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The macroeconomic effects of exchange rate movements in a commodity-exporting developing economy

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ABSTRACT

This paper empirically examines the macroeconomic effects of exchange rate movements and their transmission mechanisms (trade and financial channels) in Mongolia, a net debtor in foreign currency and a commodity-exporting developing economy, using Structural Bayesian Vector Autoregression (SBVAR) models. Our findings suggest that both the financial and trade channels of exchange rates are operative and have a notable impact at the macroeconomic level. We identify a significant financial channel, causing GDP contractions and affecting investments, particularly in sensitive sectors such as manufacturing and construction in response to DWER depreciation shocks. The traditional trade channel, driven by NEER depreciation, leads to increased net exports with pass-through to CPI. Despite these effects on key macro variables, exchange rate shocks do not substantially destabilize the economy. Foreign shocks, including federal funds rates, China's GDP, and copper prices, have a more pronounced impact. The trade channel plays a crucial role in the transmission of external demand and commodity price shocks, while the financial channel is essential in the transmission of commodity price shocks.

1. Introduction

The effects of exchange rate dynamics on the macroeconomy are one of the primary debates in international macroeconomics. Generally, the discussion has focused on the trade channel highlighted by Mundell (1963) and Fleming (1962), in which an exchange rate depreciation will have expansionary effects on the economy due to increased net exports. This channel is based on the Marshall-Lerner condition, satisfied if the absolute sum of a country's export and import demand elasticities is greater than one and has been commonly included in open economy macro models. If the Marshall-Lerner Condition does not hold, a depreciation could also be contractionary due to trade effects (Kim and Ying 2007). Several empirical papers (i.e., Huh 1999, Kappler et al., 2013; Bussière et al., 2014) support the view that currency depreciation positively impacts net exports and output. However, economies are also linked by financial flows, and financial globalization has led many countries to be net creditors or debtors in foreign currency. This has shifted the focus of the discussion to the financial channel (also the so-called balance sheet or risk-taking channel), in which an exchange rate depreciation works the opposite direction to the trade channel. The financial channel describes how exchange rate movements affect

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the supply and cost of foreign currency funding, hence, domestic economic activity. For instance, a depreciation might worsen domestic borrowers' balance sheet in foreign currency and lenders' risk-taking capacity, deteriorating domestic economic activity through tighter financial conditions. Several papers (i.e., Krugman 1999, Céspedes et al., 2004, Aguiar 2005, Elekdag and Tchakarov, 2007, Hoffman et al., 2020, Georgiadis and Zhu 2021; Banerjee et al., 2022) show that the financial channel is operative in the sense that an exchange rate depreciation worsens balance sheets of banks and corporations, therefore reduces investment and output. Recently, empirical literature (i.e., Kearns and Patel 2016; Avdjiev et al., 2019) started to focus on disentangling these two channels of exchange rate movements and quantifying their predominant effects for advanced and emerging market economies.

In this context, the present paper empirically examines the macroeconomic effects of exchange rate movements and their transmission mechanisms (trade and financial channels) in a net debtor in foreign currency and a commodity-dependent developing economy. Specifically, our primary focus lies in assessing the impact of exchange rate fluctuations on key macroeconomic variables, including Gross Domestic Production (GDP), the Consumer Price Index (CPI), final consumption, gross capital formation (investment), net exports, and the value-added contributions of various sectors. Using Mongolia as a representative case study, we estimate Structural Bayesian Vector Autoregression (SBVAR) models with the block exogeneity assumption of a small open commodity-exporting economy. Following Kearns and Patel (2016), we construct Mongolia's debt-weighted exchange rate (DWER) and use the trade-weighted exchange rate (NEER) to separate the trade and financial channels. The empirical analysis is applied to Mongolia by considering the size of its external debt (about 220 percent of its GDP) and commodity dependence (i.e., commodity exports account for more than 90 percent of total exports). The Mongolian economy currently faces challenges in maintaining external debt sustainability, diversifying exports, reducing import dependence, and transforming its natural resource wealth into assets that support sustainable growth. Therefore, findings from the case study would be highly relevant for formulating policy choices to maintain macroeconomic and financial stability in commodity-exporting developing economies with high external debt.

Our paper contributes to the existing literature in three distinct ways. First, it identifies and quantifies the significance of both the financial and trade channels using a novel approach by combining the constructed DWER index and SBVAR modeling. It highlights the pivotal role of the financial channel in affecting GDP and investment, especially in sensitive sectors, while also demonstrating the continued relevance of the traditional trade channel for driving changes in net exports. Second, the paper imparts valuable insights into the macroeconomic stability of commodity-exporting developing economies concerning exchange rates and foreign shocks. It reveals that while NEER and DWER exchange rate shocks have meaningful effects on economic activities at the aggregate, GDP component, and sectoral levels, they do not substantially destabilize the economy. Instead, it underscores the predominant role of foreign shocks in driving domestic macroeconomic fluctuations. Lastly, the paper provides a better understanding of exchange rate channels in transmitting both foreign and domestic shocks, offering policy implications for managing economic stability in the face of adverse shocks. In this regard, our study provides evidence-based implications for developing the Integrated Policy Framework (IPF),[1] tailored to economies bearing similarities to Mongolia.

Very few empirical works have been recently done to examine the effects of exchange rates by disentangling these two channels. Using a univariate autoregressive distributed lag (ARDL) model, Kearns and Patel (2016) disentangle the trade channel from the financial channel by comparing the effects of movements in trade-weighted and debt-weighted exchange rate indices. They show that the financial channel can significantly offset the trade channel for EMEs. Moreover, they find evidence that i) in advanced economies, the trade channel dominates, while the financial channel has a substantial impact on EMEs with higher foreign currency debt, and ii) the investment is found to be strongly sensitive to the financial channel. Using structural panel vector autoregression on aggregate data and panel regression on firm-level data, Avdjiev et al. (2019) find that a stronger U.S. dollar has real macroeconomic effects that go in the opposite direction to the trade channel. A stronger dollar is associated with lower real investment (predominant effects of the financial channel over the trade channel) in EMEs.

Our paper is also related to the literature on assessing the effects of exchange rates on domestic economic activity. Since Magee (1973)'s seminal work, which introduced the concept of the J-curve phenomenon,[2] numerous empirical investigations have been conducted to examine the delayed impact of exchange rate fluctuations on the trade balance. Over time, various methodological approaches aimed at assessing the J-curve effect have been developed, as evidenced by studies conducted by Rose and Yellen (1989) and Boyd et al. (2001). The existing studies focused on emerging and least-developed economies (i.e., Bahmani-Oskooee 1985; Rose 1990; Wilson 2001; Bahmani-Oskooee and Ratha 2004, and Auboin and Ruta, 2013) have suggested that the short-run responses of the trade balance to currency depreciation are country-specific and depend on characteristics such as the degree of economic integration, the linkage with global production networks, the pricing strategy of firms engaging in international trade and the structures of production, exports, and imports. In addition, some studies suggest that domestic currency depreciation can have adverse effects on investment, capital, and output. For instance, using firm-level data for five Latin American countries, Bleakley and Cowan (2008) document that following a depreciation, firms holding dollar debt do not invest less than their domestic currency indebted counterparts. They argue that for firms holding higher levels of dollar debt, the negative balance sheet effect is more than offset by higher current and future earnings caused by the competitiveness effect of depreciation. However, Druck et al. (2018) find a negative relation between the strength of the U.S. dollar and emerging markets growth: when the dollar is strong, EMEs' real gross domestic production

[1] The framework 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).

[2] Because of lag structure, currency devaluation worsens the trade balance first and improves it later resulting in a pattern that resemble the letter J. If the Marshall-Lerner condition (i.e., the absolute sum of export and import demand elasticities is greater than one) is satisfied, then when a country's currency depreciates, its balance of trade will improve over time.

(GDP) growth decreases. Kohn et al. (2020) show that local currency devaluations can be contractionary by studying the role of financial frictions and balance-sheet effects in accounting for the dynamics of aggregate exports in large devaluations. They find that financial frictions (i.e., financing constraints) and foreign-denominated debt channels have a negative impact on capital accumulation and output, and they only explain a modest fraction of the gradual increase of exports.

Several papers have examined the effects of bilateral exchange rates (Mongolian tögrög against the U.S. dollar) on trade, consumer price, and output in the case of Mongolia. Based on the econometric analysis, Gan-Ochir (2011) shows that the exchange rate pass-through to consumer price is asymmetric, and the pass-through is 0.4–0.5 when a nominal depreciation occurs, while it is reduced to 0.2 when the exchange rate appreciates. Using a Markov-Switching Phillips curve and time-varying VAR models extended with commodity prices, Davaajargal (2015) finds that i) inflation is mainly driven by exchange rate depreciation for the period 2013–2014, and ii) exchange rate pass-through is reduced to 0.16 when the nominal exchange rate is appreciated due to high inflows of foreign direct investment (FDI), while it is increased to 0.3 for the period of exchange rate depreciation. Based on a structural VAR analysis, Byambatsogt and Tsenguunjav (2016) demonstrate that a nominal exchange rate depreciation reduces outputs of production sectors with high import inputs, hence nominal GDP in the short run (1–2 quarters); however, the depreciation has a positive effect on the domestic activities by increasing outputs of exporting sectors in the medium run. Using the vector error correction model (VECM), Gan-Ochir (2018) find that real exchange rate depreciation improves trade balance in both the short and long run. In particular, he emphasizes that the well-known Marshall-Lerner condition holds in the long run; however, there is no evidence of the classic J-curve effects in the short run. Davaajargal and Khuslen (2019) find that a nominal exchange rate depreciation increases real GDP, and the exchange rate pass-through to GDP is estimated at 0.2–0.3. Using Threshold structural VAR extended with commodity prices, Davaajargal and Tsolmon (2019) show that a real exchange rate depreciation reduces real GDP when government debt is high (i.e., the government debt to GDP ratio is above 34 percent), while the depreciation increases real GDP of the government debt is low.

The rest of this paper is structured as follows. Section 2 provides an overview of the Mongolian economy and constructs the debt-weighted exchange rate index, helping capture the financial channel of the exchange rate. Section 3 presents SBVAR models for the Mongolian economy, including restrictions used to identify structural shocks. Section 4 describes the data, choice of hyperparameters, and shock identification. Section 5 reports the main findings and robustness checks. Finally, Section 6 concludes the paper and discusses policy implications.

2. Overview of the Mongolian economy and construction of debt-weighted exchange rate (DWER)

Mongolia's fundamental economic problems are its lack of diversification and its proclivity to boom-bust cycles. Because of the country's narrow economic base, the economy is highly vulnerable to foreign shocks, namely commodity price fluctuations and volatility in FDI. In the economy, commodity (mineral and animal products) exports account for about 95 percent of its total exports, equivalent to 40 percent of its gross domestic product (GDP). Both volatile capital flows and commodity prices have led to more significant business and financial cycle fluctuations (Fig. 1).

The Mongolian economy is highly dependent on imports. The import-to-GDP ratio is high (about 65 percent), and almost 50 percent of the household consumption basket consists of imported goods. It is the primary origin of high exchange rate pass-through, and the exchange rate adjustment affects the trade balance mainly through the import channel.

