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# ASYMMETRIC EFFECTS OF EXCHANGE RATE CHANGES ON INDIA'S TRADE BALANCE: AN EMPIRICAL INVESTIGATION

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**Abstract**

This study examines the asymmetric effects of exchange rate changes on India's trade balance and its repercussions on the external sector policy, with a focus on the foreign exchange reserves and real Gross Domestic Product (GDP). The paper provides key definitions of various exchange rates within the context of India's economic landscape. A comprehensive literature review delves into the ongoing debate surrounding the adoption of a strong or weak exchange rate policy and its implications on the overall economy. Subsequently, the paper introduces a model illustrating the cyclical nature of currency fluctuations in an economic framework. Empirical findings reveal that currency depreciation correlates with an increase in foreign exchange reserves and economic growth. Utilizing data from the International Financial Statistics of the International Monetary Fund and World Development Indicators of the World Bank, econometric tests and software are employed to validate the hypothesis. The results are thoroughly examined, leading to concluding remarks. The study acknowledges certain limitations in its research approach.

## Introduction

In straightforward terms, foreign exchange is the representation of one currency's value in relation to another currency. This exchange rate serves as a benchmark for comparing the relative values of two currencies, playing a crucial role in facilitating their comparison. Exchange rates are influenced by both the value of the domestic currency and that of the foreign currency. The calculation of exchange rates is imperative as it determines the pricing and quantity of goods exchanged between countries, providing essential information for businesses on a global scale.

Historically, India has experienced a consistent weakening of its exchange rate. Going back to 1947, the INR – USD exchange rate was 4.16. However, as of October 20, 2022, this rate has surged to 83.20, signifying a substantial twentyfold increase. A study conducted by the RBI in 2010 highlighted that the Indian rupee was indirectly pegged to gold through the British Pound (GBP) sterling until 1971. Following the balance of payments crisis in 1990-91 and subsequent exchange rate fluctuations, the Rupee was left free of intervention in 1993 and has since exhibited a steady depreciation.

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As defined by the International Monetary Fund (Balance of Payments Manual, and Guidelines on Foreign Exchange Reserve Management, 2001), foreign exchange reserves represent external assets available and controlled by monetary authorities. These reserves serve various purposes, such as addressing external payment imbalances, influencing currency exchange rates through market interventions, and enhancing confidence in monetary and exchange rate policies. The central bank of a country holds foreign exchange reserves for reasons including maintaining confidence in monetary policies, intervening in foreign exchange markets, ensuring liquidity during foreign exchange crises, and improving the government's credit rating by meeting external obligations (Reddy, 2002).

The third key variable in this study is the real Gross Domestic Product (GDP), a metric that captures the aggregate value of goods and services produced by all sectors of the economy, measured at constant prices of a base year. Serving as the standard measure of a country's economic growth, real GDP is integral to any macroeconomic study, providing insights into the implications of the variables under consideration on the nation's economic trajectory (Thapa, 2002).

Therefore, the focus of our discussion revolves around three macroeconomic variables: foreign exchange rate, foreign exchange reserves, and real GDP of India. This paper seeks to establish the impact of foreign exchange rate changes on India's trade balance, with a specific emphasis on the asymmetric effects. The examination takes into account other factors held constant. Empirical evidence is presented, indicating that fluctuations in currency depreciation lead to notable effects on both foreign exchange reserves and economic growth. This hypothesis forms the crux of the study and is systematically validated in the later sections of the paper.

**Review of Literature**

Deepak Adhikari, Assistant Director of the Nepal Rastra Bank (NRB), used the Ordinary Least Squares (OLS) method in 2018 to ascertain that the depreciation of the Nepalese rupee leads to an increase in economic growth and foreign exchange reserves of Nepal while improving the trade deficit of the country. Since the scope of our studies is similar, the economic relationship between the variables postulated by him has been incorporated into this model for analysis. Nephil Matangi Maskay, Deputy Director of the NRB, established in 2001 that the foreign exchange rate is impacted by interest rates, inflation, money supply and national income collectively, among other variables. Some insights and concepts from his papers in 2001 and 2007 have been incorporated herein. Relevant ideas from studies in Vietnam (Thuy & Thuy, 2019), Somalia (Sharif & Ali, 2016), and India (Sut, 2019) with similar results have also been used. The theoretical foundation has been formed with ideas from Jeffrey Frankle's 1999 NBER (National Bureau of Economic Research) publication and several other Indian studies concerning trade balance and how it is affected by exchange rate fluctuations. These studies have been cited later in the literature review as we cover concepts starting with exchange rate regimes and the systems they comprise, forward and spot exchange rates, and nominal and real exchange rates, before finally discussing currency appreciation and depreciation in the general scenario with some insights into India's trade balance status.

Exchange rates can be classified into three broad types and nine subtypes based on how they are determined (Frankle, 1999). The exchange rate of a country can be determined wholly by the government and central bank, independent of market forces. This is called a *fixed* or *pegged* exchange rate. Under this system, the weaker of the two exchange rates is said to be pegged to the stronger one. This is done through the purchase of forex when the exchange rates are high and the sale of forex when the exchange rates are low. It is common to see small economies peg their currency to the USD as most of their revenue comes from the USD. Besides, this also helps stabilize the economy as it increases its ability to withstand exchange rate volatility. There are 3 kinds of rigid pegs in order of increasing flexibility (Frankle, 1999):

i. Currency Union: The domestic currency in a currency union is the same as that of major neighbouring countries. This is the firmest commitment to a fixed exchange rate possible. The best example of a currency union is the European Monetary Union (the Euro being the common currency).

ii. Currency Board: A currency board is a monetary institution that only issues currency that is fully backed by foreign assets. It aims to create a credible policy environment; in order to achieve this it forbids monetary authorities from the option of printing money to finance government deficits. The currency board has been seen to be effective in Argentina to counter hyperinflation in the 1980s. However, it should be noted that a currency board requires solid fundamentals of adequate reserves, fiscal discipline, and a strong and well-supervised financial system, in addition to the rule of law in order to be successful in achieving a country's monetary objectives.

iii. A truly fixed exchange rate: This comprises countries that have fixed their currencies to stronger currencies like the Dollar with no intervention by monetary authorities to alter the value of the currency.

