Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2022.vol9.no1.0189

Global Oil Prices and Exchange Rate: Evidence from the Monetary Model

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Received: September 30, 2021 Revised: December 05, 2021 Accepted: December 15, 2021

Abstract

The study empirically examines the impact of monetary fundamentals along with global oil prices on the Pak-rupee exchange rate using the monthly data over 2001–2020. Employing the cointegrating vector autoregressive with exogenous variables (VARX) and vector error correction model with exogenous variables (VECMX), the study analyzes the impact of domestic monetary fundamentals while considering the foreign variables as weakly exogenous. In order to account for the structural breaks in the data, the Lagrange multiplier (LM) unit root test with two structural breaks has been used (Lee & Strazicich, 2003). The empirical results reveal that the domestic and foreign monetary variables significantly explain the exchange rate movements in Pakistan both in the long run and in the short run. The dynamic properties of the monetary model of exchange rate have been analyzed using the persistence profile analysis and generalized impulse response functions (GIRFs). The results reveal that the responses of shocks to domestic monetary fundamentals are consistent with the predictions of the monetary model of the exchange rate. Furthermore, being a net oil importer, a rise in global oil prices significantly depreciated the Pak-rupee exchange rate over the period of study. The global financial crisis (GFC) and pandemic (COVID-19) were also found to cause the Pak-rupee exchange rate depreciation.

Keywords: Monetary Fundamentals, Global Oil Prices, VECMX, GFC, COVID-19

JEL Classification Code: E4, E5, F31, F41, G1

1. Introduction

Exchange rate modeling has remained an inquisitive research area in economics and finance with the continuous evolution of theories and techniques over time. The exchange rate is believed as a key factor to stabilize inflation, boost investment, maintain external competitiveness and enhance overall growth in an economy (Oliveira, 2014; Cheung et al., 2019; Khan & Nawaz, 2018). A stable exchange rate is a prerequisite for export-based economic growth, as a misaligned exchange rate may generate prolonged macroeconomic instability in developing countries (Dumrongrittikul & Anderson, 2016). The exchange rate is also deemed as a means to understand the impact of monetary policy on its internal and external position in the global economy predominantly, utilizing the monetary model of the exchange rate (Junttila & Korhonen, 2011). According to the monetary model, the exchange rate is the relative price of two countries' currencies, which is governed by their money demand and supply functions (Neely & Sarno, 2002). The monetary model of the exchange rate is regarded as an attractive instrument of analysis in international finance (Ibhagui, 2018). It acts as a long-term benchmark for comparing the value of two currencies and evaluating whether a currency is overvalued or undervalued (Rapach & Wohr, 2002).

Despite its theoretical appeal and policy relevance, the monetary model fails to provide a convincing explanation of exchange rate movements. Following Meese and Rogoff's (1983) criticism of the monetary model's poor performance, a number of scholars have sought to identify its sources of misspecification (for instance, Rapch & Wohr, 2002; Beckmann, 2013; Cheung, 2005; Cheung et al.,

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2019). Abbott and De Vite (2002) and Beckmann (2013) argued that the weak performance of the monetary model is associated with a priori restrictions on the parameters in the reduced-form monetary model. They noted that the reduced-form monetary model restricts the variables without structural identification of the cointegrating relationships and further imposes restrictions on the adjustment parameters of the monetary model. Furthermore, Yunus (2001) and Zhang et al. (2007) affirmed that relaxing the a priori equality restrictions on the parameters associated with domestic (foreign) monetary fundamentals is expected to provide more realistic results.

Besides, the internationalization of the global economies has raised preoccupation with the exchange rate in recent times. Therefore, modification of the traditional exchange rate models can provide deeper insights to understand the complex exchange rate dynamics. In this regard, the monetary model of the exchange rate might be theoretically accused of ignoring factors that directly influence the current account position and thereby alter the exchange rate, such as oil prices (Lizardo & Mollick, 2010; Rasasi, 2018). The inclusion of real factors in the monetary model might be of high relevance as they affect the international capital movements and portfolio choices. Oil is considered one of the valuable commodities in the global market and the exchange rate is highly vulnerable to oil price changes (Qiang et al., 2019). The rise in oil prices directly influences the U.S Dollar exchange rate and the causality runs to other trading currencies as well (Alam et al., 2020). An increase in oil prices raises production costs, prices of petroleum products, import bills, and inflation, all of these hinder economic activity and stifle trade and thereby, affect the exchange rate (Cavalcanti & Jalles, 2013). Furthermore, oil price can alter the currency value directly through terms of trade effect, wealth effect, and portfolio channels, which in turn affect the balance of payments (Beckmann & Czudaj, 2013; Habib et al., 2016; Beckmann et al., 2020).

Against the above backdrop, the current study aims to consider the role of monetary fundamentals along with crude oil prices to examine exchange rate movements in Pakistan. In the last two decades, Pakistan has been facing wide fluctuations in exchange rates, and the persistent weakening of the Pak-rupee led to massive private capital outflows, depleted foreign exchange reserves, increased reliance on external borrowing, and enhanced inflation (Asadullah et al., 2021). In recent times, exchange rate management, along with the escalating inflationary pressures has turned into a major concern in Pakistan. Price stability is the main goal of the State Bank of Pakistan; and the exchange rate and monetary policy are closely linked, despite the absence of explicit exchange rate targeting. Further, the role of external shocks in the form of increased production costs due to the crude oil price hike severely hit the currency value. A rise in oil prices also puts pressure on the demand for US Dollar, which kept Pak-Rupee under severe pressure.

It is worth mentioning that the effects of global variables on developing countries are not orthogonal, and therefore, require an identification. Most empirical literature used the Cholesky identification scheme, which is sensitive to the ordering of variables. However, this study analyzes the effect of domestic monetary variables on the Pak-rupee exchange rate, while considering foreign variables as weakly exogenous under the vector autoregressive framework with exogenous variables (VARX). While employing the un-restricted monetary models, monetary fundamentals for the USA economy are taken as weakly-exogenous to the system since, Pakistan being a relatively smaller economy, is unable to directly influence the USA fundamentals. Besides, Narayan (2020), Iyke (2020), Gongkhonkwa (2021) and Devpura (2021) concluded that COVID-19 has changed exchange rate bubble activity, exchange rate resilience to shocks, exchange rate return predictability, and the oil market globally. Therefore, this study employs the Lee and Strazicich (2003) Langrage Multiplier (LM) unit root test with two structural breaks and caters to the effect of global financial crises (GFC) and COVID-19 through dummy variables.

