0.5$ $\lambda_{l,q}=0.5$, $\lambda_d=0.01$, $\lambda_i=0.1$ | | $\lambda_{k,y}=0.25$, $\lambda_{j,cr}=0.5$ $\lambda_{l,q}=0.5$, $\lambda_d=0.125$, $\lambda_i=0.1$ | |
|---|---|---|---|---|---|---|---|
| | | Cooperative | Noncooperative | Cooperative | Noncooperative | Cooperative | Noncooperative |
| Conventional Monetary policy | $\gamma_i$ | 0.9204 | 0.9955 | 0.7673 | 0.9836 | 0.9967 | 0.9923 |
| | $\gamma_\pi$ | 1.5064 | 181.73 | 2.3899 | 227.96 | 403.20 | 99.631 |
| | $\gamma_y$ | 0.0471 | -0.0209 | 0.0789 | 7.2120 | 26.225 | 3.2145 |
| | Loss value, $\mathcal{L}_{CMP}$ | | 45.59 | | 58.573 | | 58.573 |
| Unconventional monetary policy | $\varrho_{cr_{CB}}$ | 0.9999 | 0.9999 | 0.8904 | 0.9999 | 0.9582 | 0.9999 |
| | $\varrho_y$ | 0.1751 | 0.1752 | 0.1803 | 0.1753 | 0.7622 | 0.1751 |
| | $\varrho_{cr}$ | 0.1796 | 0.1798 | 0.2305 | 0.1815 | 6.026 | 0.1797 |
| | Loss value, $\mathcal{L}_{UMP}$ | | 1694.30 | | 329.22 | | 329.22 |
| Macroprudential policy | $\varpi_{car}$ | 0.9330 | 0.0429 | -0.1104 | -0.0309 | -0.0675 | 0.9986 |
| | $\varpi_y$ | 0.3700 | 0.0317 | 0.2001 | 0.2429 | 0.5046 | 2.3827 |
| | $\varpi_{cr}$ | 0.0629 | 0.1717 | 2.4546 | 1.4848 | 2.585 | 26.833 |
| | Loss value, $\mathcal{L}_{MPP}$ | | 172.66 | | 132.77 | | 132.77 |
| Foreign exchange intervention | $b_b$ | 0.2001 | 0.7331 | -0.0026 | 0.2369 | -0.2976 | 0.3413 |
| | $b_d$ | 0.0612 | -0.0037 | 0.2601 | 0.0209 | 0.8043 | 0.2550 |
| | $b_q$ | 0.1606 | 0.0207 | 0.8041 | 0.1672 | 0.5486 | 0.0758 |
| | Loss value, $\mathcal{L}_{FXI}$ | | 25.87 | | 23.701 | | 146.26 |
| Fiscal policy | $\vartheta_g$ | 0.6157 | 0.9979 | 0.8853 | 0.9976 | 0.9896 | 0.9946 |
| | $\vartheta_y$ | 0.1060 | 10.014 | 0.3422 | 9.921 | -13.710 | -57.533 |
| | $\vartheta_d$ | -0.0008 | -234.46 | -0.0221 | -117.53 | -61.616 | -172.113 |
| | Loss value, $\mathcal{L}_{FP}$ | | 169.88 | | 58.908 | | 43.1627 |
| | $\tau_\tau$ | 0.1391 | 0.3696 | 0.9999 | -0.4183 | 0.9992 | 0.0699 |
| Capital flow management | $\tau_q$ | 0.3569 | 2.5179 | 1.1196 | 4.1670 | 7.684 | 3.6513 |
| | $\tau_\phi$ | 0.7439 | -2.002 | 0.6752 | -1.3324 | -12.509 | -2.9638 |
| | Loss value, $\mathcal{L}_{CFM}$ | | 25.87 | | 8.7875 | | 8.8424 |
| Total loss function value, $\mathcal{L}$ | | 2039.48 | 2216.39 | 556.74 | 611.96 | 688.19 | 718.83 |

*Notes*: For cooperative case, value of $\mathcal{L}_t$ calculated using (78); for noncooperative, sum of values of $\mathcal{L}_{t,p}$ calculated using (72)-(77).

In the policy response analysis under the optimized policy rules, we rely on the case of inflation and output stabilization objectives (i.e., $\lambda_{k,y} = 0.125$, $\lambda_{j,cr} = 0.01$, $\lambda_{l,q} = 0.01$, $\lambda_d = 0.01$ and $\lambda_i = 1$) with cooperation shown in the first column of Table 2. The absence of corner solutions implies that all policies should be systematically used to help stabilize inflation and output within the IPF. In the case, the policy rate should be more responsive to inflation, and UMP should be less responsive to the change in output and bank credit. FXI should respond mildly to the change in the real exchange rate compared to the business-as-usual practice (i.e., the estimated rules). It is in line with consistent with a postulate that under a flexible inflation targeting regime, real exchange rate changes should not be stabilized through FXI (i.e., Lama and Medina 2020).

Impulse responses under the optimized policy rules to external shocks are shown in blue lines with the '⋆' marker of Figures X.2-X.5 of the Appendix. In the case of commodity export demand shock, there is no significant difference between the impulse responses of the estimated model and the optimized policy rules (Figure X.2). In the case of positive commodity export price shocks, the policy responses suggest a continuous CFM action to raise tax on capital outflow and FXI to sell foreign currency initially, but to buy foreign currency later. The responses also endorse the tight FP but does not recommend active UMP and MPP. The policy mix stabilizes the output better compared to the Ramsey optimal policy, but at the cost of a little higher inflation (Figure X.3).

In the case of risk premium shock, the responses of the optimized policy rules suggest a more aggressive FXI (to sell the foreign currency) and CFM measure (i.e., raising tax on capital outflow) with a tighter CMP compared to those of the estimated model. However, no responses of MPP, UMP and FP are recommended. With the policy mix, real exchange rate depreciates, leading to raises in imported inflation, net export (low import and high export) and real borrowing spread. The increase in real borrowing rate reduces consumption and investment more, but the output is quickly stabilized for the first quarters because of the lower import (Figure X.4).

The optimized policy rules stabilize the output well when a positive oil price shock hits the economy. The policy responses suggest a strong FXI to buy foreign currency and higher tax on capital outflow for the first 8 quarters in addition to the gradual tightening of CMP. The policy measures help lessen the pressure on real exchange rate appreciation, leading to a rise in imported inflation and an improvement in net export. The initial higher inflation reduces the ex-ante real interest rate, which lowers the fall in consumption and promotes the raise in investment. To balance the contraction of output, MPP and FP start to loosen in the medium term (Figure X.5).

