



## **RBI Working Paper: Predicting Exchange Rate in India- A Non-parametric Causality-in-Quantiles Approach**

The RBI has published a working group paper on predicting the exchange rate (USD/INR) in India using a non-parametric approach. This paper is authored by Seema Jaiswal, Director in the Department of Payment and Settlement Systems, Reserve Bank of India (RBI). In this RBI paper the author has attempted to move away from standard statistical techniques & study the existence of causal relationships between a multitude of domestic and international market indicators, and more specifically, the impact of volatility in domestic and international asset prices on the USD/INR.

### **Background:**

The Annual report on Exchange Rate Arrangements and Exchange Restrictions classifies India as country following a flexible exchange rate regime. The determination of exchanges rates of the rupee vis-à-vis the US Dollar or any other currency happens purely through the market mechanism, i.e. forces of demand and supply. The market forces are in turn affected by various macroeconomic factors such as trade balance, current account balance, net capital flows, movements in major global currencies, domestic and global political developments, market expectations of relative interest rate and relative inflation for the INR (Indian Rupee) and the USD (US Dollar). The RBI does intervene in the forex markets, as it has been doing recently, to curb extreme volatility and maintain orderly conditions in financial markets. There has been a significant evolution in the foreign exchange markets in India with a wide variety of instruments being added to the armoury, and major developments in institutional and market infrastructure enabled by a more liberalised regulatory environment.

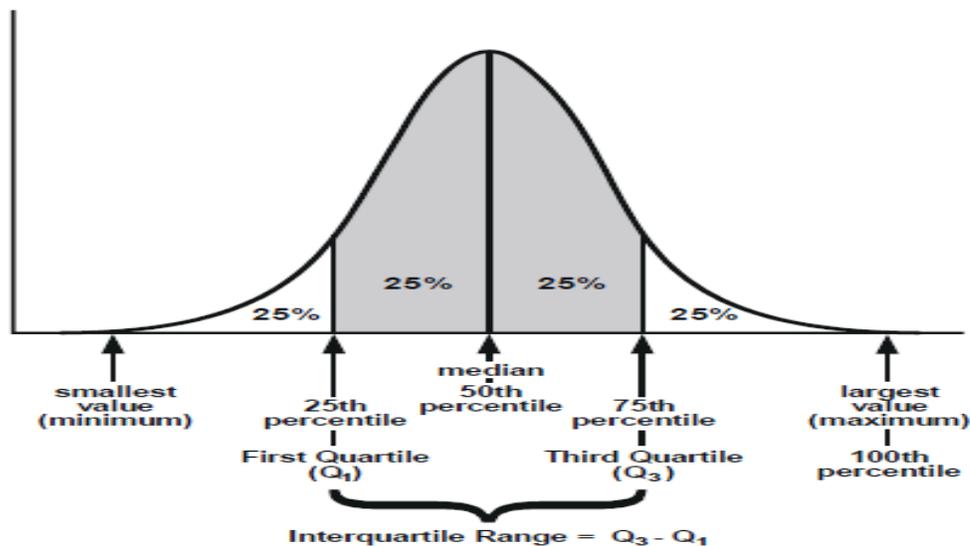
According to the Bank for International Settlements (BIS), over-the-counter trades in the Indian rupee constituted 1.7 per cent of the total USD 6.6 trillion global foreign exchange markets. The turnover of the average daily USD/INR pair jumped up to USD 110 billion in April 2019 from USD 56 billion in April 2016. The calibrated and gradual opening up of the capital account and other external sectors of the economy the Indian forex market has become increasingly integrated with the rest of the world. This is reflected in the increased volume of capital flows and growing trade in the foreign exchange market, and is reflected more in the turbulence and calm seen in the Indian rupee in sync with the movements of the major global currencies.

