

## The Transmission of Volatility among Exchange Rate, Gold, Crude oil and Indian Stock

### Market: Non-linear ARDL Approach

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### Abstract

The causal relationship and interdependence among Indian stock market, crude oil prices, exchange rate and gold prices are checked through NARDL model. The data for all variables are collected for thirteen years (2010-2023) and all variables are collected in the form of US dollar except BSE100 index. In the long run, when stock market is taken as dependent variable, the positive change in exchange rate are found significantly impacting the stock market. The changes in other variables are found insignificant to create impact on stock market. The negative changes in crude prices are significantly and negatively affect the stock market performance in short-run. The changes in exchange rates significantly impacted the Indian stock market in a negative way without any asymmetric impact. The negative changes in crude oil up to lag three are significantly impacting exchange rate in a negative way. The stock market changes and gold prices are significantly impacting exchange rate in an asymmetric way. These findings are important for all market participants in deciding investment portfolio by providing insight about transmission of impact among commodity market and stock market.

**Key words: NARDL, Asymmetric, Exchange Rate, Crude oil**

### Introduction

The research work of (Hamilton, 1983) that examined the impact of crude oil shocks on different economic variables developed a new era of research to study the relationship of higher fuel prices with stock market performance. The money and wealth of oil importing economies moves to oil exporting countries as the nature of non-elastic demand for energy fuels (Golub, 1983). The problem is become more serious as current account deficit is increased for oil importers and surplus is increased for oil exporters. Many studies favoured that oil prices shocks impacts the exchange rate directly or indirectly (Krugman, 1983). Oil is commonly used fuel source in world economy for production activities. The real as well as virtual economies are getting affected by fluctuations in oil prices (Ding, Liu, Zhang, & Long, 2017). For the last three decades, the oil prices are becoming more flexible and

unpredictable creating impact on almost all activities of world economies. India is the third largest importer of crude oil after US and China and largest consumer of gold. Many research works are related to study the impact of one or two variable on stock market performance, but in this work, efforts are made to check the interconnection between crude oil, gold, exchange rate and stock market of India.

### **Literature Review**

The co-integration among crude oil, exchange rate, gold price and stock market of India was investigated by taking daily prices from 1994 to 2019 through NARDL model. The stock market performance is positively affected by oil price fluctuations but it is negatively affected by fluctuations in exchange rate during short term. The changes in gold prices are irrelevant to stock market creating no impact(Suresh Kumar, Kumar, & Singh, 2023).

The correlation and interrelationship among crude oil, natural gas and Indian stock market is studied through various variants of MGARCH model. The existence of asymmetry in oil market and Indian stock market but absence of asymmetry in natural gas market was noted in the results that can be very beneficial for investors to design their portfolio strategy(Satish Kumar, Pradhan, Tiwari, & Kang, 2019).

In this work, the impact of fluctuations in stock market was studied on exchange rate and the contribution of asymmetry was also verified in this interconnection. The whole data was divided into two parts: before crises and after crises. The results favoured the portfolio balance theory with nexus between the studied variables and this theory became more prevalent after crises(Salisu & Ndako, 2018).

The asymmetric impact of variables (exchange rate, interest rate, inflation and money supply) was examined on monthly data (2001-2017) through NARDL model on Vietnam stock market. The interest rate created negative impact while money supply created positive impact on Vietnam stock market in short as well as long run. The exchange rate showed insignificant impact on market(Phong, Van, & Bao, 2019).

The inter-linkage was examined among different variables (exchange rate, gold, crude oil and BSE) by applying NARDL approach on data from 2003-2020 during financial crises of 2008. The time period is divided into three parts (before crises, after crises and whole period). The results concluded asymmetric impact of all variables before crises but after crises, the impact of exchange rate and oil shocks (negative) was insignificant(Asad, Tabash, Sheikh, Al-Muhanadi, & Ahmad, 2020).

The survey of recent studies showed inconclusive results about the asymmetric impact of macroeconomic variables on stock market performance. So, this study tried to analyze the interconnection and interdependence among crude oil prices, exchange rate, gold prices and Indian stock market.

