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The Transmission of Pricing Information for Stock Cross-Listed on US and Indian Stock Market: A Case of Dr. Reddy's Laboratories

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Abstract
Purpose: *This study aims to examine possibility of long term relationship between the underlying stock of Dr. Reddy's Laboratories listed on the Bombay Stock Exchange (BSE) in India and its ADR cross- listed on the New York Stock Exchange (NYSE) in USA.* ***Design/ Methodology:*** *The study employs various financial econometric models like Augmented Dickey Fuller (ADF) test, Johansen Co-integration test, Vector Error Correction Model (VECM), Wald test and Variance Decomposition to analyze the long term relationship and causality between the cross-listed prices.* ***Results:*** *The results reveal a strong long run relationship between the ADR price and the underlying share price of Dr. Reddy's Laboratories. Both the prices are found to granger cause each other in short run. The results of variance decomposition indicate that the underlying stock price at home market (BSE) plays a significant role in influencing the ADR price at NYSE. However, the ADR plays a weak role in influencing the underlying stock price at BSE.* ***Conclusion:*** *This shows that home market plays a dominant role in transmission of price information for cross- listed stock of Dr. Reddy's Laboratories.*

Keywords: *ADR, cross- listing, stationarity, cointegration, VECM, Variance decomposition.*

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I. Introduction

Capital markets across the world are getting interconnected at a very fast pace. Not only multinational companies access global capital market, but there is an increasing trend among companies from emerging economies also to tap international capital market to raise debt and equity capital. While debt capital in terms of Foreign bonds, Eurobonds, FCCBs (Foreign Currency Convertible Bonds) etc have dominated the scenario, equity fund raising has come through Depository Receipts (DRs) - American Depository Receipts (ADRs) and Global Depository Receipts (GDRs).

ADRs are issued when a foreign company issue shares and convert these into DRs and list these DRs in any American exchange, either in NASDAQ, NYSE or in OTC. GDRs are listed and traded in London, Luxembourg, Frankfurt, Singapore and Exchanges of few other countries other than the USA. DRs (both ADRs and GDRs) can be sponsored or unsponsored. At the end of 2019, there are around 3500 global companies having issued DRs both in sponsored and unsponsored form and the total investment by investors in it is around $1.25 trillion. This depicts the huge size of the DR market (Source: JP Morgan & CMIE Database). India has also been a major player in the DR market. In fact, Indian companies have issued the maximum number of DRs in last two decades, though majority of these DRs are GDRs.

With the DR listing, the shares of a given company trade simultaneously in two different markets giving rise to arbitrage opportunity. However, if Law of One Price (LOP) holds true, DRs and their locally traded stocks should have identical prices after adjusting for exchange rates thereby leaving no opportunity for arbitrage. Motivations for this research comes from LOP only. The past few years have seen several researches conducted on different aspects of DRs from different countries with very few on DRs from India.

The present study aims at finding the linkage between the prices of Dr. Reddy's Laboratories' ADR listed on NYSE and its underlying stock on BSE. It addresses the specific questions like If there is any long term relationship between the ADR and the underlying stock? If there exists any causal relationship between the two prices? If the transmission of pricing information of individual stock is driven by itself or is driven by the cross-listed stock from other market?

II. Review of Literature

(Geeta Duppati & Scrimgeour, 2017) concluded that majority of cross-listed stocks from US and Chinese markets are not co-integrated and that US market leads the Chinese market in short run. They also concluded that information flow is stronger from the NYSE to SSE than the reverse way in the short run.

To verify if the law of one price (LOP) holds true (Rajib, 2011) conducted a study on Infosys ADR and the underlying shares price in India. The analyses show existence of significant price difference between the two price series, clearly indicating that the two markets are not integrated. A similar study by (Madhavan & Ray, 2014) found strong association and a bit of similarity between the GDR prices and their underlying stocks. The price and volatility linkages between London GDRs and underlying stock are found to be qualitatively similar to that of Luxembourg GDRs and underlying stock. Such similarity in findings, reflects the stock-exchange-invariant nature of Law of One Price (LOP), which indicates a less significant impact of foreign stock exchange per se, when it comes to price dynamics of dually-listed Indian stocks.

