MSR

Working Papers 004-2020

Nov

2020

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Publisher and Distributor

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Investigating exchange rate dynamics in Mozambique: a hybrid model approach

Aurélio Bucuane[1]

Abstract

The purpose of this article is to explain the dynamics of the exchange rate in Mozambique. The applied VAR model reveals that, in fact, it is the exchange rate that determines the macroeconomic variables (fundamentals), and not the opposite (at least in the short run), as predicted in exchange rate monetary models. Variables based on market microstructure (Order Flow) have the potential to predict exchange rates, as the IRF shows a significant and consistent reaction of exchange rates to structural shocks on order flow (demand pressure), while the exchange rate reacts not only significantly less, but also in the opposite direction to that predicted in the models based on fundamentals. These results are consistent in the long run, as demonstrated by the VECM model. In addition, the exchange rate forecast, based on a hybrid model which combines macro and micro variables, exceeds the benchmark model (random walk). Furthermore, since agents' interpretations of fundamentals are incorporated in order flows, this appears to be the transmission mechanism between macroeconomic indicators and exchange rates, and in this way, order flow helps to clarify the exchange rate puzzle identified in the literature. Finally, this article suggests the use of microstructure variables of the foreign exchange market to predict exchange rates, as well as using them as a proxy for expectations, which can contribute to effective implementation of forward-looking monetary policy.

[1] Economist at the central bank of Mozambique (Bank of Mozambique)

1. Introduction

The exchange rate is a crucial variable in open economies (Krugman, Obstfeld and Melitz 2018). As the economic success of many emerging economies has been seen as linked to their increasing openness to international trade, alongside the general tendency of economies to adopt more flexible exchange rate regimes, this reinforces the need for a clear understanding of exchange rate dynamics, as it is through this variable that international shocks are transmitted to domestic economies (Erten 2012; Desroches 2004).

The explanation of exchange rate determinants has been the subject of controversial debate for a long time, however, there seems to be no general consensus yet, and in some cases the assumptions considered in macroeconomic exchange rate models are not applicable in cases of developing economies. The first exchange rate models established were based on the Purchase Power Parity (PPP) principle, such that exchange rate changes were viewed as related to the demand and supply of foreign currency in response to import and export of goods and services, therefore a country with a current account deficit (surplus) would experience currency depreciation (appreciation). The purchase and sale of financial assets were also included as determining the demand and supply of foreign currency, thus explaining exchange rate fluctuations. This view is underpinned by Uncovered Interest Parity (UIP).

These macroeconomic models of exchange rate were further developed as fixed rate regimes were being abandoned (in the early 1970s), and most of them built on the Mundell-Fleming approach, which can be subdivided into two main perspectives (Flood & Taylor 1996), firstly, a flexible-price monetary model[2], driven by studies such as those by Frenkel (1976) and Bilson (1978): as the exchange rate is defined as the relative price of two currencies (with prices perfectly flexible), the supply of both currencies by each central bank is the main proximate determinant of exchange rate[3]. Therefore, as money demand in each currency is assumed to depend on real GDP, inflation and interest rates, these variables are also included

[2] Also designated by the classical approach.

[3] For instance, depreciation of one currency relative to another occurs if the domestic money supply increases compared to the foreign one, as the money supply leads to an increase in domestic prices, so that the PPP can hold.

in the models as determining exchange rates. Secondly, there is the sticky-price monetary model[4] (Dornbusch 1976), where the exchange rate jumps (overshooting) in response to shocks to fundamentals, to compensate for the stickiness of other variables, mainly goods price levels[5]. The first case assumes that PPP holds in the short and long run, while for the second approach PPP is considered only in the long run.

In this context, the seminal work by Evans and Lyons (2002) came up with a model that better explains exchange rate movements, by including microstructure elements of exchange markets, combined with some key macroeconomic variables, constituting what in the literature is called hybrid models of exchange rate. Many other more recent studies (Mokoena, Gupta & Eyden 2009; Hoosain, Joubert & Kabundi 2017) still suggest that market microstructure factors (information asymmetry, risks, uncertainties, heterogeneity of players, etc.), in many cases measured by order flows, help to explain exchange rate dynamics as well as conveying information about the future evolution of economic fundamentals (Evans & Lyons 2002; Evans & Lyons 2008; Osler & Wang 2013; Marsh & O'Rourke 2005).

Critique on macroeconomic models of exchange rates has emerged since these models were not able to explain exchange rate dynamics, mostly in the short run (Obstfeld & Rogoff 2000). For example, Meese and Rogoff (1983) found that the monetary models of exchange rates could not outperform a simple random walk model in forecasting exchange rates[6]. Furthermore, Engel and West (2005) further argued against these models, highlighting their main findings of reverse causality, where it appears to be, instead, the exchange rate determining macroeconomic variables.

In addition, hybrid models have the advantage of not only exploiting the potential explanatory power of each variable, but also providing a clear way of comparing the two (fundamental versus microstructure), which is especially relevant in Mozambique, where there are few publicly available academic models of exchange rates.

Mozambique is largely vulnerable to international shocks, as a small open economy with structural balance of payment deficits, therefore its inflation, including economic

[4] Referred as the Keynesian view.

[5] Under perfect capital mobility, unlike the flexible price case, here the money supply does not cause direct and proportional changes in exchange rates in the short run, because due to price stickiness, interest rates fall in response to an increase in the money supply, which leads to capital outflows, and consequently the exchange rate jumps immediately away from the equilibrium. This exchange rate overshooting precipitates the expectation of appreciation, under the UIP, pushing the exchange rate back to the equilibrium.

[6] However, some studies consider that, because the exchange rate is an asset price, random walk is a better model to forecast exchange rates, such that they consider comparing any exchange model forecasting performance with random walk as unfair (Mitchell & Pearce 2007).

performance as a whole, is considerably affected by exchange rate variations (Biggs 2011). The central bank is forced to actively intervene in the exchange market despite the fact that the exchange rate regime in the country has been officially flexible (free floating) since 1994 (Pimpao 1996).

As shown in Figure 1 below, since 2015 the domestic currency (Metical) has been continuously depreciating against the USD[7], while at the same time the interest rate has been rising, which seems to show an opposite sign to what would be expected from the theory, where by the UIP principle, following an increase in the interest rate, the domestic currency should appreciate (as demand for domestic currency assets rises relative to foreign assets). This suggests that there might be an endogenous reaction in interest rates (initiated by the central bank) to exchange rate depreciation, as depreciation clearly seems to induce inflation in many small open developing economies. This unclear and in some cases non-existent relationship between exchange rates and fundamentals is known as the exchange rate puzzle. It needs to be explained through a clear understanding of exchange rate dynamics, considering the possibility of endogeneity with macroeconomic fundamentals, as well as inclusion in the exchange models of other variables mostly related to the microstructure of the exchange market that are expected to influence exchange rate movements. For instance, Figure 2 in the Annex shows, according to market principles, that an increase in demand for exchange, indicated by the order flow, leads to depreciation, and as soon as pressure shows an opposite movement (from August 2016 in the graph shown in Figure 2), the exchange rate immediately follows the same movement, revealing appreciation in response to a fall in currency demand pressure.

The objective of this paper is to estimate to what extent the microstructure of exchange markets can help to explain exchange rate dynamics in Mozambique. This is done by applying hybrid models of exchange rates, as in Evans and Lyons (2002), combining macro and micro variables to model the exchange rate, which is important to help explain the exchange rate puzzle and propose a variable that can potentially improve exchange rate predictions and monetary policy implementation.

[7] According to the quotation style in Mozambique, a depreciation (appreciation) means an increase (decrease) in exchange rate (MT/USD).

The article's main contribution is primarily the inclusion of microstructure variables to model exchange rates in Mozambique for the first time; secondly, it extends the hybrid model of Evans and Lyons (2002) by including one more fundamental variable, and other relevant factors that specifically affect the exchange market, such as central bank exchange interventions, commodity prices and an uncertainty indicator. This paper also supplements Evans and Lyons (2002) by applying a VAR model to control for possible endogeneity between exchange rate and fundamentals.