Although, a number of studies investigated the variants of the monetary model of the exchange rate with reference to Pakistan (for instance, Zakaria et al., 2007; Zakaria & Ahmad, 2009; Khan & Qayuum, 2011; Khan & Nawaz, 2018). However, no study applied the VARX methodology. In this regard, the present study makes three-pronged distinct contributions to the literature. Firstly, the study considers the monetary model of exchange rate augmented with the global oil prices through altering the foreign money demand function. The study also analyses the impact of global financial crises and COVID-19 on the Pak-rupee exchange rate. Secondly, we considered the unrestricted version of the monetary approach, which has gained very little attention. The unrestricted version of the monetary approach assists in determining whether domestic monetary fundamentals are more dominant than foreign fundamentals in the determination of Pak-rupee exchange rate or not? Thirdly, the study also makes a distinct contribution in the way that it employs vector autoregressive with exogenous variables (VARX) framework being useful to investigate the segregated impact of the internal and external factors in exchange rate determination in Pakistan.

The rest of the paper is structured as follows; Section 2 provides the review of the existing literature and Section 3 demonstrates the theoretical considerations of the monetary model of exchange rate; while Section 4 describes the research methodology and data utilized in the study. Section 5 illustrates the empirical results of the study, and Section 6 concludes the study.

2. Literature Review

Throughout the development of a monetary model of the exchange rate, it has appeared to face criticisms on the theoretical and empirical suggested that the depreciation of the dollar leads to the rise in oil import demand due to the fall in prices measured in the U.S dollar (Meese & Rogoff, 1987). However, a number of studies have retained their attention towards testing the relevance of monetary fundamentals in explaining the exchange rate movements. Such as Mark (1995) found the deviation from monetary fundamentals, money supply, and income level as significant drivers of exchange rate movement for the US Dollar exchange rate. Further, Rapach and Wohr (2002) have attempted to test the monetary model for 14 industrialized economies and found the results in favor of the long-run monetary model for more than half of the sample countries. Likewise, the findings of Cerra and Sexana (2010), Georgoutsos and Kouretas (2017), and Ibhagui et al. (2019) also supported the monetary model of exchanges rate.

Some studies have also contributed to the role of non-monetary factors in explaining exchange rate movements. For instance, Evans and Lothian (1993) Yousefi and Wirijanto (2004), Krichene (2006), and Zhang et al. (2008) confirmed the significant role of oil prices in explaining the exchange rate fluctuations. Rassai (2018) further argued that instead of relying on a-theoretical relation between oil prices and exchange rates, a monetary model might be used. In this regard, Lizardo and Malik (2010) utilized the monetary model and found out that an oil price significantly explains the USD exchange rate movements. Likewise, Rassai (2018) also found evidence of a negative relationship between oil prices USD exchange rate against other 12 major currencies.

Since then, the globe has evolved into a global village; the impact of international crude oil prices on the exchange rate entails the realization of the dollar effect and further entails a spillover effect. Studies such as Fratzscher et al. (2013) suggested that the causality from exchange rate to oil prices originates from the U.S Dollar. The changes in U.S Dollar influence the demand and supply of the oil as dollar being the common transaction currency in the international oil market and it further affect the relevant trading currencies. Yousefi and Wirjanto (2005) find that on the supply-side the depreciation of the U.S Dollar results in the decline in oil supply by the OPEC countries and results in the rise in oil price in vague to stabilize the purchasing power of exports revenue in terms of U.S Dollars. On the other hand, De Schryver and Peesman (2015) suggested that the depreciation of the dollar lead to the rise in oil import demand due to the fall in prices measured in the U.S dollar. Further, Beckmann and Czudaj (2013), Habib et al. (2016), and Beckmann et al. (2020) affirm the relevance of the U.S Dollar in the global oil market. The review of existing studies points out the relevance of oil prices in altering the demand function for the U.S Dollar; thereby, the theoretical explanation of the monetary model augmented with global oil prices utilized in the study is provided in the next section.

3. Monetary Model of Exchange Rate: Theoretical Consideration

The monetary model of exchange rate hypothesized that supply and demand for currencies are a result of transactions in international financial markets. The central building block is purchasing power parity which establishes equilibrium conditions of goods markets (Frenkel, 1976; Dornbusch, 1976; Bilson, 1978).

$$s_t = p_t - p_t^* \tag{1}$$

Where s_t is the logarithm of the nominal exchange rate, p_t and p_t^* are the logarithm of the domestic and foreign price levels, respectively. An important feature of the monetary approach is that the exchange rate between two countries is determined through the money market equilibrium conditions. The domestic money demand function is positively associated with real income (y_t) and negatively related to nominal interest rate (i_t). The equilibrium in the domestic money market is assumed to be of the form;

$$m_t = p_t + \sigma y_t - \gamma i_t \tag{2}$$

Where, m_t represent the logarithm of the domestic money supply. Interest rate is expressed in percentage form and σ and γ are income and interest elasticities. Since U.S Dollar is the main invoicing currency in the global crude oil market, it is reasonable to include oil prices in the foreign money demand function. Following Egert and Leonard (2008), Lizardo and Mollick (2010), and Rasasi (2018), the equilibrium in the foreign money market can be expressed as:

$$m_t^* = p_t^* + \sigma^* y_t^* - \gamma^* i_t^* + \omega^* op_t^* \tag{3}$$

Where m^*, p^*, y^*, and op^* are the logarithms of the foreign money, foreign price, foreign real income, and global oil price index, while i^* is the foreign interest rate. By arranging and substituting equation (2) and (3) into equation (1) gives:

$$s_t = m_t - m_t^* - \sigma y_t + \sigma^* y_t^* + \gamma i_t - \gamma^* i_t^* - \omega\, op_t^* \tag{4}$$