A study by (Leung & Kang, 2016) reveals that ADRs intraday returns are driven by the U.S. market sentiments and overnight returns are driven by home market sentiments. (Hansda & Ray, 2002) concluded that the quotes of both Indian and US stock the markets share not only a stock-wise bi-directional causality but are also efficient in quick transmission of the pricing information across the dually listed stocks, limiting the scope for arbitrage-profit out of any prior information on the closing market. The study conducted by (Kumar) revealed that most of the Indian firms recorded decline in volatilities of underlying domestic shares after the listing of GDR on foreign exchange. To study the impact of Foreign Exchange Rate, (Bhatnagar & Khan, 2015) analyzed that forex returns has significant relation on ADR Return while ADR Returns did not Granger Cause Forex return.

(Sriram, 2015) could not find long term relationship between Indian Depository Receipt (IDR) and the respective underlying share price of the IDR issue of Standard Chartered PLC in India. He also found that price discovery happens in the respective markets and investors' can study their respective markets for appropriate strategies. (Bora & Kumar, 2017) conducted research on Long Term Dynamics of Indian ADRs Market to investigate the nature of the return generating process of the Indian ADRs market and the results revealed that returns series of Indian ADRs market: (a) do not exhibit random walk behavior and rather depict both nonlinear behavior and persistence.

A market-based indicator of currency risk: Evidence from American Depositary Receipts by (Eichle & Rövekamp, 2016) was conducted to identify the economic fundamentals that drive the currency risk perceptions of ADR investors. 831 ADRs located in 23 emerging markets were chosen for study and the results are: deterioration in the fiscal and current account balance, as well as higher inflation, increases currency risk as anticipated by ADR investors. Fundamental variables have a significant impact on currency risk, particularly in countries with managed exchange rates, low levels of foreign exchange reserves, and poor sovereign credit ratings.

To find out if the returns of the GDR affects the underlying securities returns or vice-versa, 35 GDRs of Indian companies for a period of 2009-10 were chosen by (Chopade & Sisodia, 2012). Their conclusions are the returns from the underlying securities affect the returns of the respective GDRs but not vice-versa. The study also shows that the informational factors of the home market (market where securities are issued) have more prominent effect on the GDR returns than the host market (market where GDR are issued). (Tripathy & Jha) investigated the impact of cross listing of ADRs on the Indian stock market using 9 ADR issuing Indian companies for a period of June 2004 to July 2009. The results reveal that ADR listings have no tangible benefit impact to the local shareholders. This finding suggest that diversification into foreign equities provide returns similar to the market. Considering the additional risk associated with ADRs such as currency risk, the country's economy, asymmetric information problems and others, the performance may not provide adequate rates of return to satisfy some investors.

III. Research Methodology

3.1 Data and Period of Study

Table 1 shows the detail of ADR issue of Dr. Reddy's Laboratories used in the study. We use daily data since there are no overlapping trading hours between the NYSE and the BSE. The daily adjusted closing prices are extracted from yahoo finance and the period of study is from effective listing date of ADR, i.e. 24-04-2001 to 31-08-2020. A total of 4563 observations are used for the study. As the prices of ADR are quoted in US Dollar, they are converted into Rupees using the corresponding daily exchange rate of USD-INR for the sake of comparison. The data for USD-INR exchange rate is obtained from the Reserve Bank of India website. The natural logarithms of daily closing prices are taken for the purpose of analysis.

Table1: Details of ADR Employed in the Study

Dr Issue	Symbol	Exchange	Industry	Ratio DR: ORD	Eff. Date
Dr. Reddy's Laboratories	RDY	NYSE	Pharma. & Biotech.	1:1	Apr 24, 2001

3.2 Error Correction model

ECM is very useful time series modeling technique to examine both the short run and long run dynamics of the series if the non-stationary time series are integrated of first order , I(1) and found to be cointegrated. Conventional ECM for cointegrated series is stated as

$$\Delta y_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta y_{t-1} + \sum_{i=0}^{n} \delta_i \Delta x_{t-1} + \varphi z_{t-1} + \mu_t \quad (1)$$

Where z is the Error Correction Term (ECT) and is defined as

$$z_{t-1} = ECT_{t-1} = y_{t-1} - \beta_0 - \beta_1 X_{t-1} \quad (2)$$

ECT is the variable of lagged OLS residuals from the long run cointegrating equation and measures the rate of convergence to the long run equilibrium. The coefficient (φ) of ECT is the speed of adjustment and measures the speed at which dependent variable returns to equilibrium after a change in explanatory variable.