The paper is structured as follows: next the model is presented, firstly from a theoretical perspective, including the explanation of each variable considered in the model, then the econometric model is discussed followed by results displayed by Impulse Response Functions (IRF) and Variance Decomposition (VD). The consistency of the results is then checked using a long run model (VECM) and also by comparing the main model forecast with a random walk, and finally the conclusions are presented.

2. Model

2.1. Variables

The variables are described in addition to Table 1, with the main descriptive statistics, and this section also intends to explain the economic logic of each variable in the analysis, presenting, in this sense, the economic model.

Exchange rate

This is the key variable to be explained in this study. It refers to the price of one unit of foreign currency (USD) in terms of domestic currency (Meticals), whereby an increase (decrease) in the exchange rate means depreciation (appreciation) in the domestic currency, relative to USD. The bulk of Mozambican net international payments are made in USD, and the country's international reserves are also denominated in USD, therefore central bank intervention in exchange markets is only done in this currency, such that the exchange rate against the USD is the base from which exchange rates against other foreign currencies are derived. Furthermore, the exchange rate deeply affects the domestic economy through different mechanisms such as inflation (from depreciation), trade flows, companies' profits, asset valuations and economic growth (Biggs 2011; Hassan & Simione 2013; Zita & Gupta 2007). In this context, these studies highlight the importance of exchange rates in the

Mozambican economy, as it is so in many small open economies. This country has been using a flexible exchange rate regime since 1994 (Pimpao 1996).

The exchange rate in Mozambique has mostly presented a steep depreciation trend since 2015. In accumulative terms it depreciated around 200% between 2007 and 2016, and within a period of less than two years (2015 and 2016) the domestic currency depreciated by approximately 145%[8]. For better macroeconomic management it is crucial to understand the relationships between the exchange rate and the fundamentals, as well as other variables directly related to the exchange market, such as order flow. The variables described below make up the market microstructure and macroeconomic indicators recommended in the literature as determining the exchange rate, which will be combined in a hybrid exchange rate model.

Microstructure

The approach of explaining exchange rates by analysing the institutional characteristics of the exchange market is known in the literature as the microstructure model of exchange rate determination. Many key aspects of the market are assumed as given, or irrelevant in the case of macroeconomic models, namely: (i) information is not publicly available – a significant part of the factors explaining exchange rates is ignored by not including important information on exchange transactions (real time specific trade volumes and prices)[9], (ii) exchange market players are heterogonous – the exchange rate is affected differently by transactions depending on the features of each player (exchange demands can be for import of goods and services and also for speculation and hedging), and (iii) institutional arrangements – the way business is done in a market also affects price formation. For instance, in a less transparent market, where quantities and prices for each transaction are not available in a timely manner, price adjustments given in response to new information are slower.

[8] These strong shocks in the exchange rate are often followed by riots, strikes, and popular manifestations due to their direct impacts on the cost of living (Brito 2017).

[9] In many undeveloped financial systems, in general, and in the specific case of Mozambique, details of foreign exchange transactions are not public (due to confidentiality rules); therefore, exchange dealers (mainly banks) are privileged to have important private information that can help predict exchange rates and obtain speculation gains.

The microstructure models of exchange rates use quantity and price indicators to reflect market characteristics, namely order flows and spreads (bid and ask rates), respectively. In some cases, market turnover (total transaction volume) is used as an indicator of quantity (Hoosain, Joubert & Kabundi 2017), however, order flow has the advantage of being a signalled volume (Lyons 2001), depending on whether the market is under pressure or not.

For the purpose of this paper, order flow is used as the microstructural variable, indicating purchases of exchange currency with a positive sign (demand), and sales with a negative sign (supply), so that the net value indicates demand pressure in the market, which is expected to have a positive impact on exchange rates (Gereben, Gyomai & Kiss 2005; Evans & Lyons 2002). However, as microstructure models were first used in liquid and developed markets, Hassan and Simione (2013) do not identify the relevance of its use in the case of Mozambique with infant financial markets, small market turnover and also because the demand for exchange in the country is essentially for importing goods. While it may be true that the country’s foreign exchange market is still very small compared to other markets internationally, it nevertheless appears to be a rapidly growing market, with an increasingly significant share of the country’s GDP, in addition to its segmented structure and also rising participation of multinational players[10] with experience and exposure to developed financial markets, suggesting the existence of important information to be explored in the market, which can help to predict exchange rates and other macroeconomic variables.

Table 1, below, shows foreign exchange market turnover overtime. In 2007 the exchange market turnover was 31% of GDP and by 2014 it had reached a share of 79%.

Table 1: Foreign exchange market turnover

	billions USD						
Year	Banks_Customers	Interbank	Exchange Bureaus	CB_Interventions	FX Market Turnover	GDP	Share of GDP
2007	2.52	0.29	0.24	0.15	3.21	10.42	**31%**
2014	9.23	2.59	0.10	2.09	14.02	17.72	**79%**

Source: Bank of Mozambique (The central bank): www.bancomoc.mz

The table also reveals the structure of the exchange market in Mozambique. This market is regulated by the central bank, which is responsible for implementing monetary and exchange

[10] International commercial banks, multinational companies involved in the exploration of mega projects in mining and other natural resources, most of them listed on the largest stock exchanges in the world.

policy. According to the Foreign Exchange Law[11] of Mozambique, only the following institutions are authorised to operate exchange business in Mozambique: commercial banks, bureaus of exchange, travel and tourism agencies, and some specific hotels and shops authorised by the central bank. In this group only commercial banks can transact large amounts with companies, and they also operate as dealers, intermediating foreign exchange business. As can be seen in the Table 1, most transactions are made by commercial banks and their customers (primary markets) where orders are initiated; then banks, if they cannot meet demand, seek to get it from other banks or from the central bank, in the interbank foreign exchange market segment. It is in this sequence that the order flow signals are transmitted and reflected in the exchange rate.

More importantly, as Lyons (2001) finds, order flows carry important information about foreign currency exchange buyers or sellers' perceptions of fundamentals, received firsthand by dealers (banks)[12] that interpret and consider them in price (exchange rate) formation. In this sense order flow intermediates the relationship between fundamentals and exchange rates, therefore explaining the exchange rate puzzle.

This study considers commercial banks and their customers, for measuring order flow, as this is the main and largest segment of the exchange market, from which the demand in the interbank market is mostly derived. Exchange demand is dominated by fuel imports (made by a syndicate of banks indicated by the Government) and the supply side is majority led by multinational corporations operating in minerals, fisheries, agricultural and other key natural resource exploitation. Given the expertise of these players and confronted with some signs of speculation, the central bank updated specific regulations in order to oblige all exporters to convert export revenues (mostly in USD) within 90 days after receiving them.

Macroeconomic fundamentals

The variables presented below are part of traditional models of exchange rate determination, based on price levels and interest rate differences between domestic and foreign counterparty economies.

The first model builds on the PPP principle, as demonstrated below:

[11] Law no. 11/2009, of March 11 (www.bancomoc.mz).
[12] This is not publicly available information.

$e = \frac{\mathrm{P}}{P^*}$

(a)

where, e is nominal exchange rate, and P and P^*, are prices in the domestic and foreign economy, respectively. Taking logs of equation (a), we obtain:

$\ln e = \ln p - \ln p *$

(b)

$\Delta e = \pi - \pi^*$

(c)

Taking the first difference of each logarithm results in inflation differentials, in which a country with increasing inflation relative to its foreign partner is expected to face currency depreciation, as its goods are becoming more expensive than those from abroad, hence increasing demand for foreign currency (implying a fall in demand for domestic currency). In the same way, appreciation is expected to occur in the case of decreasing domestic relative prices.

As a measure of prices, the CPIs of both countries are used in this paper, which is the most used indicator for inflation, despite the fact that there are controversies on what price index to use, on whether to consider only traded goods, and even identifying an index that also includes commodity prices[13] (Frenkel 1976). Another subject of debate on PPP models is related to causality, where although there is a demonstrated correlation between exchange rates and price differentials, there is no certainty about the direction of causality; in most cases it is assumed to be a bidirectional relationship (Isard 1995).