In testable form, equation (4) can be expressed as:

$$s_t = \beta_1 m_t + \beta_1^* m_t^* + \beta_2 y_t + \beta_2^* y_t^* + \beta_3 i_t + \beta_3^* i_t^* + \beta_4^* op_t^* + \varepsilon_t \quad (5)$$

Where, ε_t represents the error term. The parameters $\beta_2 = \sigma$, $\beta_2^* = \sigma, \beta_3 = \gamma$ and $\beta_3^* = \gamma^*$. The restriction $\beta_1 = -\beta_1^* = 1$ holds in the original form of the monetary model (Frenkel, 1976; Bilson, 1978). An increase in the domestic money supply or a rise in domestic interest rate results in excess money supply and consequently an increase in domestic prices, restoring money market equilibrium. As PPP is assumed to hold, the domestic currency depreciates due to the rise in domestic prices. On the other hand, an increase in the domestic interest rate would boost the capital inflow and thus, brings an appreciation of the domestic currency. In case of an expansion of domestic income, the demand for real money balances increases, the domestic prices fall and the currency appreciates.

The sticky-price monetary model by Dornbusch (1976) asserted that an increase in the domestic money supply would increase the domestic real money balances, which in turn causes a fall in interest rate to maintain money market equilibrium. The initial fall in the domestic interest rate would reduce the capital inflow and the domestic currency would depreciate in the short run. That short-run exchange rate would be determined through the uncovered interest rate parity (UIRP) condition, implying that expected appreciation would become equal to the interest rate differential (Macdonald & Taylor, 1992; Neely & Sarno, 2002; Zakaria & Ahmad, 2009). The fall in the domestic interest rate along with the depreciation of the domestic currency would enhance the demand for domestic goods. Consequently, the domestic prices would begin to rise in response to the enhanced demand for the short-run fixed domestic output level. Thus, the short-run depreciation of the domestic currency would boost the external competitiveness of the domestic goods and their increased demand would result in the slow appreciation of the domestic currency in the long run and the PPP relationship would be restored.

Finally, the relationship between oil prices and exchange rate works under three channels; term-of-trade, wealth effect, and portfolio reallocation channel (Chen & Chen, 2007; Habib et al., 2016; Beckmann et al., 2017). The most common channel to link oil price shocks and exchange rate in economic and finance literature is reckoned as wealth effect and consequent portfolio-reallocation channel. The wealth effect measures the short-to-medium term impact of oil price while the portfolio effect considers its medium-to-long-term impact. A positive oil price shock is expected to improve the current account position of the oil-exporting economy and thereby, enhancing their wealth and appreciating the exchange rate. Whereas, the exchange rate of oil-importing countries is expected to depreciate due to the current account burden from enhanced oil import bills (Beckmann & Czudaj, 2013). Further, the short-to-medium term value of the currencies depends on the relative reinvestment preference of the oil-exporting countries on the subject of the earning originating from enhanced exports bills (Castro & Jime´nez-Rodrı´guez, 2020). Intuitively, U.S Dollar being the dominant currency in the oil market faces substantial currency valuation changes, and thereby, this effect in itself affects the other linked currencies in the world economy (Beckmann et al., 2020).

4. Research Methodology and Data

The first step of our econometric methodology is based on the testing of the time-series properties of the data in terms of unit root tests. To this end, we applied the Augmented Dickey-Fuller (ADF) unit root test. To account for the structural breaks, the minimum Lagrange multiplier (LM) unit root test introduced by Lee and Strazicich (2003) has been employed. The test is used to test the null hypothesis of unit root against the break-stationary alternative.

In the second step, this study uses the Vector autoregressive model with a weakly exogenous variable (VARX) to examine the dynamic interaction between exchange rate, domestic and foreign monetary fundamentals. Unlike the VAR model of Sims (1980), which considers all variables as endogenous to the system; the VARX model developed by Pesaran et al. (2000) considers the foreign variables as weakly- exogenous to the system. To explain the VARX model, let ($k \times 1$) be the vector of domestic variables (x_t) and ($k^* \times 1$) be the vector of foreign variables (x_t^*). The VARX (p, q) model can be expressed as;

$$x_t = \alpha_0 + \sum_{i=1}^{p} \varphi_i x_{t-i} + \sum_{i=1}^{q} \omega_i x_{t-i}^* + \varnothing_0 D + \tau t + \varepsilon_{xt} \quad (6)$$

$$x_t^* = c_0 + \sum_{i=1}^{q} \delta_i x_{t-i}^* + \varepsilon_{x_t^*} \quad (7)$$

Equation(s) (6–7) specifies the endogenous and exogenous variables in the system, α_0 and c_0 are the ($k \times 1$) vector of intercepts, φ is ($k \times k$) matrix of lagged coefficients of endogenous variables [$x_t = (ex, m, y, i)$], while ω and δ_i represent ($k \times k^*$) matrix of coefficients of weakly-exogenous variables $\left[x_t^* = \left(m^*, y^*, i^*, op^*\right)\right]$; $\varnothing_0$ is the ($k \times 1$) vector of coefficients of shift dummies D_t (D_{GFC} and D_{covid}) τ denotes the coefficient of time trend (t), while ε_{xt} and $\varepsilon_{x_t^*}$ and the idiosyncratic shocks associated with domestic and foreign variables that are serially uncorrelated and normally and independently distributed.