Here, ECM approach is used to investigate both long run and short run dynamics between the prices of Dr. Reddy's ADR and its underlying stock. The models under consideration are

$$\Delta P_t^{BSE} = \beta_0^{BSE} + \sum_{i=1}^{n} \beta_i \Delta P_{t-1}^{BSE} + \sum_{i=0}^{n} \delta_i \Delta P_{t-1}^{NYSE} + \varphi^{BSE} z_{t-1} + \mu_t^{BSE} \quad (3)$$

$$\Delta P_t^{NYSE} = \beta_0^{NYSE} + \sum_{i=1}^{n} \beta_i \Delta P_{t-1}^{NYSE} + \sum_{i=0}^{n} \delta_i \Delta P_{t-1}^{BSE} + \varphi^{NYSE} z_{t-1} + \mu_t^{NYSE} \quad (4)$$

3.3 Wald Test

The Wald test also called the Wald Chi-Squared Test is a method to find out if explanatory variables in a model are significant, i.e. if the short run coefficients of explanatory variables add something to the model. Here, it is used to test if the ADR price at NYSE is powerful and effective in explaining the movement of the underlying stock price at BSE and vice versa.

3.4 Variance decomposition

Variance decomposition provides a different method of depicting the system dynamics. It helps in determining how much of the variability in dependent variable is lagged by its own variance. In addition, it also shows which of the independent variables is "stronger" in explaining the variability in the dependent variable over time. Here, variance decomposition is used to find how much variability in ADR price at NYSE is lagged by its own variance and also due to variability in underlying stock price at BSE. The same is also tested for the price series when interchanged.

IV. Findings and Discussions

4.1 Descriptive Statistics

Table 2 depicts the results of descriptive statistics. It is revealed that there is no much fluctuation in the closing price of both the series.

Table 2: Descriptive statistics

Variable	RDY(BSE)	RDY(NYSE)
Mean	7.019725	7.022419
Std. Dev.	0.839042	0.836014
Maximum	8.453731	8.447822
Minimum	5.465197	5.423007
Skewness	-0.105312	-0.090609
Kurtosis	1.468341	1.458602
Jarque-Bera	454.4635	457.9632

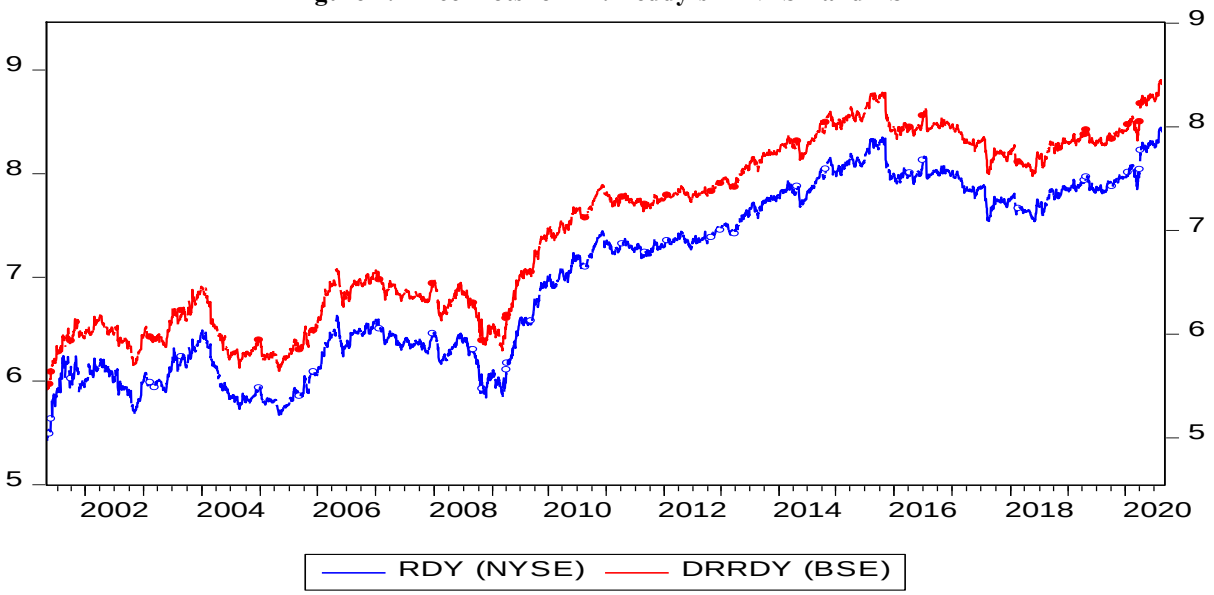
Probability	0.000000	0.000000
Observations	4563	4563

Note: The table reports natural log of daily adjusted closing prices. ADR prices are converted in terms of Rupees. NYSE= New York Stock Exchange. BSE= Bombay Stock Exchange.