This hypothesis has been criticised as having unrealistic assumptions, mostly when considering economic differences between countries, such that assumptions of perfect substitutability between the traded goods, law of one price, factor equalisation and same shares of the goods in CPI cannot hold. Moreover, with imperfect competition in the market (product diversification), we would hardly have the same price of goods (even if the same product) sold in different countries, mainly in the short run where prices are sticky (Krugman & Obstfeld 2018), and finally, the law of one price fails in scenarios of transport costs, import taxes and other barriers to trade. However, empirical analysis and tests support the PPP

[13] Commodity price is also considered as an exogenous variable in the model presented in this paper.

hypothesis in the long run, where studies find significant results (Flood & Taylor 1996) including for the particular case of Mozambique (Zita & Gupta 2011; Hassan & Simione 2013). Also, as exchange demand in Mozambique is mostly driven by the import and export of commodities with prices defined internationally, it seems sensible to assume that PPP would hold, at least in the long run.

The other endogenous variable considered in this analysis is the interest rate differential, based on another well-known principle of interest rate parity. Keynes (1932) intuitively presented the interest parity hypothesis, where monetary authorities increase interest rates to appreciate domestic currency. This approach has two types: one is Covered Interest Parity (CPI), which includes a forward premium to cover exchange risk while the other, Uncovered Interest Parity (UIP), does not at first, and in this case it is difficult to test as there is a lack of reliable data to measure expectations (Wong et al 2002). The UIP can be represented by the following equation:

$$E_{t+1} - e_t = \beta(i_t - i_t^*) + u_{t+1}$$
(d)

being E_{t+1}, expected exchange rate, and i and i^*, the interest rates of the domestic and foreign countries, respectively. Assuming that UIP holds and agents have rational expectations, following an increase in the domestic interest rate relative to the foreign one, due to arbitrage opportunity, domestic currency is expected to depreciate and parity can be maintained[14] (investors become indifferent between having the same assets in domestic or foreign currency). This theory is further reinforced by Dornbusch (1976), who identified an exchange rate overshooting effect following an increase in interest rates (via expectations), then it bounces back to the new equilibrium. However this line of thought is contested as, in reality, the coefficient β in equation (d) is generally negative, where domestic currency appreciates in response to an increase in interest rate differentials, because agents do not have rational expectations and they invest in currencies that ensure better returns (Engel 2014)[15], therefore demand for that currency increases, then appreciation occurs. This principle is also

[14] As before parity occurs, with a higher interest rate in domestic currency, agents will prefer to borrow in a foreign country where interest rates are lower to invest in domestic currency, exploring arbitrage opportunities.
[15] Regarding this debate, Engel (2014) refers to a postponed overshooting that explains the UIP puzzle.

highly criticised due to its strong assumptions, according to which assets denominated in both currencies are perfect substitutes of each other, which may not be realistic due to capital controls[16], transaction costs and different country risks involved in each asset. Although it may not seem wise to assume UIP conditions when modelling the exchange rate in Mozambique due to its relatively small financial market and as it is less connected to international financial markets, however, as companies involved in international trade are authorised by law to maintain part of their capital in domestic and foreign deposits, it is worth having a theoretical basis to analyse the effects of these relations on the exchange rate. For this purpose, the paper uses the rate of interbank money market, which, in the case of Mozambique, is the most liquid and has less friction[17] relative to other segments of the country's financial markets[18], to compare with the similar rate in the US (effective federal funds rate).

Mozambique-specific case variables

Central bank intervention in foreign exchange is the first variable considered in the particular case of Mozambique to be included in the model. This is a common situation, mostly in emerging economies, as reported by a Bank for International Settlements (BIS) study by Miyajima and Montoro (2015), due to difficult substitutability between domestic and foreign assets, and less transparent systems where central banks have better information about market conditions. The effectiveness of these interventions, mainly those where central banks intend to transmit signals so that expectations can be anchored, is questioned based on the fact that the political credibility of many central banks in developing economies is still weak, therefore interventions end up creating uncertainties, making exchange rates more volatile (Beckmann & Czudaj 2017).

In Mozambique, the central bank intervenes in the exchange market fundamentally to stabilise the exchange rate, considering the inflationary implications of having a depreciating currency. In this sense the central bank intervenes mostly from the sale side, which with the same objective of combating inflation, also uses these interventions to mop up excess

[16] UIP also assumes perfect capital mobility.

[17] Omer, Haan and Scholtens (2012) also use LIBOR rates to empirically test UIP. They do so to avoid market friction that may lead to forcing the rejection of UIP. Furthermore, interbank markets are the initial and key stages of the monetary policy transmission mechanism where expectations start to be formed.

[18] Other empirical studies use the rates on Treasury Bills, however, in the case of Mozambique, this market is still in the early stages of development (still illiquid), and it carries the most fiscal risk. Treasury Bills are issued by the central bank on behalf of the Government for mopping up excess liquidity.

liquidity in the domestic currency. The central bank intervenes with exchange purchases to contain domestic currency appreciation (which is less frequent) and in many cases to meet the international reserves target. Table 2 below shows that in general the central bank intervenes more in the market when there is more demand pressure that leads to higher exchange rates. In 2007, when foreign currency demand (measured by order flow) was relatively lower (demand was around USD 237.5 mio above supply), so was the exchange rate (25.5 MT/USD). As the order flow increased, the central bank strengthened its presence in the market, such that net sales increased from USD 409.3 mio in 2007 to approximately 4.1 USD billion and then reduced in 2014, following falls in the order flow and the exchange rate.

Table 2: Impact of exchange interventions

	mio USD		
Year	**OF***	**Intervention****	**Exchange rate**
2007	237.52	409.31	25.46
2010	564.66	4,079.53	33.15
2014	143.69	1,157.38	30.75

* Net purchase, ** Net Sale

It is worth mentioning that the central bank also intervenes in the foreign exchange market through moral persuasion, mobilising banks based on the risks that society faces due to excessive depreciation, however, this is not captured in this analysis due to the difficulties in identifying it. So, the net sales of the central bank are used to indicate exchange intervention, which also helps in analysing the impacts of order flow on exchange rates.[19]

Another special case that is considered in the model is the uncertainties from certain adverse events that the economy frequently faces. The salient event in this context is political instability, mostly following elections where opposition parties protest election results with riots, demonstrations and some cases involving military instability. As in other studies on exchange rates in African countries (where this kind of political instability is common), including a specific dummy to control for these events which have significant effects on

[19] Zhang, Chou and Zhang (2013) found that the impact of order flow on exchange rates was minimised by central bank interventions in exchange markets.

exchange rates is generally recommended[20]. According to Asteriou, Sarantidis and Dimitras (2019), excessive volatility in exchange rates is one the main manifestations of the impacts of uncertainties from political instability in an economy. Applying a simple GARCH model, this article obtains the exchange rate variations (variances) used to indicate volatility and, from this series, a simple average is calculated to function as a threshold above which a value of 1 is assigned and 0, if otherwise, deriving in this case a dummy variable. It is possible to observe that, in fact, the greatest exchange rate volatilities coincide with periods in which political instability is registered. These periods also coincide with times of natural disasters that the country often faces. Figure 3, below, shows that high volatilities were observed during episodes of political and military instability after the 2004, 2009 and 2014 elections, in addition to after recorded floods and earthquakes.

2.2. Econometric model

The data on the variables described above are cleaned before performing the model. The variables are seasonally adjusted, in logarithm form, except interest rates, and stationarity is observed for all of them. Series on the Mozambican economy are obtained from the country's official sources, namely the Bank of Mozambique (www.bancomoc.mz) and the National Institute of Statistics (www.ine.gov.mz). Time series of external variables such as overnight effective federal funds rates and commodity prices are downloaded from the Federal Reserve Bank of Saint Louis database (FRED at www.fred.stlouisfed.org).The analysis covers the period between January 2005 and December 2019.

Evans and Lyons (2002), using a hybrid model that combines macroeconomic and microstructure variables, find encouraging results about the explanatory power of order flow regarding exchange rate determination. Adding to this seminal work and controlling for the risk of endogeneity amongst variables in the model[21], here a VAR model is applied instead[22], considering all variables in the model as endogenous (excluding ones previously identified as exogenous, such as commodity prices and an uncertainty proxy). Furthermore, some important variables are added to the original model defined by Evans and Lyons (2002) as the

[20] In Mozambique, these instabilities can be characterised by military attacks on civilians on main roads, completely paralysing the movement of people and goods and retracting all forms of investment.

