J. Int. Financ. Markets Inst. Money 75 (2021) 101439

Contents lists available at ScienceDirect

Journal of International Financial Markets, Institutions & Money

journal homepage: www.elsevier.com/locate/intfin

# The effectiveness of currency intervention: Evidence from Mongolia☆

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A R T I C L E I N F O

*Jel Codes:*
C14
C32
E58
F31

*Keywords:*
Currency intervention
Exchange rate
Treatment effect
Causal effect
Local projection
Mongolia

A B S T R A C T

There is a long-running debate on the effectiveness of currency interventions with the issue of how to overcome the two empirical manifestations of the problem of endogeneity (simultaneity and self-selection bias), a constant challenge in this literature. To address this problem of endogeneity, we employ a recent extension of the potential outcomes approach of micro-econometrics to a time-series setting. Another crucial contribution of our study is that we made every effort on a high-frequency basis in controlling for the effects of monetary policy on the exchange rate, a crucial aspect often neglected in this literature. We conduct our analysis using unique daily data on currency interventions in Mongolia to examine the impact of these interventions on the changes in the MNT/USD exchange rate and its volatility. Our results confirm some of the previous findings from the literature, but also offer some new key findings. Both purchases and sales of US dollars are effective in moving changes in the MNT/USD in the desired direction when implemented frequently, and the effects are quite persistent. Mainly sales of USD when also implemented frequently can help reduce the volatility in the MNT/USD exchange rate. Although, our full sample estimates using quantile local projections show that both sales and purchases of USD can reduce volatility at low and moderate levels, while frequent and smaller sales of USD can help reduce high volatility in the exchange rate.

## 1. Introduction

Foreign exchange interventions (currency interventions from hereon), either the sales or purchases of foreign currency assets, which are typically in US dollars (USD from hereon) are aimed at affecting the level and/or the volatility of a country's exchange rate. According to Domanski et al. (2016) and BIS (2019), since the Great Financial Crisis (GFC from hereon), currency interventions are

☆ The views expressed herein are solely those of the authors and do not necessarily reflect the views of the Bank of Mongolia, The SEACEN Centre, Globalization Institute, or SEACEN member central banks/monetary authorities.

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https://doi.org/10.1016/j.intfin.2021.101439
Received 9 December 2020; Accepted 26 September 2021
Available online 7 October 2021
1042-4431/

more of an emerging market economy (EME from hereon) phenomenon with the monetary authorities in these economies having been more active in the use of such a tool. This is understandable in light of the shifting tides in foreign exchange market conditions experienced by these economies from the resulting appreciation pressures due to capital inflow surges and commodity booms to depreciation pressures brought about by the tightening of global liquidity conditions and falling commodity prices (Domanski et al., 2016). The extensive use of currency interventions in recent years by EMEs is also partly a reflection of the structural features inherent in most of these economies where excessive exchange rate fluctuations mainly due to thin foreign exchange markets and domination by a small number of agents, can have large and adverse effects on the real side of the economy (Disyatat and Galati, 2007).[1]

The case of Mongolia is no exception. Mongolia provides an interesting case study because of what the country went through during the recent commodity price boom and bust. Typical of a commodity-exporter, the country's fundamental economic problems are its lack of diversification and its proclivity to boom–bust cycles. Given the extent of its mineral endowments, Mongolia is and will remain a mining economy for many decades to come. Because of the country's narrow economic base, it is highly vulnerable to external shocks, namely commodity price fluctuations and volatility in FDI, and the lack of diversification makes the economy prone to repeated boom–bust cycles. Capital inflows played an important role in financing investment and external deficits, and higher commodity prices supported external balances and growth outcomes. But large capital flows and volatile commodity prices have led to greater macroeconomic volatility and the build-up of balance sheet vulnerabilities. Although Mongolia's fiscal framework is designed to prevent such procyclicality, it has been essentially set aside in recent years. Against this backdrop, this then makes currency intervention such an important macroeconomic policy instrument for the authorities in Mongolia.

Using a unique dataset on daily currency interventions and a recently introduced method designed to estimate causal effects in time-series data, this study examines the effectiveness of currency interventions on the changes of the Mongolian tugrik per USD (MNT/USD from hereon) exchange rate as well as its volatility. As will be elaborated later, this study finds that currency interventions by the authorities in Mongolia can play an important role in affecting exchange rate changes and volatility. The assessment of the effectiveness of currency interventions occupies an important and enduring place in the literature mainly because the active use of currency interventions in practice, however, does not necessarily translate into its effectiveness in terms of achieving the desired objective of impacting exchange rate changes and volatility. For instance, studies that use available daily data on currency interventions, the most commonly used data frequency for these studies, have mostly found that for developed economies, currency interventions have either no effect on the level of the exchange rate or can even increase exchange rate volatility (e.g., Bailie and Osterberg, 1997; Dominguez, 1998; Edison et al., 2006; Broto, 2013). Also, the survey papers of Edison (1993), Sarno and Taylor (2001), and Villamizar-Villegas and Perez-Reyna (2017) concluded the lack of a firm relationship between currency interventions and exchange rates in advanced economies. Somewhat contrasting views were provided by Dominguez and Frankel (1993), Fatum and Hutchison (1999), Fatum and Hutchison (2006), Fatum and Hutchison (2010).

The abundance of evidence on the effectiveness of currency interventions for advanced economies as opposed to EMEs is due to data limitations. The main reason being that very few EMEs publish their daily currency interventions. Among the EMEs, a few of the Latin American countries make their data available, which then explains the small number of country studies assessing the effectiveness of currency interventions for these group of economies. Chamon et al. (2019) in their contribution to a book-length treatment on the same topic for Latin American economies, make the observation that there is still no consensus on the effectiveness of currency intervention for this group of economies.[2] Similar observations can also be made to findings outside of Latin American economies, for which evidence is relatively fewer. For example, using published data from the central bank of Turkey, Akinci et al. (2006) and Onder and Villamizar-Villegas, 2018 both found that currency interventions have been effective under certain conditions. Disyatat and Galati (2007), using official statistics from the Czech National Bank on currency interventions, found that interventions had weak effects on the spot rate, but no effect at all on exchange rate volatility. Also using official statistics from the Czech National Bank, Gersl and Holub (2006) found less favorable results in which interventions did not have any impact on the spot exchange rate, and a slight increase in its volatility. Fry-McKibbin and Wanaguru (2013), using official statistics on currency interventions from the Central Bank of Sri Lanka, found that interventions were effective, albeit in different ways.

Even if data on currency intervention is available, the next major challenge is the method by which the problem of endogeneity between currency interventions and exchange rates can be surmounted. There are two sources of endogeneity in this literature, which render the task of isolating the causal effect of currency interventions on the exchange rate complicated. These two threats to identification are simultaneity and self-selection bias. With regards to the former, the two-way causation between currency interventions and exchange rates complicates causality because while our main aim is to uncover the effect of intervention on the exchange rate, the monetary authorities may also be prompted to intervene when the exchange rate moves in a contrary direction. Thus, failing to control for the reverse causation renders our estimates of the effects of currency intervention on the exchange rate inconsistent. With regards to the latter, the decision to intervene by monetary authorities is not a random occurrence. The bias occurs because rather than having the amounts of official interventions determined upon them as would be the case in a randomly controlled experiment, the decision to

[1] This then explains the vast number of studies that examine the impact of exchange rate volatility on international trade. See, for instance, Ćorić and Pugh (2010) for a meta-regression analysis of the effect of exchange rate volatility on international trade. The rationale of examining the impact of exchange rate volatility on international trade is that exchange rate volatility introduces uncertainty into international transactions. This uncertainty can decrease international trade and economic welfare, particularly, for a number of commodity producers (Bahmani-Oskooee et al., 2020; Bahmani-Oskooee et al., 2019; Bahmani-Oskooee and Harvey, 2017, Karabulut et al., 2020, among others). As found by previous studies, this impact of exchange rate volatility can also be asymmetric across industries and countries.

[2] Hutchison (2003) and Menkhoff (2013) in earlier surveys devoted to EMEs, in general, also made the same conclusion.

intervene is influenced by various observed variables (also known as "confounding factors"). Because of this, it is then necessary to first model the selection decision by the monetary authorities as a function of observed confounders, which in our case is achieved by the estimation of an intervention reaction function.

Another challenge arises because currency interventions are done only intermittently, such that there is a substantial number of observations within the sample that take on zero values. Obviously, a linear estimation is not suitable. Because of all these complications, a number of studies have resorted to a two-stage instrumental variable approach, based on estimates of the central bank intervention reaction function, but without resorting to ordinary least squares estimation (e.g., Catalán-Herrera, 2016; Disyatat and Galati, 2007; Echavarria et al., 2017; Onder and Villamizar-Villegas, 2018; Ordoñez-Callamand et al., 2018; Pontines, 2018; Villamizar-Villegas, 2016).[3]

In this study, we use a recent approach that borrows from the potential outcomes literature of micro-econometrics which transfers naturally into a time-series context in terms of determining the effectiveness of a policy through the estimation of the so-called average treatment or causal effect. Angrist et al. (2018) (AJK from hereon) developed a semiparametric time-series method to estimate the causal effect of US monetary policy on certain macroeconomic aggregates. AJK first adopted the propensity score framework to model the probability of US federal funds rate target changes via multinomial or ordered treatment. The resulting set of conditional distributions defines a function, which they referred to as the *policy propensity score*. Once these scores are obtained, AJK use a local linear projection type estimator to measure the average effect of policy changes on future values of the macroeconomic aggregates or so-called outcome variables (inflation, industrial production, and unemployment), in combination with using inverse probability weights calculated from the propensity scores. The use of inverse propensity weights relates to the well-known micro-econometric treatment literature which uses such weighting to adjust for non-random samples.

We follow AJK and, in our specific context, we obtain an estimate of the average treatment or causal effect of currency interventions on exchange rate changes and volatility. This marks the first time that this approach is applied to examine the issue of the effectiveness of currency intervention in an emerging economy context. One caveat, however, regarding any study on the effectiveness of currency interventions is that such interventions are typically accompanied by other policy measures such as monetary policy. For instance, typical of an EME, during times of high volatility in domestic currency markets, it is the case that foreign currency sales are accompanied by an increase in the policy rate and/or the imposition of higher reserve requirement on foreign currency. Thus, the finding, if any, of an effect of currency intervention on exchange rate changes and volatility may be misleading if the effects of such other policies are not sufficiently controlled.[4] In the specific case of Mongolia, apart from currency interventions, the main levers of monetary policy are the policy rate as well as domestic and foreign-exchange reserve requirements, which makes this important caveat very crucial in our study.

Because of this, we deviate slightly from AJK on how we implement the identification in our case of the "unanticipated currency intervention".[5] Specifically, after obtaining the policy function through the policy propensity score as in AJK, we are able to conduct in a way similar to a doubly-robust estimation of removing from exchange rate changes and volatility the influence of the other instruments of monetary policy.[6] We are able to conduct this step in our investigation because we also have unique daily data on the target policy rate as well as domestic and foreign-exchange reserve requirements in Mongolia. Once this extra step is done, we can then use local linear projection type estimators to measure the average effect of currency intervention on the future values of the changes in the MNT/USD exchange rate and its volatility, combined with using inverse probability weights calculated from the propensity scores. In doing so, to the best of our knowledge, this study belongs to only a handful of studies that examine the dynamic effects of currency interventions as well as examine separately the effectiveness of purchases and sales of USD.