Overall, the exercise based on the optimized policy rules suggests more active FXI and CFM measures in responding to the considered external shocks compared to those of the estimated rules. The active use of the measures can help stabilize the output better, especially in the event of the risk premium and oil price shocks.

## 5. Conclusion

This paper has developed an estimated New Keynesian model of a commodity-exporting economy for the IPF. Our model incorporates the full range of policies used in practice and featuring a range of nominal and real rigidities, macro-financial linkages, and transmission channels of commodity export demand, commodity export price, risk premium, and oil price shocks. The policy analysis framework is applied empirically to Mongolia, a small open and developing economy highly dependent on imports and commodity exports.

We empirically show that commodity export demand, commodity export price, risk premium and oil price shocks are vital sources of Mongolian economic fluctuations. These four external shocks account for more than 40 percent of the forecast error variance of key macro and financial variables and have led the recent business cycles including the recession during the COVID-19 pandemic. Within the external shocks, risk premium and oil price shocks apparently generate difficult policy trade-offs as inflation rises and output drops simultaneously. The estimated transmission mechanisms of policy instruments within the IPF suggest that an eclectic policy mix has the potential to resolve policy tradeoffs. We also find a lack of cooperation among policy authorities may result in conflicting policies, hence suboptimal results for overall economic stability. Particularly, our results suggest that when many objective variables are included in the loss functions, a better cooperation among policies is essential as losses under non-cooperation (compared to cooperation case) increase significantly. The results are robust to alternative parameters of policymaker's preferences and to setting of Ramsey policy or optimized policy rules.

Our optimal policy analysis shows that policy mix adjustments should differ depending on the type of external shocks and policy objectives. When we rely on the case of inflation and output stabilization objectives with all shocks, the Ramsey policy results broadly supports the general tendency such as i) conventional monetary policy plays the central role in stabilizing inflation and output when the external shocks hit the economy, ii) FXI and CFM enhance monetary autonomy through a supporting role in stabilizing import inflation, and iii) fiscal and macroprudential policies can help to offset the destabilizing effects of policy rate, FXI and CFM measures on the real variables. Our analysis also shows that the optimized rule parameters are sensitive to changes in the preference parameters of the objective function and the form of cooperation among authorities. Moreover, the policy responses under optimized policy rules suggest more active use of FXI and CFM measures in responding to risk premium and oil price shocks as the measures can help stabilize the output better.

Finally, these findings suggest that the estimated model-based integrated policy analysis framework can help policymakers choose their policy mix adjustments to deal with external shocks in an integrated and optimal way. Though the results have provided significant insights about the optimal policy mix under the IPF in economies with larger international trade and financial exposures, there are some ways to extend our model and enrich deepen the policy analysis. The model can be extended to incorporate some constraints for movements in policy instruments capturing institutional realities (i.e., prescribed adjustments to instruments should fall within conventional discrete response thresholds or should not be beyond a certain threshold level). For example, using FXI to support the exchange rate may lead to a risk of destabilizing losses of reserves if external shocks are persistent and the size of reserves (in terms of imports) is quite low, which is the case for central banks of EMDEs. Further enrichment of policy analysis may consist of incorporating other tools of fiscal and macroprudential policies, searching for optimal policy mixes under different economic circumstances, and allowing more generalized functional forms for policy rules and loss functions derived from micro foundations.