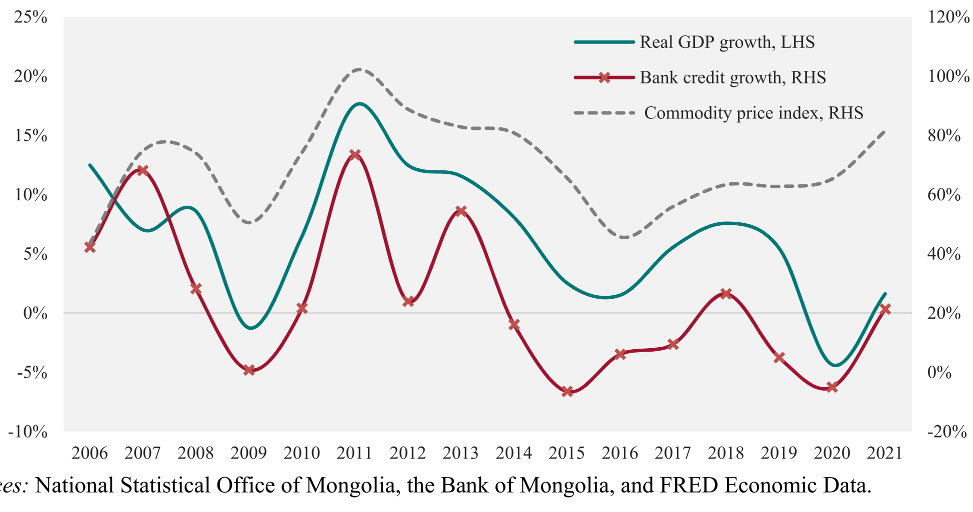


Fig. 1. Mongolian real GDP growth, bank credit growth, and commodity prices.
Sources: National Statistical Office of Mongolia, the Bank of Mongolia, and FRED Economic Data.

The economy also faces challenges in maintaining external debt sustainability and transforming its natural resource wealth into assets that support sustainable growth. The persistent current account deficits over the last two decades have accumulated external debts. At the end of 2021, the economy's total external debt reached 33.8 billion USD (equivalent to about 220 percent of its GDP) (Fig. 2). As of 2021, banks' external debts totaled approximately 1.6 billion USD, representing around 5 percent of the overall external debt. In terms of maturity, the majority, or 77.8 percent, of these bank debts are categorized as long-term debts. Furthermore, 11.3 percent of these debts take the form of deposits, while 82.1 percent are in the form of loans obtained from foreign financial institutions.

People's Republic of 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: dollarization of bank deposits is about 30 percent; dollarization of bank loans is about 10 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.

In the context of financial interconnection, the U.S. dollar's interest rate assumes heightened relevance for the Mongolian economy. For instance, as of 2021, a substantial 80 percent of the country's total external debts are denominated in U.S. dollars. Moreover, a predominant portion of sovereign and private-sector bonds are issued in international markets, specifically in the U.S. dollar denomination. Consequently, fluctuations in the US federal funds rate wield a direct and consequential influence on the refinance rate of Mongolia's existing debt obligations. Furthermore, Mongolia's trade landscape is characterized by a substantial reliance on the U.S. dollar, denoted as 'dominant currency pricing'. Notably, U.S. dollars constitute a significant share, ranging between 70 and 75 percent, of crucial economic dimensions, including export revenues, import payments, and foreign exchange transactions within the country. This pattern endures, even as the Chinese renminbi (RMB) remains a substantially smaller contributor, accounting for less than 15 percent of foreign exchange transactions in the Mongolian economy. Besides, the federal funds rate is a key determinant of the exchange rate of tögrög against the U.S. dollar.

The main sectors have short foreign exchange (FX) positions, and the balance sheets of both private and public sectors are vulnerable to movements in the exchange rate. For instance, FX positions in the government sector (−59 percent of GDP), other depository corporations (−11 percent of GDP), and the non-financial private sector (−203 percent of GDP) are short (Gan-Ochir et al., 2019). Foreign currency exposure on an economy's external balance sheet may cause financial difficulties for borrowers and lenders when the exchange rate depreciates. It implies that the financial channel of the exchange rate may play a significant role in the economy.

The economic profile of Mongolia comprises several typical characteristics shared with commodity-dependent emerging and developing economies.[3] Regarding the World Bank's statistics on the import-to-GDP ratio, Mongolia is among the forty countries with a higher proportion of imports relative to its GDP. The import-to-GDP ratio for Mongolia is similar to that of other emerging and developing economies such as Georgia, Bulgaria, Moldova, Thailand, Malaysia, and Montenegro. The percentage of natural resource exports in the economy is in line with that of most low- and lower-middle-income resource-rich countries (where the share of exports from natural resources is above 70 percent), as indicated by Venables (2016). With reference to the IMF's database on total external debt as a percentage of GDP, Mongolia's external debt level in 2021 is closer to that of Bahrain and significantly higher than the levels observed in the Middle East and North Africa (MENA) low-income developing countries (at around 106 percent of GDP) and the Caucasus and Central Asia (CCA) emerging markets and middle-income countries (about 95 percent of GDP). Mongolia also exhibits commonalities with CCA and MENA countries in terms of economic characteristics, including relatively high dollarization, underdeveloped financial markets, the need for maturing monetary policy frameworks, and the imperative to enhance credibility in the economy. Nevertheless, it's worth noting that the economy's levels of dollarization in deposits and loans are significantly lower compared to CCA countries, standing at around 40 percent. Hence, the results from the specific case of Mongolia can be extrapolated to other commodity-dependent developing economies that are net debtors in foreign currency.

Following Kearns and Patel (2016), we use the debt-weighted exchange rate index (DWER) to capture the financial channel of the exchange rate in this paper. The DWER uses the shares of foreign currency debt to weigh a country's bilateral exchange rates. We employ bilateral exchange rates, denominating the Mongolian debts (USD, EUR, JPY, SDR, CNY). There are several possible ways to select the debt weight. In particular, the debt measure could differ along two main weighting types: currency denomination and residence of debt holders (Table 1).

At the end of 2022, Mongolia's gross external debt is 33.6 billion USD, while the share of total external debt denominated by local currency is only 0.3 percent. Hence, the weighting options A and C do not significantly differ in this case. In this paper, we calculate the debt weights using foreign currency-denominated total debt (cell B in Table 1). Foreign currency-denominated total debt weight covers gross external debt stock and domestic banking sector loan stock at the end of the quarter. The debt weight of currency j at quarter t in the DWER index is calculated using the following formula:

$$weight_t^j = \frac{EXL_t^j + IDS_t^j + LL_t^j}{\sum_j \left(EXL_t^j + IDS_t^j + LL_t^j\right)} \tag{1}$$

[3] As an example, UNCTAD member States are considered to be commodity-dependent if more than 60 percent of their merchandise export value comes from commodities. The commodity-dependent developing countries are vulnerable to negative shocks that affect the quantities and/or the prices of the commodities exported.

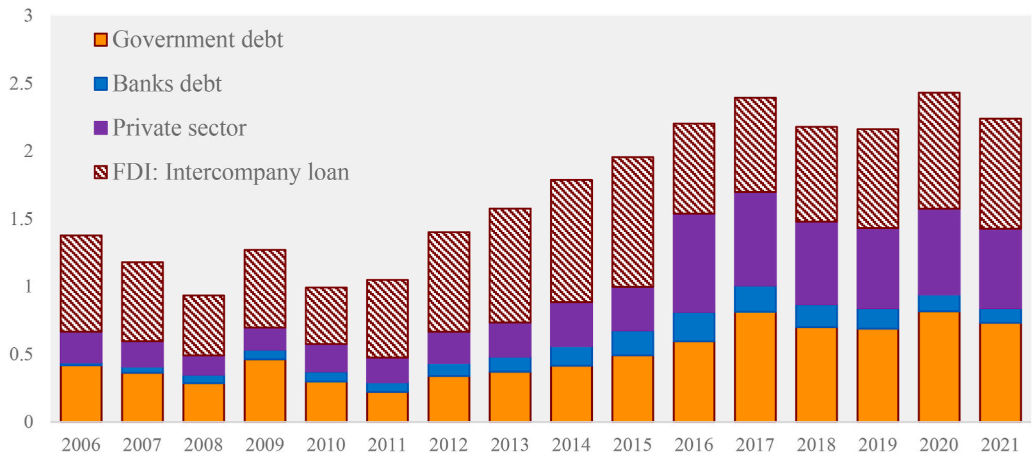


Fig. 2. External debt to GDP ratio.
Source: National Statistical Office of Mongolia and the Bank of Mongolia.

Table 1
Available weighting options for DWER.

Residence of lenders:	Currency denomination:	
	Foreign currency	All currencies
External debt	A	C
Total debt	B	D

Source: Kearns and Patel (2016).

where *EXL* is external loans to banks and non-banks denominated in foreign currencies, *LL* is local loans to non-banks denominated in foreign currencies, and *IDS* is international debt securities denominated in foreign currencies issued by non-banks. For example, the government's external loans are included in *EXL,* while sovereign (government) debt securities issued in international markets are counted in *IDS* in the weight calculation. Debt weights are calculated on a quarterly basis.

The constructed DWER index, together with the nominal effective exchange rate (NEER) index are shown in Fig. 3. As weights of the U.S. dollar in total debts are high (about 82 percent), the calculated DWER index closely goes along with the bilateral U.S. dollar exchange rate. Kearns and Patel (2016) also found similar results for most of the Latin American countries, including Chile, Brazil, Argentina, Columbia, and Peru. The general co-movement between NEER and DWER is also observed. A similar case is also found in emerging European countries (Czech Republic, Hungary, Israel, Poland, and Turkey) in the sample of Kearns and Patel (2016).

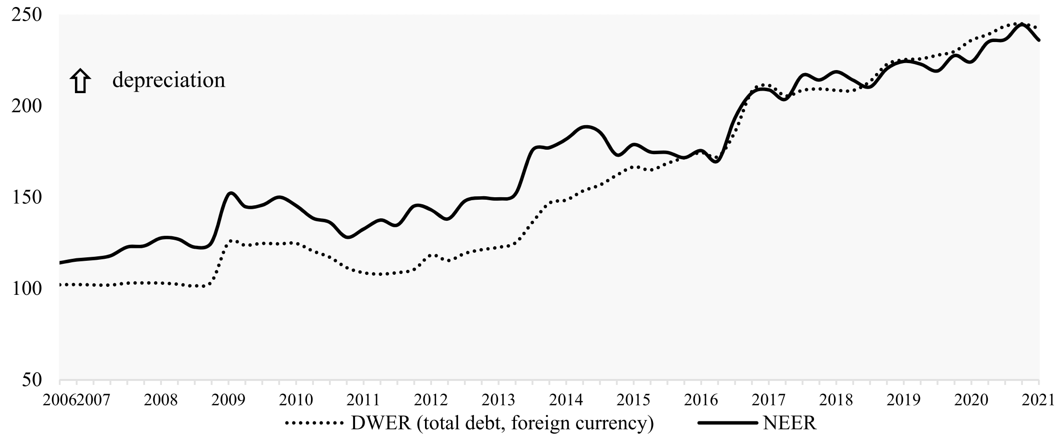
As shown in Fig. 2, the total external debt of Mongolia has continuously increased since 2011, and DWER has also depreciated. However, DWER and NEER moved in a different direction between 2014 and 2016 as the Development Bank of Mongolia and the Bank of Mongolia increased their debts in Japanese Yen and Chinse RMB for the same period, respectively. Particularly, DWER has depreciated much quicker compared to NEER since 2014. Both indices strongly fell during the global financial crisis (GFC), and then appreciated during the mining boom period of 2010–2011. Expansionary macroeconomic policies in response to ending commodity price super-cycles have led to vast and continuous depreciation for 2013–2016. As the government of Mongolia implemented the Extended Fund Facility program of the IMF for 2017–2020, the exchange rate fluctuations have stabilized. At the beginning of COVID-19, the exchange rate was relatively stable as the domestic demand fell and the Bank of Mongolia kept intervening in the foreign exchange market.