### Research Methodology

NARDL model that is given by Shin et al.,2014 is used to check the interconnection among different economic variables and stock market. Before applying this model, the stationarity of data is checked through ADF (Augmented Dickey and Fuller test). The asymmetric impact and inter-relationship can be checked through NARDL in short run as well as long run. This model can be explained through following equation:

$$x_t = \alpha + y_t^+ + \alpha - y_t^- + e_t$$

Here  $x_t$  is dependent variable and  $y_t$  is independent variable where  $y_t^+$  and  $y_t^-$  are partial sums of positive and negative changes vector of regressors.

The asymmetric equation can be explained as:

$$\Delta BSE_t = \alpha_0 + \alpha_1 BSE_{t-1} + \alpha_2 GOLD_{t-1}^+ + \alpha_3 GOLD_{t-1}^- + \alpha_4 CRUDE_{t-1}^+ + \alpha_5 CRUDE_{t-1}^- + \alpha_6 EXC_{t-1}^+ + \alpha_7 EXC_{t-1}^- + \sum_{i=1}^m \gamma_{1i} \Delta VX_{t-i} + \sum_{i=0}^n \gamma_{2i} \Delta GOLD_{t-i}^+ + \int_{i=0}^p \gamma_{3i} \Delta GOLD_{t-i}^- + \sum_{i=0}^q \gamma_{4i} \Delta CRUDE_{t-i}^+ + \sum_{i=0}^r \gamma_{5i} \Delta CRUDE_{t-i}^- + \sum_{i=0}^s \gamma_{6i} \Delta EXC_{t-i}^+ + \sum_{i=0}^v \gamma_{7i} \Delta EXC_{t-i}^- + e_t$$

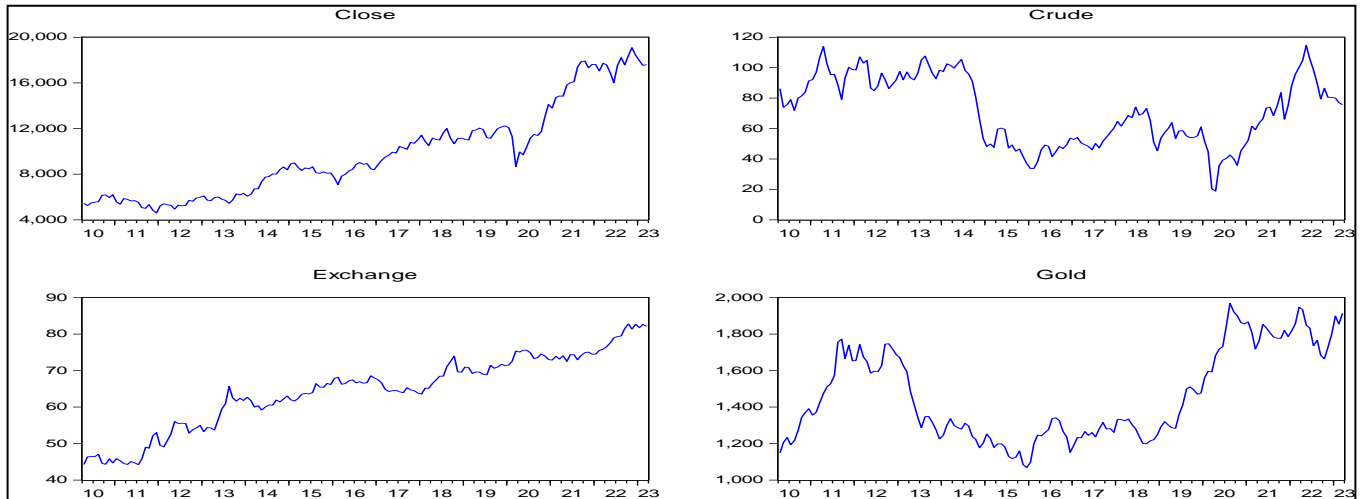
In above equation, BSE denotes the Bombay stock exchange that is taken as representative stock market for India and EXC denotes the exchange rate. Through this equation, the co-integration is checked by taking one variable as dependent and other variables as independent variables. This process is followed for all variables. The long run form test is applied to find the value of F-statistics to compare it to upper and lower bounds to decide for inter-dependencies.