An additional interesting extension that we examine in this study is whether the effectiveness of currency interventions is dependent on the regime or state of low and high exchange rate volatility. For this purpose, we follow an idea proposed by Adrian et al (2019) in working with the entire conditional distribution of a variable,[7] which in the present case is our measure of exchange rate volatility. We implement their idea by estimating what is referred to as quantile local projections (Loria et al., 2020) which involve estimating the local linear projections in the final step above, across various quantiles of the distribution of the exchange rate volatility. This marks also the first time that this technique is applied to the issues that we contend in this study.

Our study confirms some of the previous findings from the literature, but also offer some new key findings. Both purchases and sales of USD are effective in moving changes in the MNT/USD in the desired direction when implemented frequently, and the effects are quite persistent. These results, especially pertaining to the frequency of interventions and its persistence are in line with those found in Chamon et al., 2019; Fratzscher et al., 2019; Kuersteiner et al., 2018; Onder and Villamizar-Villegas, 2018; Villamizar-Villegas, 2016; Arango-Lozano et al., forthcoming; Menkhoff et al., forthcoming. In terms of the effect of currency interventions on exchange rate volatility, mainly sales of USD when also implemented frequently can help reduce the volatility in the MNT/USD exchange rate.

[3] Fratzscher et al. (2019) provide a comprehensive discussion on the methods that can be utilized to address the problem of endogeneity when assessing the effectiveness of currency interventions on exchange rates.

[4] In various estimations, Fratzscher et al. (2019), Echavarria et al. (2017), Villamizar-Villegas (2016), Onder and Villamizar-Villegas, 2018, Ordoñez-Callamand et al. (2018), Pontines (2018) acknowledged and controlled for the effects of monetary policy.

[5] The term is in reference to the popular vernacular of empirical macroeconomics of the effects of "unanticipated monetary policy" (AJK, 2018).

[6] See, for instance, Lunceford and Davidian (2004) and Glynn and Quinn (2010) which introduced the framework of doubly-robust estimation in the micro-econometric treatment effect literature. While, Jorda and Taylor (2015) adopted it to examine the average treatment effect of fiscal policy using panel-data.

[7] Adrian et al., (2019) examined the entire conditional distribution of future U.S. real GDP growth.

Although, our full sample results show that both sales and purchases of USD can reduce volatility at low and moderate levels, while frequent and smaller sales of USD can help reduce high exchange rate volatility. Our finding on the effectiveness of currency interventions on exchange rate volatility is generally line with the studies of Menkhoff et al. (forthcoming), Arango-Lozano et al. (forthcoming), Fratzscher et al. (2019), Chamon et al. (2019), and Onder and Villamizar-Villegas, 2018. The paper is structured as follows. The next section presents a discussion of the existing empirical evidence on the effectiveness of currency intervention in EMEs. The third section provides a description of the institutional details of currency interventions in Mongolia as well as the currency intervention data. The fourth section discusses the empirical strategy employed in the paper. The fifth section presents the empirical results and the battery of robustness tests. The sixth section concludes.

## 2. Related empirical evidence for EMEs

There is a long-running debate on the effectiveness of currency interventions, not just for developed economies, but also for EMEs. Evidence coming from cross-country studies have found support for an impact of currency interventions on exchange rates. For instance, across a sample of 33 advanced economies and EMEs, Fratzscher et al. (2019) found evidence for the effectiveness of currency interventions in reducing exchange rate volatility but found less convincing evidence as to its impact on the level of the exchange rate. Across a panel of 18 EMEs, Daude et al. (2016) found, on average, currency intervention to be effective in moving the real exchange rate in the desired direction, controlling for deviations from the equilibrium and short-term changes in fundamentals and global financial variables.

By far, however, findings from individual country studies provide the bulk of the evidence on the effectiveness of currency interventions. Existing evidence for EMEs, mostly from Latin American countries, is mixed overall. For instance, Kohlscheen and Andrade (2014) analyzed the effect of currency swap auctions by the Central Bank of Brazil on the USD/BRL rate, and found that such official currency swap auctions impacted the exchange rate in a significant way. Tapia and Tokman (2004) found that in the case of Chile, currency interventions through the direct spot market and US Dollar denominated papers did not have significant effects. In the case of Colombia, Echavarria et al. (2017) compared the effects of pre-announced day-to-day intervention with respect to discretionary intervention and found that the former had a larger effect than the latter. Also for Colombia, Kuersteiner et al. (2018) exploiting a discontinuous policy rule used by the Central Bank of Colombia found that interventions had significant effects on the exchange rate, although short-lived. Humala and Rodriguez (2010), using Markov regime switching techniques, found that interventions are larger in periods of high exchange rate volatility in the case of Peru. Catalán-Herrera (2016), using official currency intervention data from the Central Bank of Guatemala, found that interventions had a dampening effect on exchange rate volatility but did not have an effect on the level of the exchange rate. Finally, Broto (2013) conducted individual country estimations on currency interventions for Chile, Colombia, Mexico and Peru and found that while it is difficult to establish regularities across the four countries, one clear pattern emerges from the results of this study: isolated interventions help to curb currency volatility, whereas sizable interventions do not have a great influence on the exchange rate.

Outside of Latin American economies, the evidence is relatively fewer and also mixed overall. Using published data from the Central Bank of Turkey, Akinci et al. (2006) found asymmetry in the results in which currency purchases seem to be successful, especially after stabilization of financial markets. Also using published data from the Central Bank of Turkey, Onder and Villamizar-Villegas, 2018 found that unannounced currency purchases had a significant effect in reducing exchange rate volatility but appeared to have no effect on exchange rate changes. Announced interventions, on the other hand, did have a significant effect on exchange rate changes and volatility. Using official currency intervention data from the Central Bank of the Czech Republic, Disyatat and Galati (2007) found that interventions did not have an effect on exchange rate volatility, and also had a weak and limited influence on the spot exchange rate. Also using official currency intervention data from the Central Bank of the Czech Republic, Gersl and Holub (2006) find less favorable results compared to Disyatat and Galati (2007), where they found that interventions did not have any impact on the spot exchange rate, while there was a slight increase in its volatility. Finally, Fry-McKibbin and Wanaguru (2013), using official currency intervention data from the Central Bank of Sri Lanka found that currency interventions were effective, although in different ways. Specifically, during what they referred to as the low volatility, pre-GFC period foreign currency purchases were effective relative to foreign currency sales. In contrast, during the high global volatility period, foreign currency sales were more important.

## 3. Institutional details and data

### 3.1. Institutional framework

In 1993, Mongolia abandoned the pegged exchange rate against the Soviet rouble, which had been in operation since the communist era. It became evident that the regime was untenable amid the transition to a market economy, trade liberalization and increased activity in the foreign exchange market. After a series of devaluations of the Mongolian tugrik *vis-à-vis* the US dollar, the legal framework to adopt a flexible exchange rate regime was set up in 1996.

Today, Mongolia is a developing economy, driven largely by its mining sector. Due to its natural resource based economic structure, the Mongolian tugrik can be viewed as a commodity currency. Over the recent years, exchange rate expectations have been rather one-way as the Mongolian tugrik continues to depreciate against the US dollar, partly due to persistent current account deficits and increased foreign-currency denominated public debt. In line with its mandate for setting exchange rate policy, the Bank of Mongolia (BOM from hereon) undertakes regular foreign exchange operations to address disorderly market conditions. Intervention activities are directed towards dampening exchange rate volatility and strengthening foreign exchange reserves. The BOM intervenes in the

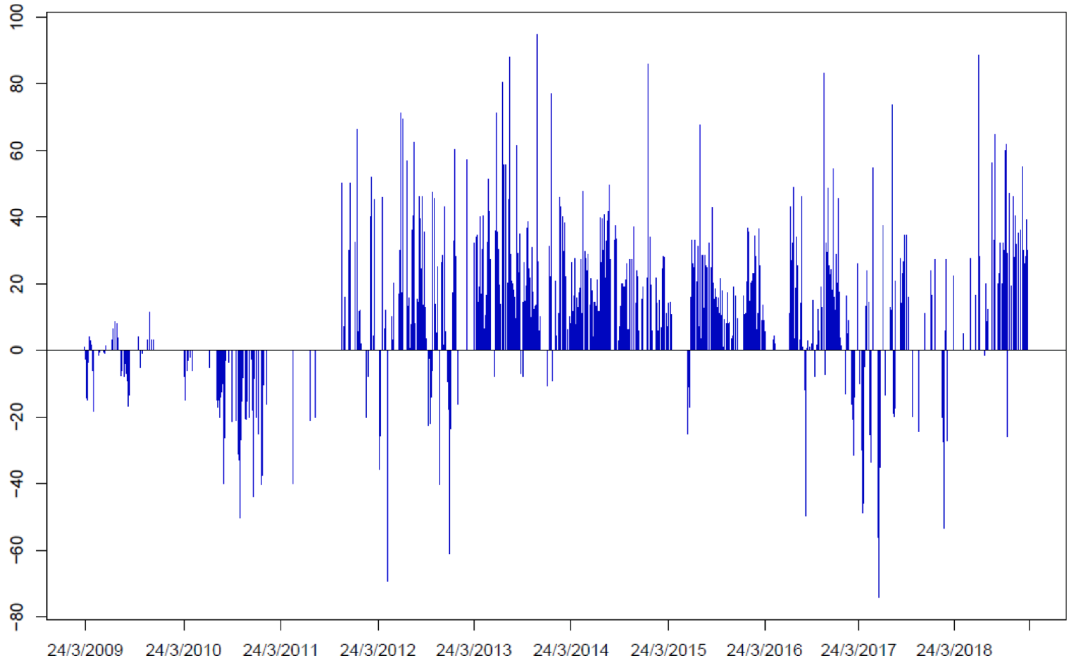



**Fig. 1.** Daily intervention volume (in millions of USD), 24 March January 2009 – 31 December 2018, Notes: All amounts are in millions of USD. On days with intervention, negative amounts are purchases of USD, while positive amounts are sales of USD. Non-intervention days carry zero amounts.

foreign exchange market mainly via its auction mechanism, which we briefly discussed below.

### *3.2. Foreign exchange auction mechanism and the interbank market*

#### *3.2.1. Foreign exchange auctions*

The BOM introduced an auction mechanism on the 24 March 2009 to facilitate the development of the domestic foreign exchange market. This allows the central bank to operate directly in the interbank market and manage liquidity needs. The FX-auctions have since served as the main platform to determine FX market conditions. Foreign exchange is mainly traded at spot prices, with only a few forward transactions taking place among banks for reserve management purposes. Depending on market conditions, the BOM conducts single-price and multiple-price auctions which are not announced beforehand.

The auctions are held regularly on Tuesdays and Thursdays, inviting bids from commercial banks only. Non-banking financial institutions, businesses and private individuals may engage in trading indirectly through these banks. The auctions take place between 09:30 and 10:00 am, where banks submit foreign exchange orders indicating the direction, amount and the exchange rate. Banks may place up to three bids, each bid ranging from 1 to 8 million USD. The auction committee[8] meets at 10:30 am to decide on the amount and exchange rate to be offered. In fulfilling these orders, the auction committee does not allow deviation of more than 2 percent from the BOM reference rate. Unfulfilled orders or rejection of bids are not explained.