3. A structural bayesian VAR model with block exogeneity for the Mongolian economy

We employ the structural vector autoregression (SVAR) model in examining the transmission mechanism of exchange rates in Mongolia. A SVAR describing the dynamics of economic relations takes the form

$$\mathbf{A}\mathbf{y}_t = \mathbf{B}\mathbf{y}_{t-1} + \mathbf{u}_t \tag{2}$$

for $\mathbf{y}_t$, which is a $n\times1$ vector of observed variables at date $t = 1,\ldots,T$, $\mathbf{A}$ is an $n\times n$ matrix summarizing their contemporaneous structural relations, $\mathbf{y}_{t-1}$ is a $(k\times1)$ vector (with $k = mn+1$) containing a constant and m lags of $\mathbf{y}$ $((y'_{t-1}, y'_{t-2}, \ldots, y'_{t-m}, 1)')$, $\mathbf{B}$ is a $k\times k$



Source: Authors' calculation (DWER) and National Statistical Office of Mongolia (NEER).

Fig. 3. DWER and NEER indexes, 2000 = 100, 2006Q3-2021Q1.
Source: Authors' calculation (DWER) and National Statistical Office of Mongolia (NEER).

matrix summarizing constants and lagged structural relations, and $\mathbf{u}_t$ is $n\times1$ vector of structural shocks that are assumed to be i.i.d. $\mathscr{N}(0,\mathbf{D})$ and mutually uncorrelated (i.e., $\mathbf{D}$ is diagonal). The reduced-form VAR parameter and residual are given by $\mathbf{\Phi}=\mathbf{A}^{-1}\mathbf{B}$ and $\varepsilon_t=\mathbf{A}^{-1}\mathbf{u}_t$, and residual covariance matrix is $\mathbf{\Omega}=\mathrm{E}(\varepsilon_t\varepsilon_t^{'})=\mathbf{A}^{-1}\mathbf{D}(\mathbf{A}^{-1})^{'}$.

Grounding on small open and commodity-exporting economy models (i.e., Dungey and Pagan 2009, Dungey et al., 2014, Gan-Ochir and Davaajargal 2019; Gan-Ochir et al., 2023), the vector of endogenous variables, $\mathbf{y}_t\equiv[F_t^{'},D_t^{'}]^{'}$, comprises foreign ($F_t$) and domestic ($D_t$) variables. Choice of variables and theoretical foundations for them are detailed in Section 4.1. We include key variables to capture possible interlinks and transmission channels of exchange rates. In such way, it is purely empirical exercise to obtain the fact on the trade and financial channels of exchange rates.

As Mongolia is a small open economy with negligible influence on international quantities and prices, the foreign variables (F_t) affect all domestic variables (D_t) contemporaneously or through the lags. However, the domestic variables do not affect the foreign variables contemporaneously or through the lags. Therefore, we employ this block exogeneity assumption in the VAR setting, in line with Cushman and Zha (1997) and Manalo et al. (2015).

We estimate our VAR models using the Bayesian approach, which helps deal with the over-parameterization problem by imposing prior beliefs on the parameters.[4] The simplest and most frequently used form of prior distributions for VAR models is the Minnesota prior, advocated by Litterman (1980). In this framework, it is assumed that the VAR variance-covariance matrix Ω is known. Hence, the only object left to estimate is the vector of parameters $\varphi=vec(\Phi)$. For this purpose, we employ an independent normal-Wishart prior, where Ω would be treated as unknown, and an arbitrary structure could be proposed for the covariance matrix of φ ($\widetilde{\Sigma}$), with no assumed dependence between residual variance and coefficient variance, is employed in this paper. The independent normal-Wishart prior is given by

$$\varphi|\Omega\sim\mathscr{N}(\widetilde{\varphi},\widetilde{\Sigma}),\Omega\sim iW(\widetilde{\Omega},\alpha) \tag{3}$$

with prior mean and variance $E(\varphi)=\widetilde{\varphi}$, $\alpha>n$, and $Var(\varphi)=(\alpha-n-1)^{-1}\widetilde{\Sigma}$, $\alpha>n+1$, where α is the prior degrees of freedom. Concerning prior for φ, it departs from the normal-Wishart assumption by assuming that φ follows a multivariate normal distribution with mean $\widetilde{\varphi}$ and covariance matrix $\widetilde{\Sigma}$, but $\widetilde{\Sigma}$ is now not necessarily adopting the Kronecker structure. In typical applications, $\widetilde{\Sigma}$ will take the form of the Minnesota covariance matrix, but any choice is possible.

For the choice of $\widetilde{\varphi}$, a conventional Minnesota scheme will be typically adopted as

$$\widetilde{\varphi}_{l,ij}=\begin{cases}\delta_i, i=j, l=1\\ 0,\text{otherwise}\end{cases} \tag{4}$$

It implies that setting values for δ_i for own first lag ($i=j$, $l=1$, where i is for equation, j is for variable, l is for lag considered by the coefficient) coefficients, and 0 for cross variable and exogenous coefficients. Based on the empirical fact that most observed macroeconomic variables seem to be characterized by a unit root, Litterman (1986) suggests that $\delta_i=1$ for its first lag. However, as

[4] In Bayesian econometrics, every parameter of interest is treated as a random variable characterized by some underlying probability distribution. The aim is thus to identify these distributions to produce estimates and carry inference on the model.

highlighted by Dieppe et al. (2018), in the case of variables known to be stationary, this unit root hypothesis may not be suitable, so a value around $\delta_i = 0.8$ may be preferred.

In terms of $\widetilde{\Sigma}$, a Minnesota type of variance matrix can be adopted:

$$\widetilde{\Sigma}_{l,ij} = \begin{cases} \left(\frac{\lambda_1}{l^{\lambda_3}}\right)^2, i = j \\ \left(\frac{\sigma_i^2}{\sigma_j^2}\right)\left(\frac{\lambda_1\lambda_2}{l^{\lambda_3}}\right)^2, \text{otherwise} \end{cases} \tag{5}$$

where λ_1 is overall tightness parameter, λ_2 represents a cross-variable specific variance parameter, λ_3 is a scaling coefficient controlling the speed at which coefficients for lags greater than 1 converge to 0 with greater certainty, and σ_j^2 and σ_j^2 denote the OLS residual variance of the autoregressive models estimated for variables *i* and *j*. The parameter, λ_1 controls the importance given to the priors. In this paper, we manually set the hyperparameters based on values commonly employed by empirical papers. The hyperparameters of prior distributions are carefully selected in Section 4.2.

In isolating structural macroeconomic shocks, $\mathbf{u}_t$, the most common identification scheme for $\mathbf{D}$ and $\mathbf{A}^{-1}$ is Choleski factorization, which assumes that $\mathbf{D} = \boldsymbol{I}$ and $\mathbf{A}^{-1}$ is the Choleski factor of the residual covariance matrix in' the reduced-form VAR, Ω. However, the assumption that $\mathbf{D} = I$ may constitute an excessively restrictive hypothesis. Indeed, this assumption implies that all the structural shocks have similar unit variance; however, the variance may differ from 1, and different shocks may have very different sizes. As a simple solution to this problem, a triangular factorization is employed in this paper. The theoretical and empirical foundations for the ordering of variables are discussed in Section 4.3. Bayesian estimation with the independent normal-Wishart prior and shock identification are done using the BEAR toolbox, a flexible MATLAB routine developed by Dieppe et al. (2018).

4. Data, choice of hyperparameters, and shock identification

4.1. Variable choice and data

We estimate different groups of VAR models, such as an aggregate model, a component model, and sectoral models. The selection of variables is as follows. All models include same foreign variables (F_t) to reflect foreign shocks' effects on the domestic economy. The foreign variables include the federal funds effective rate, world copper price, and China's GDP. To account for the financial interconnection of the economy, we include the federal funds effective rate as a proxy for the foreign interest rate in our model. The empirical fact provided by Dedola et al. (2017) also suggests that the inclusion of the federal funds rate helps to capture international spillovers of the US monetary policy shocks. As the Fed funds rate is a return on the U.S. dollar, changes in the funds rate directly affect the exchange rate, its expectation, and dollarization in the banking sector. Alternative measures to foreign interest rates could include the shadow federal funds rates estimated by Krippner (2013) and Wu and Xia (2016). These measures have the potential to provide a more accurate reflection of U.S. monetary policy shocks, particularly those arising from the Federal Reserve's unconventional policy measures. However, the current paper is primarily dedicated to examining the transmission mechanisms of exchange rate shocks, as opposed to investigating the underlying factors influencing movements in exchange rates. Consequently, the incorporation of these alternative measures falls outside the immediate scope of this study. These alternative metrics can be used in future research, with the aim of comprehensively assessing the effects of Federal Reserve policy shocks and examining whether inclusion of these measures results in alterations to the transmission mechanisms of exchange rate shocks.

In Mongolia, mineral exports account for 90 percent of total exports of which 45 percentage point is solely attributed to copper exports. Thus, the copper price is a good proxy for reflecting the effects of the global commodity price cycle. Moreover, Mongolian exports to China account for about 90 percent of total exports and 40 percent of imports. Hence China's GDP is a good proxy for the export demand. Existing studies (i.e., Gan-Ochir and Davaajargal 2019, 2023) show that copper price and China's GDP play a vital role in predicting the Mongolian inflation and business cycle fluctuations.

As we aim to investigate the effects and transmission channels of exchange rate movements on the domestic economy, we include key domestic macroeconomic variables (D_t) in the system. In the aggregate model, we include domestic GDP, CPI, policy rate, and exchange rates, which are four critical macro variables in New Keynesian open economy models. GDP and CPI are used to measure economic activities and distinguish domestic aggregate demand and supply shocks. The policy rate is included as a proxy for the domestic interest rate (monetary policy). The policy rate is determined by Monetary Policy Committee (MPC) of the Bank of Mongolia (BOM) and is equivalent to BOM's short-term (up to 4 weeks) central bank bills' rate. Finally, the inclusion of exchange rate, a key variable for open economy macroeconomics, allows us to analyze the effects of exchange rate movements and the role of the exchange rate in the transmission of external and domestic shocks. In the structural VAR setting, it is almost impossible to jointly include NEER and DWER in one system because i) there is no clear theoretical foundation for that the exchange rate indexes could affect each other, ii) it leads to problems in shock identification (i.e., which exchange rate index should place first), and iii) it makes difficult to explain some results such as significant response of one exchange rate index to another or a strong contribution of one index's shock to variance of another index. Therefore, we have decided to estimate a separate VAR for each exchange rate indexes of NEER and DWER. The system with NEER is included to capture the trade channel, whereas DWER proxies for the financial channel of exchange rate. As we estimate separate VAR models using alternative definitions of exchange rates, our paper focuses on statistical significance and transmission mechanisms of trade and financial channels rather than the relative importance of the channels.[5]

We also estimate a component model to investigate the transmission channels of the exchange rate passing through GDP components. In the component model, we replace the domestic GDP by its components of the expenditure approach such as consumption, investment, and net export, and retain the other variables same as in the aggregate model. We also estimate a separate VAR for each sector of the Mongolian economy. In each sectoral model, we replace the domestic GDP by sectoral production measure, and retain the other variables same as in the aggregate model. As sectoral production measure, we observe ten sectors' value added, in line with the GDP's production approach.