### Data and Sample Size

The data for crude oil price is collected from the official website <https://www.eia.gov>, for gold from <https://www.gold.org>, for exchange rate from <https://www.rbi.org.in> and for Indian stock market closing prices for BSE 100 index is collected from the official website [www.bseindia.com](http://www.bseindia.com). The time period of the study is taken from 2010 to 2023. Monthly data for all variables is collected in US dollar as all imports and exports of India is performed in US dollar.

**Results and Analysis**

The present work is performed to check the interrelationship among exchange rate, gold prices, crude oil prices and Indian stock market. At first, all variables are plotted on graph given in figure 1. The stationarity of all variables is checked through ADF test and results are presented in table 1 that shows that all variables are stationary at the order of integration one.



**ADF Test for Stationarity**

Variables	Level	1 <sup>st</sup> Difference	Order of Integration
<b>BSE 100</b>	0.092772	-12.3633*	I(1)
<b>Crude</b>	-1.86375	-10.8745*	I (1)
<b>Gold</b>	-1.15931	-9.94364*	I (1)
<b>Exchange</b>	-1.0833	-13.0041*	I (1)

Then all variables are analysed through summary statistics given in table 2 that shows that the mean value is highest for stock market (BSE100) and least for exchange rate. The SD (Standard Deviation) values show that stock market is more volatile and exchange rate is less volatile among all studied variables. All variables are positively skewed except exchange rate. The kurtosis is highest for stock market (BSE). The Jarque-Bera probability shows that all variables are following non-normal distribution.

**Table 2. Descriptive Statistics**

	<b>BSE</b>	<b>CRUDE</b>	<b>EXCHANGE</b>	<b>GOLD</b>
Mean	9816.94	71.33795	64.38163	1463.93
Median	8859.86	69.28	65.6035	1347.95
Std. Dev.	4015.641	22.65011	10.12544	250.7065
Skewness	0.747899	0.001948	-0.43537	0.411364
Kurtosis	2.539613	1.849062	2.428364	1.725612
Jarque-Bera	15.9209	8.610372	7.052157	14.95614
Probability	0.000349	0.013498	0.02942	0.000565
Observations	156	156	156	156

When data is analysed through descriptive statistics and stationarity is verified through ADF test, then ARDL long run form test is applied to check and verify the interconnection among variables on the basis of F-stats given in table 3. The co-integration is found among variables when stock market and exchange rate are taken as dependent variables as we can see the F-stats value is more than the value of upper bound at significance level of 10% and 5%. But there is no interdependence found when gold is taken as dependent variable and results are inconclusive when crude oil is taken as dependent variable on the basis of F-stats value lies in between the upper and lower bound values. So, results of NARDL model for short term and long term are analysed in two cases when stock market and exchange rate are taken as dependent variables.

**Table 3. ARDL Bound Cointegration Test**

Dependent Variable	Lag structure	F-Stats	Decision
BSE 100	(1,1,1,2)	4.035438	Co-integration
Crude	(2,1,0,0)	2.630537	Inconclusive
Gold	(2,1,0,0)	0.940811	No Co-integration
Exchange	(1,0,1,3)	4.555708	Co-integration
Significance Level			
10%	Lower Bound	2.12	2.45
5%	Upper Bound	3.223	3.61

In the long run, when stock market is taken as dependent variable, the positive change in exchange rate are significantly impacting stock market performance. The changes in other variables are insignificant to create impact on stock market in the long run as provided in table 4. But exchange rate is affected by changes in all variables as we can see in below table. The positive changes in crude and stock market (BSE 100 closing prices) are significantly impacting the exchange rate. 1% changes in crude oil are creating 9% changes in exchange rate but stock market changes are creating impact that is less than 1%. Again, negative changes in gold prices are creating negative impact on exchange rate that is 1.13%.