#### *3.2.2. The interbank market*

In contrast to mature interbank markets in developed economies, interbank trading accounts for a relatively small fraction in the Mongolian foreign exchange market. Prior to the establishment of a screen-based system for interbank foreign exchange transactions by the BOM in 2017, commercial banks mostly traded with each other via telephone. Currently, trading activity is mainly conducted through the screen-based system with T + 1 settlement. Due to liquidity needs, interbank trading with same-day settlement can be undertaken over the telephone from time to time. Trading between commercial banks tends to dry up if the MNT is expected to depreciate further, a common case scenario in the Mongolian foreign exchange market.

### *3.3. Data*

The period of study is from 24 March 2009 (the beginning of the foreign exchange auctions) to 31 December 2018 during which the BOM conducted official daily amounts of interventions of both purchases and sales of USD, mainly effected through FX auctions. Fig. 1

[8] The auction committee members are: First Deputy Governor, Director of Reserve Management Financial Markets Department, Director of Monetary Policy Department and Chief Economist.

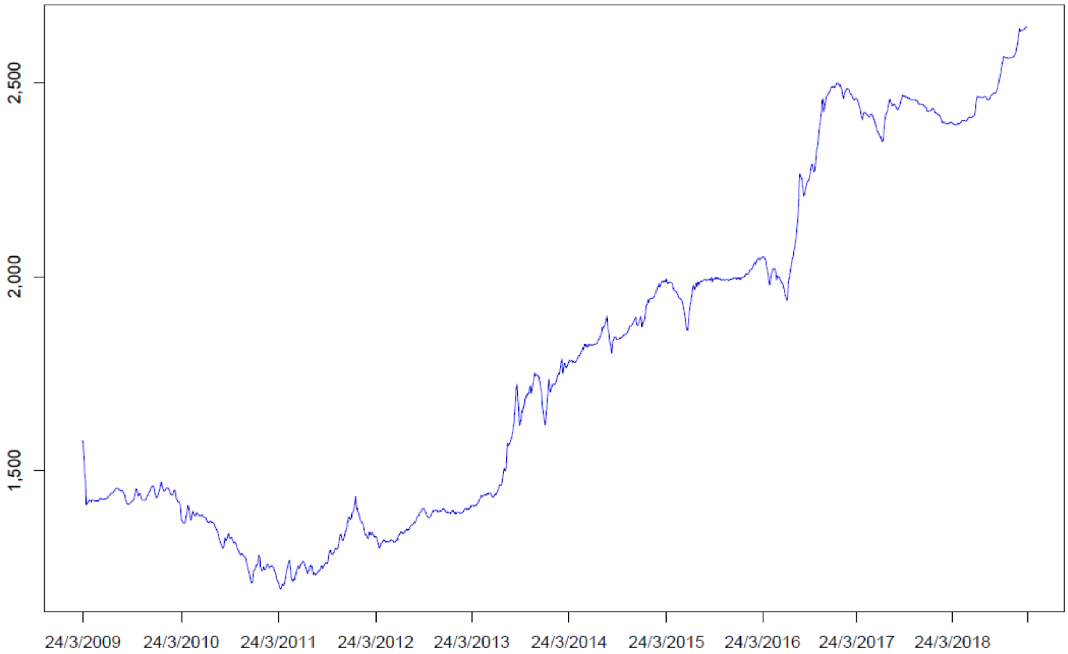



**Fig. 2.** MNT/USD exchange rate, 24 March 2009–31 December 2018.

**Table 1**
Official Mongolian daily foreign exchange interventions.

| | Full sample period: 24 March 2009 to 31 December 2018 (1) | First sub-period: 24 March 2009 to 17 October 2012 (2) | Second sub-period: 18 October 2012 to 20 February 2017 (3) | Third sub-period: 21 February 2017 to 31 December 2018 (4) |
|---|---|---|---|---|
| Total intervention days | 570 | 156 | 319 | 95 |
| Total days of purchases of USD | 128 | 80 | 19 | 29 |
| Total days of sales of USD | 442 | 76 | 300 | 66 |
| Average daily amount of intervention | 13.8 | 1.1 | 20.4 | 12.5 |
| Purchases of USD (Maximum daily amount) | 74 | 69.3 | 61.1 | 74 |
| Purchases of USD (Minimum daily amount) | 0.5 | 0.5 | 7 | 1.5 |
| Sales of USD (Maximum daily amount) | 94.7 | 71.3 | 94.7 | 88.7 |
| Sales of USD (Minimum daily amount) | 8.9E-16 | 0.5 | 0.7 | 8.9E-16 |
| Purchases of USD of more than 30 million (# days) | 21 | 10 | 3 | 8 |
| Purchases of USD less than or equal to 30 million (# days) | 107 | 70 | 16 | 21 |
| 0 (No currency intervention) (# days) | 1894 | 752 | 773 | 369 |
| Sales of USD less than or equal to 30 million(# days) | 328 | 58 | 227 | 43 |
| Sales of USD of more than 30 million (# days) | 114 | 18 | 73 | 23 |

Notes: All amounts are in millions of USD. Purchases of USD are recorded with a negative sign (−) (absolute values are reported in the table), while sales of USD are recorded with a positive sign (+). Average daily amount refers to intervention days only.
Source: Raw data obtained from Bank of Mongolia.

depicts all sales and purchases of US dollars conducted by the central bank on days of intervention as well as the days that it did not intervene. There are two notable observations in the plot that are worth highlighting. First, currency interventions in Mongolia involved more currency sales of USD than currency purchases of USD, which reflect the depreciating trend of the MNT vis-à-vis the

USD for the entire period of the analysis (Fig. 2). Second, interventions tend to be in clusters, some more noticeable than others, and definitely there are times during which the central bank intervened more frequently.

The first column of Table 1 below provides a more detailed discussion of the currency intervention data for the entire period. Out of a total of 2464 trading days, currency interventions were conducted on a total of 570 days, which suggest that there were 1894 days on which the BOM did not intervene. The average daily amount of intervention is around USD 14 million. Purchases of USD were conducted for 128 days of which the maximum amount was USD 74 million, while sales of USD were conducted for 442 days of which the maximum amount was about USD 95 million. Purchases and sales of USD worth less than or equal to USD 30 million were conducted for 107 and 328 days, respectively. On the other hand, purchases and sales of USD amounting to more than USD 30 million were conducted for 21 and 114 days, respectively. Again, in view of the depreciating trend of the MNT with respect to the USD for the entire period, the BOM had conducted more frequent and larger sales of USD compared to purchases of the same currency.

In addition to our empirical analysis for the entire period, we also conducted similar analysis for certain splits in our sample period. We rationalize our sub-sample analysis based on explicit policy statements made by the BOM as recorded or published in its official documents. For instance, in its 2012 Annual Report, the BOM categorically announced that beginning October 2012 it had to a large extent supported its domestic currency by selling foreign currency "in order to smooth the short term volatility of the MNT and fixed the distorted expectations in the market" (p. 37). Then, following the steep depreciation of the MNT vis-à-vis the USD during the second half of 2016, its declared policy as contained in its 2017 Annual Report was to sell USD "to smooth the rapid fluctuations in the exchange rate" (p. 31) and "to avoid a possible financial crisis and maintain financial stability" (also on p. 31). Based on these expressed policy pronouncements by the BOM, we then opt to conduct our empirical analysis for the full sample of 24 March 2009 (the start of the auction mechanism) to 31 December 2018 and across three sub-periods: (i) 24 March 2009 to 17 October 2012; (ii) 18 October 2012 to 20 February 2017, and (iii) 21 February 2017 to 31 December 2018.[9]

Columns two to four of Table 1 provide a description of the official daily amounts of intervention by the BOM across these three sub-periods. During the first sub-period, out of a total of 908 trading days, currency interventions were conducted on a total of 156 days, which implies that there were 752 days on which the BOM did not intervene. On intervention days, purchases and sales of USD worth less than or equal to USD 30 million were conducted for 70 and 58 days, respectively, of which the minimum intervention amount was USD 0.5 million for both purchases and sales of USD. On the other hand, purchases and sales of USD amounting to more than USD 30 million were conducted for only 10 and 18 days, respectively, in which the maximum amount was USD 69 million for purchases of USD, while USD 71 million for sales of USD. In other words, in contrast to the full sample period where more frequent and larger sales of USD as opposed purchases of USD were noted, for this first sub-period, there is a balanced conduct of currency interventions on either side. The reason being that apart from the size of the interventions being quite similar on either side, in terms of frequency, purchases and sales of USD each respectively account for half of the total days of interventions.

In contrast, the second sub-period can be characterized by a relatively different intervention tactic pursued by the central bank compared to the first sub-period. For one, the average daily amount of intervention for this sub-period was USD 20.4 million compared to the USD 1.1 million average daily amount of intervention observed during the first sub-period. Out of a total of 319 intervention days, purchases of USD accounted for only 19 days, whereas sales of USD accounted for 300 days. Furthermore, the maximum daily amount of sales of USD amounted to USD 95 million, whereas the maximum amount for purchases of USD amounted to 61 million. In short, this sub-period, compared to the first sub-period, can be characterized by an intervention tactic whereby currency purchases are relatively infrequent, while currency sales are more frequent and in larger amounts.

The intervention tactic of the third sub-period is quite similar to the second-sub-period. On intervention days, similar to the second sub-period, currency sales were conducted more frequently compared to currency purchases. Out of a total of 464 trading days, currency interventions were conducted on a total of 95 days, of which sales of USD were conducted on 66 days, while purchases of USD on 29 days. A differing nuance, however, between the two sub-periods is that in terms of purchases of USD, the maximum daily amount of USD 74 million in the third sub-period is larger than that of the observed maximum daily amounts of purchases of USD in the first and second sub-periods. In terms of currency sales, the maximum daily amount of intervention is relatively smaller compared to the second sub-period but relatively larger than the first period. In other words, the third sub-period can be characterized as a preference for also conducting larger currency sales, but to a lesser extent compared to the second sub-period. The reason for this lesser maximum amount of sales of USD in the third sub-period compared to the second is that the BOM had also exemplified at the same time a preference for larger purchases of USD, of which the maximum amount of purchases of the same currency in the third sub-period is almost comparable to the one observed in the first sub-period.

## 4. Estimation strategy

When investigating the effectiveness of official currency interventions on the movement of the exchange rate, the main challenge is to address the issue of endogeneity. The endogeneity of interventions to exchange rate movements can produce inconsistent estimates which lead to incorrect causal inferences. The sources of endogeneity that need to be addressed in order to isolate the causal effect of intervention on the changes in the MNT/USD exchange rate and its volatility are simultaneity and self-selection bias.

Simultaneity, or reverse causality, relates to the two-way causation between currency intervention and currency movements. Intervention operations may influence the exchange rate, but movements in the exchange rate may also affect the authorities' decision

[9] To examine the robustness of our empirical results, we also examine alternative sub-sample splits that we present in our later analysis.

to intervene. To overcome this simultaneity problem, we use a two-stage instrumental variable estimation approach. In the first stage, an ordered probit model is used to estimate the intervention reaction function, from which inverse probability weights are constructed.[10] Then, in the second stage, these weights are combined with a local linear projection type estimator to estimate the outcome equation. We also note that another advantage from the use of an order probit model is that it allows for negative values of the currency intervention instrument, i.e., purchases of USD against sales of MNT.[11]

The two-stage estimation approach also allows us to address the second source of endogeneity, i.e., self-selection bias, where central bank official interventions do not occur randomly, but instead are "self-selected" by the authorities on when to intervene. Considering intervention as a "treatment" and the estimation of the intervention reaction function in the first-stage through an ordered probit model, we can then estimate the "average treatment effect" (ATE) of currency intervention using multinomial propensity scores. This is possible because the inverse probability weights obtained in the first stage are used to adjust our intervention or so-called "treatment variable" to a randomly selected setting, or to mimic a situation of "as if" the decision to intervene by the authorities in Mongolia had been taken at random. We provide further details of these in the discussions below.