Our VARs are estimated in (log) levels over the sample period 2006Q3-2021Q1. In the aggregate model, the following variables are observed: The federal funds effective rate (*FEDR*), the log of seasonally adjusted China real GDP (GDP_{CH}), the log of the copper price index (P_{copper}), the log of seasonally adjusted domestic real GDP at 2005 constant prices (*GDP*), the log of domestic CPI (all items, 2015 = 100) (*CPI*), the (annual) policy rate (*PR*), the log of the NEER index (*NEER*), and the log of the DWER index (*DWER*). In line with Leu (2011), we observe nominal exchange rates rather than real exchange rates since i) a New Keynesian model assumptions are used in the shock identification and ii) domestic inflation, short-term interest rate and foreign short-term interest rate are also included in the system. The inclusion of nominal exchange rates in the system allows us to identify a risk premium shock (i.e., nominal exchange rate shock) and assess its impacts on inflation and outputs. In the component benchmark model, the log of seasonally adjusted final consumption ($C+G$), where C is household consumption and G is government consumption, the log of seasonally adjusted gross capital formation (I) and the log of seasonally adjusted net exports (NX) are additionally observed. For the sectoral models, we also observe the log of seasonally adjusted value added of agriculture, forestry, fishing and hunting (VA_{ag}), mining and quarrying (VA_m), manufacturing (VA_{ma}), electricity, gas, steam, air conditioning supply (VA_{el}), construction (VA_{co}), wholesale and retail trade (VA_{tr}), transportation and storage (VA_{trs}), information and communication (VA_{in}), taxes less subsidies on products (VA_{nt}), and other (VA_{os}) sectors.

Federal funds effective rate and China's GDP are observed from FRED economic data of the Federal Reserve Bank of St. Louis,[6] while copper price index is collected from the Primary Commodity Price System of IMF database. Domestic GDP, final consumption, gross capital formation, net exports, value added of the sectors, NEER index and CPI are retrieved from the National Statistical Office (www.1212.mn). We use DWER index calculated in Section 2. All remaining data are obtained from the Statistical Bulletin of the Bank of Mongolia (stat.mongolbank.mn).

In the empirical analysis, variables in VAR models are specified in levels (consisting of 'log' and 'percent' variables). We follow a conventional approach: Differencing or linearly detrending the variables throw away important information about the long-run properties of the data and running a VAR in differences will be mis-specified (Canova 2007; Bjørnland and Thorsrud 2015). If unit root behavior of the series is not of importance, Sims et al. (1990) have also argued in favor of using VAR in level as modeling strategy, by pointing out that there is no real advantage to differencing the variables. Moreover, our setting of VAR in level is in line with the modelling strategy suggested by Bjørnland and Thorsrud (2015): The modelling strategy should depend on the focus of analysis. When the purpose is to analyze the effects of structural shocks, they use VARs in level, and they respectively employ a VAR in differences and VECM in producing the most accurate forecast and examining the long-run equilibrium relationships. Our paper focuses on examining the macroeconomic effects of exchange rate shocks. However, in recent years, Bayesian analysis of cointegrated VAR is intensively developed (e.g., Kleibergen and Paap 2002; Koop et al., 2010), and the Bayesian cointegration analysis for the same topic is left for the future research.

4.2. Choice of hyperparameters and lag lengths

Bayesian estimates are sensitive to the prior distribution specification when estimating small samples. Therefore, we set standard hyperparameters of prior distributions to deal with the issues.

Values typically found in the literature are chosen for the overall tightness, $\lambda_1 = 0.1$ [7] and the lag decay, $\lambda_3 = 2$. As suggested by Bobeica and Hartwig (2023), the choice of higher degree of prior shrinkage helps to mitigate the problem of changing parameters after adding the COVID-19 observations. For the autoregressive coefficient prior, δ_i, we set $\delta_i = 0.8$ as selected by Sznajderska and

[5] In such a sense, our paper also deviates from Kearns and Patel (2016) who include both indexes in a single regression model to test empirically the relative importance of the trade and financial channels on the GDP and its components.

[6] China's real GDP is calculated as a ratio of seasonally adjusted current price GDP in China (CHNGDPNQDSMEI) to CPI, all items for China, index 2015 = 100 (CHNCPIALLQINMEI), both data are collected from FRED economic data of Federal Reserve Bank of St. Louis.

[7] Dieppe et al. (2018) suggest setting λ_1 for the Normal-Wishart prior at a smaller value than for the Minnesota prior to ccompensatingfor the lack of extra shrinkage from λ_2, which controls tightness on cross-variable parameters in the case of Minnesota prior. Our choice of $\lambda_1 = 0.1$ is much smaller compared to the value of $\lambda_1 = 0.2$ selected by Sznajderska and Kapuściński (2020) for the Minnesota prior.

Kapuściński (2020) for quarterly data.[8]

Lag length is determined based on the Deviance information criterion (DIC). For the aggregate model with DWER, the DIC test results for $\mathscr{M}_1$: BVAR(1), $\mathscr{M}_2$: BVAR(2), and $\mathscr{M}_3$: BVAR(3) are estimated as −804.13, −697.32, and −642.37, respectively. For the aggregate model with NEER, the DIC test results for $\mathscr{M}_1$: BVAR(1), $\mathscr{M}_2$: BVAR(2), and $\mathscr{M}_3$: BVAR(3) are estimated as −761.83, −642.34 and −567.23, respectively. According to the test, the model with a smaller DIC value is preferred, hence lag length is chosen as $m=1$ for the aggregate models. For the component model with DWER, the DIC test results for $\mathscr{M}_1$: BVAR(1), $\mathscr{M}_2$: BVAR(2), and $\mathscr{M}_3$: BVAR(3) are estimated as −759.93, −535.72, and −195.11, respectively. In the case of the component model with NEER, the DIC test results for $\mathscr{M}_1$: BVAR(1), $\mathscr{M}_2$: BVAR(2), and $\mathscr{M}_3$: BVAR(3) are estimated as −716.95, −514.51, and −192.29, respectively. Hence, we also choose the lag length as $m=1$ for the component models. For the sectoral models, we also use the DIC test and choose $m=1$ for each sectoral model. However, models with 2 lags are also estimated, and results have been robust shown in Section 4.4. The total number of iterations of the Gibbs sampling algorithm is selected as 10000, and 5000 iterations discarded as burn-in iterations.

4.3. Shock identification

As the triangular factorization scheme is utilized, structural shocks are identified using a simple recursive ordering. Regarding the ordering of variables in the VAR, most exogenous (endogenous) variables are placed first (last) following the general guiding principle, and the ordering also considers whether the variable is quick responder or not. For the aggregate model, the ordering is set as follows: *FEDR*, GDP_{CH}, P_{copper}, *GDP*, *CPI*, *PR*, *NEER* or *DWER*. For the component model, the ordering of *FEDR*, GDP_{CH}, P_{copper}, *NX*, $C+G$, *I*, *CPI*, *PR*, *NEER* or *DWER* is used. For the sectoral model, the following ordering is chosen: *FEDR*, GDP_{CH}, P_{copper}, VA_k , *CPI*, *PR*, *NEER* or *DWER*, where $k=\{ag, m, ma, el, co, tr, trs, in, nt, os\}$.

In all models, ordering of the foreign variables (F_t) is same. *FEDR* comes firs7t by assuming that the setting of policy rate in the US economy is less dependent on the developments in the Chinese economy and commodity markets. Our assumption is in line with the existing literature. For instance, Zhang et al. (2022) show that spillover effect from the US to China is immediate and tightness in US monetary policy increases inflation in China by 0.2 percent and drives down output by 1 percent. Ratti and Vespignani (2015) also find that global liquidity is an essential factor in commodity prices. GDP_{CH} comes before P_{copper}, motivated by given that Chinese economic activity is a key determinant of global commodity prices. It is consistent the ordering employed by Dungey et al. (2020). Hence, commodity (copper) price responds to the US financial condition and Chinese demand contemporaneously. Foreign variables influence each other through the lags. For all models, we also employ the block exogeneity assumption: The foreign variables (F_t) affect all domestic variables (D_t), while the domestic variables do not affect the foreign variables contemporaneously or through the lags.

The ordering of the domestic variables (D_t) aligns with open economy SVAR studies and New Keynesian models. For instance, Phillips curves explain why GDP (or VA_k) comes before CPI; Taylor rule suggest that policy rate should be placed after GDP (or VA_k) and CPI; and uncovered interest rate parity (UIP) describes why exchange rates are placed in the last. As the exchange rate contemporaneously responds to all variables, the VAR model can capture that exchange rates of commodity-exporting countries reflect changes in the country risk premium and developments in the global commodity market. For the component model, *GDP* is replaced by *NX*, $C+G$, *I*, and the motive for the ordering is as follows: *NX* is mainly driven by commodity demand and prices; $C+G$ are contemporaneously affected by revenues from exports and imports; and *I* is financed by savings, remaining incomes after the consumptions.

5. Empirical results

5.1. Aggregate model

We first discuss aggregate responses to an unanticipated NEER and DWER depreciation before moving to the sectoral and component implications. We scale the initial shock so that it causes a 1 percent depreciation of the exchange rates. As our model is linear, the effects of an appreciation and a depreciation are symmetric. In all figures, an increase in exchange rate represents a depreciation, and the solid lines are the median impulse responses of posterior distributions, while the shaded areas represent the 68 percent posterior probability interval of the estimated responses. In Fig. 4, we show responses of key macroeconomic variables (GDP, CPI and exchange rates) to NEER and DWER shocks.

The aggregate model estimates suggest that the trade channel captured by NEER has strong and significant effect on consumer prices, while the financial channel characterized by DWER is evident for the domestic output. For instance, the NEER depreciation causes a persistent increase in CPI. The point estimate suggests that the maximum effect of the depreciation occurs 8 quarters after the

[8] To assess how different values of the overall tightness, λ_1, affect the model fit, we estimate four models with $m=1$ such as baseline $\mathscr{M}_b(\lambda_1=0.1, \lambda_3=2)$, data-dominant (OLS version) $\mathscr{M}_{ols}(\lambda_1=0.001, \lambda_3=2)$, prior-dominant $\mathscr{M}_p(\lambda_1=0.999, \lambda_3=2)$, and neutral $\mathscr{M}_n(\lambda_1=0.5, \lambda_3=2)$ models. For aggregate model with DWER, log marginal likelihoods for $\mathscr{M}_b$, $\mathscr{M}_{ols}$, $\mathscr{M}_p$ and $\mathscr{M}_n$ are estimated as 134.12, −12219.19, 77.22, and 113.79, respectively. For aggregate model with NEER, log marginal likelihoods for $\mathscr{M}_b$, $\mathscr{M}_{ols}$, $\mathscr{M}_p$ and $\mathscr{M}_n$ are estimated as 118.72, −12227.51, 78.16, and 57.52, respectively. For component model with DWER, log marginal likelihoods for $\mathscr{M}_b$, $\mathscr{M}_{ols}$, $\mathscr{M}_p$ and $\mathscr{M}_n$ are estimated as 115.72, −10499.46, 13.54, and −3.33, respectively. For component model with NEER, log marginal likelihoods for $\mathscr{M}_b$, $\mathscr{M}_{ols}$, $\mathscr{M}_p$ and $\mathscr{M}_n$ are estimated as 111.02, −10487.09, 10.40, and 80.11, respectively. These results suggest that our choice of $\lambda_1=0.1$ improves the fit of the aggregate and component models compared to three alternative choices (i.e., $\lambda_1\to 0$, $\lambda_1\to 1$ and $\lambda_1=0.5$).