On the contrary, the exchange rate of a country can be determined without the interference of the government or central bank, and entirely by the market forces of demand and supply. This is called the *free* or *floating* exchange rate, as it is free of government intervention. The most commonly traded currencies in the world such as the US Dollar, the Euro, the British Pound, and the Japanese Yen are the closest to following the floating exchange rate regime. The exchange rate is determined by the amount of currency where the demand for forex equals the supply. This can be better illustrated with the help of a demand-supply schedule of foreign exchange.

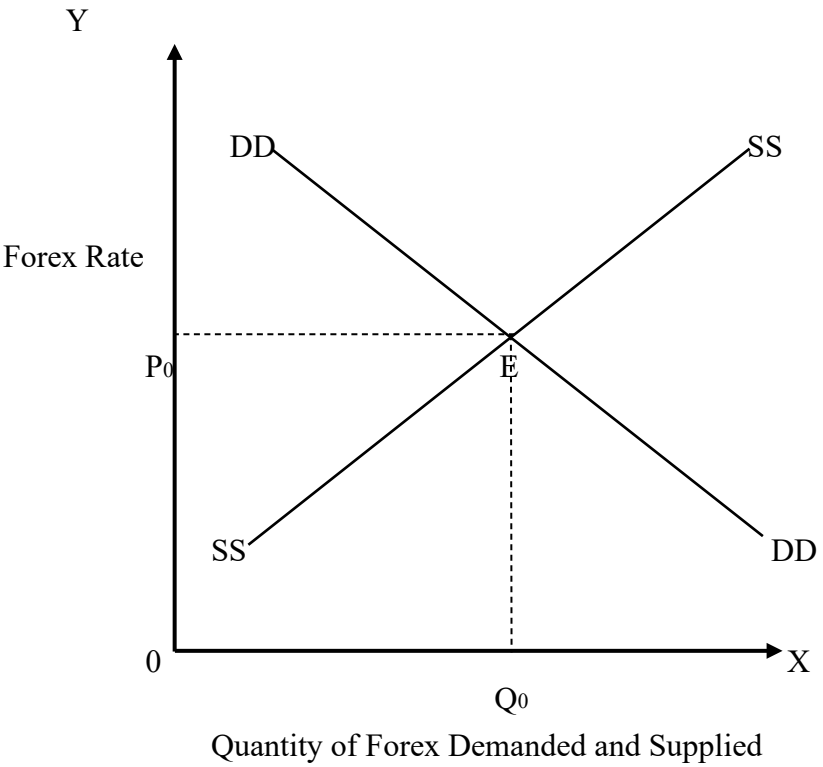


*Figure 1.* Determination of Foreign Exchange Rate Under Freely Floating Exchange Rate System

In the figure above, the X axis shows the quantity of forex of the country demanded by the rest of the world and the quantity supplied by the country to the rest of the world. The Y axis shows the forex rate. The DD curve shows the quantity of forex demanded while the SS curve shows the quantity of forex supplied by the country. The point where the DD curve intersects the SS curve, i.e. the point where demand for forex is equal to the supply of forex,

is called the equilibrium point E. $P_0$ and $Q_0$ highlight the equilibrium forex rate and the equilibrium amount of foreign exchange that should be traded with the rest of the world respectively.

The third and most common type of exchange rate regime is the *intermediate* exchange rate regime. Herein, the monetary authority has partial control over the value of the currency. In essence, it lies between the polar cases of fixed and flexible exchange rate regimes. The Reserve Bank of India and its allies now intervene occasionally in the foreign exchange markets not to support the rupee from plunging to new lows but rather to avoid an appreciation in its value (Chakrabarti, n.d.). The intermediate regime is the most common exchange rate regime and has several sub-types with varying degrees of flexibility. Countries often employ any one of the exchange rate systems that fall under the category of the intermediate regime to achieve the optimum tradeoff between the advantages of fixed and flexible exchange rate regimes. The different exchange rate systems, in order of increasing flexibility, that fall under the bracket of the intermediate exchange rate regime are (Frankle, 1999):

i. Adjustable peg: Exchange rate pegs that are fixed to another currency but can still be adjusted periodically by the monetary authority are called adjustable pegs. Currency pegs under the Bretton Woods regime were mostly adjustable pegs.

ii. Crawling peg: Exchange rate pegs that can be reset regularly in a series of mini devaluations are called crawling pegs. This is the most effective in countries with high inflation, as it makes it easier to regulate the currency's value in response to price changes as often as weekly. Latin American countries of Chile, Brazil, Uruguay and Paraguay used this system to their advantage in the late 1970s to tackle rising inflationary pressures.

iii. Basket peg: Instead of one major currency, the domestic currency can be pegged to a basket of currencies with different weights assigned to each currency. This approach is tenable for countries with diversified trade patterns, like in Asia.

iv. Target zone or band: The monetary authority intervenes to maintain the exchange rate within a target zone or band. As soon as the exchange rate dips below or marginally exceeds the band, the monetary authority sells/purchases foreign exchange as a means to reach the target zone again.

v. Managed/Dirty float: The monetary authority intervenes against the exchange rate fluctuations caused by market forces of demand and supply i.e., it purchases the currency when its value is rising and vice versa.

From a fixed exchange rate regime, India shifted to a more deregulated exchange rate system in 1992−1993 and since then there exists a managed floating regime wherein the Reserve Bank of India intervenes from time to time to prevent excessive destabilisation in the exchange rate market (Bhat & Bhat, 2021).

Another classification of exchange rates is nominal and real exchange rates. The nominal exchange rate or simply the exchange rate is the price of one currency in terms of another. It's usually expressed as the domestic price of the foreign currency (Catão, 2007). The real exchange rate between two countries may be defined as the relative price of one country's consumption basket in terms of the consumption basket of the other country (Mussa, 1986). The real exchange rate (RER) between two countries is the nominal exchange rate (e) multiplied by the ratio of prices in the two countries (P* / P) (Catão, 2007). Or,

$$RER = e.P^* / P$$

We now discuss the dilemma many may encounter while studying exchange rates. The choice between a strong and a weak exchange rate policy has been evaluated by comparing their respective economic implications, taking into account the winners and losers in the economy as a result of both. Common misconceptions like considering a strong exchange rate to be strictly beneficial to the economy and a weak exchange rate to be strictly harmful to the economy are discussed. For conceptual clarity, before getting to the crux of the topic itself, one must understand the mechanism of currency valuation under the freely floating exchange rate system. Currencies under

the freely floating exchange rate system are valued in the forex market by the market forces of demand and supply, as mentioned earlier.