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# Annexes

## Tables

### Table X.1. Prior densities and posterior estimates

| | Parameters | Prior Distribution | | | Posterior Distribution | |
|---|---|---|---|---|---|---|
| | | Density | Mean | Sd. | Mode/ Mean | [5, 95] prob. |
| *Modified Euler equation* | | | | | | |
| $\varkappa_c$ | Habit | B | 0.5 | 0.15 | 0.82/0.81 | [0.68, 0.94] |
| $\sigma$ | Intertemporal ES | G | 1.0 | 0.2 | 0.81/0.82 | [0.52, 1.11] |
| *Private borrowing spread* | | | | | | |
| $\rho_\psi$ | Spread, smoothing | B | 0.5 | 0.2 | 0.19/0.2 | [0.04, 0.36] |
| $\rho_q$ | Spread, real exchange rate | G | 0.1 | 0.05 | 0.06/0.07 | [0.03, 0.12] |
| $\rho_{car}$ | Spread, CAR | B | 0.5 | 0.1 | 0.36/0.38 | [0.22, 0.53] |
| $\rho_{npl}$ | Spread, NPL | B | 0.2 | 0.1 | 0.21/0.24 | [0.07, 0.42] |
| $\rho_{CB}$ | Spread, UMP | G | 0.1 | 0.075 | 0.009/0.013 | [0.001, 0.024] |
| *Oil, core consumption* | | | | | | |
| $\eta^{o,\bar{c}}$ | Elasticity $O$-$\bar{C}$ goods | G | 0.2 | 0.1 | 0.21/0.3 | [0.07, 0.51] |
| *Investment* | | | | | | |
| $\alpha_{in}$ | Weight on current credit | B | 0.5 | 0.2 | 0.65/0.61 | [0.34, 0.91] |
| *Bank credit* | | | | | | |
| $\theta_{cr}$ | Credit, smoothing | B | 0.5 | 0.2 | 0.42/0.46 | [0.25, 0.67] |
| $\theta_r$ | Credit, interest rate elasticity | G | 0.25 | 0.1 | 0.22/0.26 | [0.10, 0.41] |
| $\theta_{car}$ | Credit, CAR elasticity | G | 0.25 | 0.1 | 0.22/0.26 | [0.09, 0.41] |
| $\theta_{CB}$ | Credit, UMP elasticity | G | 0.25 | 0.1 | 0.09/0.09 | [0.04, 0.13] |
| *Non-performing loan* | | | | | | |
| $\xi_{npl}$ | NPL, smoothing | B | 0.5 | 0.2 | 0.69/0.68 | [0.48, 0.88] |
| $\xi_y$ | NPL, output elasticity | B | 0.1 | 0.05 | 0.02/0.03 | [0.01, 0.05] |
| $\xi_{\Delta e}$ | NPL, exchange rate elasticity | B | 0.1 | 0.05 | 0.02/0.03 | [0.01, 0.05] |
| *Exports* | | | | | | |
| $\eta^x$ | Elasticity of relative price | G | 1.0 | 0.5 | 1.06/1.43 | [0.30, 2.53] |
| *UIP risk premium* | | | | | | |
| $\rho_\phi$ | Risk premium, smoothing | B | 0.5 | 0.2 | 0.10/0.10 | [0.01, 0.19] |
| $\phi_d$ | Risk premium, NFL elasticity | B | 0.01 | 0.005 | 0.007/0.008 | [0.002, 0.013] |
| $\phi_b$ | Risk premium, FXI elasticity | IG | 1.5 | 0.5 | 0.75/0.85 | [0.62, 1.08] |
| $\phi_{\varepsilon_{\bar{d}}}$ | Risk premium, debt limit shock | B | 0.01 | 0.005 | 0.008/0.01 | [0.002, 0.018] |
| $\phi_{e,1}$ | Risk premium, $E\Delta e_{t+1}$ | B | 0.5 | 0.2 | 0.75/0.67 | [0.40, 0.95] |
| $\phi_{e,2}$ | Risk premium, $\Delta e_t$ | B | 0.5 | 0.2 | 0.82/0.84 | [0.72, 0.97] |
| *Imports* | | | | | | |
| $\eta^{m,g}$ | Elasticity $H$-$M$ goods (gov.spend) | G | 1.0 | 0.5 | 0.67/1.0 | [0.22, 1.75] |
| $\eta^{m,\bar{c}}$ | Elasticity $\bar{C}$- $M$ goods (cons) | G | 1.0 | 0.5 | 0.42/0.8 | [0.16, 1.46] |
| $\eta^{m,in}$ | Elasticity $H$-$M$ goods (invest) | G | 1.0 | 0.5 | 0.51/1.13 | [0.18, 2.08] |
| $\eta^{m,x}$ | Elasticity $H$-$M$ goods (export) | G | 1.0 | 0.5 | 0.62/1.05 | [0.19, 1.86] |
| *Phillips curve for domestic inflation* | | | | | | |
| $\iota_d$ | Indexation, domestic price | B | 0.5 | 0.1 | 0.34/0.35 | [0.21, 0.49] |
| $\xi$ | Calvo, domestic price | B | 0.5 | 0.1 | 0.81/0.81 | [0.76, 0.86] |
| *Production function & capital* | | | | | | |
| $\Omega_k$ | Capital share in production | B | 0.3 | 0.1 | 0.38/0.35 | [0.19, 0.52] |
| $\Omega_o$ | Oil share in production | B | 0.3 | 0.1 | 0.17/0.17 | [0.09, 0.25] |
| $\kappa$ | Capital utilization | B | 0.35 | 0.1 | 0.11/0.14 | [0.06, 0.21] |
| $\varsigma$ | Elasticity of substitution, inputs | N | 1.0 | 0.1 | 0.94/0.94 | [0.75, 1.12] |
| *Labor Supply* | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\chi$ | Inverse Frisch | N | 2.0 | 1.0 | 1.02/1.19 | [0.72, 1.66] |
| $\vartheta_z$ | Reference shifter | B | 0.05 | 0.025 | 0.049/0.053 | [0.015, 0.091] |
| *Wage Phillips curve* | | | | | | |
| $\iota_\omega$ | Indexation, wages | B | 0.5 | 0.2 | 0.56/0.53 | [0.21, 0.86] |
| $\xi_\omega$ | Calvo, wages | B | 0.5 | 0.2 | 0.01/0.016 | [0.004, 0.028] |
| $\mathcal{M}_\omega$ | Steady state wage markup | N | 1.25 | 0.25 | 1.39/1.48 | [1.19, 1.79] |
| $\Phi$ | Wage indexation, inertia | B | 0.5 | 0.2 | 0.58/0.54 | [0.22, 0.88] |
| $\upsilon$ | Wage indexation, past inflation | B | 0.5 | 0.2 | 0.43/0.46 | [0.13, 0.77] |
| *Phillips curve import inflation* | | | | | | |
| $\iota_m$ | Indexation, import price | B | 0.5 | 0.1 | 0.36/0.41 | [0.25, 0.56] |
| $\xi_m$ | Calvo, import price | B | 0.5 | 0.1 | 0.68/0.75 | [0.66, 0.85] |
| *Taylor rule* | | | | | | |
| $\gamma_i$ | Taylor rule, smoothing | B | 0.8 | 0.1 | 0.91/0.91 | [0.86, 0.96] |
| $\gamma_\pi$ | Taylor rule, inflation | G | 1.5 | 0.25 | 1.5/1.59 | [0.81, 2.32] |
| $\gamma_y$ | Taylor rule, output | G | 0.25 | 0.125 | 0.06/0.07 | [0.02, 0.13] |
| *UMP rule* | | | | | | |
| $\varrho_{cr_{CB}}$ | UMP rule, smoothing | B | 0.5 | 0.2 | 0.90/0.89 | [0.84, 0.96] |
| $\varrho_y$ | UMP rule, output | G | 0.25 | 0.125 | 0.18/0.24 | [0.05, 0.42] |
| $\varrho_{cr}$ | UMP rule, bank credit | G | 0.25 | 0.125 | 0.18/0.25 | [0.05, 0.44] |
| *CAR rule* | | | | | | |
| $\varpi_{car}$ | CAR rule, smoothing | B | 0.8 | 0.1 | 0.94/0.94 | [0.89, 0.98] |