[21] For example, according to monetary models of exchange rates, inflation differentials can influence the exchange rate; at the same, as proven by many studies on the Mozambican economy and other developing economies, inflation is seriously affected by exchange rates.

[22] Evans and Lyons (2002) use simple OLS.

authors included, as a fundamental variable, interest rate differential only, because they find this variable sufficient to represent the macroeconomic variables in the model, based on their belief that it is the main source of exchange rate variation and more importantly, because interest rates are available on a daily frequency, while other macroeconomic variables are not. Analysing the Deutsche mark price of dollars, they find a positive and significant sign from order flow to exchange rate, meaning the power of the microstructure variable (order flow) in determining exchange rates. Although with less explanatory power than order flow, they also find consistent results for the case of interest rate differentials. From this analysis Evans and Lyons (2002) present a promising new model of exchange rate determination which does not rely exclusively on macroeconomic fundamentals, and more interestingly they identify the ability of order flow to predict future evolution of interest rates.

The VAR model performed in this paper can be represented as in equation (1) below:

$$Y_t = A_1 Y_{t-1} + \ \dots A_p Y_{t-p} + BX_t + \ e_t \qquad (1)$$

where Y_t is a vector (n x 1) with all endogenous variables described earlier and A_1 is a matrix (n x n) of the parameters on the lagged values Y_{t-p}. The vector X_t contains the two exogenous variables described earlier, and e_t is the vector of disturbances, which are assumed to be identically and independently distributed (mean zero, constant variance and without serial correlation).

The model seems to be stable, as can be seen from Figure 4 (in the Annex), where the points lie in the unit root circle, suggesting stationarity, and the model also does not suffer from serial correlation and heteroscedasticity (Table 2, Annex). The results obtained from the VAR model are reported next.

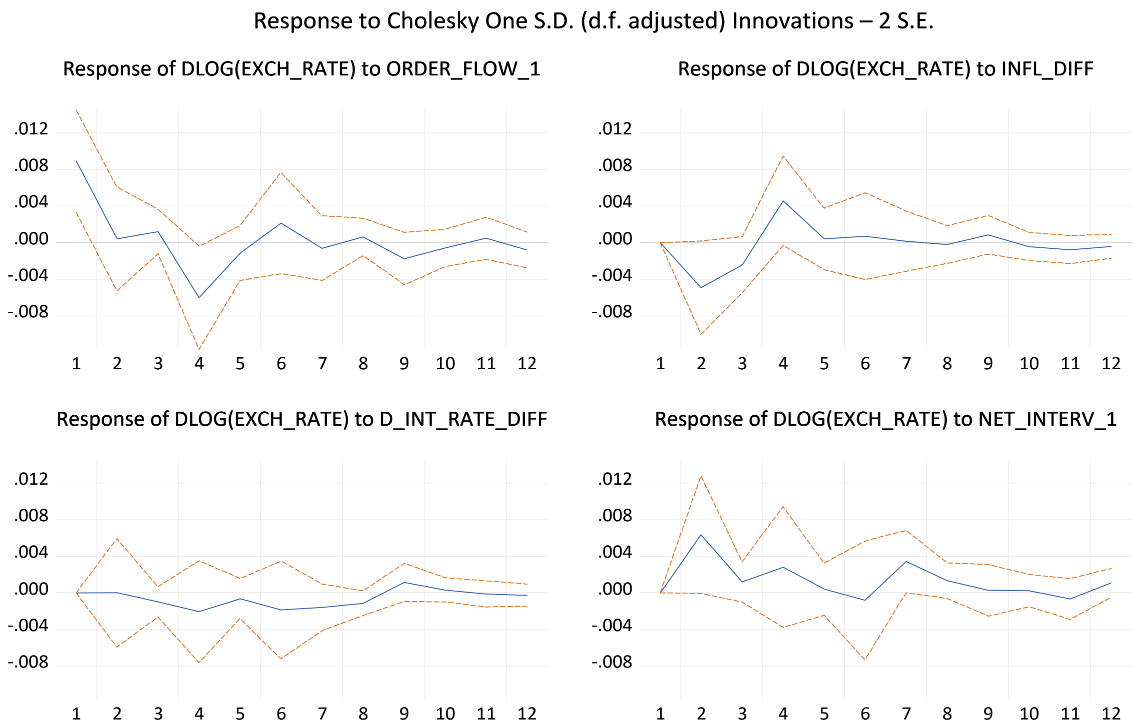
3. Results

The results are presented in terms of IRF, allowing some analysis in terms of exchange rate responses to shocks in other endogenous variables considered in the model, both fundamentals and microstructure indicators. Secondly, the results are also reported in terms of VD to identify the most important source of exchange rate variations amongst the variables in the model.

IRF

The graphs in Figure 1 below represent the responses of the exchange rate to a positive (orthogonal) shock (one standard deviation) in each of the endogenous variables, dynamically during twelve periods (one year). The graphs also include the bounds defined by a 95% confidence interval. The whole set of IRF can be seen in Figure 5 (in the Annex).

Figure 1.



(i) *Following a positive shock to order flow, the exchange rate immediately depreciates*: this result is consistent with general economic theory, where prices increase due to a rise in demand. In this case, the commercial banks in Mozambique that operate as exchange market dealers, facing demand pressure, reflect this scarcity into prices. Then after the second period the exchange rate tends to appreciate, moving back to equilibrium at the same time as the central bank strengthens its intervention in the market in response to depreciation (see Figure 5, Annex);

(ii) *Exchange rate seems to appreciate in response to an increase in inflation differentials:* this result presents an opposite sign to that expected, and it seems significant as both bounds lie in the negative region at least during the first two periods. This can be interpreted as resulting from an increase in interest rates by the central bank endogenously reacting to a risk of inflation from domestic currency depreciation. In this sense we have, in fact, exchange rates determining fundamentals and not the opposite. However, after the second period the exchange rate shows signs of depreciation. This is also consistent with previous studies on exchange rate determination in Mozambique that did not find significant results of the PPP hypothesis (Zita & Gupta 2011; Hassan & Simione 2013);

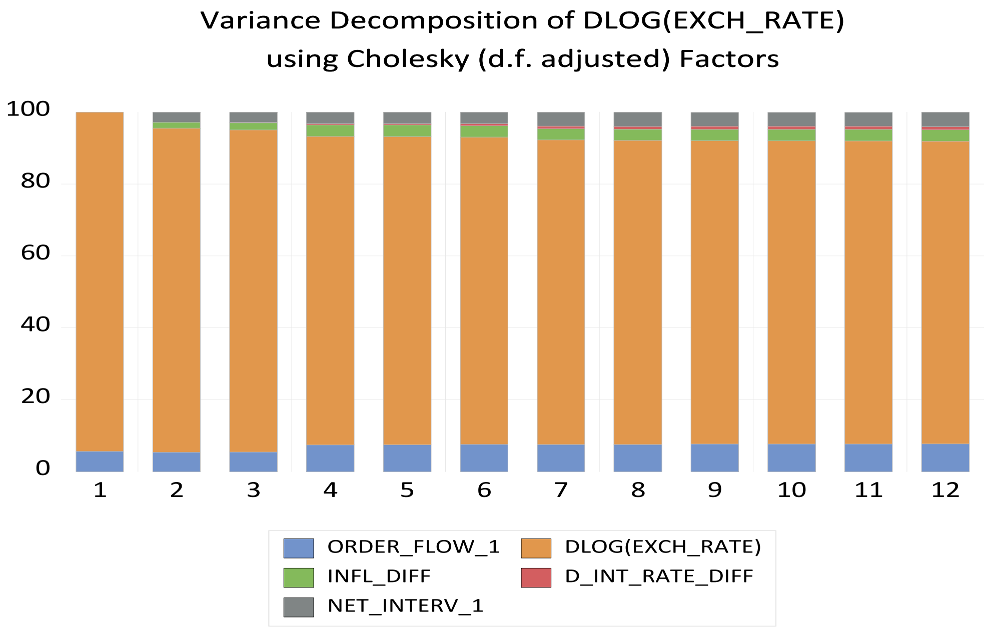
(iii) *Exchange rate does not seem to react significantly to shocks to interest rate differentials, at least in the short run:* showing signs of timid appreciation after the second period, which if confronted with the positive response observed by interest rates reacting to a depreciation shock, can lead to the conclusion that the central bank increases interest rates fearing inflation pressure due to depreciation. Again, the exchange rate appears to be the variable determining economic fundamentals;

(iv) *Surprisingly, exchange rates do not react to a positive shock to net exchange sales of the central bank in the first period and increase in the second, then moving back in the third:* considering that the central bank reacts significantly positively (rising net sale interventions) in response to depreciation (Figure 5, Annex), it is possible to infer that the intervention is not sufficiently strong to contain the depreciation, also considering that the central bank has different objectives when intervening in the exchange market and some of them are conflicting. Additionally, exchange interventions are more effective in restraining appreciation than depreciation (Daude, Yeyati & Nagengast 2014).