The greater integration of the domestic markets with global trade and financial markets has called for sharper analyses of the inter-linkages of the rupee with a plethora of financial and commodities markets like foreign currency market (exchange rate), commodity market (oil and gold prices), the stock market (domestic and global), and capital flows( foreign portfolio investments). Since all these markets are inter-linked, changes in one can affect all or one. The present study investigates the predictability of the exchange rate return and volatility suing a set of select financial variables. The

present study in the research paper investigates the predictability of exchange rate return and volatility using select financial variables. There can be diverse inter-linkages between the financial variables and exchange rate under different degrees of exchange rate movements. The causality-in-quantile helps to measure the causality for each point of the conditional distribution of exchange rate return and volatility.

### Causality in quantiles:

Explanation of the method of causality in quantiles is warranted. As it stands, earlier causality would mean Granger causality which established a casual relation between two variables looking only at the conditional mean. The Granger causality test is a statistical hypothesis test for determining whether one time series is useful in forecasting another. Mean would indicate the average of the sample and conditional being the average met after fulfilling certain criteria. A quantile is any arbitrarily chosen equal fraction of the frequency distribution, like a quartile which divides the frequency distribution into 4 equal parts. It follows from this that there will only be three quartiles in the distribution as depicted in the diagram below. Causality in quantile is the more general form of causality based on conditional quantile distribution derived, which allows to test the existence of causality at each quantile.



Source: Stack Exchange

The results based on conditional mean analysis may be ambiguous, especially when the distribution of a given variable is fat-tailed, as is the case with daily exchange rate returns. Thus, the conditional mean-based method may not delineate the complete causal relationship between two variables.



### **A new approach**

As against standard statistical techniques of using and relying solely on various parameters like mean, median, mode, variance & standard deviation, a non-parametric approach is more suited to a study of this sort since it does not make it obligatory for the researcher to depend on the shape of the underlying distribution of the variable under study.

Analysing the data, it is evident that the stock price return in India is higher as compared to the global stock price return in the US, the UK and the emerging markets. The volatility of variables as represented by standard deviation shows that the exchange rate has lower variability as compared to return on stock and commodities prices. Oil price returns and stock indices returns, as mentioned in the literature, are some of the most volatile among all commodity prices. Frequent occurrence of extreme returns is also indicated by data. All the commodity prices, stock prices and exchange rates have shown an upward trend in general. As a result of huge capital inflows into India, during the periods 2003-2008 and 2009-2011, the exchange rate recorded appreciation (downward movement). However, the exchange rate recorded a sharp depreciation during the periods of global uncertainties like the global financial crisis (2007-2009); post-announcement effects of quantitative easing programmes by the US Federal Reserve from May 23, 2013 to September 4, 2013 (Fed taper tantrum); and the recent COVID-19 pandemic (February 27, 2020 to May 29, 2020).

### **Key findings of the paper:**

Some of the key empirical findings of the paper are given below with charts given in an annexure. The Critical Value (5%), and Critical Value (10%) are used in the charts along with the causality-in-quantiles test results. The selected variable is said to have predictive power to the exchange rate only if the value of the test exceeds the critical value of 5%. The terms “stronger in mean” and “stronger in variance” indicate the strength of the causal relationship in these two moments of the distribution, or in simpler terms the predictive power of the selected variable on the exchange rate:

- WTI oil price return predicts exchange rate return over the quantile range of 0.25 to 0.90 while Brent oil return predicts over a shorter quantile range of 0.45 to 0.75. However, in variance, Brent crude oil price predicts exchange rate volatility over higher range (0.15 to 0.80) than WTI price (0.20, 0.25 and 0.40). This implies both WTI and Brent crude oil influence exchange rate barring extreme volatile periods.
- Gold price return predicts exchange rate return at all points except at lower and upper tail of its conditional distribution. Gold price return causes exchange rate volatility only around the median to moderately high quantiles (0.45 to 0.65). This implies gold serves as a hedge against the USD during the normal period.
- BSE index return predicts exchange rate for almost all quantiles except at tails (0.10 and 0.95) and similar results hold for NSE index return. For causality-in-



variance, BSE return affects exchange rate covering quantiles around the conditional mean except at lower and upper quantiles. In terms of volatility, NSE return impacts the exchange rate for a relatively shorter-range (0.15 to 0.70) than BSE. The US stock market return (S&P 500), the UK stock market return (FTSE 250) and the emerging markets stock market return (MSCI) predict exchange rate return over the quantile range of 0.15 to 0.90, 0.10 to 0.90 and 0.15 to 0.85, respectively.