| $\varpi_y$ | CAR rule, output | B | 0.5 | 0.1 | 0.37/0.39 | [0.22, 0.56] |
| $\varpi_{cr}$ | CAR rule, bank credit | B | 0.2 | 0.1 | 0.06/0.09 | [0.01, 0.16] |
| *FXI rule* | | | | | | |
| $b_b$ | FXI rule, smoothing | B | 0.5 | 0.2 | 0.19/0.1 | [0.01, 0.19] |
| $b_q$ | FXI rule, real exchange rate | B | 0.2 | 0.05 | 0.2/0.29 | [0.21, 0.38] |
| $b_d$ | FXI rule, foreign liability | B | 0.2 | 0.05 | 0.05/0.04 | [0.03, 0.06] |
| *CFM rule* | | | | | | |
| $\rho_\tau$ | CFM rule, smoothing | B | 0.5 | 0.2 | 0.10/0.20 | [0.08, 0.33] |
| $\tau_q$ | CFM rule, real exchange rate | B | 0.25 | 0.125 | 0.35/0.32 | [0.17, 0.47] |
| $\tau_\phi$ | CFM rule, risk premium | B | 0.25 | 0.125 | 0.78/0.67 | [0.49, 0.85] |
| *Fiscal rule* | | | | | | |
| $\vartheta_g$ | Fiscal rule, smoothing | B | 0.5 | 0.2 | 0.60/0.59 | [0.40, 0.80] |
| $\vartheta_y$ | Fiscal rule, output | B | 0.2 | 0.1 | 0.11/0.15 | [0.02, 0.26] |
| $\vartheta_d$ | Fiscal rule, government debt | B | 0.01 | 0.005 | 0.008/0.01 | [0.002, 0.017] |
| *Foreign variables* | | | | | | |
| $\mu_{com}$ | Commodity price adjustment | B | 0.5 | 0.2 | 0.72/0.67 | [0.44, 0.91] |
| $\rho_{p^*_{com}}$ | World commodity price, AR(1) | B | 0.8 | 0.1 | 0.94/0.93 | [0.90, 0.97] |
| $\rho_{com,y^*}$ | Foreign output | B | 0.5 | 0.2 | 0.19/0.26 | [0.04, 0.47] |
| $\rho_{p^*_o}$ | World oil price, AR(1) | B | 0.5 | 0.2 | 0.92/0.91 | [0.86, 0.97] |
| $\rho_{y^*}$ | Foreign output, AR(1) | B | 0.8 | 0.1 | 0.95/0.91 | [0.85, 0.98] |
| $\rho_{\pi^*}$ | Foreign inflation, AR(1) | B | 0.8 | 0.1 | 0.79/0.78 | [0.66, 0.91] |
| $\rho_{i^*}$ | Foreign interest rate, AR(1) | B | 0.8 | 0.1 | 0.94/0.94 | [0.9, 0.97] |
| *Persistence of the exogenous processes* | | | | | | |
| $\rho_c$ | Preference shock, AR(1) | B | 0.5 | 0.2 | 0.13/0.2 | [0.03, 0.36] |
| $\rho_{in}$ | Investment shock, AR(1) | B | 0.5 | 0.2 | 0.80/0.79 | [0.70, 0.89] |
| $\rho_a$ | Technology shock, AR(1) | B | 0.5 | 0.2 | 0.58/0.57 | [0.44, 0.71] |
| $\rho_\pi$ | Domestic markup shock, AR(1) | B | 0.5 | 0.2 | 0.53/0.45 | [0.17, 0.74] |
| $\rho_{\pi_m}$ | Import markup shock, AR(1) | B | 0.5 | 0.2 | 0.92/0.74 | [0.45, 0.97] |
| $\rho_n$ | Labor supply shock, AR(1) | B | 0.8 | 0.1 | 0.87/0.85 | [0.73, 0.96] |
| $\rho_\omega$ | Wage markup shock, AR(1) | B | 0.5 | 0.2 | 0.58/0.58 | [0.43, 0.73] |
| $\rho_\psi$ | Risk premium shock, AR(1) | B | 0.8 | 0.1 | 0.95/0.94 | [0.89, 0.99] |
| $\rho_i$ | Interest rate shock, AR(1) | B | 0.5 | 0.2 | 0.14/0.17 | [0.06, 0.28] |
| $\rho_{com}$ | Com. demand shock, AR(1) | B | 0.8 | 0.1 | 0.87/0.87 | [0.81, 0.94] |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\rho_{cr}$ | Bank credit shock, AR(1) | B | 0.5 | 0.2 | 0.68/0.65 | [0.47, 0.83] |
| $\rho_{car}$ | CAR shock, AR(1) | B | 0.5 | 0.2 | 0.42/0.43 | [0.23, 0.63] |
| $\rho_{npl}$ | NPL shock, AR(1) | B | 0.5 | 0.2 | 0.71/0.7 | [0.51, 0.89] |
| $\rho_b$ | FXI shock, AR(1) | B | 0.5 | 0.2 | 0.13/0.26 | [0.06, 0.45] |
| $\rho_p$ | Idiosyncratic component, AR(1) | B | 0.5 | 0.2 | 0.51/0.16 | [0.02, 0.29] |
| $\rho_{\bar{d}}$ | Private debt limit shock, AR(1) | B | 0.5 | 0.2 | 0.50/0.50 | [0.18, 0.83] |
| *Standard deviation of shocks* | | | | | | |
| $\sigma_{cr}$ | Sd bank credit | IG | 20.0 | 20.0 | 14.5/14.9 | [12.8, 17.0] |
| $\sigma_{npl}$ | Sd NPL | IG | 1.0 | 0.5 | 0.92/0.96 | [0.82, 1.09] |
| $\sigma_{\phi}$ | Sd risk premium | IG | 3.0 | 3.0 | 3.86/2.78 | [1.17, 4.37] |
| $\sigma_{\pi}$ | Sd domestic price markup | IG | 30.0 | 10.0 | 51.8/60.1 | [26.0, 96.5] |
| $\sigma_{\pi_m}$ | Sd import price markup | IG | 10.0 | 10.0 | 8.19/20.1 | [6.51, 42.4] |
| $\sigma_{\omega}$ | Sd wage markup | IG | 2.0 | 1.0 | 1.55/1.88 | [1.12, 2.66] |
| $\sigma_i$ | Sd interest rate | IG | 1.0 | 1.0 | 0.40/0.41 | [0.35, 0.47] |
| $\sigma_{car}$ | Sd CAR | IG | 1.0 | 1.0 | 0.96/0.98 | [0.84, 1.12] |
| $\sigma_b$ | Sd FXI | IG | 10.0 | 10.0 | 8.52/5.89 | [3.91, 7.75] |
| $\sigma_{\tau}$ | Sd CFM | IG | 1.0 | 0.5 | 4.06/0.96 | [0.44, 1.48] |
| $\sigma_g$ | Sd government spending | IG | 40.0 | 20.0 | 12.4/12.7 | [10.9, 14.4] |
| $\sigma_{in}$ | Sd investment | IG | 20.0 | 10.0 | 63.3/65.6 | [56.8, 74.9] |
| $\sigma_{y^*}$ | Sd foreign output | IG | 2.0 | 2.0 | 1.97/2.01 | [1.72, 2.31] |
| $\sigma_{\pi^*}$ | Sd foreign inflation | IG | 0.30 | 0.1 | 0.32/0.32 | [0.28, 0.37] |
| $\sigma_{i^*}$ | Sd foreign interest rate | IG | 0.15 | 0.1 | 0.09/0.09 | [0.08, 0.11] |
| $\sigma_{com}$ | Sd commodity demand | IG | 20.0 | 10.0 | 24.3/24.7 | [21.5, 27.9] |
| $\sigma_{p^*_{com}}$ | Sd world commodity price | IG | 20.0 | 10.0 | 18.8/19.3 | [16.5, 22.0] |
| $\sigma_{p^*_o}$ | Sd world oil price | IG | 15.0 | 15.0 | 16.8/17.1 | [14.8, 19.5] |
| $\sigma_p$ | Sd idiosyncratic component | IG | 2.0 | 1.0 | 1.48/19.2 | [12.9, 26.5] |
| $\sigma_c$ | Sd preference | IG | 16.0 | 8.0 | 7.34/7.83 | [6.67, 9.05] |
| $\sigma_{\bar{d}}$ | Sd private debt limit | IG | 1.0 | 0.5 | 0.73/0.93 | [0.45, 1.39] |
| $\sigma_a$ | Sd technology | IG | 8.0 | 4.0 | 7.58/7.76 | [6.38, 9.15] |
| $\sigma_n$ | Sd labor supply | IG | 6.0 | 3.0 | 7.12/7.80 | [6.04, 9.61] |
| $\sigma_{cr_{CB}}$ | Sd CB credit | IG | 20.0 | 10.0 | 38.9/40.0 | [34.4, 45.6] |