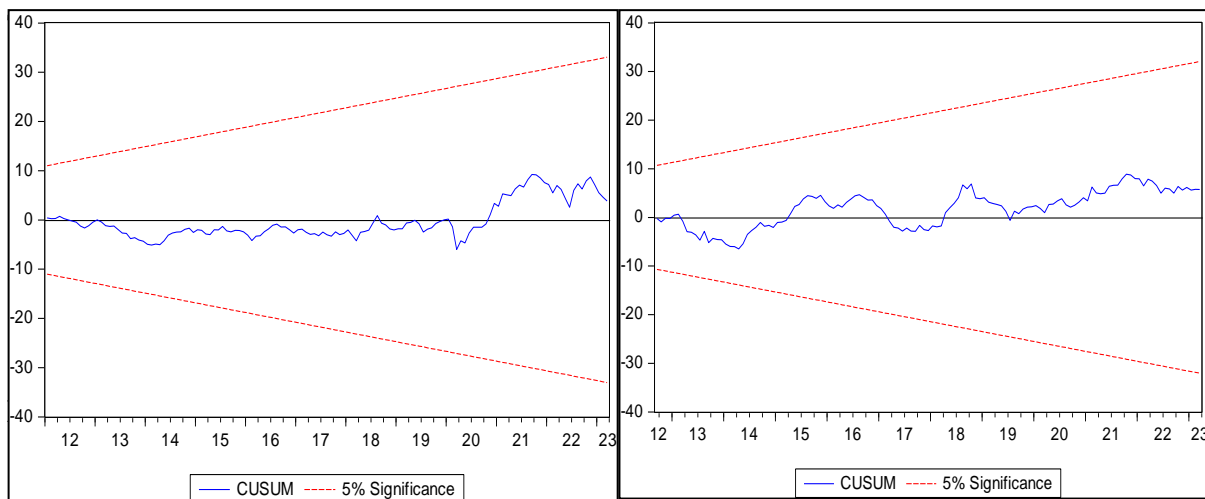
Table 4. **Estimated long-run coefficients using the NARDL approach**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
<b>BSE 100</b>				
CRUDE_POS	30.63244	34.60251	0.885267	0.3776
CRUDE_NEG	22.60725	27.70179	0.816094	0.4159
EXCHANGE_POS	-444.617	107.9076	-4.12035	0.0001*
EXCHANGE_NEG	-252.337	157.603	-1.60109	0.1117
GOLD_POS	6.024169	5.198979	1.158722	0.2486
GOLD_NEG	-7.58471	4.649375	-1.63134	0.1051
<b>Exchange</b>				
CRUDE_POS	0.09338	0.040941	2.280863	0.0242*
CRUDE_NEG	0.007065	0.036275	0.194749	0.8459
CLOSE_POS	-0.001282	0.000308	-4.15598	0.0001*
CLOSE_NEG	-0.001067	0.00062	-1.72199	0.0875
GOLD_POS	-0.001842	0.004208	-0.43776	0.6623
GOLD_NEG	-0.011303	0.004038	-2.79878	0.0059*

Table 5 presents the short-term interdependence among the studied variables. The negative changes in crude prices are significantly and negatively affect the stock market performance. The positive and negative changes in exchange rate are significantly impacting the Indian stock market in a negative way so not creating any asymmetric impact. The positive changes in gold is insignificant for stock market. The negative changes in crude oil at lag three are significantly impacting exchange rate in a negative way. The positive (up to lag one) and negative changes (up to lag two) in stock market are significantly impacting exchange rate in an asymmetric way. In the same way gold prices are creating asymmetric impact on exchange rate. After that the robustness of the model is checked through CUSUM test.