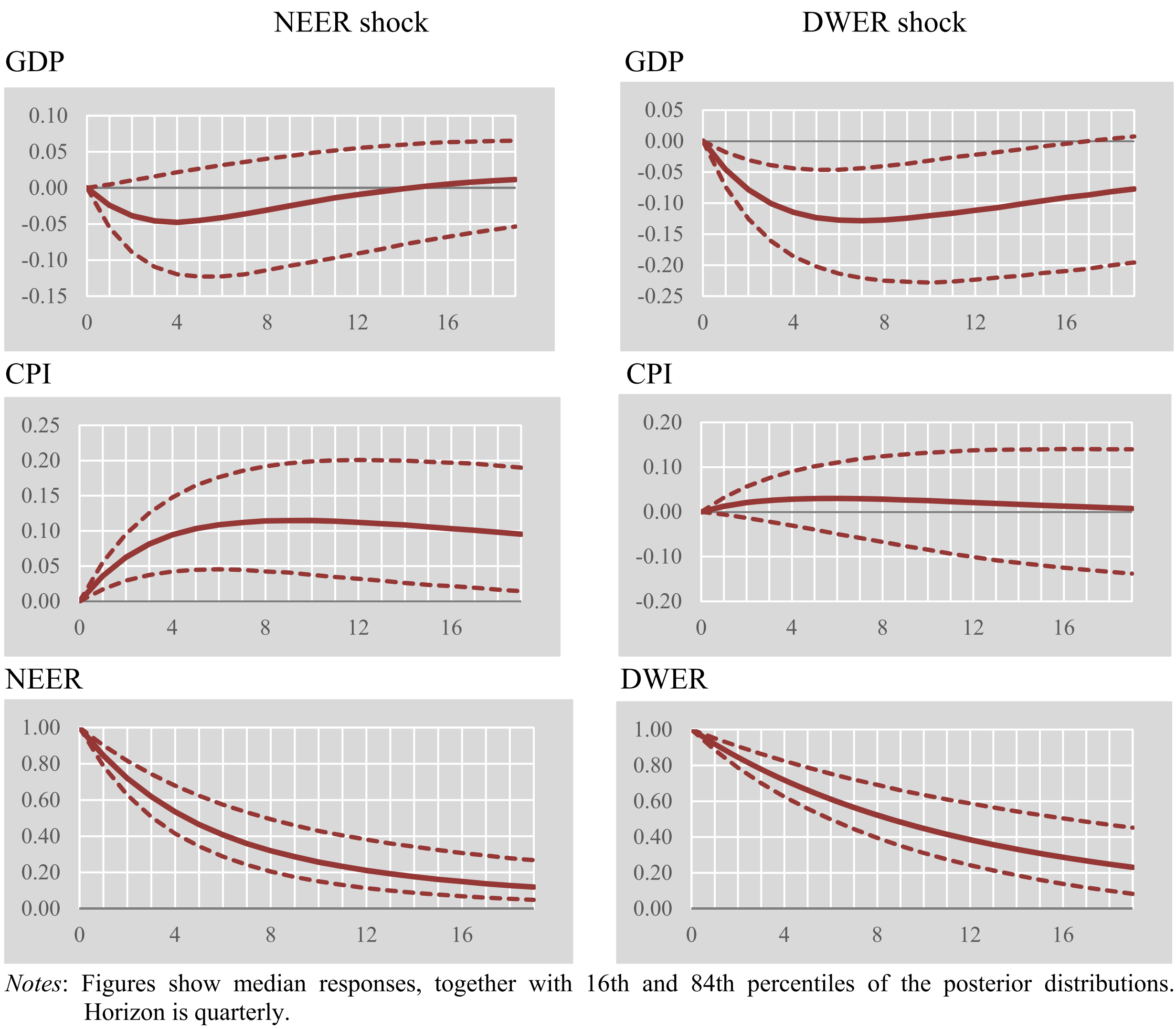


Fig. 4. Impulse responses of domestic GDP and CPI to exchange rate shocks
Notes: Figures show median responses, together with 16th and 84th percentiles of the posterior distributions. Horizon is quarterly.

shock, at which time CPI rises by 0.12 percent. The increase in CPI is statistically significant at the 68 percent confidence level for the 20 quarters. The depreciation also triggers a fall in GDP. However, the effects are not statistically significant. The exchange rate is allowed to evolve endogenously following the shock, and the exchange rate depreciation is relatively long lived, with the exchange rate returning to its initial level after 5 years of the shock.

The DWER depreciation leads to a persistent contraction in GDP. The peak effect of the depreciation happens 7 quarters after the shock, at which GDP falls by 0.13 percent. The contraction is statistically significant at the 68 percent confidence level for the first 16 quarters. The result implies that the financial channel dominates the trade channel in terms of the output. However, the effect of depreciation on CPI is not statistically significant. The DWER depreciation is also long lived. This empirical evidence of the financial channel is in line with the finding of Kearns and Patel (2016) [9] for emerging market economies.

5.2. *Component model*

To assess the transmission mechanisms of the financial and trade channels, we estimate the component model. According to the

[9] They highlight that a local currency depreciation could deteriorate domestic borrowers' creditworthiness, consequently increasing the cost of lending and shrinking the supply of credit. Therefore, a contraction in financial conditions and economic activity will follow a local currency depreciation. These effects will generally be stronger in cases where domestic borrowers have unhedged foreign currency exposures because of less developed financial systems.

expenditure approach of the GDP, final consumption ($C+G$), total investment (I) and net export (NX) account for 78.5 percent, 38.6 percent and −17.0 percent (i.e., 67.3 percent for export and 84.4 percent for import) of nominal GDP at the sample average, respectively. In the component model, we include $C+G$, I, and NX instead of GDP. Fig. 5 displays how the component of the GDP responds to NEER and DWER shocks.

Consistent with a decrease in aggregate output (GDP) following exchange rate depreciation, final consumption, and investment fall. As expected, both exchange rate shocks lead to an increase in net export (NX). The response to NEER shock is statistically significant for the first 3 quarters, and the effect on DWER shock is also statistically significant for much longer periods. The 1 percent NEER (or DWER) depreciation leads to a 0.2 (or 0.3) percent rise in net exports after 3 quarters. It implies strong evidence of the trade and financial channels of the exchange rate passing through the net export. According to the trade channel, the NEER depreciation leads to the contraction in import demand and the rise in non-mining exports. In terms of the financial channel, the DWER depreciation leads to the rise of credit rate spread and the fall in credit, which decreases the import demand.

Both exchange rate shocks cause a contraction in final consumption ($C+G$), and the contraction in response to DWER shock is much stronger. Regarding the trade channel, the depreciation causes a rise in consumer price, which reduces the demand for consumer goods. For the financial channel, DWER depreciation increases the credit rate and decreases the consumer credit, reducing the consumption. However, the decreases of final consumption are not statistically significant. The response of the investment (I) to the NEER depreciation is also not statistically significant.

There is strong evidence of the financial channel passing through the investment (I). DWER depreciation leads to a strong contraction in investment. The maximum effect on the investment occurs 5 quarters after the shock, at which time investment decreases by 0.56 percent. The effect is statistically significant for 20 quarters.

Overall, the substantial decline in investment and the modest reduction in final consumption take precedence over the increase in net exports, resulting in a decline in GDP when DWER depreciates. The finding is totally consistent with the definitions of the financial channel highlighted by Aghion et al. (2001) and Hoffman et al. (2020): 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 domestic firms and households (tightens financial conditions), especially when a substantial part of borrowing represents unhedged foreign currency debt, and therefore investment, consumption, and output in a credit-constrained economy. Our result is also in line with the finding obtained by Gan-Ochir (2023) who shows that exchange rate depreciation increases the domestic private sector's credit spread, leading to falls in both loans issued by domestic banks and employment in Mongolia[10].

Consistent with the finding of the aggregate model, the NEER depreciation causes a persistent and significant increase in CPI, while the response of CPI to DWER shock is not statistically significant.

5.3. Sectoral model

According to the production approach of the GDP, agriculture, forestry, fishing and hunting (VA_{ag}), mining and quarrying (VA_{m}), manufacturing (VA_{ma}), electricity, gas, steam, air conditioning supply (VA_{el}), construction (VA_{co}), wholesale and retail trade (VA_{tr}), transportation and storage (VA_{trs}), information and communication (VA_{in}), taxes less subsidies on products (VA_{nt}), and other (VA_{os}) sectors account for 15.1 percent, 19.4 percent, 6.4 percent, 1.9 percent, 2.8 percent, 11.0 percent, 8.5 percent, 3.1 percent, 12.0 percent and 19.8 percent of GDP at the sample average, respectively. Fig. 6 shows how the output of the different industries responds to 1 percent NEER and DWER depreciations.

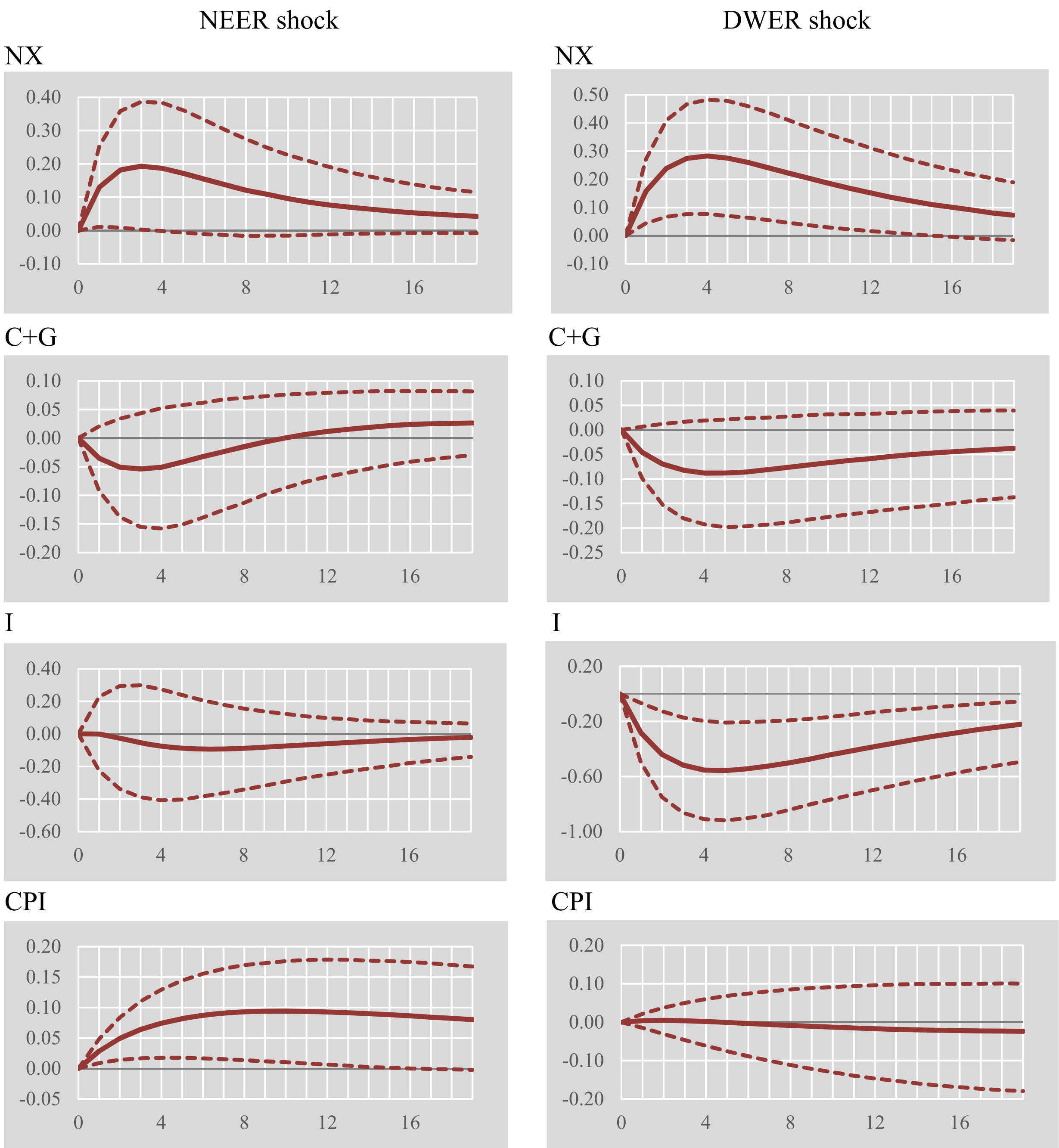
Consistent with the decrease in aggregate output following both exchange rate depreciations, most sectors experience a reduction in activity. We find that the trade channel works well for manufacturing, electricity, gas, steam, air conditioning supply, and construction, highly trade-exposed industries. In contrast, the financial channel is evident for electricity, gas, steam, air conditioning supply and construction, highly debt-exposed industries, and net taxes (taxes less subsidies on products).