## Table X.2. Variance decomposition of selected variables, in percent

| | | $y_t$ | $c_t$ | $g_t$ | $\pi_{c,t}$ | $e_t$ | $q_{c,t}$ | $cr_t$ | $npl_t$ | $\xi_{c,t}$ | $u_t$ | $n_t$ | $4*i_t$ | $car_t$ | $b_t$ | $cr_{CB,t}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| External shocks | $e_{com,t}$ | 39.7 | 5.0 | 2.0 | 4.5 | 19.2 | 17.2 | 0.3 | 11.8 | 23.0 | 5.4 | 23.0 | 6.0 | 15.9 | 24.6 | 0.1 |
| | $e_{p^*_{com},t}$ | 2.2 | 30.3 | 0.4 | 3.1 | 12.8 | 21.8 | 0.1 | 1.1 | 13.0 | 0.0 | 9.7 | 5.3 | 0.9 | 28.5 | 0.0 |
| | $e_{p^*_o,t}$ | 3.4 | 3.4 | 0.2 | 22.9 | 12.7 | 10.3 | 0.1 | 1.9 | 4.9 | 0.7 | 3.1 | 24.1 | 1.3 | 0.6 | 0.1 |
| | $e_{\phi,t}$ | 0.3 | 2.8 | 0.0 | 4.5 | 12.3 | 5.4 | 0.1 | 0.3 | 0.6 | 0.0 | 1.7 | 6.4 | 0.1 | 0.6 | 0.0 |
| | $e_{y^*,t}$ | 0.8 | 2.4 | 0.1 | 0.5 | 0.6 | 2.0 | 0.0 | 0.3 | 1.8 | 0.0 | 0.8 | 1.3 | 0.4 | 1.9 | 0.0 |
| | $e_{\pi^*,t}$ | 0.3 | 1.1 | 0.2 | 2.9 | 6.2 | 2.5 | 0.0 | 0.2 | 0.6 | 0.0 | 0.4 | 5.3 | 0.1 | 0.2 | 0.0 |
| | $e_{i^*,t}$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| Supply shocks | $e_{a,t}$ | 0.9 | 0.5 | 0.0 | 2.5 | 1.3 | 0.5 | 0.0 | 0.4 | 6.5 | 6.2 | 8.0 | 1.5 | 0.4 | 0.1 | 0.0 |
| | $e_{\pi,t}$ | 8.2 | 4.6 | 0.5 | 31.2 | 13.0 | 4.9 | 0.2 | 3.8 | 13.1 | 0.2 | 4.8 | 14.4 | 4.4 | 1.0 | 0.0 |
| | $e_{\pi_m,t}$ | 2.6 | 0.6 | 0.1 | 9.5 | 0.8 | 4.6 | 0.0 | 0.9 | 1.3 | 0.0 | 0.8 | 6.0 | 1.3 | 3.1 | 0.0 |
| | $e_{\omega,t}$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 77.2 | 0.13 | 0.0 | 0.0 | 0.0 | 0.0 |
| | $e_{n,t}$ | 0.8 | 0.4 | 0.0 | 1.6 | 1.8 | 0.5 | 0.0 | 0.4 | 10.6 | 2.7 | 7.2 | 2.1 | 0.4 | 0.1 | 0.0 |
| Dema nd & | $e_{c,t}$ | 4.4 | 10.6 | 0.2 | 0.3 | 0.3 | 0.4 | 0.1 | 0.9 | 2.1 | 0.5 | 3.9 | 0.8 | 1.5 | 0.5 | 0.0 |
| | $e_{in,t}$ | 32.2 | 29.4 | 1.6 | 6.8 | 6.1 | 23.3 | 1.0 | 7.1 | 16.1 | 6.7 | 32.2 | 6.9 | 11.3 | 22.8 | 0.0 |
| | $e_{p,t}$ | 0.1 | 0.1 | 0.0 | 2.3 | 2.4 | 2.2 | 0.0 | 0.2 | 0.2 | 0.1 | 0.3 | 1.1 | 0.1 | 3.6 | 0.0 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $e_{\bar{d},t}$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | $e_{npl,t}$ | 0.1 | 0.5 | 0.0 | 0.2 | 0.0 | 0.3 | 0.0 | 70.0 | 0.4 | 0.0 | 0.1 | 0.6 | 0.1 | 0.1 | 0.0 |
| | $e_{cr,t}$ | 1.9 | 3.7 | 0.1 | 0.7 | 0.4 | 1.7 | 79.5 | 0.4 | 1.8 | 0.1 | 2.4 | 0.9 | 6.0 | 1.4 | 0.4 |
| Policy shocks | $e_{i,t}$ | 0.3 | 0.2 | 0.0 | 1.8 | 0.4 | 0.4 | 0.0 | 0.1 | 0.5 | 0.0 | 0.1 | 8.6 | 0.2 | 0.2 | 0.0 |
| | $e_{car,t}$ | 1.0 | 3.3 | 0.1 | 2.7 | 3.8 | 0.5 | 1.0 | 0.2 | 2.8 | 0.0 | 0.4 | 7.5 | 53.3 | 0.6 | 0.0 |
| | $e_{b,t}$ | 0.0 | 0.0 | 0.0 | 1.3 | 1.2 | 1.2 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | 0.0 | 9.5 | 0.0 |
| | $e_{cr_{CB},t}$ | 0.7 | 1.1 | 0.0 | 0.3 | 0.5 | 0.5 | 17.5 | 0.2 | 0.6 | 0.0 | 0.8 | 0.7 | 2.6 | 0.7 | 99.4 |
| | $e_{\tau,t}$ | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| | $e_{g,t}$ | 0.3 | 0.1 | 94.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 |

*Notes:* The numbers in the table are the posterior mean conditional variance decomposition at period 20, approximating (long-horizon) stationary variance (or unconditional variance).