In the general scheme of exchange rate mechanics, there are various reasons for a currency to be in high demand. According to Schilling (1998), the desire of foreign citizens to purchase financial securities and assets of the country, high borrowings by the sectors of the economy and an increased reliance on credit are among a few of them. Often, the high borrowings are funded by the savings of the public. However, in many cases, the borrowing requirements of the economic sectors are funded by borrowing funds from abroad. When funds from abroad help meet the demand for money, the interest rates in the economy tend to rise. It is also a common practice for central banks to control the money supply, to curtail inflation in the economy. This too results in higher interest rates in the economy, which enables foreign investors to get higher returns by investing in the country's financial markets. Therefore, the demand for the domestic currency increases i.e. it is more attractive to foreign investors. This increases the price of the currency in the forex market. Generally, as we can understand from the mechanism described above, the forex market is governed by the laws of demand and supply under the freely floating exchange rate system. Prices set for each currency are determined by whether investors want to hold more of it or less of it. Put simply, the price of a currency in the forex market *increases* as its demand increases, and *decreases* as its demand decreases. Conversely, the price of a currency in the forex market *increases* as its supply decreases, and *decreases* as its supply increases (Schilling, 1998). We can hence conclude that the exchange rate of a currency is *directly* related to its demand and *inversely* related to its supply in the forex market.

To the layman, the point of this discussion may seem perplexing, as a "strong" exchange rate seems more desirable than a "weak" exchange rate. However, when talking about a country's currency, it's not as straightforward. While currency appreciation[iii] may seem ideal to many, it has certain drawbacks i.e. it affects some parts of the economy negatively (Wolla, 2015). Meanwhile, while many consider currency depreciation[iv] to be harmful to the economy, it positively affects some parts of the economy. Both currency appreciation and depreciation affect the various economic agents[v]: one may positively impact a particular agent while the other may hurt the same agent. This varies depending on the economic agent in question.

The standard theoretical contours presume that a domestic currency depreciation/devaluation would make exports cheaper and imports more expensive, thereby improving the trade balance of the country whose currency depreciates (Bhat & Bhat, 2021). According to Forbes (2002), there are however, a number of reasons why devaluations may not have this desired effect, such as if the demand for exports is relatively inelastic or imported inputs are a large component of production. Ghei and Pritchett (1999) provide a detailed summary of why devaluations may or may not improve export performance, as well as why it is difficult to measure these effects. After a review of the 4 empirical works on this subject, they conclude that exports typically increase after a devaluation and that most of this response occurs rapidly (in about one or two years). Sudden capital flows can hurt macroeconomic stability through rapid credit expansion and real exchange appreciation that may lead to a current account deficit (Chakrabarti, n.d.). In the short run, currency appreciation deteriorates the trade balance and currency depreciation improves it. In the long run, again a similar response is observed (Bhat & Bhat, 2021). Bhat and Bhat (2021) highlight another important concept that is applicable to the Indian case study. If the imports are priced in foreign currency and exports are priced in domestic currency, certain rigidities prevent the improvement of the trade balance immediately following a currency depreciation. This is because at the time of depreciation, while the previous purchase orders or contracts for import and export quantities remain unchanged, the price changes have an instantaneous effect. As a result, the value of export earnings falls and import payments rise. Therefore, in this case, depreciation worsens the trade balance in the immediate period. However, once quantity and price adjustments are made in the long run, an improvement in the trade balance is observed. This

temporary deterioration of a country's trade balance followed by an improvement due to currency depreciation is popularly known as the *'J-curve' effect* (Bhat & Bhat, 2021).

It has been observed in all related studies that, on average, there has been a strong and significant negative impact from currency appreciation and currency volatility on the international market shares of India's exporting firms, hence the trade balance and forex reserves as well (Cheung & Sengupta, 2013). According to Cheung and Sengupta (2013), a one percentage point increase in the appreciation of the Real Effective Exchange Rate[vi] (REER) causes a 6.3% reduction in the change of the share of exports in total sales of Indian firms. This statistic helps us conclude our literature review on strong and weak exchange rates' macroeconomic impacts. Following this is a further juxtaposition of the above-mentioned and some important cases in history wherein sudden exchange rate fluctuations greatly affected the economy of the countries in question.

We can further juxtapose weak and strong exchange rates with the help of a country's economic context. Theoretical comparisons and weighing out pros and cons, though essential, offer a conceptual but limited understanding of the two. Numerous empirical studies have been conducted in many countries and areas around the world to evaluate the impact of exchange rate volatility on exports. Again, the implications of the results of those studies confirm that, although exchange rate volatility has an impact on exports, the effect can be either positive or negative depending on the endowment of each country (Thuy & Thuy, 2019). It can be inferred that the dilemma between adopting a strong or a weak exchange rate can be solved to an extent by laying out the country's economic objectives and historical context: the kind of growth the economy has witnessed over the course of the last few decades and the kind of growth it aims to achieve over the next decade.

Perhaps the most important example of a sudden change in the forex rate having severe economic implications is that of the Asian Crisis of 1997-1998. According to Corsetti et al. (1998), the Asian Crisis can be attributed to macroeconomic strains in 5 countries: Thailand, Indonesia, Malaysia, Philippines, and Korea. By the end of 1996, the macroeconomic condition of *Thailand* was very shaky. Further, the Thai Baht came under attack for its peg to the USD in November 1996. This forced the Thai monetary authority to adopt a floating exchange rate regime. In *Indonesia*, the economy showed signs of overheating in 1996. The government did no more than promise efforts to control inflation and increase the efficiency of the export sector. This, coupled with a series of ineffective policy initiatives to bring the economy back on track earned Indonesia the honour of being the most corrupt country in Asia. A widening current account deficit in 1995, along with a surge in public investment (mainly in the political interests of the Prime Minister) drove *Malaysia* to the brink of an economic crisis in 1996. Crucially for the Bank Negara, foreign fund managers realised that Malaysia's interest rates were too attractive to be ignored. The Bank strategically used the weakening Ringgit to its advantage by raising the interest rates. This drove up capital inflows and bank lending tremendously. Meanwhile, *Korea* experienced a serious deterioration in macroeconomic conditions in 1996: the current account deficit widened, industrial productivity took a hit, banking conglomerates struggled financially leading to large-scale bankruptcies, and the Won weakened during 1996. Compared to other countries in the region, the *Philippines* had a more solid macroeconomy in 1996, owing largely to the structural reforms enacted under the IMF. However, the current account deficit was large and the currency had significantly appreciated in real terms (Coresetti et al., 1998).