We apply the cointegrating VARX and vector error correction with the weakly-exogenous variables (VECMX) model if variables are $I(1)$. Following Pesaran et al. (2000), we decompose the VAR model into the conditional model for the endogenous variables as;

$$\Delta x_t = c_x \pm \prod\nolimits_x z_{t-1} + \sum\nolimits_{i=1}^{p-1} \xi_t \Delta x_{t-i} + \psi_0 \Delta x_t^* + \sum\nolimits_{i=1}^{q-1} \psi_i \Delta x_{t-i}^* + \Delta D + c_t t + \upsilon_t \quad (8)$$

Where $z_t = (x_t', x_t'^*)'$ is partitioned into (4 × 1) vector of endogenous variables, $x_t = (ex, m, y, i)'$ and (4 × 1) vector of the weakly exogenous variables $x_t^* = (m^*, y^*, i^*, op^*)'$. The marginal models for weakly-exogenous variables is specified as:

$$\Delta x_t^* = c_{x^*} + \sum_{i=1}^{q-1} \xi \varpi_i^* \Delta z_{t-i} v_{xt^*} \quad (9)$$

Where ξ_i, ψ_i and ϖ_i are the short-run parameters, c_x and c_{x^*} are the vector of intercept; c_1 is the coefficient vector of the time trend term, while $đ$ is the coefficient vector of impulse dummies. The term $\prod_x = \alpha\beta$ adjustment coefficients. It is worth mentioning that Δx must change by $-\alpha$ extent in one period to correct the disequilibrium. The β is $(k + k^*) \times r$ matrix of long-run coefficients given by $(\beta z_{t-1} - c_1 - t)$. The rank of the $\prod_x$ $\{r = \text{rank}(x)\}$ provides the number of cointegration in a stable VECMX system such that $0 < r < k$. The maximal eigenvalue and trace statistics are used to identify the number of cointegrating vectors (Pesaran & Pesaran, 2010) Theoretically, equation 1–6 comprising of monetary model based on three building blocks, namely the PPP, uncovered interest rate parity (UIRP), and money demand functions (Abbott & De Vita, 2002).

This study uses the monthly data over the period of January 2001 to December 2020. The sample period is selected for two reasons; (i) the period of floating exchange rate started from July 2000, and (ii) the non-availability of data on some variables before July 2000. The data on money supply, income level, and interest rate at home and abroad are collected from the State Bank of Pakistan (SBP), Federal Reserve Bank of St. Louis, and International Financial Statistics (IFS). Further, the West Texas Intermediate (WTI) is used as a proxy for the international oil prices, and the data are taken from the Federal Reserve Bank of St. Louis. Two Dummy variables D_{GFC} and D_{covid} were introduced to capture the effect of the global financial crises (October 2008–December, 2010) and COVID-19 (March 2019-December, 2020), respectively. The United States is taken as the foreign country and the nominal exchange rate is defined as the Pak rupee value per US Dollar. The money stock is measured in terms of broad money (M_2), interest rate depicts the money market rate and industrial production index is used as a proxy for real income in both economies. Except that for interest rates, all variables are transformed in natural logarithmic form.

5. Empirical Results and Discussion

5.1. The Unit Root Analysis

Before estimating the VECMX, each variable is tested for unit root by employing the Augmented Dickey-Fuller (ADF) test. Initially, 12 lag length for each variable was selected and the optimal lag length was chosen based on the Akaike information criterion (AIC). The results presented in Table 1 reveal that all variables are non-stationary at the levels. However, at the first difference, all variables appear to be stationary indicating the presence of a cointegrating relationship among the variables.

The results of the structural break test (Table 2) reveal that all variables exhibit two-level breaks at the 10% level of significance. However, the null hypothesis of unit root with two structural breaks is rejected at the first differences, confirming the variables are to be integrated of order I(1) with two structural breaks.[1] The structural break dates are aligned with the GFC and COVID-19, thereby the impulse D_{GFC} and D_{Covid} are incorporated to cater to the effect of structural breaks.

5.2. The Cointegration Analysis

To determine the cointegration relations among the variables, we used the modified Johansen and Juselius (1992) cointegration approach. The cointegrating VARX incorporates four endogenous and four exogenous variables, unrestricted constant and restricted trend term along with two impulse dummies. Optimal lag length is based on the AIC and compliance with the absence of autocorrelation in the residuals as suggested by Ocampo and Rodríguez (2012). Based on these criteria, the lag length of the endogenous variables is chosen to be 9 and that of the exogenous variables is 3.[2]

The number of cointegration relationships is tested using the maximal eigenvalue and trace statistics and the results are reported in Table 3. Both statistics indicate the presence of a single cointegrating relationship among the variables at the 5% level of significance. We normalized the first cointegrating vector on the exchange rate by imposing the restriction that $\beta_1 = -1$. Table 4 presents the normalized cointegrating vector. The signs of the estimates of the first cointegrating vector are found to be consistent with the theoretical predictions of the flexible-price monetary model

Table 1: ADF Unit Root Test

Series	Constant		Constant & Trend	
	Log Level	Log First Difference	Log Level	Log First Difference
s_t	–0.924 (1)	–10.117 (0)***	–2.003 (1)	–10.273 (0)***
m_t	–1.420 (6)	–4.927 (6) ***	–1.439 (6)	–5.073 (5)***
y_t	–1.592 (12)	–5.916 (11)***	–1.998 (12)	–5.974 (11)***
i_t	–2.367 (1)	–18.395 (0)***	–2.364 (1)	–18.360 (0)***
m_t^*	–1.717 (1)	– 9.705 (1)***	–1.336 (1)	–9.958 (1)***
y_t^*	–1.065 (12)	–11.926 (11)***	–1.764 (11)	–11.939 (11)***
i_t^*	–2.208 (1)	–7.384 (0)***	–2.167 (1)	–7.386 (0)***
op_t	–2.525(1)	–10.804 (0) ***	–2.461 (1)	–10.849 (0)***

Note: The brackets show the lag length for each variable chosen based on the AIC criterion. ***, ** and * implies the significance at the 1%, 5% and 10% level. The Critical values for unit root with constant are 3.460, 2.874, 2.573 while, for constant with the trend are 3.977,3.428, 3.139 at 1%, 5%, and 10%. significance level.