# Figures

## Figure X.1. Selected data and one-sided predicted variables

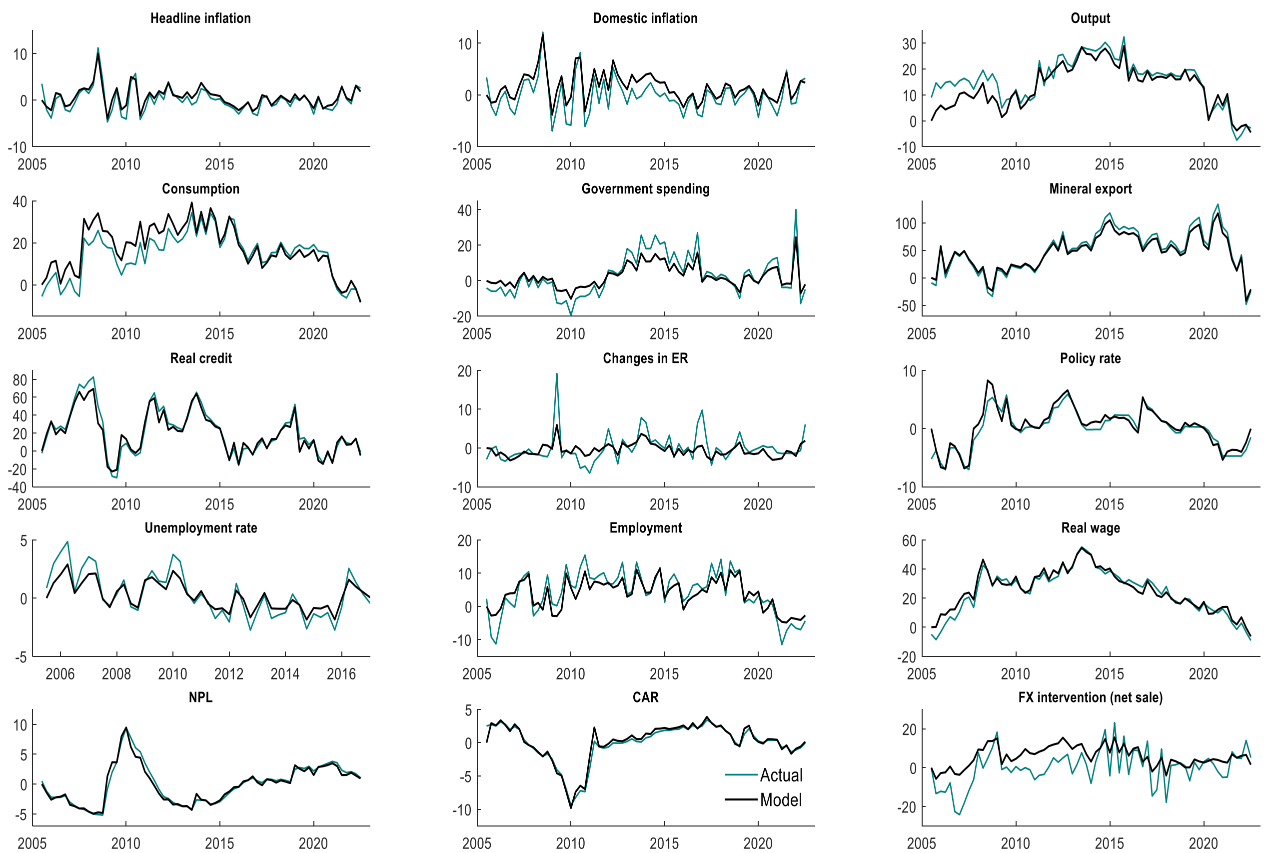