In terms of the impact of volatility from these global stock indices on exchange rate volatility, results show that the US stock market and emerging stock market returns cause volatility in the exchange rate returns over most of the quantiles other than at extreme tails on both sides of the conditional distribution, i.e., barring periods of extreme low and high exchange rate volatility. The volatility in the UK stocks (FTSE 250) exhibits nearly similar results as the other two global indices but does not have significant causalities at some lower quantiles. The association between the exchange rate and stock price (as per stock oriented model) states that a positive change in stock price of an economy encourages foreign investors in domestic markets, which in turn leads to high demand for local currency and results in an appreciation of the exchange rate. Any positive (negative) change in global stock market results in strengthening (weakening) of foreign currency. Domestic stock market and global stock market are closely integrated. Hence, the global stock market also indirectly impacts the exchange rate. The authors have used the three major global stock indices, S&P 500 (the US stock market stock index), FTSE 250 (the UK stock index) and MSCI (the emerging market index) in the analysis.

- Net portfolio is measured as the difference between gross inflows and gross outflows of portfolio investments. Portfolio investment flows are among the most volatile component of capital flows, substantial variation in these flows may result in an appreciation or depreciation of the exchange rate. Net portfolio return predicts exchange rate return around the conditional mean covering quantiles range from 0.10 to 0.85. An almost similar pattern is observed for causality in variance; however, the net portfolio prediction for exchange rate is stronger in variance than in mean.
- India VIX predicts exchange rate volatility over its entire conditional distribution. VIX predicts exchange rate volatility for the quantile range 0.15 to 0.80. The results show that domestic India's VIX impacts exchange rate volatility across all quantiles of the conditional distribution of exchange-rate volatility, while VIX does not significantly predict exchange rate volatility during periods of low and high volatility. It is also important to note that these two variables have the strongest predictive power for exchange rate volatility as compared to all other variables used in the study.