Negative skewness for both the series indicate a relatively long left tail when compared to the right one. Kurtosis values of < 3 indicate that both the series are flat curved and the distribution is platykurtic. The high value of Jarque- Bera statistic and 0.000 probability value (< 0.1) confirms that both the price series are not normally distributed.

Figure 1 presents the price plots for Dr. Reddy's ADR at NYSE and underlying share price at BSE. It indicates that prices are moving in same direction and there is possibility of co-integration between them.

Figure 1: Price Plots for Dr. Reddy's in NYSE and BSE



4.2 Stationarity Test

To check whether the two price series are stationary or not, the Augment Dickey- Fuller test is performed. The results of the test are reported in Table 3. Both price series are found to have unit root at level for all the three equations (with constant; with constant and trend; and with no constant and no trend) and hence null hypothesis of unit root is accepted. However, the data becomes stationary at first difference and is statistically significant. In general it is concluded that both price series are I(1) processes at 1% significance level. The optimal lag length is chosen based on Akaike Information Criterion (AIC) approach.

Table 3: ADF Unit Root Test for RDY(NYSE) and RDY(BSE)

	with Constant		with Constant and Trend		with no Constant & no Trend	
	t- statistic	**probability**	**t- statistic**	**probability**	**t- statistic**	**probability**
A) ADF test in levels						
BSE	-1.033961	0.7432	-2.317980	0.4235	1.913596	0.9871
NYSE	-0.624972	0.8627	-2.234994	0.4693	1.746782	0.9810
B) ADF test at first differences						
BSE	-20.95982	0.0000*	-20.95874	0.0000*	-20.85195	0.0000*
NYSE	-13.26466	0.0000*	-13.26239	0.0000*	-13.13570	0.0000*

*significant at 1% level

4.3 Johansen Cointegration Test

Because the price series under study are of the same security (i.e. Dr. Reddy's Laboratories) trading at two different markets, we expect the two prices to be cointegrated and having an equilibrium relationship in long term. Here, Johansen cointegration test is conducted to find existence of cointegrating relationship between the Dr. Reddy's ADR price and the underlying share price.

Table 4: Johansen Cointegration Test

	Trace Test			Eigenvalue Test		
Hypothesized No. of CE(s)	**Trace Statistic**	**Critical value**	**p-value**	**Max- Eigen Statistic**	**Critical value**	**p-value**
$r = 0$	88.53561	19.93711	0.0000	87.41730	18.52001	0.0000
$r \leq 1$	1.118308	6.634897	0.2903	1.118308	6.634897	0.2903

* denotes rejection of the hypothesis at the 0.1 level
**MacKinnon-Haug-Michelis (1999) p-values

The optimal number of lags in the model is determined by the Akaike Information Criterion (AIC). The trace statistic for null hypothesis ($r = 0$) is 88.53561, greater than the critical value of 19.93711. Therefore, we reject the null of no cointegration in favor of alternative hypothesis of one cointegrating vector. The second test is conducted to check for $r \leq 1$ i.e. existence of atleast one cointegrating vector. The trace statistic for the same is 1.118308 lower than the critical value of 6.634897. Hence we cannot reject the null and conclude that there is atleast one cointegrated vector. The results are same when max-eigen value test is used instead of trace test.

4.4 Error Correction Model (ECM)

As the price series are found to be cointegrated, we can now estimate an Error Correction Model (ECM) for equations (3) and (4) as below

$$\Delta P_t^{BSE} = -0.0390 ECT_{t-1} - 0.2693\Delta P_{t-1}^{BSE} - 0.1510\Delta P_{t-2}^{BSE} - 0.1067\Delta P_{t-3}^{BSE} - 0.0438\Delta P_{t-4}^{BSE} + 0.3524\Delta P_{t-1}^{NYSE} + 0.1950\Delta P_{t-2}^{NYSE} + 0.1120\Delta P_{t-3}^{NYSE} + 0.0721\Delta P_{t-4}^{NYSE} + 0.0005 \quad (5)$$
$$ECT_{t-1} = 1.000P_{t-1}^{BSE} - 1.0040P_{t-1}^{NYSE} + 0.0306$$

$$\Delta P_t^{NYSE} = -0.0542 ECT_{t-1} - 0.1005\Delta P_{t-1}^{NYSE} - 0.0228\Delta P_{t-2}^{NYSE} - 0.0291\Delta P_{t-3}^{NYSE} - 0.0491\Delta P_{t-4}^{NYSE} + 0.0548\Delta P_{t-1}^{BSE} + 0.0566\Delta P_{t-2}^{BSE} + 0.0531\Delta P_{t-3}^{BSE} + 0.0377\Delta P_{t-4}^{BSE} + 0.0006 \quad (6)$$
$$ECT_{t-1} = 1.000P_{t-1}^{NYSE} - 0.9960P_{t-1}^{NYSE} - 0.0305$$