### 4.1. Intervention reaction function

In the first stage, we use the ordered probit model to estimate an intervention reaction function for the full sample period and across the three sub-periods: (i) the start of the auction mechanism on 24 March 2009 to 17 October 2012; (ii) 18 October 2012 to 20 February 2017, and (iii) 21 February 2017 to 31 December 2018. We estimate a typical intervention reaction function modelled as follows:

$$INT_t = \alpha_0 + \beta_0 EXR_{t-1} + \beta_1 EXR_{t-2} + \beta_2 EXR_{t-3} + \beta_3 INT_{t-1} + \beta_4 INT_{t-2} + \beta_5 INT_{t-3} + \beta_6 MA21EXR_{t-1} + \varepsilon_t \quad (1)$$

where INT are the ordered intervals or categories of the intervention amount, EXR is the first difference of the logarithm of the MNT/USD exchange rate, MA21EXR is the 21-day moving average of EXR to account for the trend in the movements of the MNT/USD exchange rate and this variable is typically included in previous studies that estimate an intervention reaction function (e.g., Ito and Yabu, 2007, among others), and $\varepsilon$ is the error term.[12] In the construction of the ordered categories, we recognize that, in practice, the data will impose a limit on the fineness of the categories of the intervention amounts.[13] To construct the ordered categories for the dependent variable, INT, for the full sample period and for each of the sub-periods we first group purchases and sales of USD into two categories. One category comprises of transactions that are more than USD 30 million on either side and another category comprising those transactions of less than or equal to USD 30 million also on either side. Next, the specific values that these ordered categories take are as follows: for purchases of USD, purchases of USD more than USD 30 million take a value of $-2$, while purchases of USD less than or equal to USD 30 million take a value of $-1$. For sales of USD, sales of USD less than or equal to USD 30 million take a value of $+1$, while sales of USD greater than USD 30 million take a value of $+2$.[14] Finally, in all of the sub-periods, days of no intervention take a value of 0, which then serves as our control or benchmark policy. Based on the information reported in rows one to three of Table 1, calculations of the proportion of total days of purchases of USD to total days of intervention as well as the proportion of total days of sales of USD to total days of intervention, suggest that, with the exception of purchases of USD for the second sub-period, the cut-off of USD 30 million is a reasonable choice for the construction of the ordered categories in our currency intervention data for the full sample period and for the three sub-periods.

### 4.2. Multinomial treatment (propensity score estimation) and the causal effect of currency intervention

The predicted values from the above ordered probit estimation of the intervention reaction function are used to derive propensity scores, as well as constructing an instrumental variable for the contemporaneous intervention in the second stage outcome equation. Typical of the explanatory variables included in an intervention reaction function, Equation (1) describes the probability of intervention conditional on past interventions and lagged outcomes. The resulting set of conditional distributions defines a function called the policy propensity score.

Following the notation of AJK, formally, the policy propensity score can be expressed as $P(D_t = d_j|z_t) = p^j(z_t, \psi)$. This is a flexible parametric model with parameter determined by the policy regime ($\psi$). $D_t$ is simply the ordered intervals or categories of the intervention amount, which as discussed above, takes discrete values $d_0, \cdots, d_j$. In addition, $z_t$ are the predetermined variables found on the right-hand side of Equation (1), such as the lagged changes in the MNT/USD exchange rate and lagged $D_t$.

As discussed by AJK, their method leans on parametric models for the intervention reaction function but requires no functional

[10] We are not the first to use an order probit model in the context of the effectiveness of currency interventions. Using Japanese currency intervention, Ito and Yabu (2007) used it as well to estimate a Japanese intervention reaction function.

[11] The BOM records purchases of USD with a negative sign, while sales of USD are recorded with a positive sign.

[12] The variables included on the right-hand side of equation (1) are the typical variables found in the foreign exchange intervention literature. However, we are not making any claim that equation (1) captures exactly all those factors that the BOM reacts to in its decision to intervene.

[13] The seminal article of Hausman et al. (1992), which introduced ordered probit models into the finance literature, also made this reasonable point.

[14] We thank an anonymous referee for suggesting these ordered categories in our currency intervention data.

**Table 2**
Ordered probit estimates of the intervention reaction function Full sample period: 24 March 2009 to 31 December 2018.

| | (1) Purchases of USD of more than 30 million | | (2) Purchases of USD of less than or equal to 30 million | | (3) Sales of USD of less than or equal to 30 million | | (4) Sales of USD of more than 30 million | |
|---|---|---|---|---|---|---|---|---|
| Parameters | | | | | | | | |
| Intervention, Lag1 | 0.006*** | (0.002) | 0.024*** | (0.004) | −0.046*** | (0.007) | −0.027*** | (0.004) |
| Intervention, Lag2 | −0.011*** | (0.002) | −0.041*** | (0.004) | 0.079*** | (0.006) | 0.047*** | (0.005) |
| Intervention, Lag3 | −0.011*** | (0.002) | −0.044*** | (0.005) | 0.085*** | (0.006) | 0.050*** | (0.005) |
| Changes in Exchange Rate, Lag1 | 0.016*** | (0.003) | 0.061*** | (0.008) | −0.118*** | (0.015) | −0.070*** | (0.009) |
| 21-day moving average of Changes in Exchange Rate | 0.017*** | (0.006) | 0.066*** | (0.018) | −0.128*** | (0.034) | −0.076*** | (0.021) |
| Partition boundaries | | | | | | | | |
| Cut Point 1 | −2.646*** | (0.094) | | | | | | |
| Cut Point 2 | −1.732*** | (0.049) | | | | | | |
| Cut Point 3 | 1.265*** | (0.039) | | | | | | |
| Cut Point 4 | 2.158*** | (0.055) | | | | | | |
| Log Likelihood | −1683.45 | | | | | | | |
| Observations | 2464 | | | | | | | |

Notes:(i) Standard errors in parentheses, (ii) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

form assumptions for the outcome equation. Their approach does not define or estimate structural innovations for the policy process, nor develop, solve, or simulate a model. To then estimate, $\theta_j$, the average treatment effect of currency intervention on the changes in the exchange rate and volatility, the first few steps of AJK are as follows:

- Fit the model $p^j(z_t, \psi) = \Pr(D_t = d_j | z_t, \psi)$.
- Estimate the predicted probabilities $\widehat{p}_t^j = p^j(z_t, \widehat{\psi})$ for all $j, t$.
- Construct the inverse propensity weights, expressed as follows[15]:

$$\delta_{t,j}(\psi) = \frac{1\{D_t = d_j\}}{p^j(z_t, \psi)} - \frac{1\{D_t = d_0\}}{p^0(z_t, \psi)}$$

From this point on, we deviate slightly from AJK by incorporating the step in terms of purging our outcome variable, $y_t$, the changes in the MNT/USD and its volatility, of any influence from the other instruments of monetary policy like the target policy rate.[16] To do this, we include in the vector $z_t$ contemporaneous and lagged terms of the target policy rate, and this new vector we denote as $w_t$. After this, we regress $y_t$ on $w_t$ and a constant and construct the residuals $\ddot{y}_{t,j}$. Finally, the vector of estimated responses to policy choice $j$ relative to the control or benchmark policy are computed as:

$$\widehat{\theta}_{j,L} = \frac{\sum_{t=1}^{T} \ddot{y}_{t,L} \delta_{t,j}}{T}$$

where subscript $L$ corresponds to the trading horizon. Recall that the policy choices for the full sample period and across the three sub-periods are as follows: purchases of USD more than USD 30 million (−2), purchases of USD less than or equal to USD 30 million (−1), sales of USD less than or equal to USD 30 million (+1), and sales of USD more than USD 30 million (+2). Again, recall that the benchmark policy is of no intervention (0).

## 5. Empirical results

### 5.1. Main results

We begin by first reporting our propensity score estimates of the intervention reaction function in Equation (1). In conducting our estimation of the propensity scores using ordered probit, we first include all explanatory variables. The insignificant explanatory variables are then excluded, and a restricted version of the reaction function is re-estimated for the full sample period and across all three sub-periods. Tables 2–5 display the results. Table 2 presents the ordered probit estimates of the marginal effects of the significant

[15] Similar to AJK, prior to the construction of the inverse propensity weights, we drop observations with very low $p^j(z_t, \widehat{\psi})$when$1\{D_t = d_j\} = 1$. This is done to remove a few observations that receive extreme weights to avoid having these outliers distorting the estimate of the average treatment effect of intervention.

[16] The original codes to implement AJK (2016) are available on Prof. Guido Kuersteiner's website at: http://econweb.umd.edu/~kuersteiner/research_UMD.html. Portions of the codes were modified to implement the additional steps we carry out in this paper. We gratefully acknowledge him for making the original codes available.

**Table 3**
Ordered probit estimates of the intervention reaction function First sub-period: 24 March 2009 to 17 October 2012.

| | (1) Purchases of USD of more than 30 million | | (2) Purchases of USD of less than or equal to 30 million | | (3) Sales of USD of less than or equal to 30 million | | (4) Sales of USD of more than 30 million | |
|---|---|---|---|---|---|---|---|---|
| Parameters | | | | | | | | |
| Intervention, Lag1 | −0.019*** | (0.005) | −0.084*** | (0.011) | 0.065*** | (0.009) | 0.029*** | (0.006) |
| Intervention, Lag2 | −0.018*** | (0.005) | −0.080*** | (0.011) | 0.062*** | (0.009) | 0.027*** | (0.006) |
| Changes in Exchange Rate, Lag1 | 0.014*** | (0.005) | 0.063*** | (0.017) | −0.048*** | (0.014) | −0.021*** | (0.007) |
| Partition boundaries | | | | | | | | |
| Cut Point 1 | −2.696*** | (0.139) | | | | | | |
| Cut Point 2 | −1.593*** | (0.070) | | | | | | |
| Cut Point 3 | 1.647*** | (0.074) | | | | | | |
| Cut Point 4 | 2.482*** | (0.118) | | | | | | |
| Log Likelihood | −500.90 | | | | | | | |
| Observations | 908 | | | | | | | |

Notes:(i) Standard errors in parentheses, (ii) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

**Table 4**
Ordered probit estimates of the intervention reaction function Second sub-period: 18 October 2012 to 20 February 2017.

| | (1) Purchases of USD of more than 30 million | | (2) Purchases of USD of less than or equal to 30 million | | (3) Sales of USD of less than or equal to 30 million | | (4) Sales of USD of more than 30 million | |
|---|---|---|---|---|---|---|---|---|
| Parameters | | | | | | | | |
| Intervention, Lag1 | 0.007** | (0.003) | 0.020*** | (0.005) | −0.121*** | (0.014) | −0.075*** | (0.010) |
| Intervention, Lag2 | −0.002* | (0.001) | −0.006*** | (0.002) | 0.038*** | (0.011) | 0.023*** | (0.007) |
| Changes in Exchange Rate, Lag1 | 0.012** | (0.006) | 0.036*** | (0.009) | −0.216*** | (0.026) | −0.134*** | (0.019) |
| Partition boundaries | | | | | | | | |
| Cut Point 1 | −3.088*** | (0.196) | | | | | | |
| Cut Point 2 | −2.418*** | (0.109) | | | | | | |
| Cut Point 3 | 0.595*** | (0.052) | | | | | | |
| Cut Point 4 | 1.600*** | (0.069) | | | | | | |
| Log Likelihood | −828.54 | | | | | | | |
| Observations | 1092 | | | | | | | |