VD

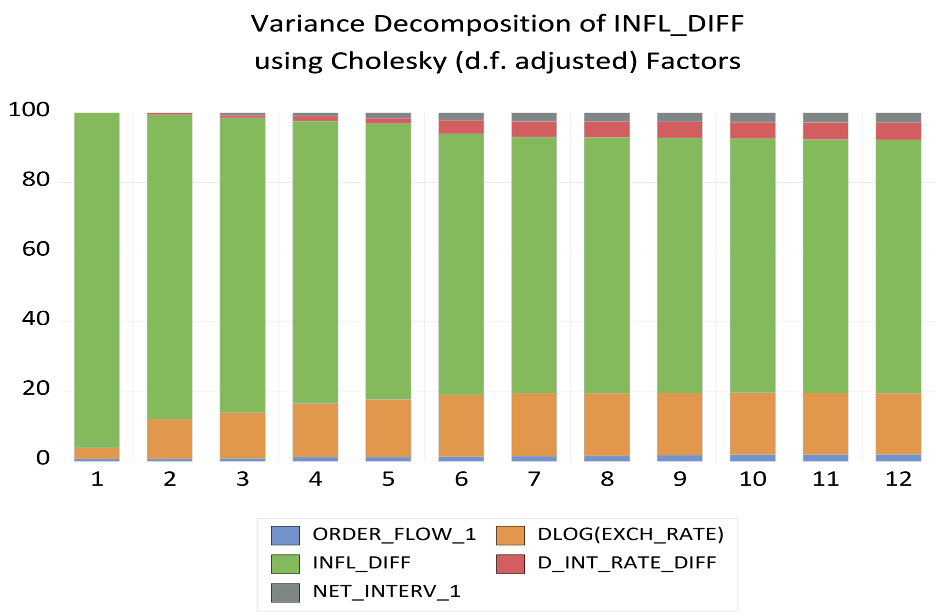
Figure 2 below contains the results of VD, showing comparatively how well exchange is explained by the variables in the model.

Figure 2.



Exchange rate variations are mostly explained by shocks to itself. Excluding its own values, this variable is mostly explained by shocks to order flow, secondly the inflation differential and, then central bank intervention. Interest rate differentials contribute a very small amount. As discussed earlier, given that the effects of order flow on exchange rates are somehow smoothed by central bank interventions, it can be concluded that shocks to order flow (microstructure) originate more changes to exchange rates than the fundamentals. From the VD of inflation (Figure 3), we can see that, excluding its own values, inflation is mainly explained by exchange rates, leading us once again to the conclusion that exchange rates determine fundamentals and not the opposite, at least in the short run.

Figure 3.



3.1.Robustness check

For the purpose of robustness checks on the results as a form of sensitivity analysis the VAR model is performed with different ordering of the variables, placing the exchange rate at the bottom, meaning that it reacts contemporaneously to all the variables in the model and the results are consistent where shocks to order flow significantly impact exchange rates as expected, while the others do not seem significant and some show opposite signs to the economic theory (Figure 6, Annex).

Another means of testing the consistency of the model is to perform causality tests both in the model (jointly – Block Exogeneity Granger Causality Test) and pairwise (Granger causality tests), which together reveal the following, at 5% level (see Tables 2 and 3, Annex):

(i) Exchange rate Granger causes fundamentals and not the opposite;

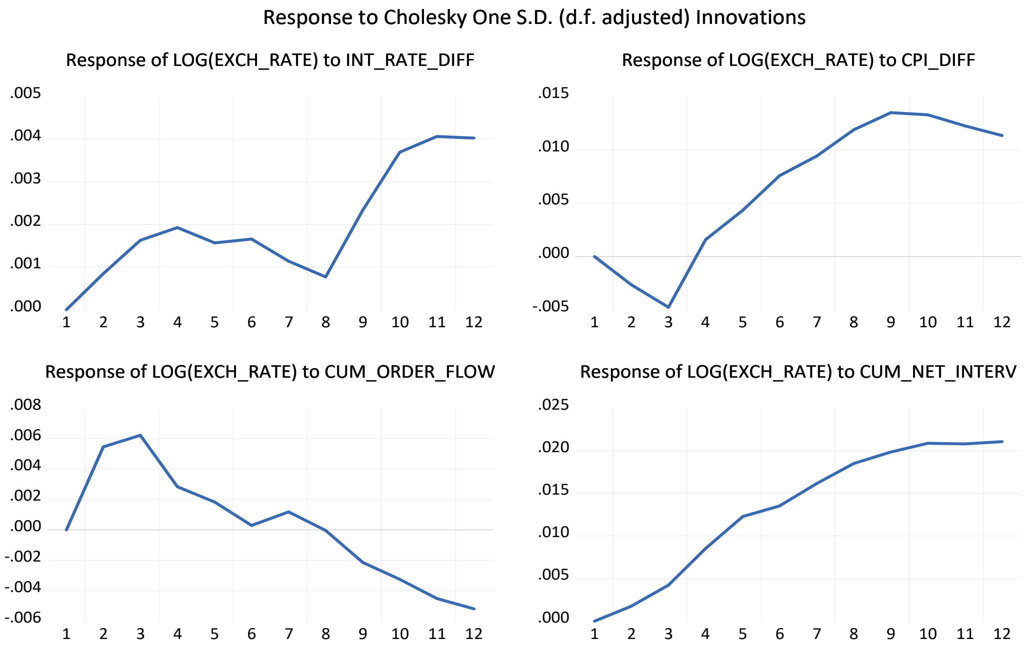
(ii) Fundamentals Granger causes order flow;

(iii) Order flow Granger causes exchange rates.

This shows that while exchange rates can help to predict fundamentals, the reverse is not true in the short run; the order flow rates are sensitive to fundamentals, therefore, order flow establishes a bridge between fundamentals and exchange rate.

Additionally, the consistence of the model is verified with the inclusion of the long run relationship, by performing a VECM with the same endogenous variables, but in non-stationary format as required. For example, instead of using inflation or exchange rate variations as in VAR, this time, CPI and exchange rate in levels are used. In the case of order flow, net intervention cumulative variations were used, as also done by Evans and Lyons (2002), for the case of order flow. These variables revealed the presence of three cointegrating equations (Trace Test) and the IRF results are as shown by Figure 4 below:

Figure 4.



Considering long run relationships, the results are still consistent with those in VAR, with the exchange rate responding positively to one standard deviation shock to order flow, while it depreciates in response to interest rate differentials, which is consistent with UIP. However, as the response to inflation is contradictory, this leads to the belief that is a case of central bank reaction to depreciation, in this sense, indicating a scenario where it is the fundamentals that adjust to changes in exchange rates and not the opposite, as also demonstrated by the weak exogeneity test performed to each cointegrating coefficient. The weak exogeneity tests show that exchange rate, order flow and net intervention are weakly exogenous while fundamental variables are not, revealing that the macroeconomic variables are the ones adjusting to long run imbalances.