There is therefore no fixed causal relationship between the strength of a country's currency and its economic development. The value of a currency in relation to other currencies does, however, affect different individuals and firms differently. The meanings of the words "strong" and "weak" can mislead people into thinking that a strong exchange rate is better for an economy, which typically is not the case (Wolla, 2015). In the context of exchange rates, the words "strong" and "weak" are not opposites, as either of them is employed by a country to achieve economic development. Also, under the freely floating exchange rate system, currencies do not always

remain strong or weak. Strong currencies may weaken over time while weak currencies may strengthen over time depending on the economic scenario. Instead of two sides of the spectrum of currency strength, strong and weak currencies can be thought of as two parts of a cyclical economic phenomenon which involves gradual fluctuations in the value of a currency until it attains a temporary equilibrium value due to changes in the prices and demand for commodities exported and imported by the country. This has been illustrated below.

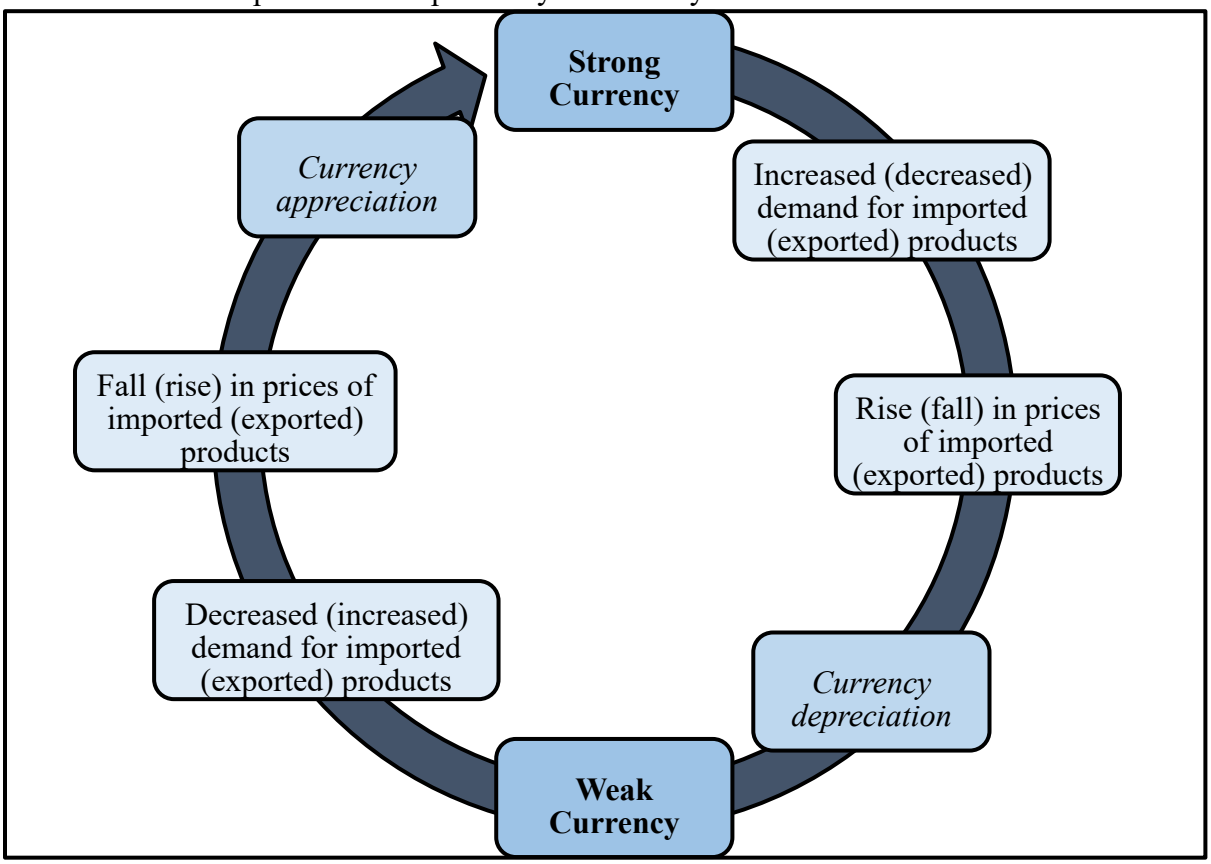


*Figure 2.* Cyclical fluctuations in the exchange rate

The figure can be explained as follows. Every currency, after appreciation or depreciation, eventually returns to an equilibrium value. In the case of currency appreciation, the demand for imported products increases due to an increased purchasing power of the public and importing firms. As per the law of demand, the price of imported products increases due to the increased demand. Simultaneously, expensive domestic exports will lose demand in foreign markets, and their prices will come down gradually as per the law of demand. These changes will continue to occur until an equilibrium exchange rate is found. In the case of currency depreciation, the demand for exported products increases due to the competitive advantage gained by export firms in foreign markets. This gradually increases the prices of exported products and their demand wears down with time. Simultaneously, expensive imports due to lower purchasing power start losing their demand over time and their prices decrease as a result. These changes will also continue to occur until an equilibrium exchange rate is found.

## 1. Methodology

This study aims to analyse the impact of the exchange rate on the real GDP and forex reserves in India. The *Ordinary Least Squares* (OLS) method has been used to regress the dependent variable on the independent variables or regressors. This method is useful when parameters are unknown and the relationship between the dependent and the explanatory/independent variable is a hypothesis that needs to be tested. The OLS estimate of

the parameters is the one that yields the least sum of squared residuals (the difference between actual and expected values of a variable) (Chumney & Simpson, 2006).