Notes:(i) Standard errors in parentheses, (ii) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

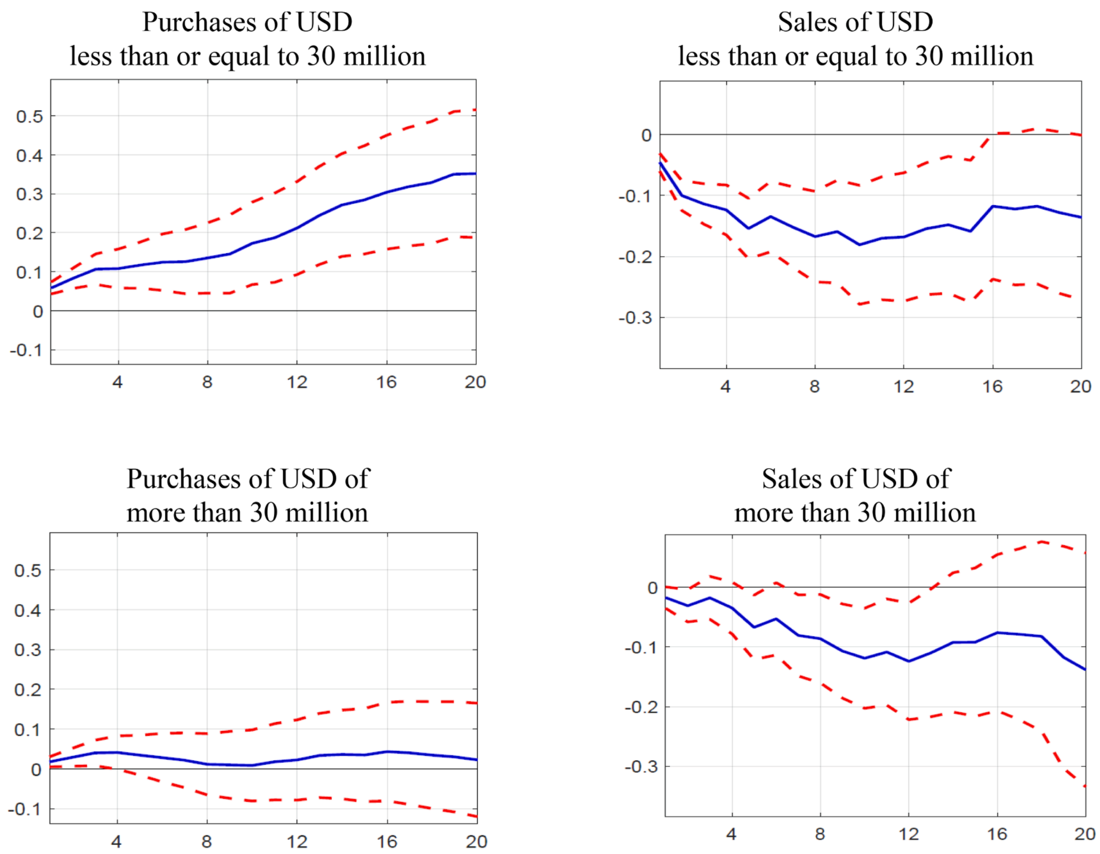
**Table 5**
Ordered probit estimates of the intervention reaction function Third sub-period: 21 February 2017 to 31 December 2018.

| | (1) Purchases of USD of more than 30 million | | (2) Purchases of USD of less than or equal to 30 million | | (3) Sales of USD of less than or equal to 30 million | | (4) Sales of USD of more than 30 million | |
|---|---|---|---|---|---|---|---|---|
| Parameters | | | | | | | | |
| Intervention, Lag2 | −0.014** | (0.005) | −0.030*** | (0.009) | 0.043*** | (0.011) | 0.037*** | (0.010) |
| Changes in Exchange Rate, Lag1 | 0.098*** | (0.035) | 0.211*** | (0.054) | −0.301*** | (0.060) | −0.261*** | (0.060) |
| Partition boundaries | | | | | | | | |
| Cut Point 1 | −2.282*** | (0.160) | | | | | | |
| Cut Point 2 | −1.609*** | (0.100) | | | | | | |
| Cut Point 3 | 1.259*** | (0.082) | | | | | | |
| Cut Point 4 | 1.883*** | (0.110) | | | | | | |
| Log Likelihood | −324.81 | | | | | | | |
| Observations | 464 | | | | | | | |

Notes:(i) Standard errors in parentheses, (ii) * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

explanatory variables in the reaction function for the full sample period (24 March 2009 to 31 December 2018), Table 3 the marginal effects for the first sub-period (24 March 2009 to 17 October 2012), Table 4 for the second sub-period (18 October 2012 to 20 February 2017) and Table 5 for the third sub-period (21 February 2017 to 31 December 2018).

Table 2 indicates that for the full sample period all ordered categories for both purchases of USD (columns 1 and 2) and sales of USD (columns 3 and 4) react to the previous day's changes in the MNT/USD exchange rate as well as to the 21-day moving average of the changes in the MNT/USD exchange rate. In addition, purchases and sales of USD conducted on a given day regardless of the size of the transaction are affected by similar types of transactions in interventions, which were carried out on the previous day as well as two and three days before. Tables 3–5 show that for the three sub-periods, all ordered categories in both purchases and sales of USD react




Note: Dashed lines indicate 68% confidence bands.

**Fig. 3.** Estimated effects of intervention on changes in the MNT/USD rate, Full sample period: 24 March 2009 to 31 December 2018, Main results. Note: Dashed lines indicate 68% confidence bands.

significantly to one lagged changes in the MNT/USD exchange rate. Moreover, purchases and sales of USD conducted on a given day regardless of the size of the transaction react significantly to interventions carried out two and three days before (first sub period, Table 3), to interventions carried out on the previous day and two days before (second sub period, Table 4), and to interventions carried out on the previous two days (third sub period, Table 5).

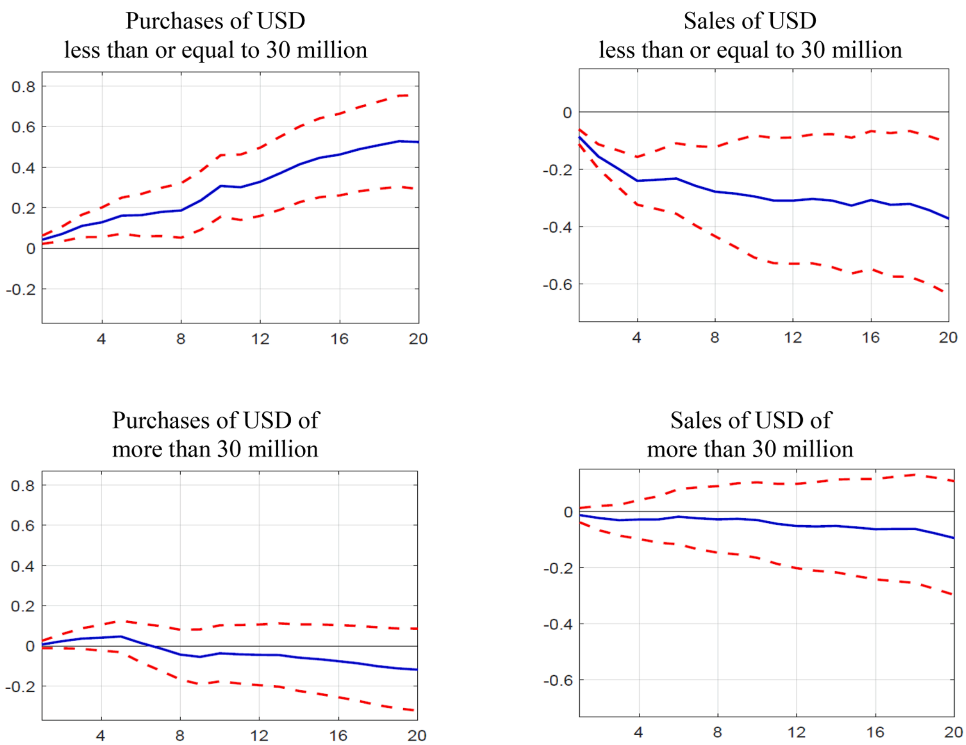
In the following sub-section, we turn to the dynamic causal effects of currency intervention on changes in the MNT/USD exchange rate. In another sub-section, we will examine in turn the dynamic causal effects of currency intervention on the volatility of the MNT/USD exchange rate.

#### *5.1.1. Outcome variable: Changes in the MNT/USD exchange rate*

All responses are measured as cumulative percent changes over a horizon of 20 trading days. Figs. 3–6 present the main results of our estimated responses, which are constructed using the propensity scores estimates presented above (Fig. 3 corresponds to propensity scores estimates reported in Table 2, Fig. 4 corresponds to propensity score estimates presented in Table 3, Fig. 5 corresponds to score estimates shown in Table 4, and Fig. 6 corresponds to score estimates shown in Table 5). The figures also show the 68 percent confidence bands.

Fig. 3 indicates that purchases of USD less than or equal to USD 30 million (upper left-hand corner of Fig. 3) for the entirety of the 20-day horizon have a statistically significant effect on the changes in the MNT/USD exchange rate. The responses are also correct in sign with the pertinent purchases of USD resulting to a depreciation of the MNT. In contrast, the responses of the changes in MNT/USD exchange rate to purchases of USD more than USD 30 million (lower left-hand corner of Fig. 3) is also correct in sign but relatively less stronger in statistical significance due to a short-lived significant effect starting on the day of intervention and lasting for up to two or three days.

On the other hand, sales of USD less than or equal to USD 30 million also have a statistically significant effect on the changes in MNT/USD exchange rate (upper right-hand corner of Fig. 3) that lasts up to a little more than two weeks. The responses are also of the correct sign with an observed appreciation of the MNT for the entire horizon. While the statistical significance of the responses of the changes in MNT/USD exchange rate to sales of USD more than USD 30 million (lower right-hand corner of Fig. 3) switch between being




Note: Dashed lines indicate 68% confidence bands.

**Fig. 4.** Estimated effects of intervention on changes in the MNT/USD rate, First sub-period: 24 March 2009 to 17 October 2012, Main results: Note: Dashed lines indicate 68% confidence bands.

significant and insignificant in earlier horizons, the responses are consistently significant a week after intervention and this lasts for almost another week. The responses are nevertheless correct in sign with an observed appreciation of the MNT.

Turning now to the dynamic causal effects of currency intervention on changes in the MNT/USD exchange rate for each of the sub-periods, Fig. 4 presents the results for the first sub-period. Purchases of USD less than or equal to USD 30 million (upper left-hand corner of Fig. 4) similarly exemplifies a statistically significant effect on the changes in the MNT/USD exchange rate for the entirety of the 20-day horizon, and the responses are again correct in sign with a resulting depreciation of the MNT. However, the responses of the changes in MNT/USD exchange rate to purchases of USD more than USD 30 million (lower left-hand corner of Fig. 4) are now statistically insignificant.