The manufacturing sector (VA_{ma}) experience larger increase in output in the cases of both NEER and DWER shocks, and the responses are statistically significant. As the manufacturing is highly trade-exposed industry, our result on the strong response of VA_{ma} to NEER shock is in line with the finding of Manalo et al. (2015) for Australia. According to the trade channel, the result suggests that the manufacturing sector is export-oriented (i.e., cashmere and meat processing) and substitutes some sorts of imports (i.e., food imports). For instance, the depreciation increases import prices, causing a rise in the demand for domestic goods, which can compete with imports. The observed positive and statistically significant response of VA_{ma} to a DWER depreciation shock indicates that the manufacturing sector carries fewer foreign currency debts and predominantly earns its revenues in foreign currency. In this scenario, concerning the financial channel, the depreciation results in enhancements to the income statements and balance sheets of firms within the sector. This, in turn, eases financial conditions, stimulates greater investment, and boosts overall output.

Output in the electricity, gas, steam, air conditioning supply (VA_{el}) decreases following the DWER and NEER shocks. The response of VA_{el} to NEER shock is statistically significant for only the first 3 quarters. However, the effect on of DWER shock on VA_{el} is statistically significant for much longer periods. Mongolia imports at least 15 percent of its domestic needs of electricity, and domestic price of electricity is controlled by the government.

Hence, NEER depreciation does not pass to the domestic price of electricity in the short run, and in such sense, the depreciation

[10] We also obtained similar result when adding credit spread and bank credit into the component model with DWER.



Notes: Figures show median responses, together with 16th and 84th percentiles of the posterior distributions. Horizon is quarterly.

Fig. 5. Impulse responses of GDP components to exchange rate shocks
Notes: Figures show median responses, together with 16th and 84th percentiles of the posterior distributions. Horizon is quarterly.

seems like a cost push or adverse supply shock to the electricity sector. Although this industry has little direct exposure to foreign trade, it does have a relatively high indirect exposure through its interactions with trade-exposed industries. Moreover, the sector has oversized debt in Mongolia, and the DWER depreciation leads to a higher credit spread for bank credits. As a result, the DWER depreciation may worsen creditworthiness and activities of the sector.

In the cases of both NEER and DWER shocks, the construction (VA_{co}) sector experiences much larger decrease in output than the whole economy. The maximum response of the construction occurs in 3 quarters for NEER shock and in 4 quarters for DWER shock. As the construction sector relies heavily on imported intermediate inputs, a NEER depreciation increases production costs. This pushes

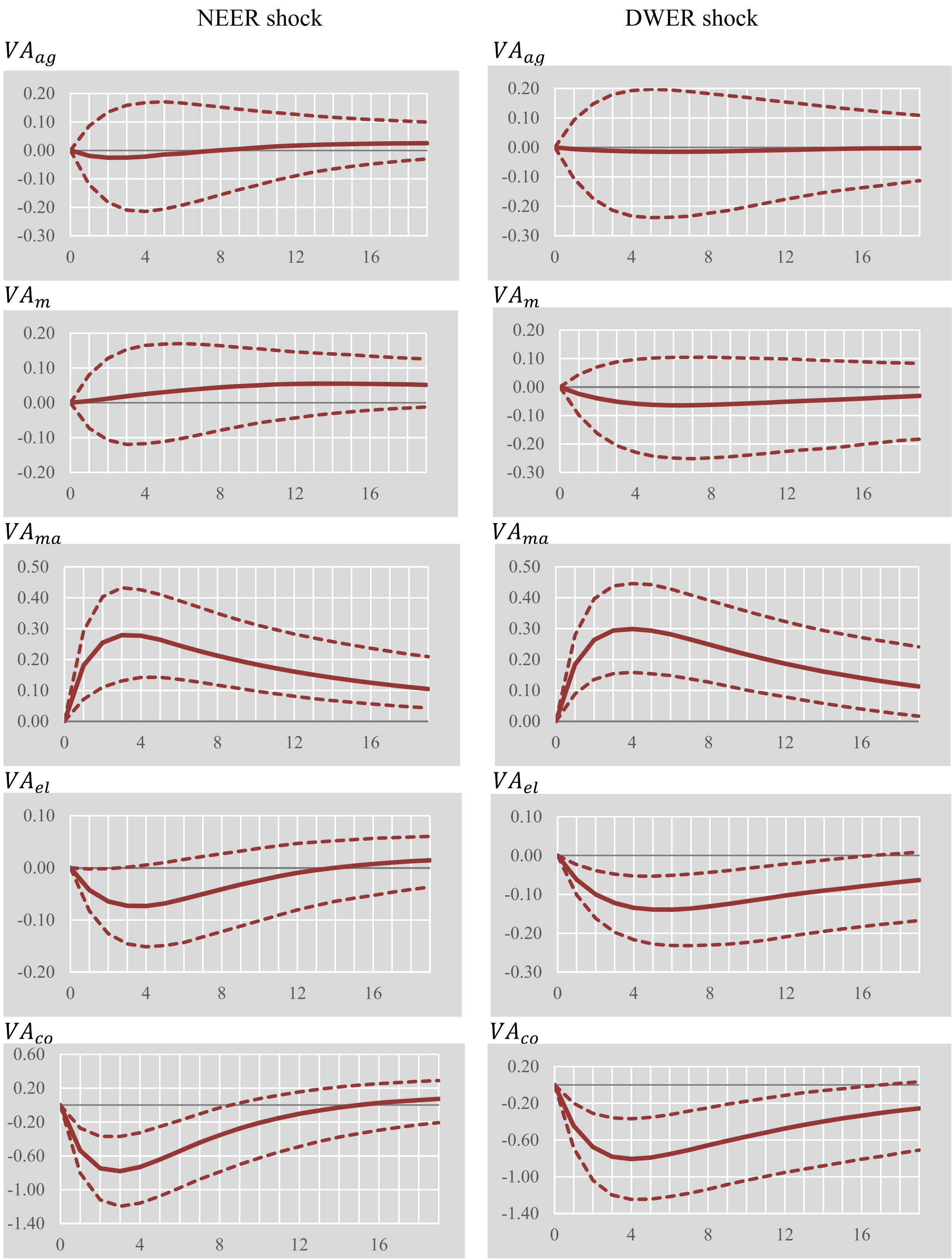
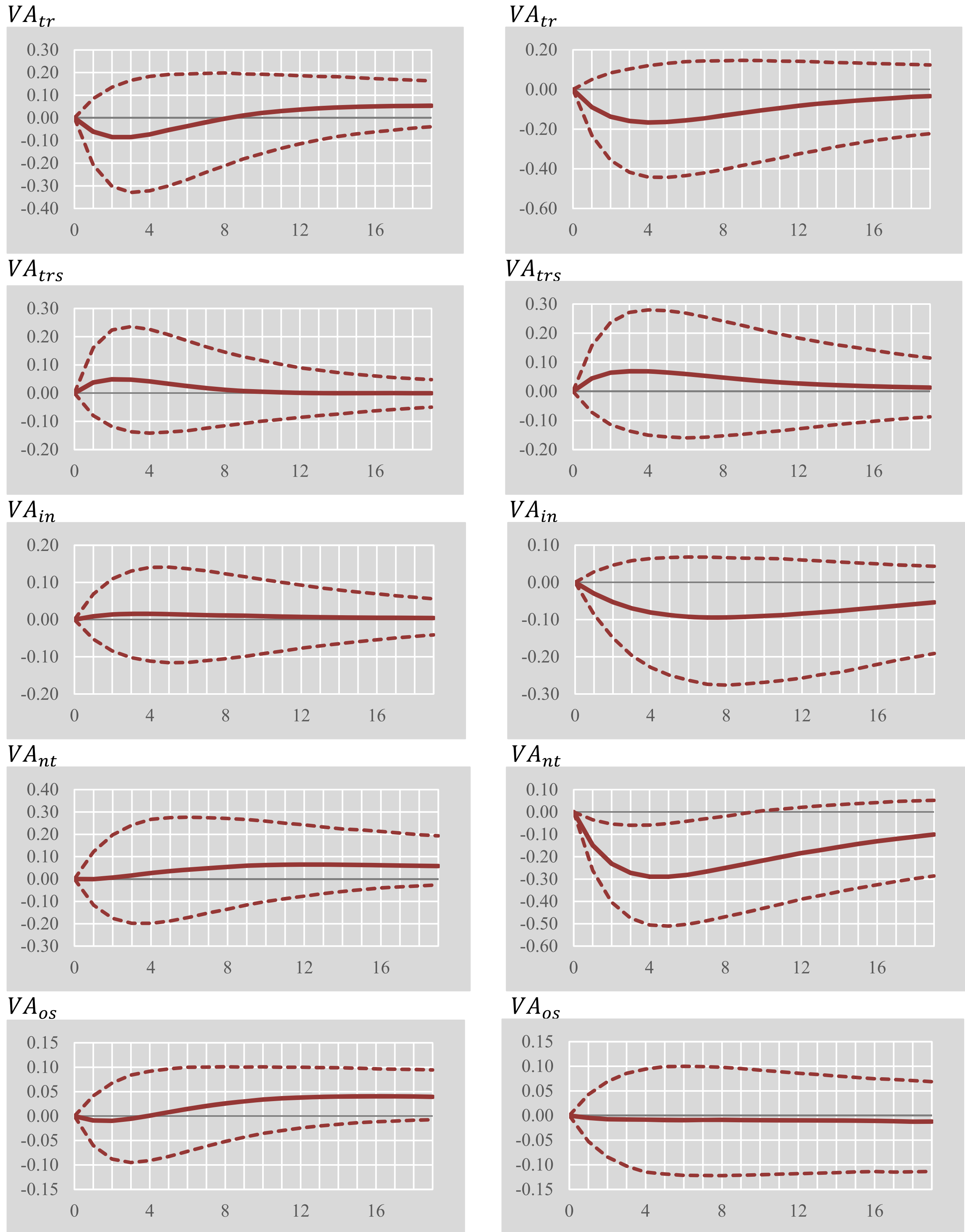


Fig. 6. Impulse responses of the output of industries to exchange rate shocks
Notes: Figures show median responses, together with 16th and 84th percentiles of the posterior distributions. Horizon is quarterly.



Notes: Figures show median responses, together with 16th and 84th percentiles of the posterior distributions. Horizon is quarterly.

Fig. 6. (*continued*).

firms in that industry to raise their prices and lower sales. As the sector is also heavily dependent on bank credit, its activity and balance sheets can be vulnerable to a rise in credit spread led by DWER depreciation.