The OLS method has certain assumptions that must be true in order for the regression analysis to achieve the most accurate results. There are 7 such assumptions in total. These are discussed below:

i. *The error term has a mean of zero*: The error term accounts for variation in the dependent variable that the independent variables do not explain and its value is determined randomly. Including a constant term in the regression model forces the mean of the residuals to be zero, which is what has been done in the model presented later.

ii. *The regression model is linear*: All the terms in the model are either the constant or a parameter multiplied by an independent variable. The regression equation is made by adding these terms together.

iii. *There is no autocorrelation between the errors*: This assumption asserts that one observation of the error term should not predict the next observation. In order to prevent this, if we possess information which shows that it is more likely that the next observation is going to be lower or higher, we need to add an independent variable to the model that captures this information.

iv. *The covariance between the independent variables and the error term is zero*: If an independent variable is correlated with the error term, we can use the independent variable to predict the error term. This violates the notion that the error term represents unpredictable random error. This information needs to be incorporated into the regression model itself.

v. *The error term has a constant variance or homoscedasticity*: The variance of the errors should be consistent for all observations. This is called homoscedasticity.

vi. *The error term is normally distributed*: This isn't an assumption that is necessarily fulfilled in successful OLS models but having the error term follow a normal distribution produces unbiased estimates with minimum variance.

vii. *No independent variable is a perfect linear function of other independent variables*: When two independent variables have a Pearson's correlation coefficient of 1 or -1, perfect correlation occurs. This implies that the two variables are different forms of the same variable and are therefore unfit for regression. Strong correlations (correlation coefficients close to 1 and -1), however, may cause the problem of multicollinearity and reduce the accuracy of OLS results.

The functional relationship between the exchange rate, which has been established as the variable of interest of the study, forex reserves, and the real GDP, is given below (Adhikari, 2017).

$$\text{Forex Reserve: FOREX} = f(\text{EX\_AV}, \text{R\_GDP}) \quad (1)$$

$$\text{Real GDP: R\_GDP} = f(\text{EX\_AV}, \text{FOREX}) \quad (2)$$

Where,

- FOREX stands for forex reserve
- EX_AV stands for the average exchange rate of the INR with the US Dollar
- R_GDP stands for real GDP

The estimating equation is schematically given below.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + u \quad (3)$$

Where y is the dependent variable, $x_1$ to $x_k$ is the set of independent variables, $\beta_0$ is the constant term, $\beta_1$ to $\beta_k$ is the set of coefficients of independent variables, and u is the error term. The equations are estimated using annual time series data. As described above, the impact of exchange rates has been examined with the Ordinary Least Squares (OLS) method of linear regression.

## 2. Data and Sample Period

The study has been conducted based on forex and growth-related variables from CY 1992 to 2021, sourced from the International Financial Statistics (IFS) of the International Monetary Fund (IMF) and the World Development Indicators of the World Bank. The variables used in the study are India's forex reserves (FOREX), Real GDP OF India (R_GDP) and the average nominal exchange rate (period average) between the Indian Rupee and the US Dollar (XR_AV). All figures are annual. The data used in this empirical analysis is presented in the Appendix in tabular form, with an Excel link to the database available as well.

## 3. Empirical Results

The empirical analysis begins with a *correlation analysis* of the variables. The relationship between the exchange rate and economic growth is examined later. Lastly, the relationship between the exchange rate and forex reserves is examined. All statistical work has been carried out using the statistical software Gretl. For the sake of interpretation in the percentage form, the OLS regressions have been conducted after taking the logarithms of all the variables in the model.

### 3.1. Correlation Analysis

A correlation analysis explains the strength and direction of the relationship(s) between two or more variables in a given dataset. The Pearson Correlation Coefficient, r, can take values from -1 to 1. A positive value of r signifies a positive relationship between the variables while a negative r signifies a negative relationship. The further away r is from 0, the higher the magnitude of the relationship between the variables.

To determine how related the variables are to each other, a correlation analysis has been carried out between the real GDP, forex reserves and the average exchange rate between the INR and the US Dollar. The output is recorded below.

Correlation Coefficients, using the observations 1992 - 2021
5% critical value (two-tailed) = 0.3610 for n = 30

| R_GDP | FOREX | XR_AV | |
|---|---|---|---|
| 1.0000 | 0.9727 | 0.9179 | R_GDP |
| | 1.0000 | 0.8919 | FOREX |
| | | 1.0000 | XR_AV |

*Source: Author's computations using Gretl*

It can be understood that the three variables are highly correlated, i.e. when one variable increases, the other two increase in very high proportion. The real GDP shows a correlation of 0.97 with forex reserves and 0.91 with the average INR – USD exchange rate. The forex reserve shows a correlation of 0.89 with the average exchange rate. One problem we might encounter during linear regression is that of multicollinearity, which is common in the case of highly correlated independent variables. This would be in violation of assumption 7 of OLS estimators as described above. To check for multicollinearity, we run the Variation Inflation Factor (VIF) test on our proposed OLS models. A variance inflation factor (VIF) is a measure of the amount of multicollinearity in regression analysis. Multicollinearity exists when there is a correlation between multiple independent variables in a multiple regression model. This can adversely affect the regression results. Thus, the variance inflation factor can estimate how much the variance of a regression coefficient is inflated due to multicollinearity.

The results are shown in the following subsections, post which the linear regression is carried out.

### 3.2. Exchange Rate and Economic Growth

Before regressing the economic growth (real GDP) on the exchange rate, we carry out the VIF test to ensure multicollinearity does not invalidate our OLS model.

```
Variance Inflation Factors
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

     l_FOREX    4.342
     l_XR_AV    4.342
```

*Source: Author's computations using Gretl*

Since the VIF test statistic lies in the acceptable range of 1 to 5 (or sometimes 10 as shown), the regressors forex reserves and average exchange rate are fit to be used in the OLS model described before.

Table 1

| **Variables** | **l_R_GDP** | **t-ratio** | **p-value** |
|---|---|---|---|
| l_FOREX | 0. 508915***. | 8.516 | 3.96e-09 |
| | (0.0597629) | | |
| l_XR_AV | 0.565696** | 2.066 | 0.0485 |
| | (0.273768) | | |
| Constant | 5.64449*** | 10.12 | 1.09e-10 |
| | (0.557603) | | |
| Observations | 30 | | |
| R squared | 0.945392 | | |
| Durbin-Watson | 0.350683 | | |

*Source: Author's computations using Gretl*

The estimated regression equation is given below.

$$l\_R\_GDP = 5.64 + 0.51\ (l\_FOREX) + 0.57\ (l\_XR\_AV) \quad (4)$$

The regression results can be interpreted as follows:

1. The regression coefficients have been mentioned alongside the regressors and the constant. Coefficients are unstandardised OLS partial regression slopes. In our model, the regression coefficients are 5.64 (constant or intercept), 0.51 (forex reserves), and 0.57 (average exchange rate). From the OLS model, it is evident that the economic growth rate of India is significantly influenced by the change in the exchange rate of the Indian rupee with the US dollar and the growth of India's forex reserves. The result shows that a depreciation of the Indian rupee by one percentage point causes an increase in the real GDP by about 0.57 percentage points. Similarly, a one percent increase in the forex reserves of India causes a 0.51 percentage point increase in the real GDP.
2. The standard errors have been mentioned alongside the regressors and the constant in parenthesis. The standard errors for each coefficient in this model are 0.56 (constant), 0.06 (forex reserves), and 0.27 (average exchange rate).
3. The t-ratio measures how many standard errors the coefficient is away from 0. Values above 2 and below -2 are generally acceptable. The t-ratios in our regression model are all statistically significant. They are 10.12 (constant), 8.52 (forex reserves), and 2.07 (average exchange rate).
4. The p-value determines whether the relationships observed in a sample exist in the population and the p-value for each independent variable tests the null hypothesis i.e., the variable has no correlation with the dependent variable. P-values below 0.05 (<0.05) are statistically significant. The p-value of the estimated equation shows that the coefficient of the average nominal exchange rate is significant at 1 percent level and that of forex reserves is significant at 0.1 percent level.

5. The Durbin-Watson statistic is a test for autocorrelation. Its value ranges from 0 to 4, with a value of 2 indicating zero autocorrelation. Values below 2 mean there is positive autocorrelation and above 2 indicates negative autocorrelation. The DW statistic in this model is 0.35, indicating positive autocorrelation between the variables.

6. We also look at the "goodness of fit" measure of the model, which is *R squared*. It measures the proportion of variance in the regressors that are successfully measured by the model. An R squared of 0.25 or more is considered good, i.e. a sufficient amount of variance in the regressors is measured by the model, hence the OLS method generates accurate results. Here, the R squared is 0.94. So, we can say that the model uses appropriate regressors and is fit for interpretation.

The linear effect of the average exchange rate on the real GDP has been shown in the graph below. The graph has been constructed without taking into account the effect of foreign exchange reserves on economic growth as determined by our model. The Y-axis shows the real GDP, with the highest value being 3,200,000 million US dollars. The X-axis shows the average exchange rate of the INR with the USD. The points signify the average exchange rate and the real GDP of India in each year from 1992 to 2021. The line of best fit, Y, explains the linear relationship between the two variables by minimising the sum of squared differences between the actual values and the predicted values (points on the regression line). As one can see, there exists a high positive linear relationship between India's economic growth and the average exchange rate of the INR with the USD.

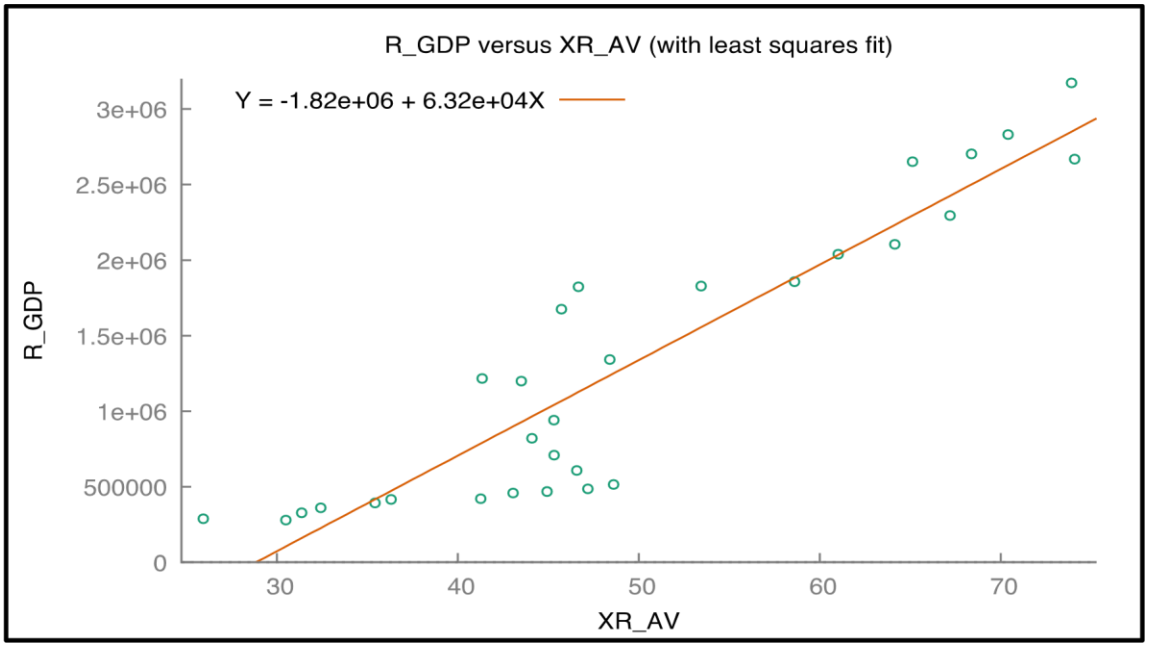


*Figure 3.* Linear Relationship between Economic Growth and Exchange Rate

*Source: Author's computations using Gretl*

**5.3. Exchange Rate and Forex Reserve**

Before regressing the forex reserves on the exchange rate, we carry out the VIF test to ensure multicollinearity does not invalidate our OLS model.

```
Variance Inflation Factors
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

     l_XR_AV    4.968
     l_R_GDP    4.968
```

*Source: Author's computations using Gretl*

Again, the VIF test statistic lies in the acceptable range of 1 to 5. The regressors: real GDP and average exchange rate are fit to be used in the OLS model as a result.

Table 2

| **Variables** | **l_FOREX** | **t-ratio** | **p-value** |
|---|---|---|---|
| l_R_GDP | 1.43184*** | 8.516 | 3.96e-09 |
| | (0.168144) | | |
| l_XR_AV | 0.280410 | 0.5708 | 0.5728 |
| | (0.491228) | | |
| Constant | −9.11848*** | −8.634 | 3.00e-09 |
| | (1.05606) | | |
| Observations | 30 | | |
| R squared | 0.937511 | | |
| Durbin-Watson | 0.257678 | | |

*Source: Author's computations using Gretl*

The estimated regression equation is given below.

$$l\_FOREX = -9.19 + 1.43\ (l\_R\_GDP) + 0.28\ (l\_XR\_AV) \quad (5)$$

The regression results can be interpreted in a similar manner as the previous regression one.