The responses of the changes in the MNT/USD exchange rate to sales of USD less than or equal to USD 30 million (upper right-hand corner of Fig. 4) show a stronger statistical significance with the significance of the responses occurring in all horizons. In contrast, the statistical significance of the responses of the changes in MNT/USD exchange rate to sales of USD more than USD 30 million (lower right-hand corner of Fig. 4) are now statistically insignificant. Nevertheless, all the responses of the changes in the MNT/USD exchange rate to sales of USD are of the correct sign which shows an appreciation of the MNT.

Fig. 5 presents the dynamic causal effects for the second sub-period. Purchases of USD less than or equal to USD 30 million (upper left-hand corner of Fig. 5) show a short-lived significant effect starting on the day of intervention and lasting for up to two or three days. Purchases and sales of USD more than USD 30 million (lower left- and right-hand corners of Fig. 5) show a statistically significant effect only on impact and become statistically insignificant in subsequent horizons. There is an observed delayed statistically significant response of the changes in the MNT/USD exchange rate to sales of USD less than or equal to USD 30 million (upper right-hand corner of Fig. 5) with the response only becoming significant two days after the intervention transaction and this significance lasts for about two weeks. All the responses are of the correct sign. In contrast, the statistical significance of the responses of the changes in MNT/USD exchange rate to sales of USD more than USD 30 million (lower right-hand corner of Fig. 5) are statistically insignificant.

Fig. 6 presents the dynamic causal effects for the third sub-period. Purchases of USD less than or equal to USD 30 million (upper left-hand corner of Fig. 6) and purchases of USD more than USD 30 million (lower left-hand corner of Fig. 6) both exemplify a statistically significant effect on the changes in the MNT/USD exchange rate for the entirety of the 20-day horizon. The responses are of the correct sign. There is a delayed statistically significant response of the changes in the MNT/USD exchange rate to sales of USD less than or equal to USD 30 million (upper right-hand corner of Fig. 6) with the response only becoming significant more than two weeks after the intervention transaction and this significance extending all the way to the end of the horizon. The responses during these horizons are of the correct sign. The effect of sales of USD more than USD 30 million (lower right-hand corner of Fig. 6) indicate statistical

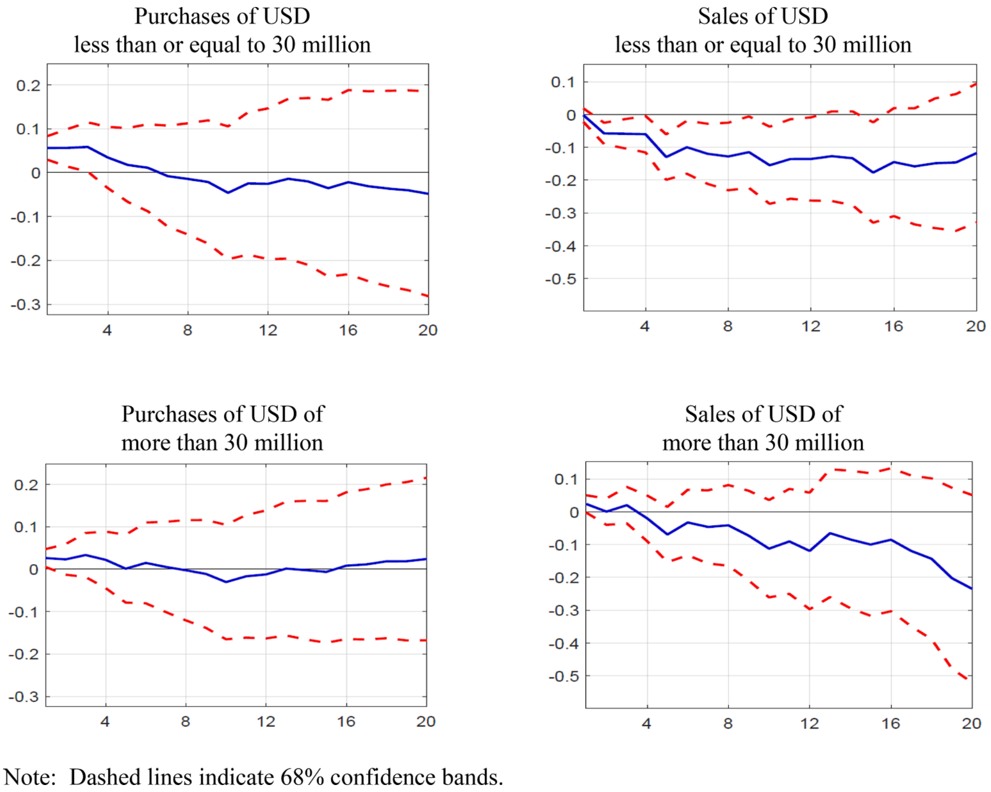



**Fig. 5.** Estimated effects of intervention on changes in the MNT/USD rate, Second sub-period: 18 October 2012 to 20 February 2017, Main results: Note: Dashed lines indicate 68% confidence bands.

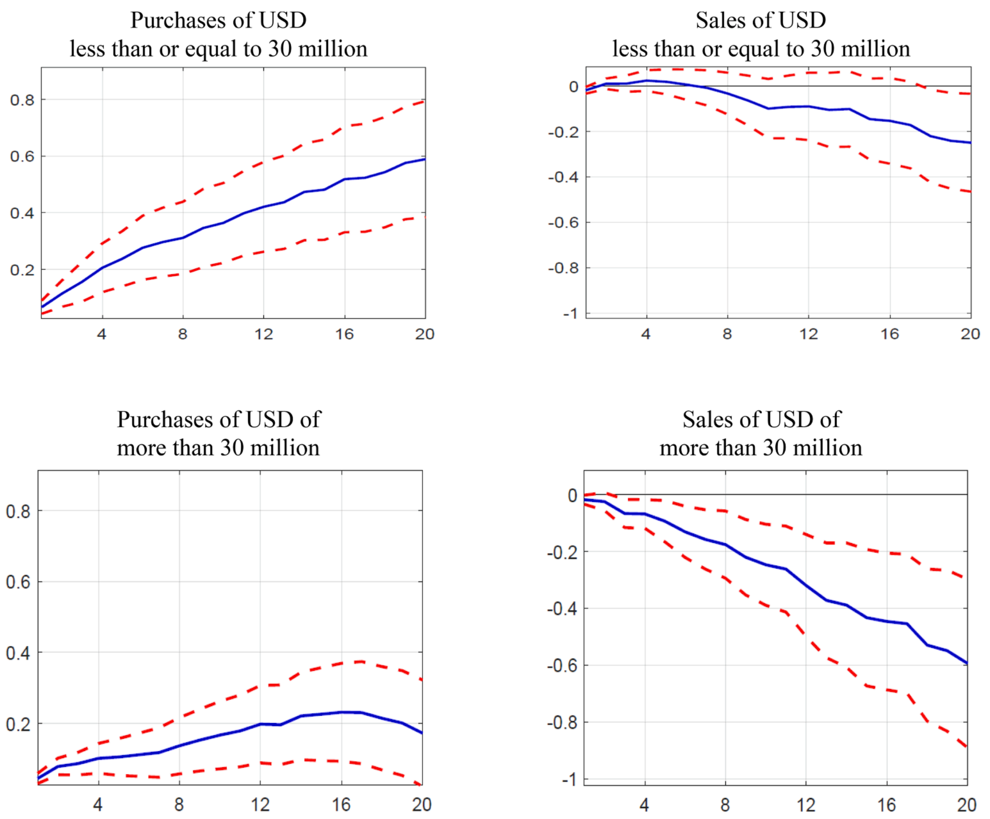
significance for almost the entirety of the horizons and the responses are also of the correct sign.

*5.1.1.1. Robustness tests.* We carry out sensitivity checks to our main results above along various dimensions: first, in addition to the inclusion of contemporaneous and lagged terms of the target policy rate in the vector $w_t$, we further control for the effects of other instruments of monetary policy in Mongolia by both including contemporaneous and lagged terms of the domestic reserve requirement and foreign-exchange reserve requirement in vector $w_t$.[17] Second, we also check for the sensitivity of our main results by including contemporaneous and lagged terms of daily gold prices (in logs) in vector $w_t$. Finally, we check for the sensitivity of our main results by using alternative sub-sample splits. In terms of the impulse responses, we again present the responses of the changes in the exchange rate to currency intervention over a horizon of 20 trading days for the full-sample period and for each of the three sub-periods.

With regard to our first robustness test (Figures A1 to A4 in the online Appendix), we obtain results that are quite similar to our main results, except that the statistically significant responses of the changes in MNT/USD exchange rate to sales of USD more than USD 30 million that we earlier observed for the full sample period are now statistically insignificant for the entire horizon (lower right-hand corner of Figure A1). Some other differences but do not alter the qualitative findings of our main results, and in one specific instance shows a stronger affirmation of a part of the main results, are as follows: first, the duration of the statistical significance of the responses to purchases of USD less than or equal to USD 30 million for the full sample period (upper left-hand corner of Figure A1) and for the first sub-period (upper left-hand corner of Figure A2) are now relatively shorter. For the latter, the statistically significant responses occur toward the end of the horizon. This observation of a shorter duration in the statistical significance of the responses also applies to the responses from the sales of USD less than or equal to 30 million for the first sub-period (upper right-hand corner of Figure A2) and so are the responses from purchases and sales of USD more than USD 30 million for the third sub-period (lower left- and right-hand corners of Figure A4). Also, for the latter, the statistically significant responses occur toward the end of the horizon. Still, in all these cases, the responses are of the correct sign. On the other hand, for the second sub-period, the responses are not only correct in sign, but the duration of the statistical significance of the responses from sales of USD less than or equal to USD 30 million (upper right-hand corner of Figure A3) are now relatively longer.

Our second robustness test (Figures A5 to A8 in the online Appendix) indicate that despite some differences, the sensitivity checks

[17] We also conducted sensitivity checks where we only include in vector $w_t$: (i) contemporaneous and lagged terms of the domestic reserve requirement, and (ii) include contemporaneous and lagged terms of the foreign-exchange reserve requirement. We obtain results that are similar to the ones we reported above with regard to our first robustness test. These results are available upon request.




Note: Dashed lines indicate 68% confidence bands.

**Fig. 6.** Estimated effects of intervention on changes in the MNT/USD rate, Third sub-period: 21 February 2017 to 31 December 2018, Main results: Note: Dashed lines indicate 68% confidence bands.

conducted does not materially impact the qualitative findings of the main results. For instance, the duration of the statistical significance of the responses from sales of USD less than or equal to USD 30 million for the full sample period (upper right-hand corner of Figure A5) is relatively shorter. Similar observation also applies to the statistical significance of the responses from purchases and sales of USD more than 30 million for the third sub-period (lower left- and right-hand corners of Figure A8). For the latter, the statistically significant responses occur toward the end of the horizon. In all these cases, still the responses are of the correct sign.

With respect to our third robustness test (Figures A9 to A11 in the online Appendix), we use alternative sub-sample splits. We use the information that the MNT/USD for our period of examination experienced two major distinct phases of devaluation.[18] One around mid-2013 when emerging market economies in general roiled after the Fed signalled its readiness to exit its QE and in mid-2016 when the economy of Mongolia experienced an economic crisis and a severe shortage of US dollar reserves. In this regard, we then consider these three alternative sub-sample splits: (i) the start of the auction mechanism on 24 March 2009 to 31 May 2013; (ii) 3 June 2013 to 31 May 2016, and (iii) 2 June 2016 to 31 December 2018.