DWER depreciation also causes a significant contraction in net taxes (taxes less subsidies on products) (VA_{nt}). The response can be explained as a spillover effect of contractions in other key sectors (i.e., construction, mining and quarrying, electricity, and wholesale and retail trade).

DWER shock causes a contraction in outputs of agriculture, forestry, fishing, and hunting (VA_{ag}), mining and quarrying (VA_m), wholesale and retail trade (VA_{tr}), information and communication (VA_{in}) and other (VA_{os}) sectors. NEER shock initially leads to falls in fishing and hunting (VA_{ag}), wholesale and retail trade (VA_{tr}) and other (VA_{os}) sectors, but rises in mining and quarrying (VA_m), transportation and storage (VA_{trs}), information and communication (VA_{in}) and taxes less subsidies on products (VA_{nt}). However, all these responses of outputs are not statistically significant.

5.4. Are exchange rate shocks destabilizing? and What shocks drive exchange rate movements?

In previous sections, we showed that NEER and DWER exchange rate shocks can have a meaningful impact on the domestic total output, consumer prices, net export, investment, and outputs of key industries. This raises the question of whether these shocks are destabilizing the Mongolian macroeconomy.

The short answer to this question is no. To demonstrate this, Table 2 shows the contribution of the exchange rate shocks and foreign shocks to the variance of other domestic variables in the respective VARs at horizons ranging from 2 quarters to 20 quarters at the median.

Regardless of the horizon, exchange rate shocks explain a small portion of the volatility in the domestic aggregate variables. For instance, NEER shock accounts for only 0.8 percent, 4.7 percent, and 5.1 percent of the 20-quarter ahead fluctuations in GDP, CPI, and policy rate, respectively. DWER shock also accounts for less than 5 percent of the fluctuations. Instead, our results show that foreign shocks are main sources of the Mongolian macroeconomic volatility. Foreign shocks account for 59 percent and 28 percent of the 20-quarter ahead fluctuations in GDP and CPI. The result on the importance of foreign shocks for the economy is line with the existing papers (i.e., Gan-Ochir and Davaajargal 2019, Gan-Ochir and Munkhbayar 2023; Gan-Ochir 2023).

At a component level, the finding is similar. NEER and DWER shocks account for less than 1.5 percent of fluctuations in *NX*, $C+G$ and *I*. As a novel finding, *FEDR*, GDP_{CH} and P_{copper} shocks play an important role in fluctuations of the components of GDP such as *NX*, $C+G$ and *I*. In particular, the foreign shocks explain 40 percent of the 20-quarter ahead volatility in the final consumption ($C+G$).

At an industry level, the pattern is also the same. NEER shock accounts for a modest portion of the variance of the manufacturing and construction sectors at horizons of more than 10 quarters. The result is in line with the fact that these are more trade-exposed industries. For remaining industries, NEER shocks play a little role in their output fluctuations. DWER shock explains more than 1

Table 2
Variance decomposition of domestic variables, percent of variance.

VARIABLE	NEER SHOCK				DWER SHOCK				FOREIGN SHOCKS[a]			
	Horizon (quarters)				Horizon (quarters)				Horizon (quarters)			
	2	5	10	20	2	5	10	20	2	5	10	20
	Aggregate model											
GDP	0.05	0.3	0.6	0.8	0.06	0.5	1.1	1.5	34.1	43.9	52.3	58.6
CPI	0.2	1.5	3.2	4.7	0.02	0.1	0.4	0.9	17.9	20.8	24.3	27.9
POLICY RATE	0.2	1.6	3.8	5.1	0.1	1.0	2.9	4.8	3.6	4.7	7.9	12.1
	Component model											
NX	0.05	0.3	0.6	0.8	0.04	0.3	0.7	1.0	19.5	20.0	21.3	22.7
$\boldsymbol{C+G}$	0.03	0.2	0.3	0.5	0.02	0.2	0.3	0.5	7.5	16.1	29.2	40.8
I	0.02	0.2	0.3	0.4	0.05	0.4	0.9	1.3	19.8	26.1	29.8	32.0
CPI	0.1	0.5	1.2	1.8	0.01	0.1	0.2	0.6	13.9	19.8	24.6	28.7
POLICY RATE	0.1	0.8	1.8	2.4	0.07	0.6	1.7	2.7	3.6	4.8	7.5	11.6
	Sectoral model											
VA_{AG}	0.04	0.3	0.5	0.6	0.02	0.1	0.4	0.5	3.1	7.1	15.2	24.7
VA_{M}	0.03	0.2	0.5	0.8	0.01	0.1	0.3	0.6	15.3	16.7	19.6	24.1
VA_{MA}	0.4	2.4	4.5	5.4	0.2	1.3	2.7	3.4	3.2	12.6	16.6	21.0
VA_{EL}	0.07	0.4	0.7	0.9	0.08	0.6	1.2	1.5	29.7	40.0	48.7	55.5
VA_{CO}	0.4	2.4	3.4	3.7	0.1	1.1	2.1	2.7	5.5	10.6	16.8	21.5
VA_{TR}	0.04	0.3	0.5	0.8	0.02	0.2	0.4	0.6	8.8	16.5	23.7	28.1
VA_{TRS}	0.05	0.3	0.5	0.6	0.02	0.2	0.4	0.5	3.2	7.1	12.5	18.2
VA_{IN}	0.03	0.2	0.5	0.7	0.02	0.2	0.5	0.9	3.2	6.2	13.7	24.3
VA_{NT}	0.03	0.2	0.5	0.8	0.06	0.5	1.0	1.3	16.4	25.4	34.3	39.3
VA_{OS}	0.03	0.2	0.5	0.9	0.01	0.01	0.3	0.5	4.6	8.4	15.8	24.6

Notes.
[a] Foreign shocks include *FEDR*, GDP_{CH} and P_{copper} shocks, and here we show the contribution of the foreign shocks of the models with DWER.

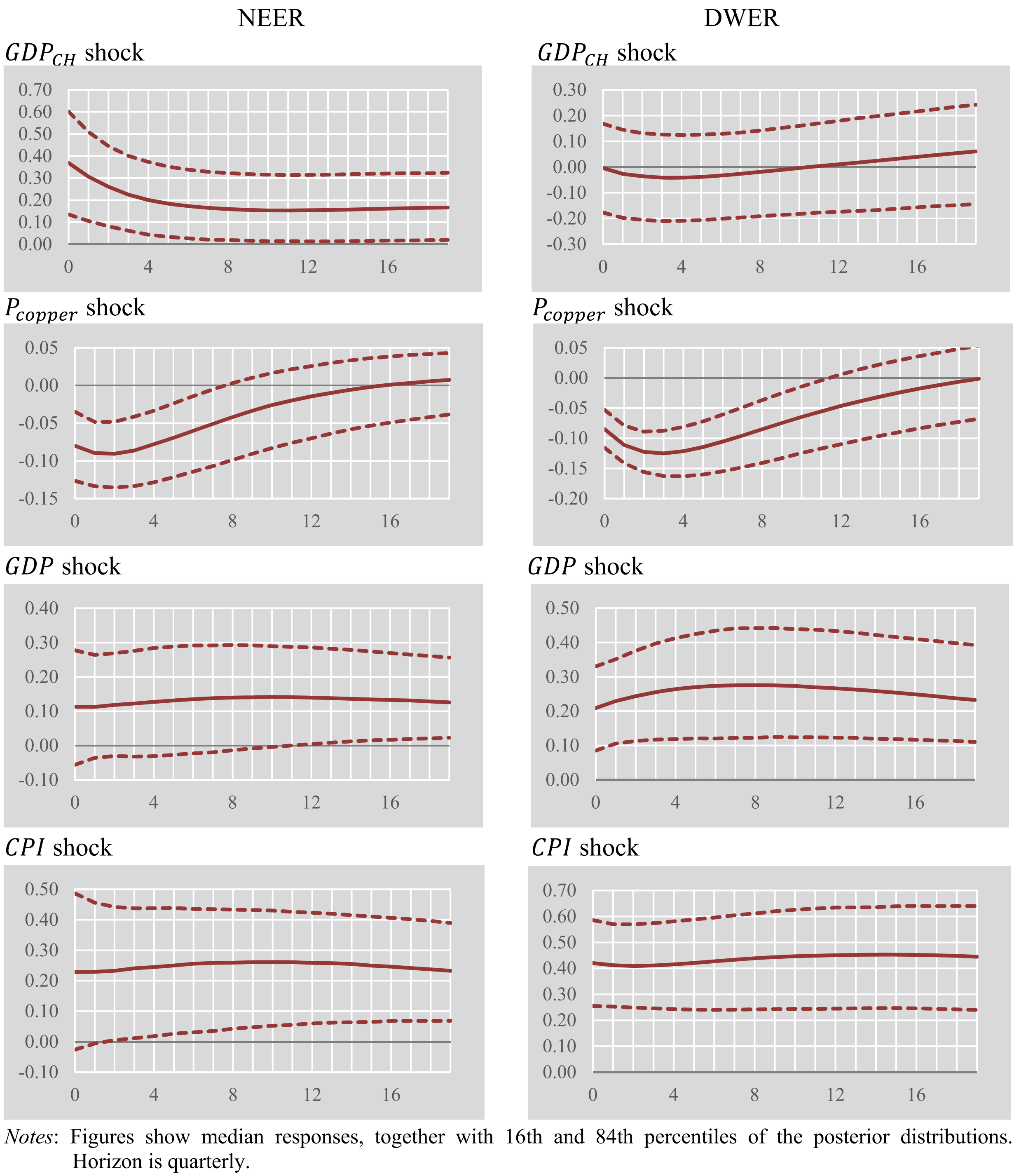


Fig. 7. Impulse responses of exchange rates to foreign and domestic shocks
Notes: Figures show median responses, together with 16th and 84th percentiles of the posterior distributions. Horizon is quarterly.

Table 3
Variance decompositions of exchange rates, percent of variance.

SHOCK	NEER				DWER			
	Horizon (quarters)				Horizon (quarters)			
	1	5	10	20	1	5	10	20
FOREIGN	9.6	13.5	15.0	17.3	11.5	22.5	24.1	22.4
DOMESTIC	8.0	7.4	9.8	13.3	13.6	14.8	18.8	25.9
EXCHANGE RATE	82.4	79.2	75.2	69.3	74.9	62.7	57.1	51.7

Notes: Foreign shocks include *FEDR*, GDP_{CH} and P_{copper} shocks; domestic shocks comprise *GDP*, *CPI* and *PR* shocks; and exchange rate shock is *NEER* shock for NEER and *DWER* shock for DWER.

percent of manufacturing, electricity, gas, steam, air conditioning supply, construction sectors, and net taxes. Electricity, gas, steam, air conditioning supply industry and net taxes have a relatively high indirect exposure through its interactions with trade or debt exposed industries. However, NEER and DWER exchange rate shocks explain little of the variance of the other industries in the Mongolian economy. Our finding is consistent with Manalo et al. (2015) who analyze the effects of trade-weighted exchange rate on industries for Australia.

The above analyses suggest that the exchange rates are not a source of shocks, but they are the transmitting channels of foreign and other domestic shocks. This raises the next question of what shocks typically drive the exchange rate movements in the Mongolian economy. To answer this question, we first examine the impulse responses of the exchange rates to external and domestic shocks, shown in Fig. 7.