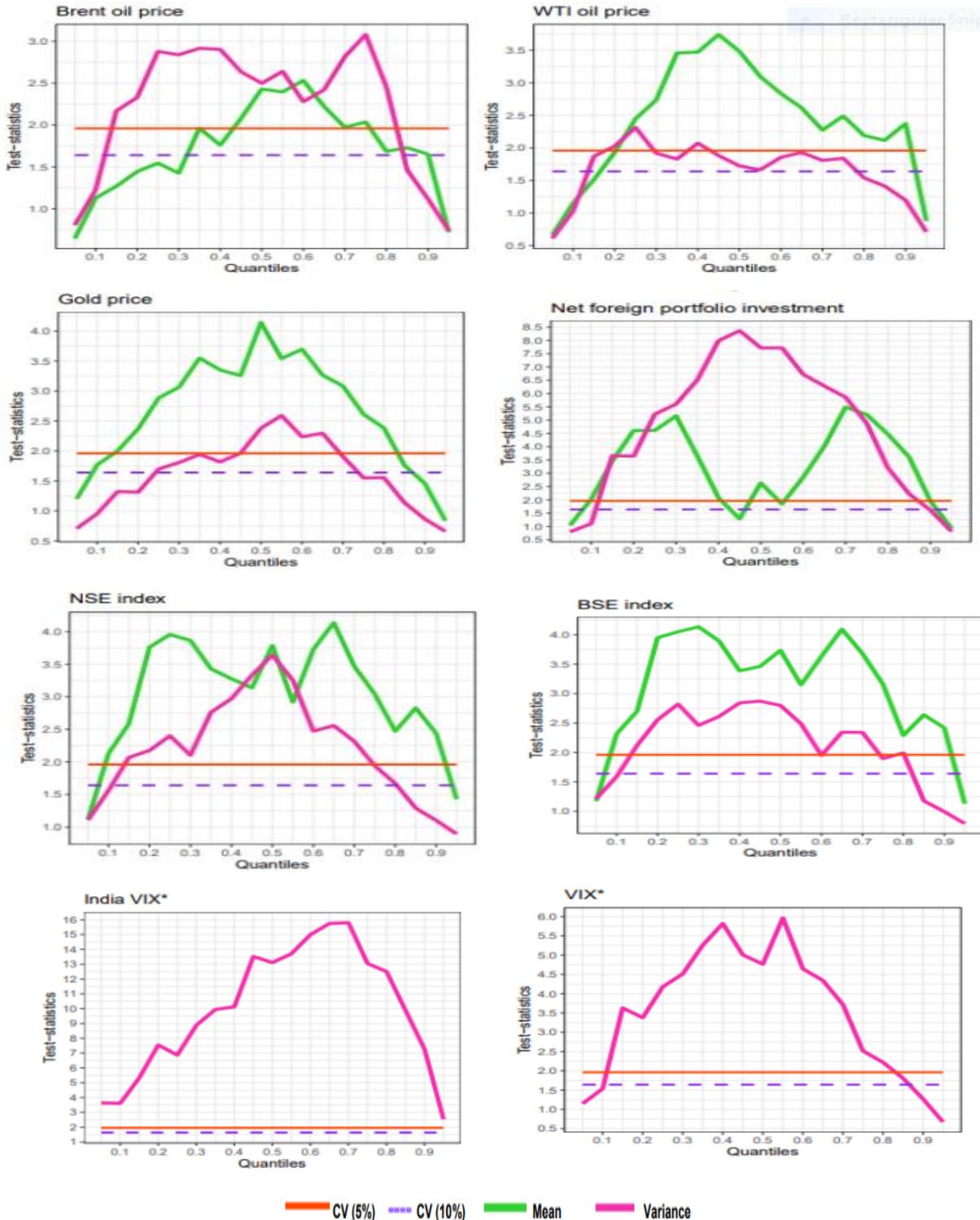
**Key Findings:**

- Both WTI and Brent crude oil influence exchange rate barring extreme volatile periods.
- Gold serves as a hedge against the USD during the normal period.
- In terms of volatility, NSE return impacts the exchange rate for a relatively shorter-range than BSE.
- The global stock market also indirectly impacts the exchange rate
- Net portfolio prediction for exchange rate is stronger in variance than in mean.
- India VIX and VIX have the strongest predictive power for exchange rate volatility as compared to all other variables used in the study.

**Conclusions:** The strength of causality of each variable with exchange rate return and volatility is asymmetric at different quantiles. Specific financial variables may have a causal relationship with exchange rate in mean but not in variance for a particular quantile. All the selected variables under consideration predict exchange rate return and volatility around the middle quantiles, i.e., during normal periods. The causality-in-quantile approach helped in ascertaining the existence/ non-existence of causality relationship between select financial parameters (pairwise) and the exchange rate in mean and in variance at various quantiles. Of course, other than these variables, market intervention, capital account-based measures by the Reserve Bank and other administrative measures by the Government also played a role in controlling the extreme exchange rate movements. In sum, the study provided insights for policymakers, international investors, and hedge fund managers to ascertain the directional causalities from select financial variables to the exchange rate in various states of forex market. The analysis is also useful to determine how these selected asset classes (financial market and commodity) can be used to minimise exchange rate risk, especially during periods of extreme exchange rate volatility.



**Annexure:** Causality-in-quantile in mean and variance from selected financial variables to exchange rate (Various quantiles are shown along the horizontal axis and nonparametric causality test statistics are plotted against the vertical axis)



Source: RBI Working Paper WPS (DEPR): 12/ 2022: Predicting Exchange Rate in India- A Non-parametric Causality-in-Quantiles Approach



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