Despite some differences, our main results remain intact.[19] The differences which do not alter the qualitative findings of our main results, and in fact in two particular instances shows a stronger confirmation of a part of the main results, are as follows: first, the duration of the statistical significance of the responses from sales of USD less than or equal to USD 30 million for the first sub-period (upper right-hand corner of Figure A9) and second sub-period (upper right-hand corner of Figure A10) are relatively shorter. For the latter, the statistically significant responses occur toward the end of the horizon. This observation of a shorter duration in the statistical significance of the responses also applies to the responses from purchases and sales of USD more than USD 30 million for the third sub-period (lower left- and right-hand corners of Figure A11). Also, for the latter, the statistically significant responses again occur toward the end of the horizon. In all these cases, the responses remain correct in sign. More importantly, however, the responses from sales of USD more than USD 30 million for the first sub-period (lower right-hand corner of Figure A9) are now statistically significant at earlier horizons from the day of the intervention and lasting for up to two to three days. Furthermore, the responses from sales of USD less than

[18] We thank an anonymous referee for providing this information and suggesting these alternative sub-sample splits.

[19] For the second sub-period, there is no reported impulse responses for purchases of USD more than USD 30 million, as there was no intervention conducted at this size for this pertinent sub-period.

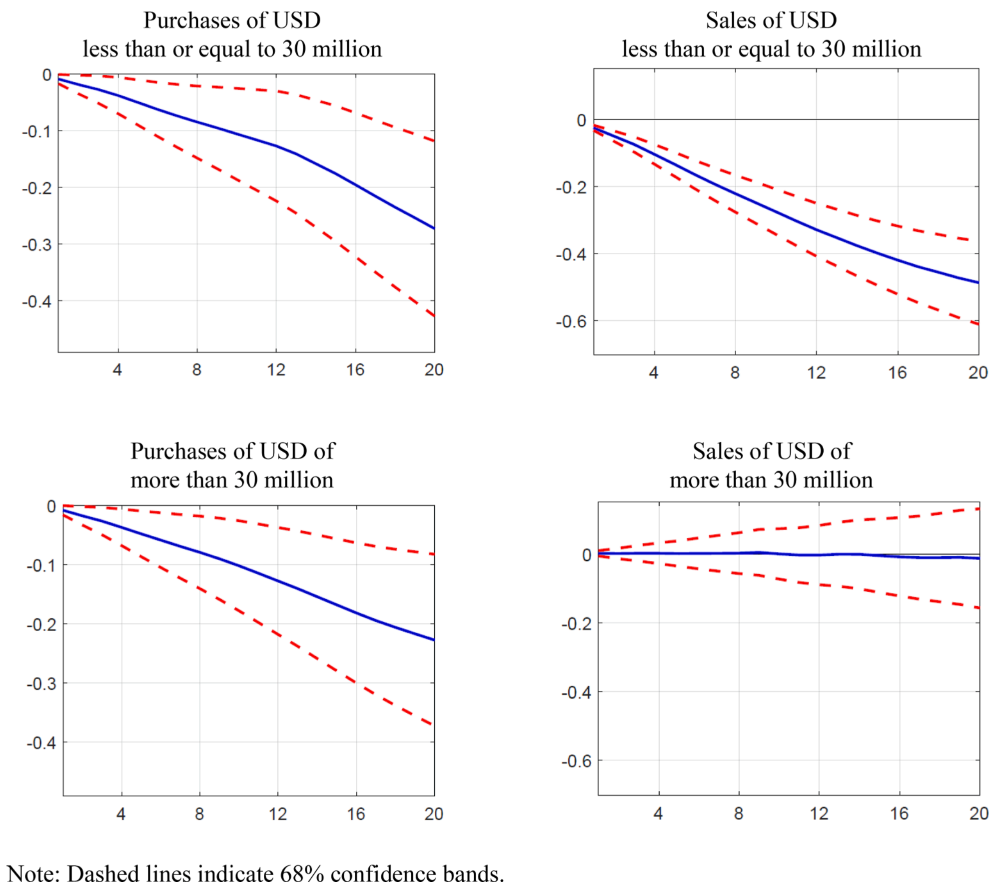



**Fig. 7.** Estimated effects of intervention on the volatility of the MNT/USD rate, Full sample period: 24 March 2009 to 31 December 2018; Main results, Note: Dashed lines indicate 68% confidence bands.

or equal to USD 30 million for the third sub-period (upper right-hand corner of Figure A11) are statistically significant for the entire horizon.

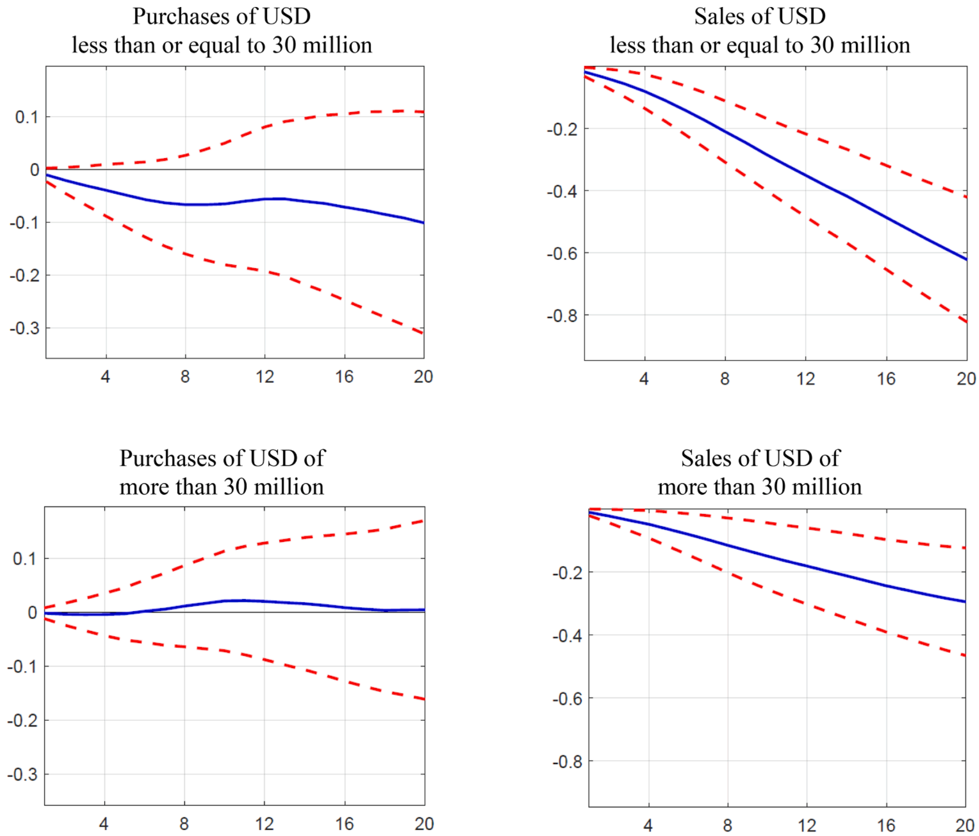
### *5.1.2. Outcome variable: Volatility of the MNT/USD exchange rate*

In this sub-section, we present our results on the dynamic causal effects of currency intervention on the other outcome variable of interest which is the volatility of the MNT/USD exchange rate (Figs. 7–10). We use the stochastic volatility measure of Taylor (1986) to calculate the volatility of the MNT/USD exchange rate.[20] With the exception of sales of USD more than USD 30 million for the third sub-period to which there is an observed increase in exchange rate volatility towards the end of the horizon, in general, our results indicate that the dynamic causal effect of currency intervention on the volatility of the MNT/USD exchange rate is that there is either no significant effect on exchange rate volatility or the intervention led to a significant decrease in the volatility of the MNT/USD exchange rate at varying horizons.

In particular, those periods and size of the interventions on either side that we noted a significant fall in the volatility of the MNT/USD exchange rate are as follows: (i) for the full sample period, both ordered categories of purchases of USD and sales of USD less than or equal to 30 million (upper left- and right-hand corners of Fig. 7); (ii) for the first-sub period, both ordered categories of sales of USD (upper and lower right-hand corners of Fig. 8); (iii) for the second sub-period, purchases of USD of more than USD 30 million and sales of USD less than or equal to 30 million (upper right- and lower left-hand corners of Fig. 9), and; (iv) for the third sub-period, purchases of USD less than or equal to USD 30 million (upper left-hand corner of Fig. 10).

*5.1.2.1. Robustness tests.* Just as we did above with respect to the examination of the causal effects of currency intervention on the changes in the MNT/USD exchange rate, we also carry out similar sensitivity checks to our main results on the causal effects of currency intervention on the volatility of the MNT/USD exchange rate. Again, we obtain results that are quite similar overall to our

[20] We use the R package **stochvol** developed by Darjus Hosszejni and Gregor Kastner to produce the stochastic volatility series of the MNT/USD exchange rate.




Note: Dashed lines indicate 68% confidence bands.

**Fig. 8.** Estimated effects of intervention on the volatility of the MNT/USD rate, First sub-period: 24 March 2009 to 17 October 2012; Main results: Note: Dashed lines indicate 68% confidence bands.

main results.

With regard to the first robustness test (Figures A12 to A15 in the online Appendix), while the decrease in exchange rate volatility stands, the statistical significance of the responses from purchases of USD of more than USD 30 million for the full sample period (lower left-hand corner of Figure A12) and for the second sub-period (lower left-hand corner of Figure A14) are muted and shorter in duration. More importantly, however, the responses to sales of USD more than USD 30 million (lower right-hand corner of Figure A14) are now statistically significant in all horizons. Again, these differences either reinforces or do not alter in a material way the qualitative findings of our main results.