Table 2: Lee and Strazicich (2003) LM Unit Root Test

Series	Log Level	Critical Values at Significance Level		Breaks	Log First Difference	Critical Values at Significance Level		Breaks
		5%	10%			5%	10%	
s_t	–2.705	–6.038	–5.696	2008:06; 2017:10	–18.327***	–5.822	–5.453	2004:10; 2018:07
m_t	–5.183	–5.897	–5.584	2006:04; 2008:04	–17.658***	–5.971	–5.653	2006:03; 2008:01
y_t	–5.122	–5.975	–5.641	2008:06; 2017:12	–14.192***	–6.061	–5.720	2019:02; 2011:08
i_t	–4.951	–6.037	–5.696	2008:09; 2018:09	–18.327***	–5.822	–5.453	2004:10; 2018:07
m_t^*	–4.026	–5.998	–5.575	2011:04; 2018:05	–5.454***	–4.288	–4.010	2009:05; 2019:03
y_t^*	–4.409	–6.689	–5.757	2008:10; 2020:05	–5.637***	–4.286	–4.007	2009:03; 2020:03
i_t^*	–4.961	–6.092	–5.691	2005:05; 2009:06	–4.190***	–4.241	–3.957	2010:08; 2011:02
Oil_t	–2.705	–6.161	–5.878	2008:10; 2014:11	–5.917***	–4.259	–3.977	2007:12; 2014:10

***, ** and * implies the significance at 1%, 5% and 10%.

Table 3: Test for Cointegration

Rank		Maximal Eigen Value	Bootstrapping Critical Values		Trace Statistics	Bootstrapping Critical Values	
Null	Alternate		95%	90%		95%	90%
$r = 0$	$r \geqq 1$	83.427**	67.655	63.074	178.770**	158.351	150.695
$r \leqq 1$	$r \geqq 2$	50.487	55.029	50.588	95.343	105.910	100.267
$r \leqq 2$	$r \geqq 3$	26.102	44.159	40.649	44.855	64.208	60.307

Note: 95% and 90% bootstrapping critical values are computed based on stochastic simulation using 1000 replications. ** and * imply the significance of maximal eigenvalue and trace statistic at 5% and 10%, respectively.

Table 4: Cointegrating Vector Normalized on Exchange Rate

Variables	s_t	m_t	y_t	i_t	m_t*	y_t*
Vector Coefficients	1	0.221** (0.10)	–0.570*** (0.20)	0.009*** (0.002)	–0.625** (0.1)	–0.289 (0.222)
		i_t*	op_t	D_{GFC}	D_{COVID}	**Trend**
		0.007* (0.004)	0.025** (0.104)	0.037*** (0.014)	0.072* (0.041)	–0.002* (0.001)

Note: ***, ** and * implies the significance of *t*-statistics at 1%, 5% and 10% level. The brackets show the standard errors.

(FPMM), particularly, with reference to the endogenous variables. For example, domestic money supply (m_t) and exchange rate (s_t) are found to have a positive relationship implying that a rise in the domestic money supply leads to the depreciation of the Pak-rupee exchange rate in the long run. The results are in-lined with the findings of the previous studies by Khan and Qayum (2011) and Khan and Nawaz (2018). The domestic income (y_t) and s_t is found to have a significant negative relationship. The domestic interest rate (i_t) has a significant positive influence on s_t, suggesting that a rise in the domestic interest rate would result in a depreciation of the domestic currency in the long run.

With regard to the weakly exogenous foreign monetary variables, the empirical sign of foreign money supply is in-lined with the theoretical predictions of the flexible price variant of the monetary model (Table 4). With respect to the foreign real income; it is found to be insignificant. The reason might be that the rise in the U.S income level has an insignificant impact on the demand for Pakistani products in the international market. As a consequence, the Pak-rupee exchange rate remains invariant with respect to US income. For the foreign interest rate, the sign is in favor of the sticky-price variant of the monetary model and Mundell-Fleming model, implying that a rise in foreign interest rate would result in depreciation of the Pak-rupee exchange rate through domestic capital outflow. Further, the international oil prices are found to have a positive relationship with the exchange rate, implying that a rise in global oil prices would result in the long-run depreciation of the Pak rupee. This finding might be supported by the term of trade, wealth effects, and portfolio channels of oil prices. The dummies D_{GFC} and D_{Covid}, are found to have a significant positive relationship with the exchange rate indicating that the global financial crisis and COVID-19 cause to depreciate of the Pak Rupee exchange rate.

5.3. Short-run Dynamics of Exchange Rate

To analyze the short-run dynamic relationship between exchange rate and domestic (foreign) fundamentals and oil prices, VECMX was estimated, and results are presented in Table 5. The results show that the impact of exchange rate changes (Δs_t) lagged by one month appear to be positive and significantly explaining the exchange rate movements in the short run. This implies that the past period's depreciation of the Pak-rupee exchange rate further weakened the current exchange rate in Pakistan. However, exchange rate changes lagged by 5–7 months period impacts current exchange rate changes negatively, revealing the inverse J-shaped relationship between current and lagged exchange rate movements. The lagged effects of exchange rate changes on current exchange rate changes validate that the exchange rate expectation affects the current exchange rate in the short run. It appears from the results that change in domestic money (Δm_t) lagged by 3 to 5 months was found to be significant, implying a delay in realization of the monetary policy changes in exchange rate determination in the short-run.

However, 3 months and 10 months lagged domestic money supply changes are found to have negative and theoretically inconsistent signs. This reveals the presence of liquidity puzzle in the short-run, suggesting that a rise in domestic money supply causes an appreciation of the Pak-rupee exchange rate in the short-run All lags of domestic income change (Δy_t) are found to be significant and sign consistent, implying continuous appreciation of Pak-rupee in the short-run with enhanced productivity growth. The short-run effect of domestic interest rate changes (Δi_t) is found to be negative and significant for different lags, supporting the sticky price variant of the monetary model. However, the effect of the domestic interest rate on the Pak-rupee exchange rate is too small and negligible, implying the weak role of monetary policy in determining the exchange rate in Pakistan.