Both foreign and domestic shock have significant impacts on the exchange rates. The positive shock to China's GDP causes a NEER depreciation, while the positive copper price shock leads to a NEER appreciation. The NEER depreciation is statistically significant at the 68 percent confidence level starting from the impact period. The maximum effect of copper price shock occurs 2–3 quarters after the shock and the appreciation is statistically significant for only the first 6 quarters. It implies that the trade channel plays a crucial role in the transmission of external demand and commodity price shocks. Both domestic GDP and CPI shocks cause a NEER depreciation. The effects of GDP and CPI shocks are statistically significant only after 11 quarters and 1 quarter, respectively.

The response of DWER to China's GDP shock is not statistically significant. The copper price shock leads to a DWER appreciation, statistically significant for the first 10 quarters. This result supports the importance of the financial channel in transmission of the commodity price shock. For instance, existing papers (i.e., Shousha 2016; Drechsel and Tenreyro 2018; Souza and Fry-McKibbin 2021) suggest that commodity price shocks cause a reduction in the interest rate spread, coming from creditors decreasing the required interest rate premium during the commodity price boom phase, as the collateral value of the economy depends directly on commodity prices through export earnings. The reduction in the credit spread supports bank credit growth, thereby promoting higher consumption, investment, and output as shown in Figs. 4 and 5.

Compared to the case of NEER, both GDP and CPI shocks drive a much stronger DWER movement. It supports the presence of the automatic economic adjustment passing through the financial channel of exchange rate. For instance, economic overheating leads to a DWER depreciation, which in turn increases the credit spread and lowers the consumption and investment.

Variance decomposition is also used to examine what shocks typically cause exchange rate movements. Table 3 shows the contribution of foreign and domestic shocks to the variances of the NEER and DWER at the median.

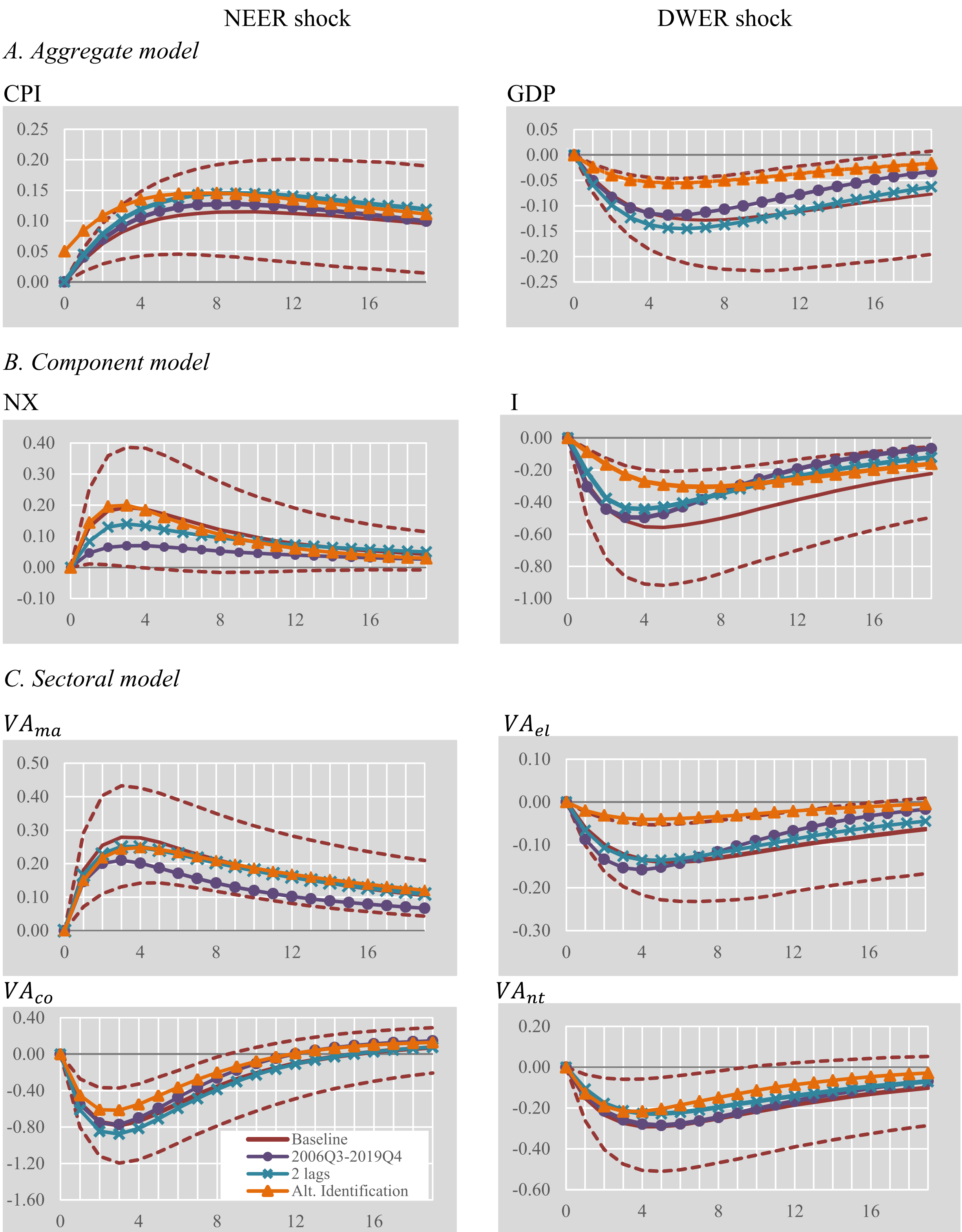
At short horizons, much of the variances of both NEER and DWER is determined by its own shocks. This is consistent with the observation that movements in nominal exchange rates cannot be explained by macroeconomic fundamentals (Meese and Rogoff 1983). At horizons beyond 5 quarters, foreign shocks account for about 15 percent of NEER fluctuations and about 23 percent of DWER volatility. Domestic shocks explain 26 percent of the 20-quarter ahead movements in the DWER.

5.5. *Robustness checks*

In this section, we discuss the robustness of our results to different model specifications: i) sample period, ii) the number of lags, and iii) shock identification. Based on novel and important findings of this paper, impulse responses to NEER and DWER shocks are chosen in the comparison of alternative specifications. For the aggregate models, we select the response of CPI to NEER shock and the response of GDP to DWER shock (Fig. 8A). For the component models, the response of NX to NEER shock and the response of I to DWER shock are selected (Fig. 8B). In the case of sectoral models, our choice are the responses of VA_{ma} and VA_{co} to NEER shock and the responses of VA_{el} and VA_{nt} to DWER shock (Fig. 8C).

Our key findings are robust for all alternative specifications. Our baseline models are estimated using VAR(1) for the period 2006Q3-2021Q1. Lenza and Primiceri (2020) propose a solution to handle a sequence of extreme observations such as those recorded during the COVID-19 and show that excluding the data from the pandemic may be acceptable for parameter estimation. Hence, we estimate the baseline models over a shorter sample ending before the pandemic in 2019Q4. Results are shown as purple lines with "o" marker in Fig. 8.

Our findings are robust to changes in the sample coverage (i.e., excluding the COVID-19 effect) as the median responses from the new sample estimations remain within the confidence intervals of the baseline models. The baseline models are also estimated using



Notes: Figures show median responses of the posterior distributions. Dashed lines are the 68 percent confidence intervals of the posterior distributions for the baseline specification. Horizon is quarterly.

(caption on next page)

Fig. 8. Impulse responses to exchange rate shocks
Notes: Figures show median responses of the posterior distributions. Dashed lines are the 68 percent confidence intervals of the posterior distributions for the baseline specification. Horizon is quarterly.

two lags. Results are shown as aqua color lines with "x" marker in Fig. 8. The median responses from the VAR(2) models remain within the confidence intervals of the baseline VAR(1) models.

An alternative ordering of variables is employed in terms of shock identification. In the ordering exchange rate rates are placed before CPI and policy rate. For example. the ordering is set as *FEDR*, GDP_{CH}, P_{copper}, *GDP*, *NEER* or *DWER*, *CPI*, *PR* in the aggregate models.[11] Compared to the baseline identification, exchange rates are now allowed to affect CPI and policy rate contemporaneously. The ordering is in line with a sign restriction employed by Leiva-Leon et al. (2022) in identifying the exchange rate shock. They assume that the depreciation shock leads to a rise in CPI as well as in policy rate on the impact period. Results from the alternative identifications are shown as orange lines with "Δ" marker in Fig. 8. The median responses from the alternative identifications are generally similar to those of the baseline VAR(1) models. A slight difference is a positive response of CPI to NEER shock on the impact period due to our identification assumption.

6. Conclusion

In this paper, we have examined the macroeconomic effects and transmission mechanisms (trade and financial channels) of exchange rate movements in Mongolia using SBVAR models and newly constructed DWER and NEER. In particular, we quantified the effects of the exchange rates on the GDP, CPI, GDP components and output of different industries.

Several novel and interesting results are obtained. First, we find a strong financial channel of exchange rate is prominent in the economy. The financial channel is influential at the aggregate level, as the depreciation shock in DWER leads to a contraction in GDP. Among the components of GDP, the financial channel is stronger and statistically significant for investment. Our results also confirm that the manufacturing, electricity, gas, steam, air conditioning supply, construction industries and net taxes (taxes less subsidies on products) are particularly sensitive to DWER movements. Second, we show that the traditional trade channel also matters. NEER depreciation shocks cause a significant rise in net exports. There exists a significant pass-through from NEER to CPI in the economy. Moreover, trade-exposed industries such as the manufacturing and construction industries are particularly sensitive to NEER movements. Third, though NEER and DWER exchange rate shocks have a meaningful impact on key macro variables, they are not destabilizing the economy. The exchange rate shocks account for a small portion (less than 6 percent) of the volatility in the domestic aggregate variables. Instead, foreign shocks (federal funds rate, China's GDP, and copper price shocks) play a critical role in domestic macroeconomic fluctuations. For instance, the foreign shocks explain about 50 percent, 30 percent, 40 percent, 33 percent of fluctuations in GDP, CPI, final consumption, and investment. Fourth, the exchange rates are the channels through which foreign and other domestic shocks transmit to the domestic economy. The trade channel plays a crucial role in the transmission of external demand and commodity price shocks, while the financial channel is important in transmission of commodity price, GDP and CPI shocks. It implies that the presence of the financial channel amplifies the business and financial cycles when the economy is hit by adverse commodity price shocks. Domestic positive GDP and CPI shocks also drive a much stronger DWER depreciation, supporting the presence of an automatic economic adjustment passing through the financial channel. These results remain robust when the model specification is changed in terms of sample size, number of lags, and identification method.

These findings provide some implications. First, constructing the DWER index is useful to assess the macroeconomic effects passing through the financial channel in developing economies, net debtors in foreign currencies. Second, it is important to explicitly incorporate the financial channel and commodity prices into full-scale macroeconomic models for the IPF in commodity-exporting developing economies. Finally, in economies like Mongolia, a fully flexible exchange rate may generate difficult policy trade-offs as a depreciation leads to a contraction in output and a rise in inflation simultaneously. Hence, policy responses to foreign and exchange rate shocks should be optimally combined under the IPF to stabilize the whole economy.

Declaration of competing interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct

[11] For the component model, the ordering of *FEDR*, GDP_{CH}, P_{copper}, *NX*, $C+G$, *I*, *NEER* or *DWER*, *CPI*, *PR* is used. For the sectoral model, the following ordering is chosen: *FEDR*, GDP_{CH}, P_{copper}, VA_k, *NEER* or *DWER*, *CPI*, *PR*, where $k = \{ag, m, ma, el, co, tr, trs, in, nt, os\}$.

communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from doojav.ganochir@yahoo.com or doojav_ganochir@mongolbank.mn.

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