Table 5 depicts the estimated values of the coefficients along with their p-values for both the equations (5) and (6). The error correction coefficient (φ) is -0.0390 and -0.0542 for equations (5) and (6) respectively. This means that around 3.9% of departure in RDY(BSE) from long run equilibrium is corrected by short run adjustment in each period while it is 5.42% in RDY(NYSE). This indicates that both price series granger causes each other but the causal effect of RDY(BSE) is little bit more than that of RDY(NYSE). The p-values for both the coefficients are also found to be statistically significant at 1% significance level.
In eq (5), the short run coefficients of the lagged values of RDY(BSE) and RDY(NYSE) are found to be statistically significant at 5% level. While in eq (6), the third and fourth lagged values of RDY(BSE) and RDY(NYSE) are statistically insignificant at 5% level. This indicates that the said values do not affect the RDY (NYSE) significantly.

Table 5: Estimated coefficients for ECM eq (5) and (6)

Error Correction	**D(RDY_BSE)**	**D(RDY_NYSE)**
CointEq1 (φ)	-0.038992	- 0.054187
	(0.0001)	(0.0000)
D(RDY_BSE(-1))	-0.269389	0.054770
	(0.0000)	(0.0238)
D(RDY_BSE(-2))	-0.150997	0.056573
	(0.0000)	0.0221
D(RDY_BSE(-3))	-0.106720	0.053137
	(0.0000)	0.0274

D(RDY_BSE(-4))	-0.043772	0.037663
	(0.0152)	0.0758
D(RDY_NYSE(-1))	0.352435	-0.100471
	(0.0000)	0.0000
D(RDY_NYSE(-2))	0.194970	-0.022770
	(0.0000)	0.3203
D(RDY_NYSE(-3))	0.111967	-0.029065
	(0.0000)	0.1994
D(RDY_NYSE(-4))	0.072105	-0.049059
	(0.0000)	0.0173
C (μ)	0.000531	0.000628
	(0.0504)	0.0589

* p-values in parentheses

4.5 Wald Test

It is conducted to see if short run coefficients of explanatory variables granger cause dependent variable.
H_o: Explanatory variable granger cause dependent variable in short run.
H_a: H_o is not true.
The results reported in Table 6 show that the p-value of chi-square is statistically significant and hence null hypothesis is rejected. This indicates that both the price series granger cause each other in short run.

Table 6: Wald Test

	Chi-square	Probability
Eq (5)	162.1371	0.0000
Eq (6)	90.12963	0.0000

4.6 Diagnostic Tests

Following diagnostic tests are employed to check the reliability of the tested models.

Breusch-Godfrey Serial Correlation LM Test

It is used to check if the tested model is free from serial correlation.
H_o: There is no serial correlation in residuals
H_a: H_o is not true.

Table 7: Breusch-Godfrey Serial Correlation LM Test

	Obs R-squared	Prob. Chi-square
Eq (5)	12.73933	0.1265
Eq (6)	9.060676	0.1067

The p-value of 12.69% and 10.67% for equation (5) and (6) respectively are above the significance level of 5%. Thus, we fail to reject H_o and hence conclude that the tested models are free from serial correlation in residuals

Jarque-Bera Normality test

H_o: The residuals are not normally distributed
H_a: H_o is not true.
The high value of Jarque- Bera statistic and p-value of 0.0000 in table 8 indicate that the residuals are not normally distributed. Wooldridge (2012) pointed out that non- normality of errors is not a serious problem when the sample size is too large.

Table 8: Jarque- Bera Normality test

	Jarque- Bera Statistic	Probability
Eq (5)	8550.460	0.0000
Eq (6)	17486.33	0.0000

ARCH Heteroskedasticity Test

H_o: There is no evidence of herteroskedasticity

H_a: H_o is not true.