Concerning the short-run dynamics of exchange rate caused by exogenous variables; the short-run impact of the foreign money supply changes (Δm_t^*) at the current and previous lags on the exchange rate are found to be significant. However, the sign of foreign supply money growth in the current month is inconsistent, validating the liquidity puzzle hypothesis. The short-run impact of lagged foreign income growth (Δy_{t-i}^*) and current foreign interest rate changes $\left(\Delta i_i^*\right)$ is found to be theoretically consistent, respectively, confirming the theoretical predictions of the sticky-price version of the monetary model. Finally, the

Table 5: Estimates of Vector Error Correction Model with Weakly Exogenous Variables (VARX) for Exchange Rate (Δs_t)

	Coefficients	Standard Errors	*P*-value		Coefficients	Standard Errors	*P*-value
Δs_{t-1}	**0.2225*** **	0.7624	0.004	Δs_{t-2}	–0.0568	0.0673	0.400
Δs_{t-3}	–0.0255	0.0197	0.197	Δs_{t-4}	0.0301	0.0200	0.135
Δs_{t-5}	**–0.0674*** **	0.0202	0.001	Δs_{t-6}	**–0.0485*** **	0.0206	0.019
Δs_{t-7}	**–0.0411** **	0.0217	0.060	Δs_{t-8}	0.0122	0.0230	0.594
Δs_{t-9}	0.0143	0.0249	0.568	Δs_{t-10}	–0.0243	0.0224	0.280
Δm_{t-1}	–0.0002	0.0125	0.986	Δm_{t-2}	–0.0005	0.0128	0.966
Δm_{t-2}	–0.0005	0.0128	0.966	Δm_{t-3}	**–0.0044** **	0.0018	0.042
Δm_{t-4}	**0.0037* **	0.0021	0.092	Δm_{t-5}	**0.0011* **	0.0006	0.091
Δm_{t-6}	–0.0051	0.0113	0.651	Δm_{t-7}	–0.0036	0.0119	0.763
Δm_{t-8}	0.0155	0.0123	0.210	Δm_{t-9}	–0.0057	0.0125	0.651
Δm_{t-10}	**–0.0219* **	0.0121	0.071	Δy_{t-1}	**–0.0288*** **	0.0072	0.000
Δy_{t-2}	**–0.0234*** **	0.0068	0.001	Δy_{t-3}	**–0.0242*** **	0.0062	0.000
Δy_{t-4}	**–0.0280*** **	0.0061	0.000	Δy_{t-5}	**–0.0227*** **	0.0053	0.000
Δy_{t-6}	**–0.0219*** **	0.0053	0.000	Δy_{t-7}	**–0.0159*** **	0.0051	0.002
Δy_{t-8}	**–0.0130*** **	0.0043	0.003	Δy_{t-9}	**–0.0141*** **	0.0045	0.002
Δy_{t-10}	**–0.0090** **	0.0042	0.034	Δi_{t-1}	0.0001	0.0002	0.563
Δi_{t-2}	0.0001	0.0003	0.626	Δi_{t-3}	**–0.0005* **	0.0003	0.071
Δi_{t-4}	–0.0004	0.0003	0.130	Δi_{t-5}	–0.0001	0.0003	0.773
Δi_{t-6}	**–0.0006*** **	0.0002	0.010	Δi_{t-7}	**–0.0004* **	0.0002	0.098
Δi_{t-8}	0.0000	0.0002	0.849	Δi_{t-9}	–0.0002	0.0002	0.305
Δi_{t-10}	0.0001	0.0002	0.628	Δm^*_t	**0.9427*** **	0.0189	0.000
Δm^*_{t-1}	**–0.2118*** **	0.0705	0.003	Δm^*_{t-2}	0.0184	0.0612	0.763
Δy^*_t	0.0048	0.0075	0.520	Δy^*_{t-1}	**0.0426*** **	0.0150	0.005
Δy^*_{t-2}	0.0038	0.0149	0.799	Δi^*_t	**0.0037* **	0.0022	0.099
Δi^*_{t-1}	0.0022	0.0026	0.401	Δi^*_{t-2}	–0.0001	0.0023	0.957
Δop^*_t	–0.0005	0.0026	0.837	Δop^*_{t-1}	**0.0098*** **	0.0025	0.000
Δop^*_{t-2}	**0.0018** **	0.0011	0.043				
ECT_{t-1}	**–0.0525*** **	0.0119	0.000	Inpt	**1.0116*** **	0.2316	0.000
$\Delta DGFC_{t-1}$	–0.0012	0.0032	0.711	$\Delta DGFC_{t-1}$	**0.0012* **	0.0010	0.096
$\Delta DCovid_{t-1}$	**0.0550*** **	0.0078	0.000	$\Delta DCovid_{t-1}$	**0.0298*** **	0.0051	0.000

Table 5: (Continued)

R-Square	0.96	
Adjusted *R*-Square	0.95	
Diagnostic Tests	***t*-statistics**	***P*-value**
Serial Correlation: χ^2 (12)	15.36	0.222
Heteroscedasticity: χ^2 (1)	0.81	0.776
Functional Form: χ^2 (1)	1.17	0.279
Normality: χ^2 (2)	2.04	0.360

***, ** and * implies significant at the 1%, 5%, and 10% level of significance.

short-run impact of one month lagged oil price (Δop_{t-1}) is found to be positive and significant implying that a rise in the oil prices results in the deprecation of the Pak rupee in the short-run. Additionally, the impulse impact of D_{GFC} and D_{Covid} is also implying a deprecation of Pak-rupee in the short-run, supporting the theoretical predictions of oil price-exchange rate linkages.

The error correction term is negative and statistically significant implying that the short-term deviations in exchange rate necessarily converge towards the long-run equilibrium. The magnitude of the ECT_{t-1} being –0.0525 suggesting that it takes almost 19 months to die down the impact of the short-term deviations. Further, the *R*-square and adjusted *R*-square of the estimated equations are 0.962 and 0.950, respectively. The diagnostic tests provide no indication of serial correlation and misspecification of the estimated VECMX model.