1. In our model, the regression coefficients are -9.12 (constant or intercept), 1.43 (real GDP), and 0.28 (average exchange rate). We can decipher from this OLS model that the growth of forex reserves of India is impacted more by the economic growth rate and comparatively less by the average exchange rate of the Indian rupee with the US dollar. A one percentage point depreciation in the Indian rupee causes a 0.28 percentage point increase in the forex reserves of India. On the other hand, a one percentage point increase in the real GDP causes a 1.43 percentage point increase in the forex reserves.
2. The standard errors for each coefficient in this model are 1.06 (constant), 0.17 (real GDP), and 0.49 (average exchange rate).
3. The t-ratios in our regression model are not all statistically significant. They are -8.634 (constant), 8.52 (real GDP), and 0.57 (average exchange rate). The t-ratio of the average exchange rate is not statistically significant as it lies between -2 and 2. Thus, we fail to reject the null hypothesis in this regard.
4. The p-value of the estimated equation shows that the coefficient of the real GDP is significant at 0.1 percent level and that of the average nominal exchange rate is not statistically significant.
5. The DW statistic in this model is 0.26, indicating positive autocorrelation between the variables.
6. Again, we look at the R squared of the model, about 0.94 in this case as well. The model is thus an accurate measure of the effect of a change in average exchange rate and economic growth on India's forex reserves.

The linear effect of the average exchange rate on the forex reserves has been shown in the graph below. The graph has been constructed without taking into account the effect of real GDP on forex reserves as determined by our

model. The Y-axis shows the forex reserves and the X-axis shows the average exchange rate of the INR with the USD. The points signify the average exchange rate and the forex reserves of India in each year from 1992 to 2021. The line of best fit, Y, explains the linear relationship between the two variables by minimising the sum of squared differences between the actual values and the predicted values (points on the regression line). As one can see, there exists a high positive linear relationship between India's forex reserves and the average exchange rate of the INR with the USD, although the relationship is slightly weaker than the previous one.

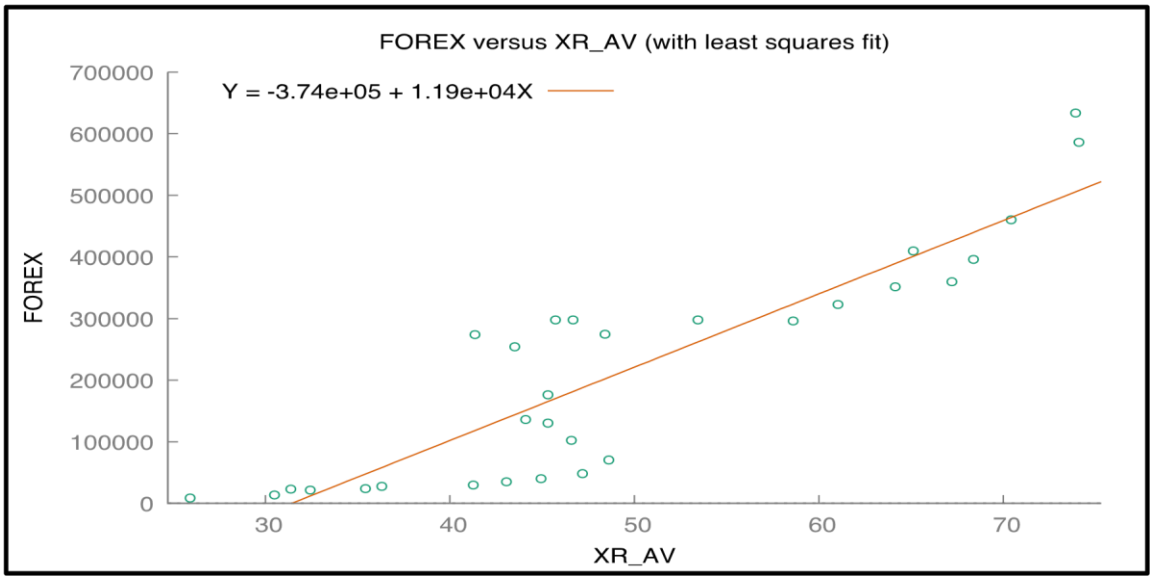


*Figure 4.* Linear Relationship between Foreign Exchange Reserves and Exchange Rate
*Source: Author's computations using Gretl*

## 4. Limitations of Research

The findings of this study have to be seen in light of a few limitations. Firstly, there exists some degree of simultaneity while postulating relationships between macroeconomic variables. Other variables like the rate of inflation and trade deficit, though not as highly correlated with the variables in the model, might be relevant to the impact of the regressors on the respective dependent variables. These have been ignored in the study due to erratic data, and more complex and difficult-to-interpret results due to the author's limited understanding of the field. Furthermore, trending time series data has been employed in the study, which means that the data's values have been affected by trend and seasonality. Hence, it can be assumed that a better part of the data presented is non-stationary. Due to the paucity of time, the Augmented DickeyFuller (ADF) test could not be applied to the data to check non-stationarity. The possibility of errors made by the software should also be kept in mind while viewing the results.

## 5. Conclusion

This paper analyses the empirical relationship of the exchange rate with forex reserves and economic growth in India. The model used is the Ordinary Least Squares (OLS) estimator, while a correlation analysis is conducted before to establish the relationship between the variables. The two equations, the forex reserves equation and the economic growth equation, have been estimated to analyse the impact of the depreciation of the Indian rupee. Results show that a one percentage point depreciation in the rupee causes a 0.28 percentage point increase in the forex reserves and an increase in the real GDP by about 0.57 percentage points. Therefore, our study's results are in line with those reported by other studies around the same theme in different countries.

The equations show that exchange rate depreciation can improve India's forex reserves and economic growth. However, one should be aware that only three variables have been studied in this model while using the findings

presented here. The variables have a high positive relationship, but a fixed causal relationship can't be ascertained. Having said that, empirical results suggest that the depreciation of the Indian rupee against the US dollar can increase forex reserves and improve India's economic growth. Recessions in the US, however, sometimes cause the rupee to appreciate against the dollar, as seen in 2007 and 2021. This is related to the economic contractions in India around the same time and is often counterproductive to India's forex reserves and economic growth.

**Statements and Declarations**

The author did not receive support from any organization for the submitted work.

The author certifies that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

The corresponding author states that there is no conflict of interest.