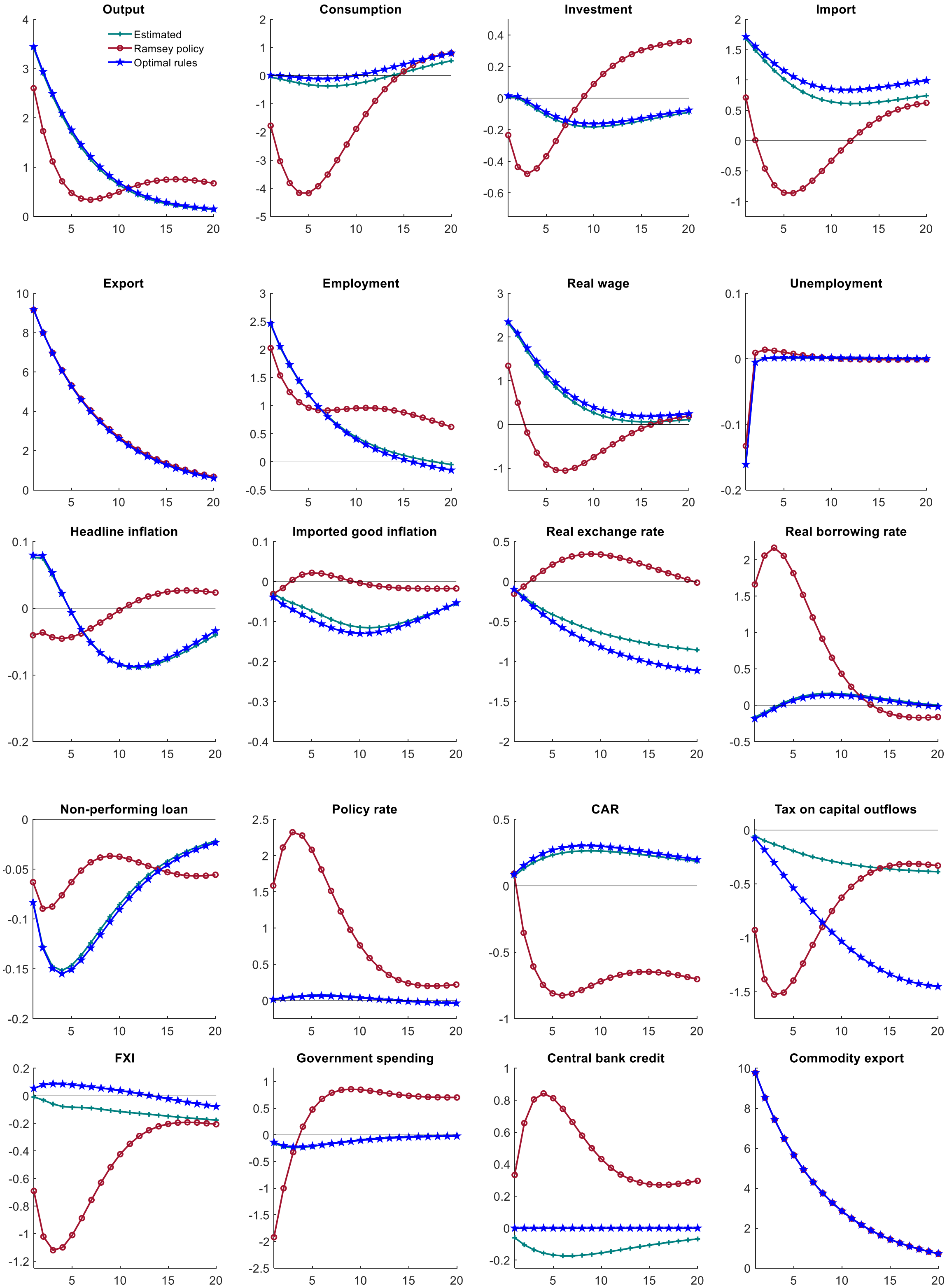
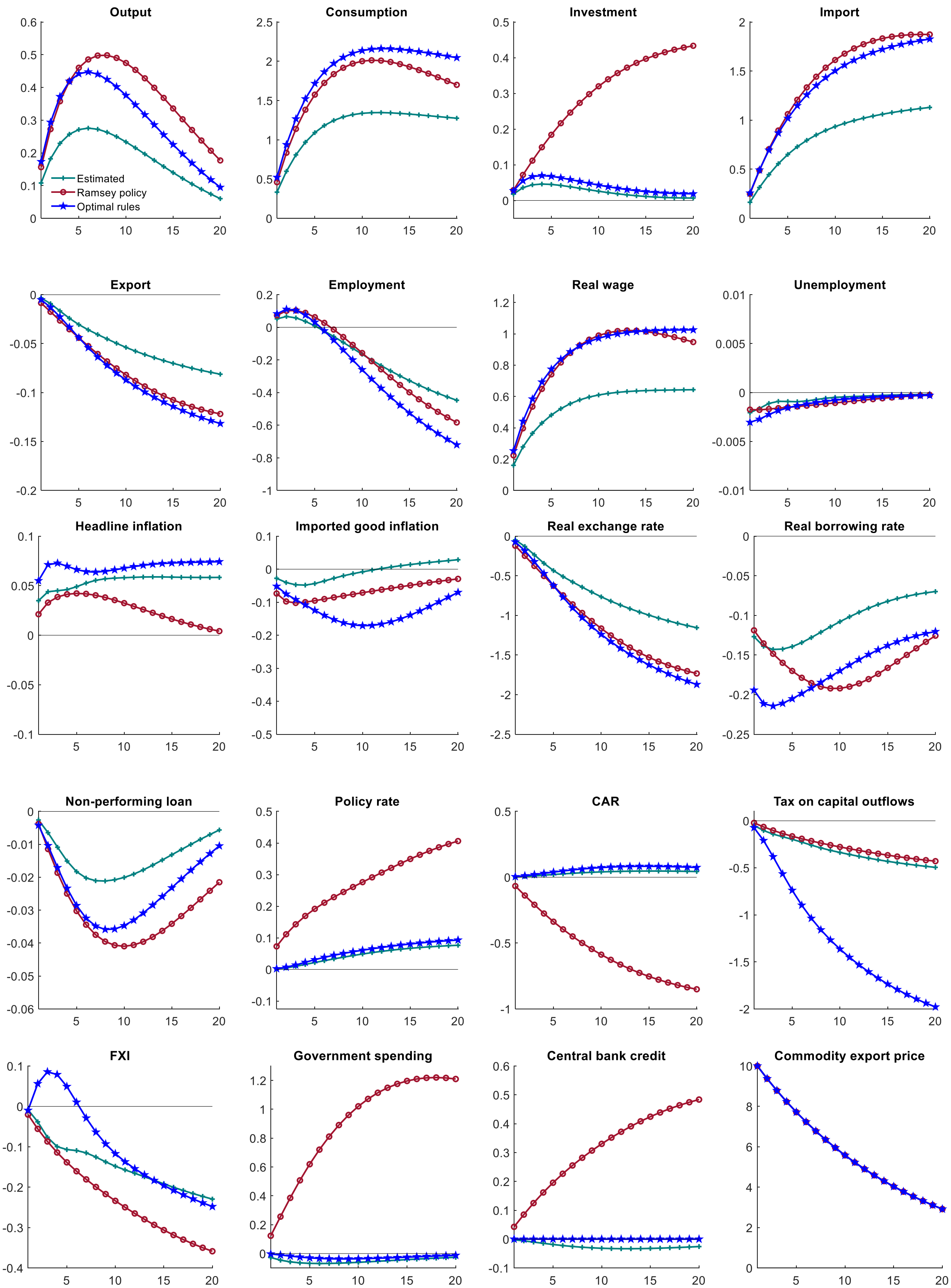