5.4. Persistence Profile Analysis

The persistence profiles show the impact of system-wide shocks on the cointegrating relationship over time (Pesaran & Shin, 1998). It also gives information on the rate at which the system approaches long-run equilibrium. Figure 1 shows the exchange rate persistence profiles with separated endogenous and exogenous factors. Overall, the impact of system-wide shocks causes the Pak-rupee exchange rate to appreciate. In response to a system-wide shock, the Pak-rupee exchange rate experiences a high appreciation for four months, followed by a sharp depreciation in the 12th month. However, over a period of roughly 17 months, the total system is heading towards equilibrium and tends to be zero, confirming the validity of the monetary model of the exchange rate in the short run.

5.5. Generalized Impulse Response Functions

The influence of one standard error positive shock to a variable on the cointegrating relation is calculated

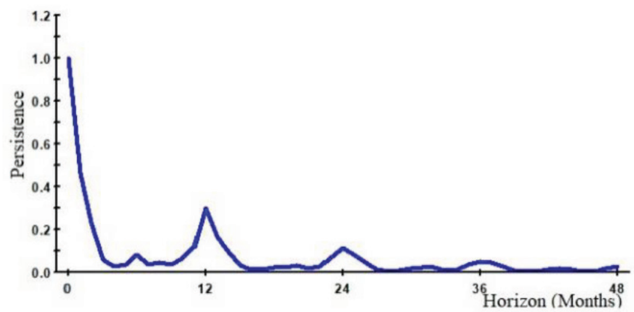

Figure 1: Persistence Profile of Exchange Rate

using generalized impulse response functions (GIRFs). Unlike orthogonalized impulse response functions, GIRFs are invariant to variable ordering, do not require a-priori constraints on variables, and do not orthogonalize the system's residuals. GIRFs are found to be very useful in large VAR systems with unidentified complex structural links since they provide a clear picture of the variable's evolution. Figures 2–8 show the influence of one standard error shocks to both endogenous and exogenous variables on the exchange rate. Over the first two months, a shock to the domestic money supply generates a considerable depreciation of the Pak-rupee exchange rate (Figure 2), before stabilizing after one month and achieving a depreciation of around 4%. Following that, it appreciates significantly for the next month, then depreciates, ranging between 2% and 1% from the 14th to the 32nd months before stabilizing. As a result, a short-term and long-term shock to the domestic money supply causes the Pak rupee to devalue, validating the monetary model's predictions. A shock to domestic income causes an appreciation of the Pak-rupee exchange rate (Figure 3), and it remains below the long-run equilibrium path with a fluctuating pattern throughout the forecast horizon. This suggests that in the long run, the Pak-rupee exchange rate appreciates in the presence of substantial economic growth. The response of the exchange rate to a domestic interest rate

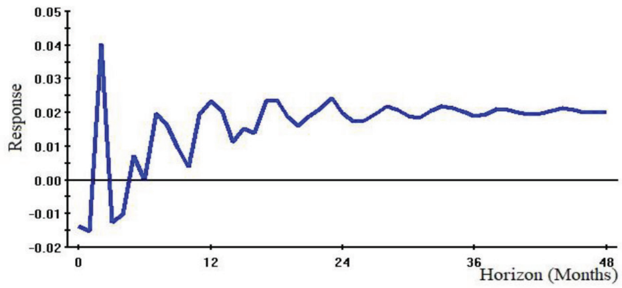

Figure 2: Impulse Response of Exchange Rate to Domestic Money Supply

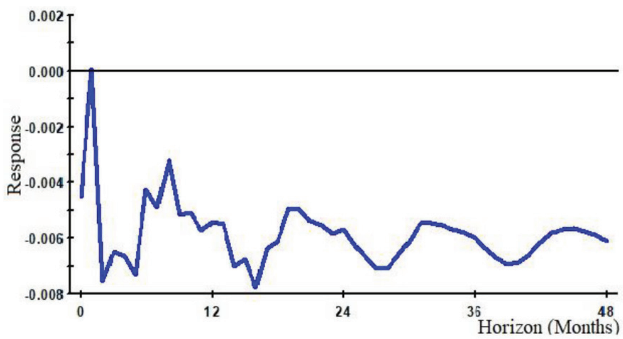

Figure 3: Impulse Response of Exchange Rate to Domestic Income

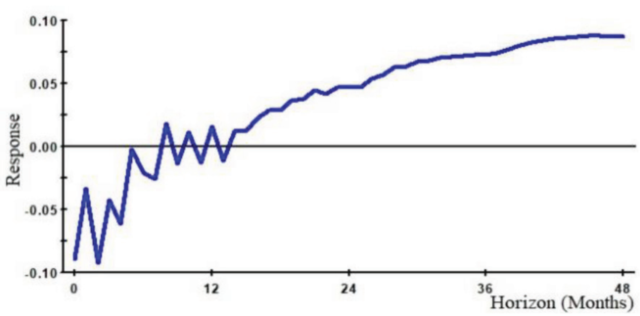

Figure 4: Impulse Response of Exchange Rate to Domestic Interest Rate

shock (Figure 4) results in continuous appreciation with a fluctuating pattern, favoring the predictions of the stochastic pricing variation of the monetary model. When looking at the influence of foreign variables shocks on the Pak-rupee exchange rate, one common mistake, a shock to the foreign money supply (Figure 5) causes the Pak-rupee exchange rate to appreciate. The response initially begins at zero and remains stable after 10 months. However, for the whole