**Table 5. Error correction description for the NARDL cointegration test results**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
<b>BSE 100</b>				
D(CRUDE_NEG)	25.75126	7.639396	3.370851	0.001*
D(CRUDE_NEG(-1))	-22.4667	7.236524	-3.10463	0.0023*
D(EXCHANGE_POS)	-197.601	38.98832	-5.06821	0*
D(EXCHANGE_NEG)	-219.177	45.86943	-4.77828	0*
D(GOLD_POS)	-0.33472	0.953367	-0.35109	0.7261
D(GOLD_POS(-1))	-1.31847	1.013428	-1.301	0.1955
D(GOLD_POS(-2))	-1.82667	1.003683	-1.81997	0.071
D(GOLD_POS(-3))	1.654919	1.009895	1.638704	0.1036
CointEq(-1)*	-0.14718	0.027757	-5.3025	0*
<b>Exchange</b>				
D(CRUDE_NEG)	-0.00863	0.021057	-0.40979	0.6827
D(CRUDE_NEG(-1))	-0.02848	0.021479	-1.32582	0.1873
D(CRUDE_NEG(-2))	-0.0125	0.021967	-0.56915	0.5703
D(CRUDE_NEG(-3))	-0.0494	0.019588	-2.5219	0.0129*
D(CLOSE_POS)	-0.00141	0.000295	-4.76842	0*
D(CLOSE_POS(-1))	0.00063	0.000281	2.245515	0.0265*
D(CLOSE_NEG)	-0.00113	0.000331	-3.40445	0.0009*
D(CLOSE_NEG(-1))	-0.00037	0.000351	-1.05125	0.2951
D(CLOSE_NEG(-2))	0.000661	0.000326	2.027234	0.0447*
D(GOLD_POS)	-0.00229	0.002704	-0.84786	0.3981
D(GOLD_POS(-1))	0.005895	0.002756	2.139023	0.0343*
D(GOLD_POS(-2))	0.000565	0.002786	0.202889	0.8395
D(GOLD_POS(-3))	0.007143	0.002584	2.764366	0.0066*
D(GOLD_NEG)	-0.00827	0.003468	-2.38518	0.0185*
D(GOLD_NEG(-1))	-0.01091	0.003265	-3.34005	0.0011*
D(GOLD_NEG(-2))	-0.00831	0.003605	-2.30433	0.0228*
CointEq(-1)*	-0.27818	0.04579	-6.07502	0*



In this work, the causal relationship in short and long term among Indian stock market, crude oil prices, exchange rate and gold prices are checked through NARDL model. This model is able to capture the asymmetric impact of changes in the studied variables. The data for all variables are collected for thirteen years (2010-2023) and all variables are collected in the form of US dollar except BSE100 index. First of all, the stationarity of all variables is checked by ADF test that shows all variables are stationary at level one that satisfy the pre-required condition for applying NARDL model. The brief summary of variables show that all are negatively skewed and jarque-bera test shows all variables are not normally distributions. The long run form test shows the co-integration among the variables is exist when stock market and exchange rate are taken as dependent variables. After that, the long term and short-term relationship is analysed through error correction forms of NARDL results. In the long run, when stock market is taken as dependent variable, the positive change in exchange rate are significant. The changes in other variables are insignificant to create impact on stock market. The positive changes in crude and stock market (BSE 100 closing prices) significantly impacted the exchange rate. 1% changes in crude oil created 9% changes in exchange rate but changes in stock market impacted the exchange rate but impact is less than 1%. Again, negative changes in gold prices created negative impact on exchange rate. The short-term interdependence among the studied variables shows that negative changes in crude prices are significantly and negatively affect the stock market performance. The changes in exchange rate (positive as well as negative) are significantly impacting the Indian stock market in a negative way so not creating any asymmetric impact. The negative changes in crude oil up to lag three are significantly impacting exchange rate in a negative way. The changes in stock market are significantly impacting exchange rate in an asymmetric way. In the same way gold prices are creating asymmetric impact on exchange rate. These findings are important for all market participants in deciding investment portfolio by providing insight about transmission of impact among commodity market and stock market. The research can further be extended by applying this model on daily data for more variables for getting comprehensive understanding.

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