Finally, to see how well the model fits the data, the model is used to forecast exchange rates and evaluate whether it can outperform the simple random walk model (In-sample static forecast from January 2019 to December 2019). As can be seen from the graphs below, both forecasts seem to work well, as in both cases the forecasted values and the actuals lie inside the boundaries of 95% confidence intervals. Looking into the forecast performance indicators shows that the model developed in this study performs better than the random walk in almost every indicator (Table 4, Annex).

Figure 5.

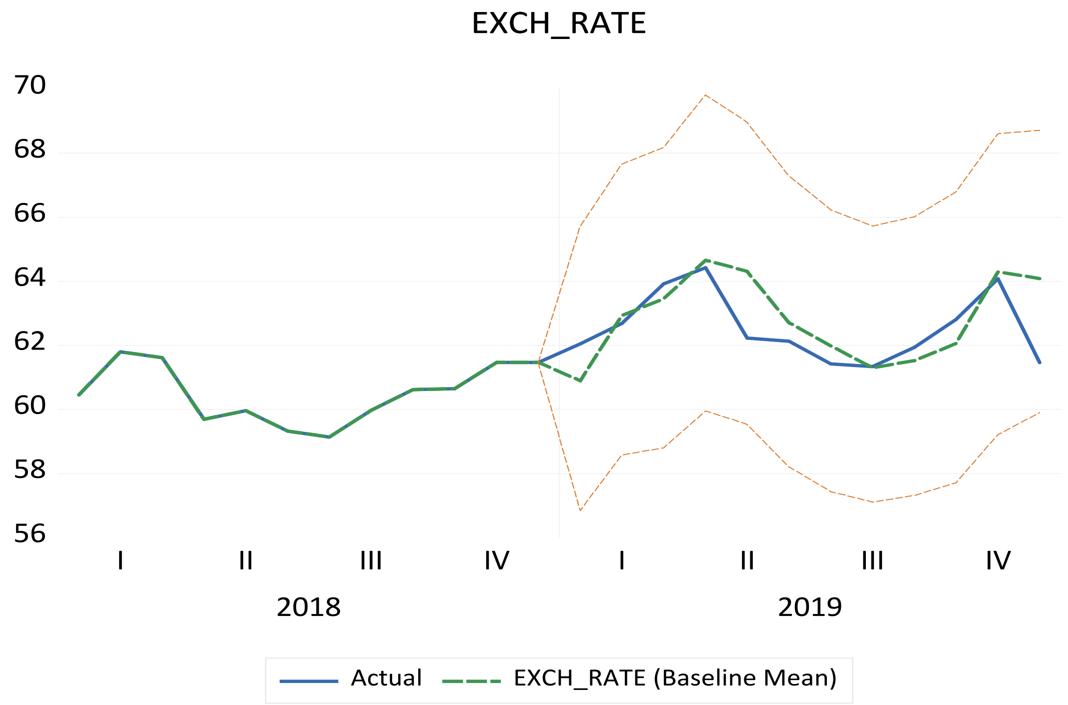
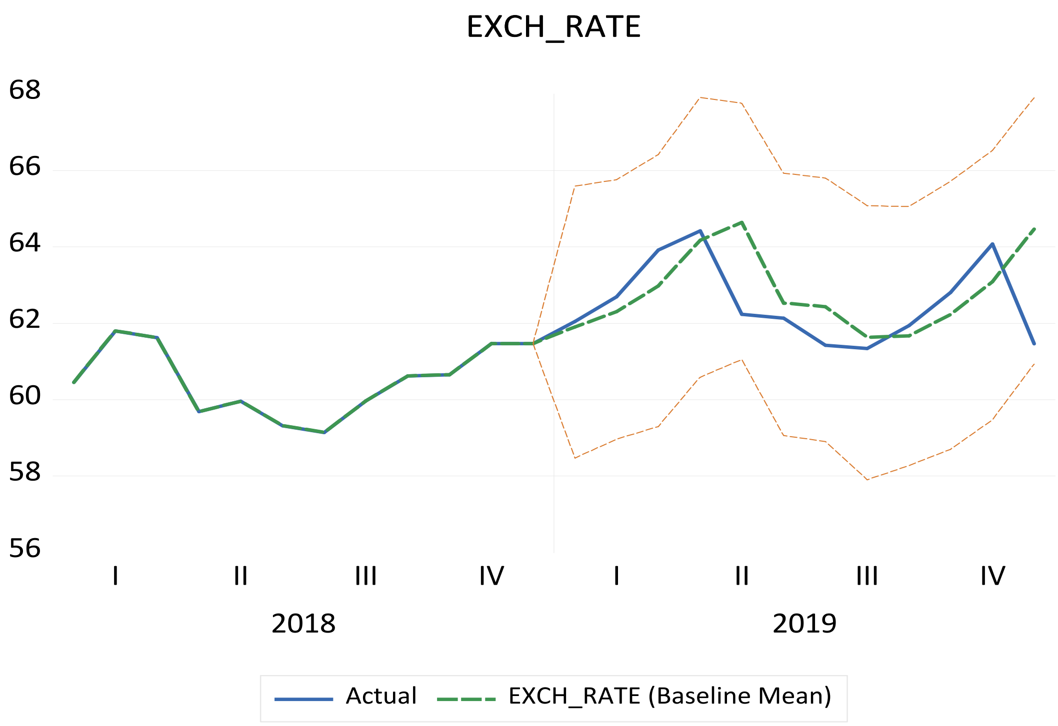


Figure 6.



4. Conclusions

As this paper has tried to demonstrate, order flow can potentially be used to explain exchange rate dynamics in Mozambique. Because order flow, primarily, reflects agents' interpretations about fundamentals, it is not only a valid instrument to predict exchange rates, but also intermediates the relationship between fundamentals and exchange rate. In this sense, order flow helps to explain the exchange rate puzzle.

Combining the traditional fundamental variables with exchange market microstructure indicators (hybrid models) has the potential to improve forecasting, and in this regard, order flow can also be used as a proxy for expectations of economic agents about the future evolution of macroeconomic variables, therefore contributing to effective forward-looking monetary policy.

The analysis in this paper also opens space for further debates and studies on micro foundations of foreign exchange demand, based on optimisation techniques (e.g. DSGE models), with high frequency data, and considering the results obtained in the process of monetary and exchange policy implementation.

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Annex

Figure 1.

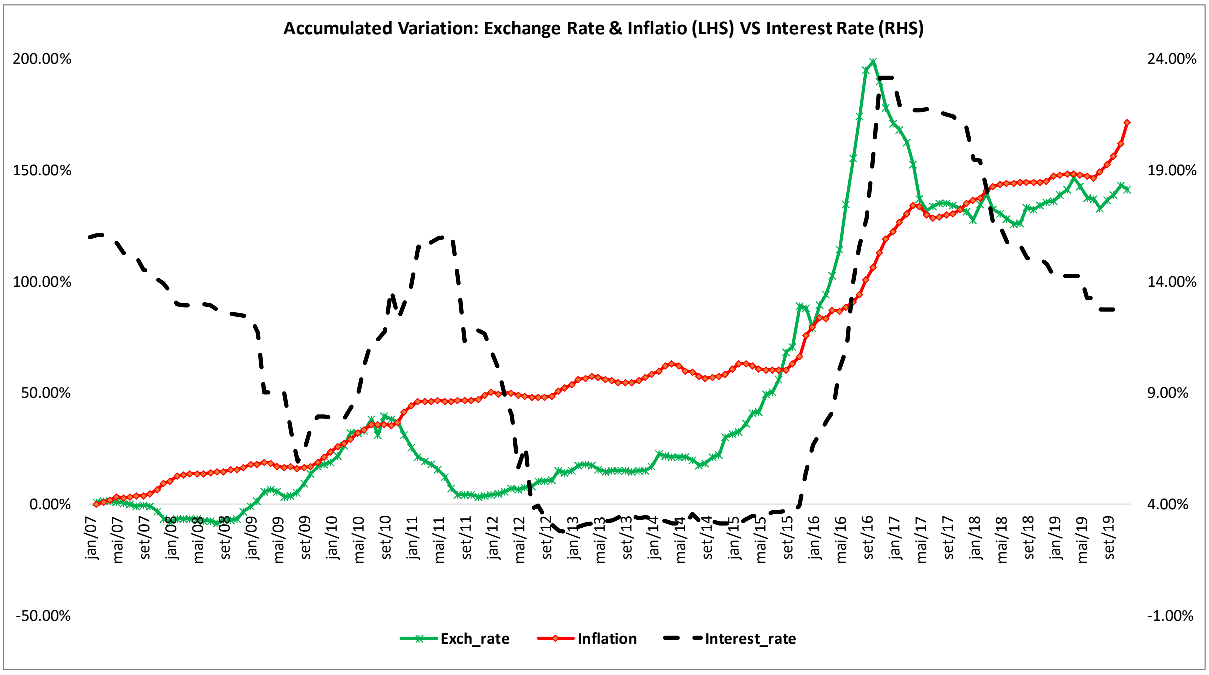

Figure 2.