**Figure X.2 Impulse response functions to a commodity export demand shock**



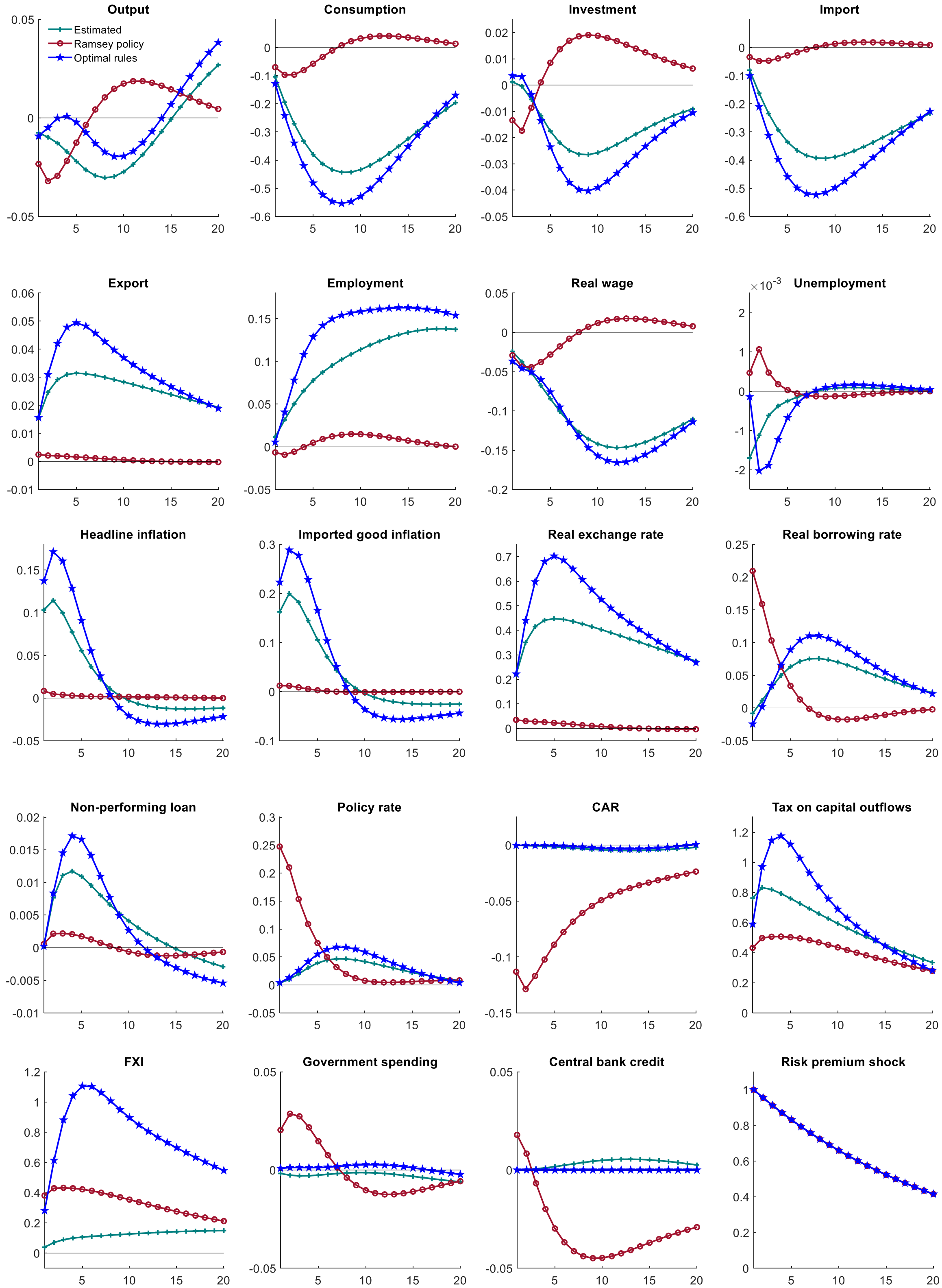

*Notes*: Lines with "+" marker represent impulse responses of the estimated model, lines with "o" marker represent impulse responses under Ramsey policy, and lines with "⋆" marker are impulses responses under optimal rules.

**Figure X.3 Impulse response functions to a commodity export price shock**



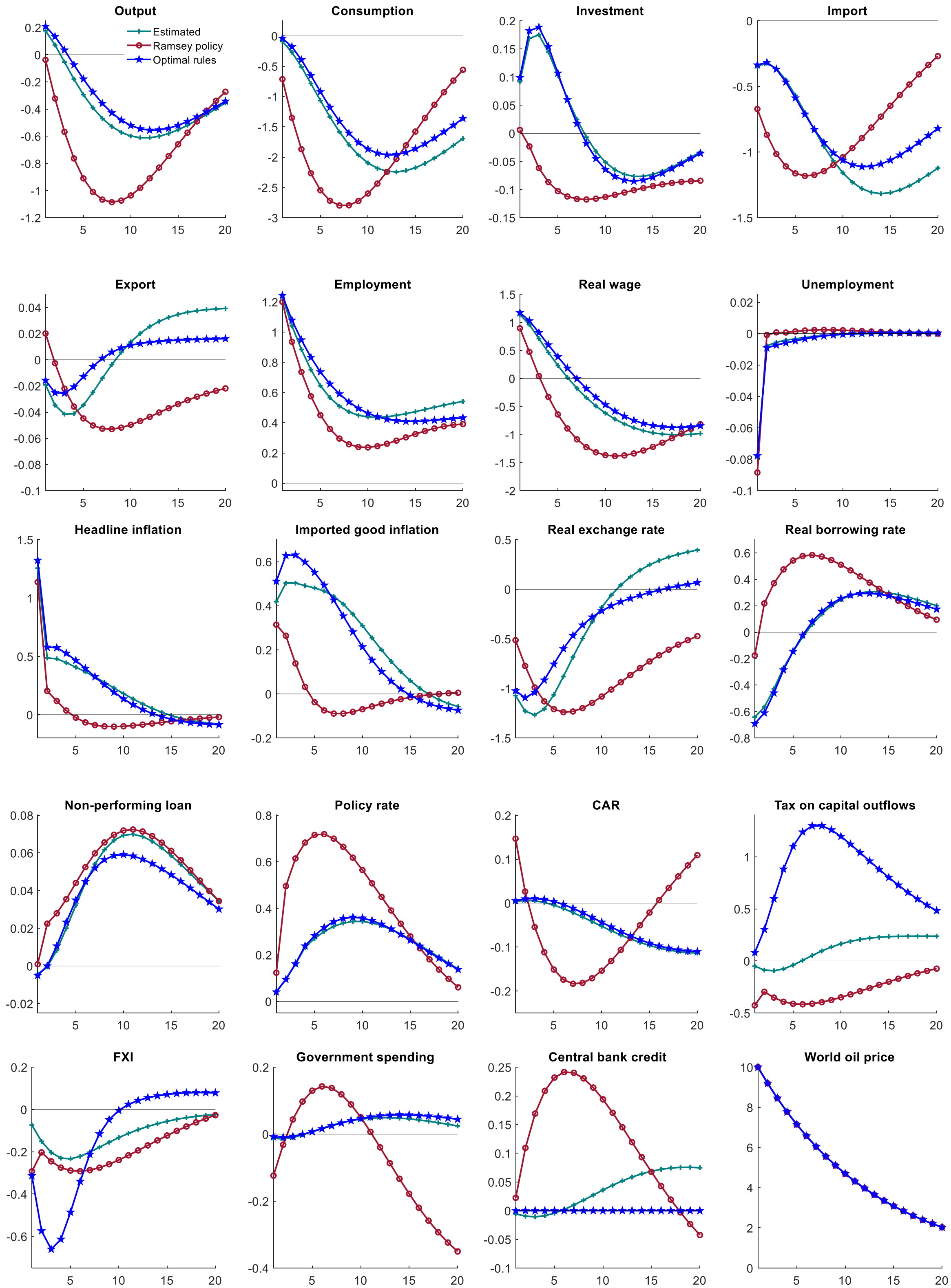

*Notes*: Lines with "+" marker represent impulse responses of the estimated model, lines with "o" marker represent impulse responses under Ramsey policy, and lines with "⋆" marker are impulses responses under optimal rules.

**Figure X.4. Impulse response functions to a risk premium shock**




*Notes*: Lines with "+" marker represent impulse responses of the estimated model, lines with "o" marker represent impulse responses under Ramsey policy, and lines with "⋆" marker are impulses responses under optimal rules.

## Figure X.5 Impulse response functions of oil price shock




*Notes*: Lines with "+" marker represent impulse responses of the estimated model, lines with "o" marker represent impulse responses under Ramsey policy, and lines with "⋆" marker are impulses responses under optimal rules.

**Figure X.6. Historical decomposition of the selected variables: Contribution of external shocks**