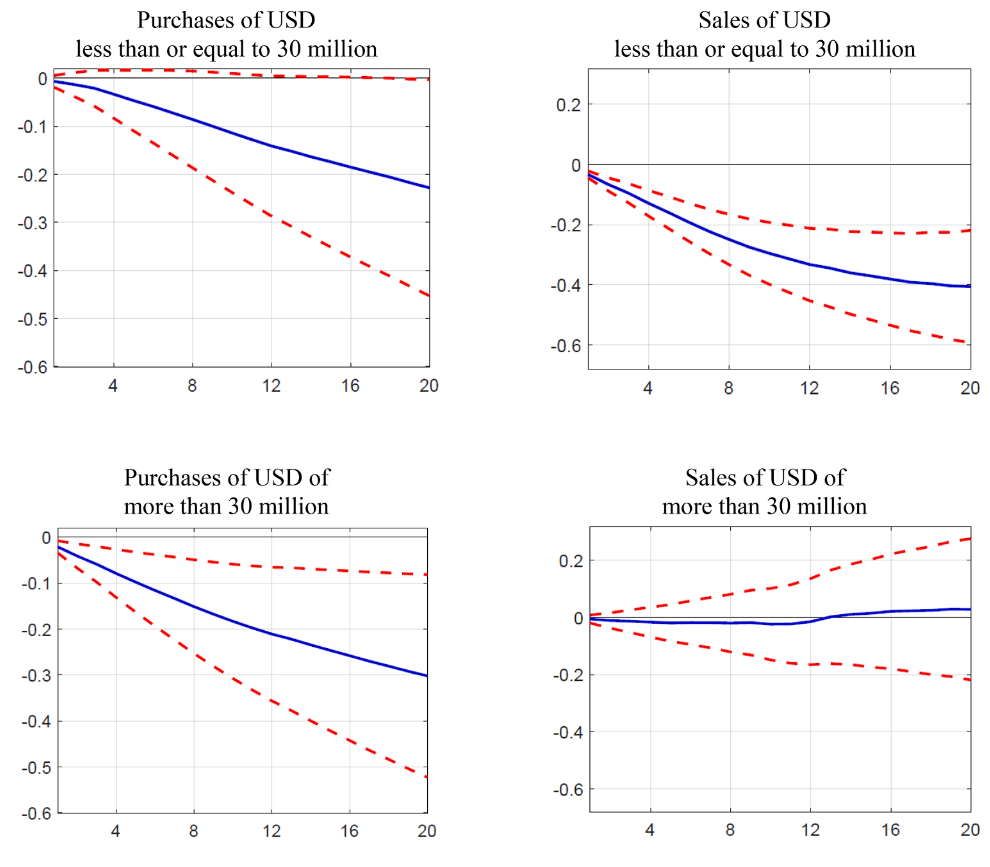
With regard to the second robustness test (Figures A16 to A19 in the online Appendix), with the exceptions of purchases of USD in both ordered categories for the full sample period (lower and upper left-hand corners of Figure A16) and sales of USD more than USD 30 million for the first sub-period (lower right-hand corner of Figure A17) to which the responses are statistically insignificant, the rest of the results are either similar or better (lower right-hand corner of Figure A18 for the second sub-period) than our main results.[21]

With regard to the third robustness test (Figures A20 to A22 in the online Appendix), the statistical significance of the responses to sales of USD more than USD 30 million for the first sub-period (lower right-hand corner of Figure A20) and the responses to purchases of USD less than or equal to USD 30 million (lower left-hand corner of Figure A22) occur at later horizons. Again, despite these differences, these do not alter in a significant way our main results. More importantly, however, the rise in exchange rate volatility in the main results with sales of USD more than USD 30 million during the third sub-period does not anymore appear in this part of the robustness test (lower right-hand corner of Figure A22)

### *5.1.3. Currency interventions during periods of low and high exchange rate volatility*

An additional interesting extension that we include in this study is whether the effectiveness of currency interventions is regime-dependent, that is, whether the effectiveness of currency intervention depends on the regime or state of low and high exchange rate

[21] Again, for the second sub-period, there is no reported impulse responses for purchases of USD more than USD 30 million, as there was no intervention conducted at this size for this pertinent sub-period.




Note: Dashed lines indicate 68% confidence bands.

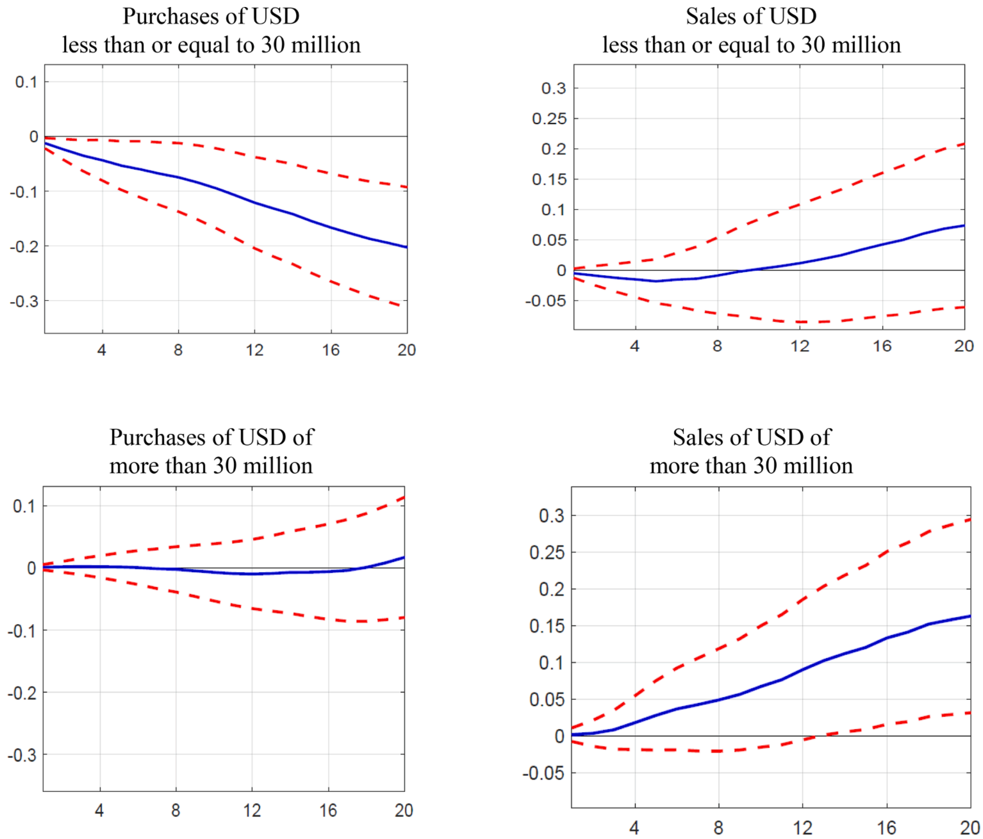
**Fig. 9.** Estimated effects of intervention on the volatility of the MNT/USD rate, Second sub-period: 18 October 2012 to 20 February 2017, Main results, Note: Dashed lines indicate 68% confidence bands.

volatility. For this purpose, we follow an idea proposed by Adrian et al (2019) in working with the entire conditional distribution of a variable, which in the present case is our measure of the second outcome variable of interest, i.e., exchange rate volatility. By working with the entire conditional distribution of the exchange rate volatility we can account for low and high volatility. Based on the steps we outlined above in section four, after we constructed the residuals $\ddot{y}_{t,j}$, in the final step, we estimate what is called quantile local projections (Loria et al., 2020), which involve running the local linear projections this time across various quantiles of the distribution of the exchange rate volatility. We estimate the quantile local projections at these quantiles, i.e., $q = 0.05, 0.25, 0.50, 0.75, 0.95$.

The results of the quantile local projections for the full sample period are presented in Figure A23 (results at the 5th quantile), Figure A24 (results at the 25th quantile), Figure A25 (results at the 50th quantile), Figure A26 (results at the 75th quantile), and Figure A27 (results at the 95th quantile).[22] It is clear from Figures A23 to A25 that at low (5th quantile) and moderate levels of volatility (25th and 50th quantiles) all ordered categories of purchases and sales of USD have a statistically significant effect in reducing exchange rate volatility at all horizons. However, at relatively high levels of volatility at the 75th and 95th quantile, currency interventions lead to a statistically significant increase in exchange rate volatility. The lone exception to this result is the sales of USD less than or equal to USD 30 million (upper right-hand corner of Figure A26) which leads to a reduction in exchange rate volatility at the 75th quantile.[23]

[22] We only estimate the quantile local projections at the full sample period because since we work with the entire conditional distribution, we would require a much longer time horizon compared to the sub-periods we considered in this study in order to alleviate any estimation uncertainty. We leave this to further research to extend the estimation of our quantile local projections with available currency intervention data from 2019 onwards.

[23] These results are robust to sensitivity checks when including the contemporaneous and lagged terms of the domestic reserve requirement and foreign-exchange reserve requirement in vector $w_t$ as well as the inclusion of the contemporaneous and lagged terms of daily gold prices (in logs) also in vector $w_t$. These results are available upon request.




Note: Dashed lines indicate 68% confidence bands.

**Fig. 10.** Estimated effects of intervention on the volatility of the MNT/USD rate, Third sub-period: 21 February 2017 to 31 December 2018, Main results: Note: Dashed lines indicate 68% confidence bands.

## 6. Conclusion

Although EME central banks actively intervene in currency markets, there is a long-running and far from settled debate as to its effectiveness in affecting exchange rates. In this study, we use unique daily data on currency interventions by the BOM to analyze the impact of these interventions on changes in the MNT/USD exchange rate as well as its volatility. The period we examined spans the time in which the country, as a major commodity exporter, experienced the dramatic rise and fall in international commodity prices with significant consequences on its exchange rate. We then employed a recent innovation that extends the potential outcomes approach of micro-econometrics to a time-series context, which allows us to address two empirical manifestations of the problem of endogeneity (simultaneity and self-selection bias) in a time-series setting. How to overcome both these issues of simultaneity and self-selection bias is an empirical challenge constantly encountered in this literature. Another crucial contribution of our study, which we believed is an often neglected aspect of this literature is that we made every effort on a high-frequency basis in controlling for the effects of monetary policy on the exchange rate. This is important because finding, if any, of an effect of currency intervention on the exchange rate is misleading if the effects of monetary policy are not controlled for.

In light of our ultimate goal of obtaining consistent estimates of the effects of currency intervention on the exchange rate, our results show that currency interventions are effective in Mongolia and this effectiveness can particularly vary to a certain extent depending on the time period and circumstances. Nevertheless, from the battery of robustness checks that we conducted to check the sensitivity of our main results, we can distill some overall key findings. One, both purchases and sales are effective in moving changes in the MNT/USD in the desired direction when implemented frequently. Two, the size of the intervention transactions while important does not appear to be as strong and compelling compared to the frequency of interventions in determining the effectiveness of currency interventions. Three, the duration of this effectiveness is quite persistent which can last between one to four weeks. Four, mainly frequent sales of USD can help reduce the volatility in the MNT/USD exchange rate. Five, when discriminating between regimes of low and high exchange rate volatility, our full sample results show that both sales and purchases of USD can reduce volatility at low and moderate levels. More importantly, frequent and smaller sales of USD can help reduce high exchange rate volatility.

It is then interesting to compare some of our findings with few other studies on the effectiveness of currency intervention, subject to the caveat that existing studies employed distinct methods and different sample periods. Our finding that the size of intervention can matter is similar to those of Fatum and Yamamoto (2014), although we note that Fatum and Yamamoto (2014) derived their finding using advanced economy currency interventions, i.e., Japanese intervention data. In terms of the frequency of the intervention, our results are also similar to Echavarria et al. (2017) and Dominguez et al. (2013). The former found that pre-announced and constant daily interventions by the Central Bank of Colombia were more important than discretionary or infrequent interventions, while the latter study found that only daily or frequent reserves sales by the Czech National Bank effect a statistically significant appreciation of the Czech Koruna. Based on the explanation by Dominguez et al. (2013), it may well be that frequent currency interventions can be interpreted by the market as a permanent policy, with such intervention operations to endure. Finally, our finding that currency interventions by the central bank of Mongolia had persistent effects that lasted from one to four weeks is also in line with recent evidence from Colombia (Kuersteiner et al., 2018) which found that the central bank's intervention had short run effects that lasts up to 1 month after intervention.

## CRediT authorship contribution statement

**Victor Pontines:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Supervision. **Davaajargal Luvsannyam:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – review & editing, Supervision. **Enkhjin Atarbaatar:** Conceptualization, Validation, Data curation, Writing – review & editing, Supervision. **Ulziikhutag Munkhtsetseg:** Software, Investigation, Data curation, Writing – original draft.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.intfin.2021.101439.

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