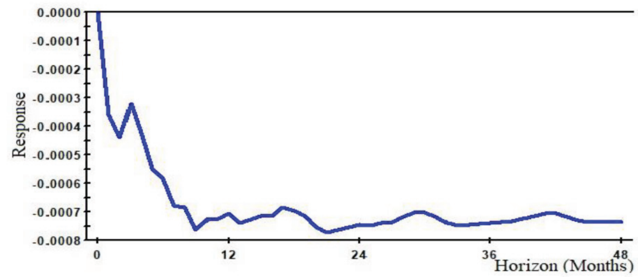

Figure 5: Impulse Response of Exchange Rate to Foreign Money Supply

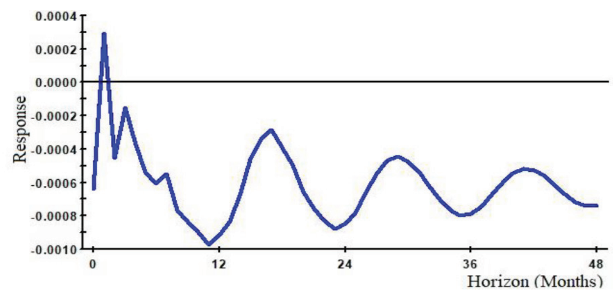

Figure 6: Impulse Response of Exchange Rate to Foreign Income

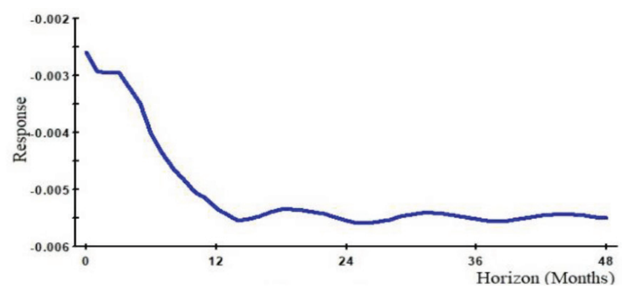

Figure 7: Impulse Response of Exchange Rate to Foreign Interest Rate

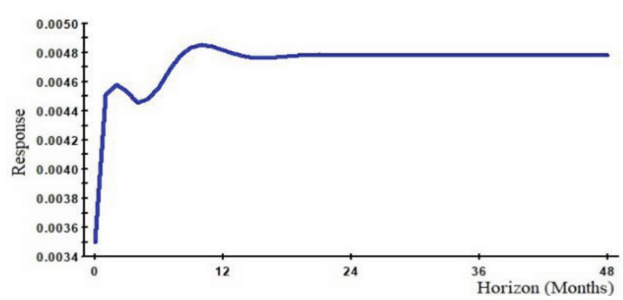

Figure 8: Impulse Response of Exchange Rate to International Oil Prices

forecast horizon, the exchange rate response stays negative, showing that the appreciating impact is permanent both in the short and long run.

The response of the exchange rate to a foreign income shock (Figure 6) shows the depreciation of the Pak-rupee exchange rate over the first two months, followed by appreciation until the eleventh month. Following that, it depreciates and continues in the negative territory in a shifting pattern. The influence of foreign interest rate shocks on the exchange rate (Figure 7) suggests that the Pak-rupee exchange rate will continue to appreciate over the projection period. This pattern of response favors the prediction of the monetary model's flexible price variatiant. Furthermore, the shock to worldwide oil prices (Figure 8) causes the Pak-rupee exchange rate to depreciate over the projected period. After the 14th month, however, the impact becomes stable. Overall, the GIRFs for endogenous and exogenous variables confirm the importance of shocks to domestic and international monetary fundamentals, as well as global crude oil prices, in explaining changes in the Pakistani rupee exchange rate from 2001 to 2020.

6. Conclusion

The findings show that in the long run, domestic monetary fundamentals perform similarly to the flexible price variant of the monetary model. Foreign monetary fundamentals, on the other hand, are yielding mixed results. In the long run, foreign revenue, for example, has little effect on the value of the Pakistani rupee. Similarly, the effect of foreign interest rates confirms the predictions of the sticky price variant of the monetary model and the Mundell-Flemming model. Furthermore, worldwide crude oil prices are found to have a positive association with the Pak-rupee exchange rate, implying that higher global oil prices contribute to a long-term depreciation of the domestic currency. The dummies of global financial crises and Covid-19 have a positive association with the exchange rate, indicating that these events have resulted in the depreciation of the Pakistani rupee in the long run.

Further, the VECMX model is utilized to gain understanding from the short-run dynamics of the Pak rupee exchange rate. The endogenous monetary fundamentals and exogenous factors are found to be significant in explaining the exchange rate behavior at variant lags. Additionally, the coefficient of adjustment is valued at –0.053 indicating that the system takes 19 months to converge towards the long-run equilibrium. The persistence profile analysis also validates this converging behavior towards long-run equilibrium. Moreover, the GIRFs verify the relevance of the domestic and foreign monetary fundamentals along with the global oil prices in Pak-rupee fluctuations.

Overall, the analysis provides an important insight into the exchange rate dynamics of the Pak-rupee exchange rate and suggests some important policy implications which might be relevant for other developing economies facing similar scenarios. Firstly, the significant impact of domestic monetary fundamentals signifies that these fundamentals can be utilized as the stabilization tools for the exchange rate determination in Pakistan in the short and the long run. External competitiveness, which is the primary goal of currency management, can be achieved by effectively channeling these fundamentals. Particularly, the role of money supply indicates the significance of the contractionary monetary policy in managing the exchange rate in Pakistan.

Economic activity, on the other hand, is a strong predictor of exchange rate movements, necessitating efficient monetary and fiscal policy coordination. Furthermore, the persistence of the policies is the key to obtaining the desired outcome such as stabilizing the exchange rates. Overall, a stable monetary policy instills confidence-building among the market participants and reduces exchange rate fluctuations. Secondly, the insignificant long-run impact of the foreign income on the Pak-rupee exchange rate indicates that Pakistani exports are uncompetitive in the international market. Therefore, measures are required to enhance the production of quality-based and diversified exports to compete with the external economies, particularly to compete with Pakistan's trade competitors. Thirdly, the role of rising global oil prices in the depreciation of the Pak-rupee exchange rate demands the accumulation of sustainable levels of foreign exchange reserves for precautionary measures. Besides, there is a need to develop renewable energy resources to reduce reliance on imported oil. Finally, the global financial crisis and pandemic (COVID-19) significantly depreciate the Pak-rupee exchange rate. Therefore, there is a need to deepen the financial and real sectors of Pakistan's economy to absorb abrupt external shocks.

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Endnotes

[1] The Lee and Strazicich (2003) Langrage multiplier (LM) unit root test with two endogenous structural-breaks is performed using econometric package RATS Estima.

[2] All the estimations of VARX model are performed using econometric packing Microfit 5.