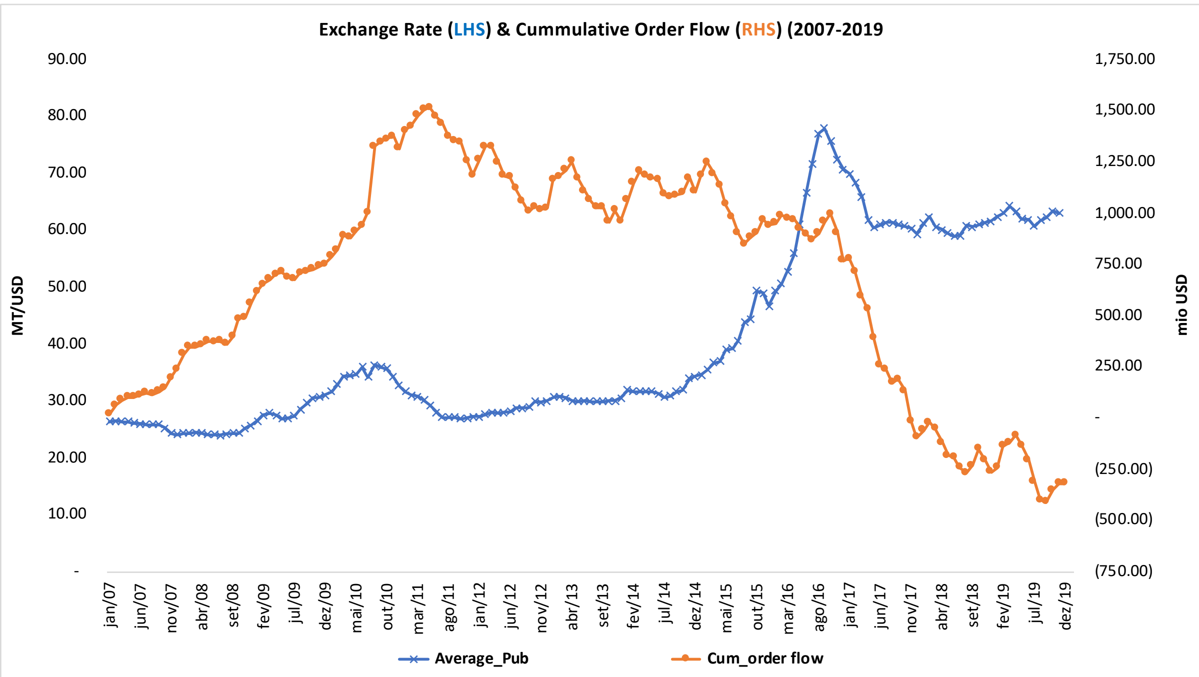

Figure 3.

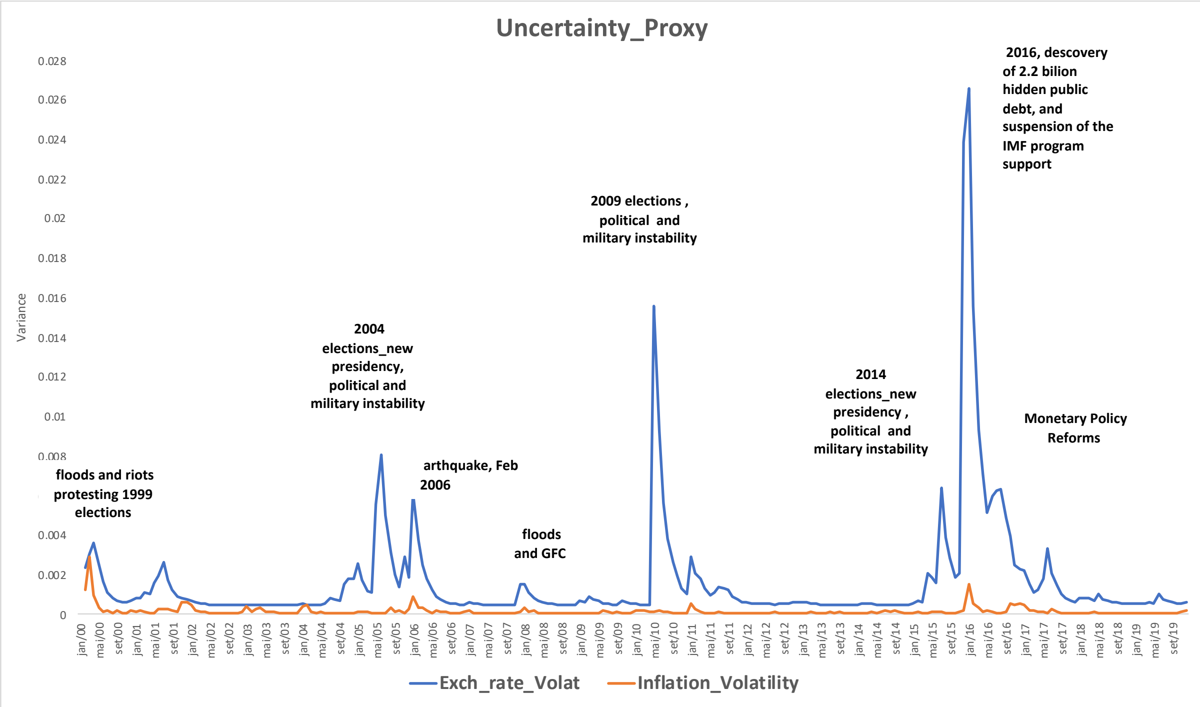

Figure 4.

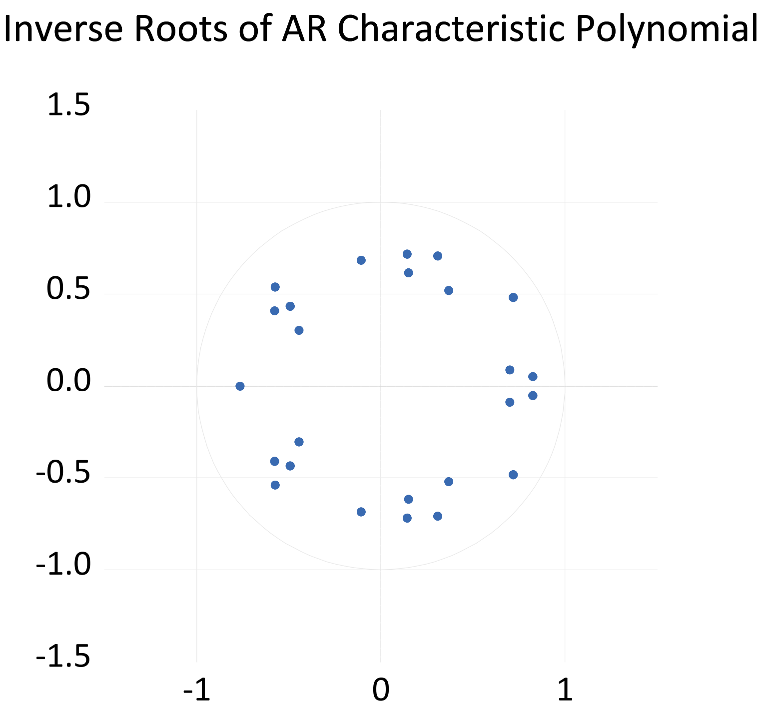

Figure 5.