Table 9 reports the results of ARCH heteroskedasticity. 0.5325 and 0.4423 p- values of chi- square for eq (5) and eq (6) respectively is higher than the significance level of 5% and we fail to reject H_o. Hence, it is concluded that there is no heteroskedasticity in residuals. Thus, the residuals from the tested VECM models are homoskedastic and not heteroskedastic.

Table 9: ARCH Heteroskedasticity Test

	Obs R-squared	Prob. Chi-square
Eq (5)	55.49840	0.5325
Eq (6)	160.1687	0.4423

4.7 Variance decomposition

Table 10a reports the results for variance decomposition analysis on RDY(BSE). We analyze that in short run 100% forecast error variance in RDY(BSE) is explained by itself while contribution from RDY(NYSE) is strongly exogenous, i.e. the latter has a very weak influence on the DY(BSE). With lapse of time, i.e.as we move from period (here, day) 1 to 10, it can be seen that the influence of RDY(BSE) prices is still strong around 87% on itself while the contribution from RDY(NYSE) prices is not that strong.

Table 10a: Variance Decomposition of RDY(BSE)

Period	S.E.	LNP_BSE	LNP_NYSE
1	0.019039	100.0000	0.000000
2	0.027650	94.28688	5.713119
3	0.034218	91.46741	8.532595
4	0.039723	89.77552	10.22448
5	0.044822	88.85925	11.14075
6	0.049282	88.67184	11.32816
7	0.053414	88.42017	11.57983
8	0.057237	88.19300	11.80700
9	0.060818	87.99536	12.00464
10	0.064206	87.83466	12.16534

Table 10b: Variance Decomposition of RDY(NYSE)

Period	S.E.	LNP_BSE	LNP_NYSE
1	0.022393	43.19343	56.80657
2	0.030257	46.66235	53.33765
3	0.036801	49.29398	50.70602
4	0.042470	51.46677	48.53323
5	0.047298	53.17502	46.82498
6	0.051781	54.27723	45.72277
7	0.055858	55.25575	44.74425
8	0.059638	56.15150	43.84850
9	0.063178	56.99102	43.00898
10	0.066509	57.77800	42.22200

The results of variance decomposition on RDY(NYSE) are shown in table 10b. In period 1, the influence of RDY(NYSE) is 56.80% on itself and that of RDY(BSE) is 43.19% on RDY(NYSE). This shows that RDY(NYSE) is equally influenced by both- RDY(BSE) as well as itself in short run. As we move from period 1 to 10, the influence of RDY(BSE) is gradually increasing on RDY(NYSE) while the influence of RDY(NYSE) is reducing gradually on itself. Thus, it can be interpreted that RDY(BSE) has strong influence on

itself as well as on RDY(NYSE). Hence, we conclude that ADR price of Dr. Reddy's Lab on NYSE is driven by home country and not the country in which the ADR is listed.

V. Conclusion

The present study is conducted to check for the existence of long run relationship between the ADR price and its underlying stock for Dr. Reddy's Laboratories. In order to test the long and short run relationship, VECM is applied. The daily prices for both the stocks are taken for a period of 20 years from 24-04-2001 to 31-08-2020. Since the ADR prices are quoted in US Dollars, they are converted into rupees before comparison. For any test to be applied in time series, it is prerequisite for the price series to be stationary. The application of ADF test reveals that two price series are stationary at first difference, .i.e. both the series are I(1) processes. Then the Johansen cointegration test is used to check for cointegrating relationship and the results reveal one cointegrating relationship between the RDY(NYSE) and RDY(BSE) price series.

As the two series are cointegrated, it is possible to apply VECM here. The results exhibit that the error correction coefficient (ECT) for both RDY(NYSE) and RDY(BSE) are statistically significant and indicate adjustments towards long run equilibrium in case of any disequilibrium situation. The results of Wald Test establish that the short run causality runs in both the directions i.e. both the price series affect each other in short run. Lastly, one of the important revelations of this study is that the underlying stock price of Dr. Reddy's at BSE plays an important role in influencing its ADR price at NYSE as well as on its own price at BSE. However, the ADR price is not influencing the underlying stock price at BSE. This clearly indicates the significant role of home market in influencing the prices of cross- listed stocks in host (foreign) country. Hence, we can conclude that there is a possibility of arbitrage opportunities in case of cross- listed stocks. The same research if extended to study the price linkage for all the dually listed stocks from India then the results would give a more clear possibility of arbitrage opportunity to exist.

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