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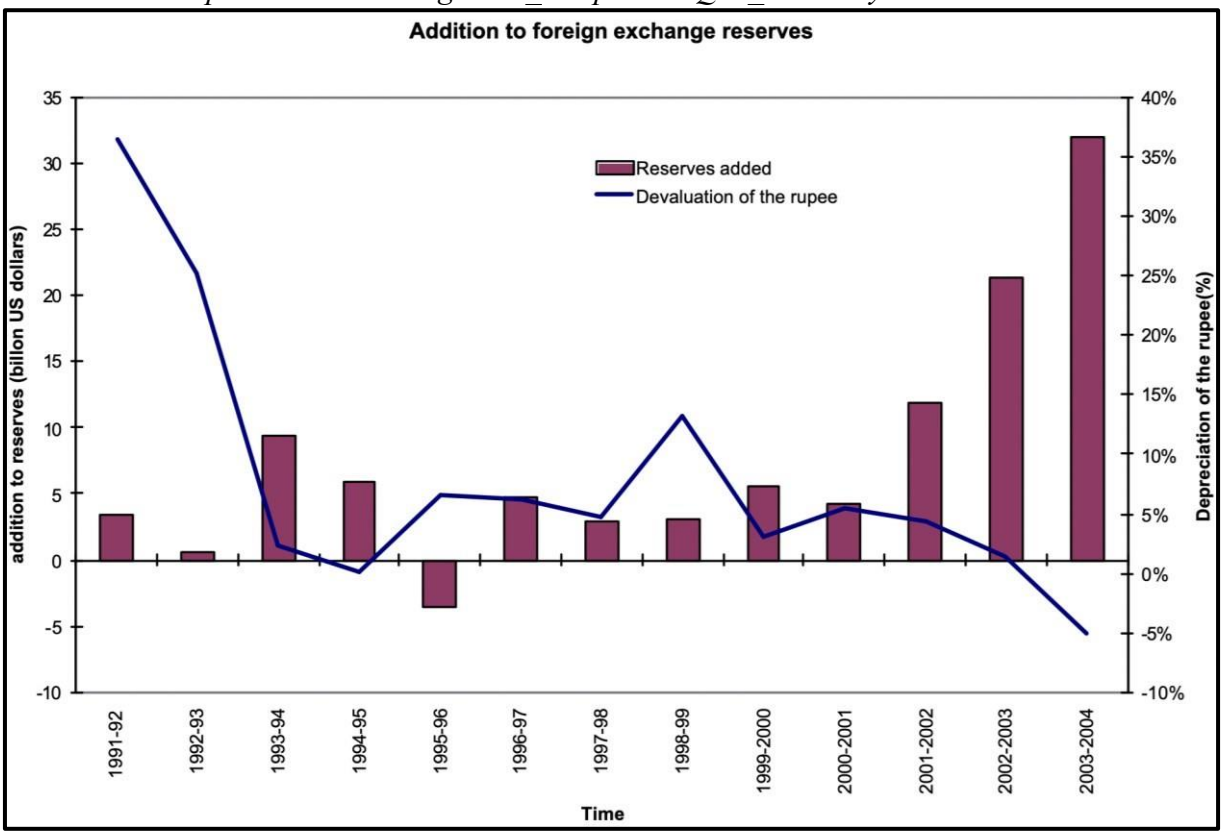
**Appendix**

**Database used in Empirical Analysis**

Amounts in Million US Dollars

| CY | R_GDP | FOREX | XR_AV |
|---|---|---|---|
| 1992 | 288208.43 | 8664.65 | 25.92 |
| 1993 | 279296.02 | 13524.20 | 30.49 |
| 1994 | 327275.58 | 23053.03 | 31.37 |
| 1995 | 360281.95 | 21591.25 | 32.43 |
| 1996 | 392897.05 | 23783.74 | 35.43 |
| 1997 | 415867.75 | 27568.28 | 36.31 |
| 1998 | 421351.48 | 29832.91 | 41.26 |
| 1999 | 458820.42 | 35069.39 | 43.06 |
| 2000 | 468394.94 | 40154.59 | 44.94 |
| 2001 | 485441.01 | 48199.55 | 47.19 |
| 2002 | 514937.95 | 70377.04 | 48.61 |
| 2003 | 607699.29 | 102260.73 | 46.58 |
| 2004 | 709148.51 | 130401.34 | 45.32 |
| 2005 | 820381.60 | 136026.05 | 44.10 |
| 2006 | 940259.89 | 176104.88 | 45.31 |
| 2007 | 1216735.44 | 273859.45 | 41.35 |
| 2008 | 1198895.58 | 254024.14 | 43.51 |
| 2009 | 1341886.60 | 274668.11 | 48.41 |
| 2010 | 1675615.34 | 297746.12 | 45.73 |
| 2011 | 1823049.93 | 297905.70 | 46.67 |
| 2012 | 1827637.86 | 297806.34 | 53.44 |
| 2013 | 1856722.12 | 296217.78 | 58.60 |
| 2014 | 2039127.45 | 322832.72 | 61.03 |
| 2015 | 2103587.81 | 351551.07 | 64.15 |
| 2016 | 2294797.98 | 359729.30 | 67.20 |
| 2017 | 2651472.94 | 409771.77 | 65.12 |
| 2018 | 2702929.72 | 396115.08 | 68.39 |
| 2019 | 2831552.22 | 460209.17 | 70.42 |
| 2020 | 2667687.95 | 586044.79 | 74.10 |
| 2021 | 3173397.59 | 633761.00 | 73.92 |

*Source: International Financial Statistics (IFS) Metadata by Country; World Development Indicators Database available at: https://1drv.ms/x/s!AgAbSR_RaLpFhCWQ-A_oDTL0SyDX*




*Source: RBI Bulletins*

[i] abbreviated as "forex" throughout the paper [ii]often termed as "economic growth" in the paper, as the real GDP is the best measure of economic growth [iii] currency appreciation: Appreciation of a currency means the increase in its price in the forex market relative to other currencies under the freely floating exchange rate system.

[iv] currency depreciation: Depreciation of a currency means the decrease in its price in the forex market relative to other currencies under the freely floating exchange rate system.

[v]economic agents: For the sake of understanding the concept of the effects of currency appreciation and depreciation on the economy, the scope of this term shall be limited to households (individuals) and firms (exporters of goods).

[vi] REER: The real effective exchange rate (REER) is the weighted average of a country's currency in relation to an index or basket of other major currencies.