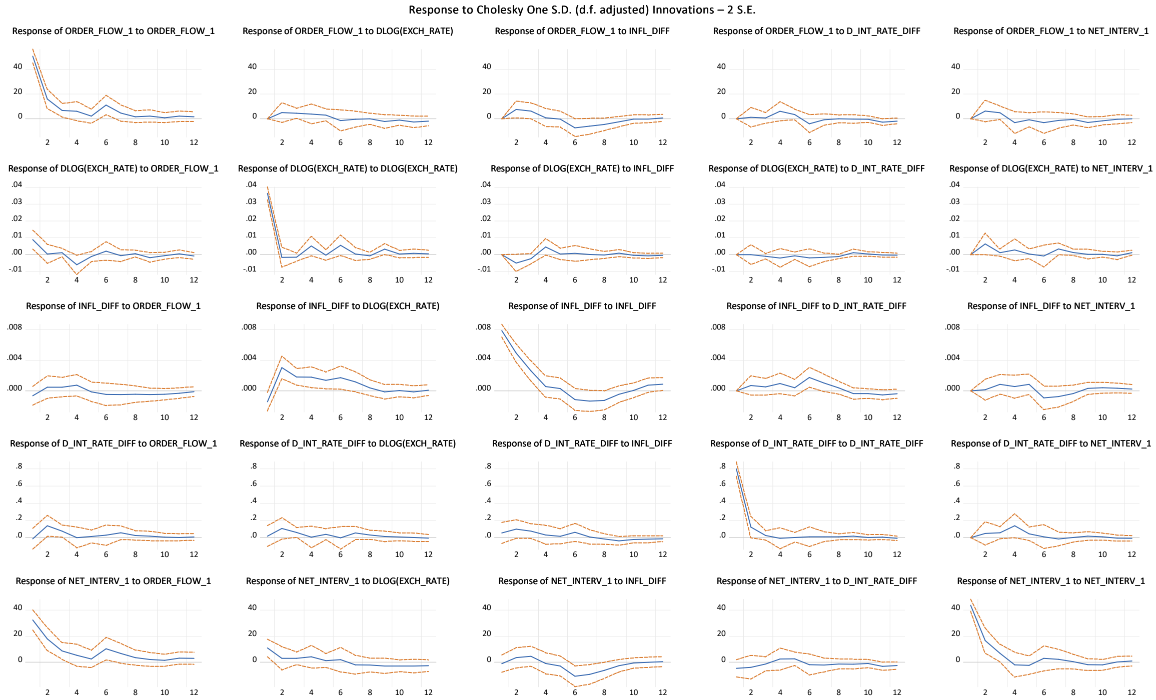

Figure 6.

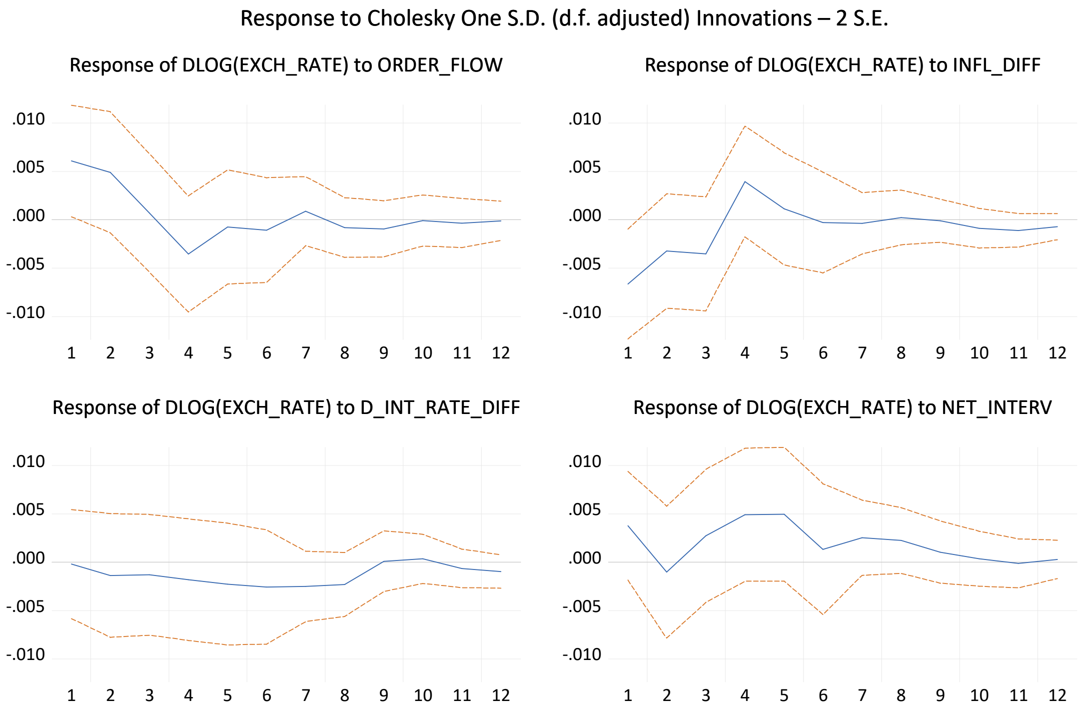

Table 1. Descriptive statistics

	Exchange Rate	Order Flow	Inflation Differential	Int_rate differential	Commodity Price
Mean	0.66	0.26	0.50	0.02	0.21
Median	0.17	9.03	0.25	-	0.80
Maximum	25.00	321.57	5.71	4.33	7.98
Minimum	(18.45)	(147.76)	(2.33)	(2.81)	(20.15)
Std. Dev.	4.01	56.49	1.16	0.96	4.39

Table 2.

Pairwise Granger Causality Tests

Sample: 2005M01 2019M12
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Prob.
INFL_DIFF does not Granger Cause D_INT_RATE_DIFF	175	2.42259	0.0377
D_INT_RATE_DIFF does not Granger Cause INFL_DIFF		2.24109	0.0526
ORDER_FLOW does not Granger Cause D_INT_RATE_DIFF	175	1.31147	0.2616
D_INT_RATE_DIFF does not Granger Cause ORDER_FLOW		2.04698	0.0747
DL_EXCH_RATE does not Granger Cause D_INT_RATE_DIFF	175	3.87739	0.0024
D_INT_RATE_DIFF does not Granger Cause DL_EXCH_RATE		0.28082	0.9231
ORDER_FLOW does not Granger Cause INFL_DIFF	175	1.04767	0.3916
INFL_DIFF does not Granger Cause ORDER_FLOW		6.01077	4.00E-05
DL_EXCH_RATE does not Granger Cause INFL_DIFF	175	8.84163	2.00E-07
INFL_DIFF does not Granger Cause DL_EXCH_RATE		1.82365	0.1109
NET_INTERV does not Granger Cause ORDER_FLOW	175	0.64259	0.6675
ORDER_FLOW does not Granger Cause NET_INTERV		2.83299	0.0176
DL_EXCH_RATE does not Granger Cause ORDER_FLOW	175	0.97908	0.4323
ORDER_FLOW does not Granger Cause DL_EXCH_RATE		0.71929	0.6098

Table 3.

Block Exogeneity Granger Causality Test

Dependent variable: EXCH_RATE

Excluded	Chi-sq	df	Prob.
ORDER_FLOW	8.71304	3	0.0334
INFL_DIFF	9.264799	3	0.026
D_INT_RATE_DIFF	0.77812	3	0.8547
NET_INTERV	6.494768	3	0.0899
All	**21.83606**	**12**	**0.0394**

Table 4.

	Null (H0): there is no SC/H	
Joint Test	**P_value**	**Observation**
Serial correlation (SC)	0.5775	no serial correlaion
Heteroskedasticity (H)	0.0722	no heterosk.

Table 5:

Forecast evaluation statistics	VAR	RW*
Bias	0.306	0.296
Mean square error (MSE)	1.195	1.550
Root mean square error (RMSE)	1.093	1.245
Standard forecast error (SE)	1.10	1.46
Mean absolute error (MAE)	0.781	0.889

* Random Walk